Community-Based Problem Solving in STEM:

A Qualitative Case Study of K-8 STEM Education

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Abstract

A theoretical framework grounded in constructionism and pragmatism theories supported research on learning by doing. This framework underpinned the purpose of this qualitative case study to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. The problem was a lack of connection between community-based problems with current standards and pedagogy designed to develop a globally competitive workforce. A gap in the literature existed for studies investigating the combination of community-based problems and innovative technology. In examining the problem, the qualitative case study used interviews with 15 STEM teachers in the Midwest United States. Qualitative data analysis software NVivo version 14.23.0 was used to code the interview data. The final analysis relied on a bottom-up approach with inductive reasoning to draw conclusions. The results demonstrated how teachers in STEM programs designed purposeful learning for students and resulted in five themes: STEM Habits of Mind, Lens of Empathy, Connecting Beyond the Classroom, Designing Purposeful Learning, and Innovative Solutions. Conclusions drawn from the results may inform STEM teachers' pedagogical choices and future programming decisions. Using resources and experts outside the classroom could spark ideas and generate problems and solutions from different perspectives. Solving real-world problems for others moved students from skills-based learning with technology to a problem-solving focus, generating innovative solutions. Teachers learning from this research could harness technology's power for society's good by creating lessons that focus on empowering students to find solutions to current problems in their communities.

Keywords: community-based, empathy, innovative solutions, innovative technology*, K-8* STEM, place-based, problem solving, STEAM, STEM, technology

Dedication

This dissertation is dedicated first to my parents. My mom, Nancy Schueler, earned a master's degree in education in 1962. She was invited to continue into a doctoral program but chose instead to teach in Japan, followed by decades of parenting. She was a remarkable person and lived long before society appreciated women in academia. While she has been gone for many years, I hope this makes her proud. To my dad, who liked to warn people to look out for me because I had ideas, he was right.

To the ones I love, Maddy, Jeff, and Riley. May you never stop learning. Maddy, your help on the literature review brought order to the chaos and helped my thinking flow in a way that made sense. You were always willing to listen when I needed to think through an idea. I hope I have inspired you as you begin your collegiate journey. Jeff, your ongoing support, love and encouragement, ideas, snacks, and time to work got me across the finish line. Riley, thanks for keeping the lawn mowed, the cats cared for, and the pizza flowing. Chuck and Susan, thanks for the Saturday morning phone calls for encouragement and connection when I was in the middle of overthinking everything.

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The Bannockburn School third grade class of 2018-2019 deserves a thank you for inspiring me to start this journey. They showed me the power of what a lens of empathy can do for STEM learning, and I have been changed forever because of them.

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Chapter 1: Introduction

The Next Generation Science Standards (NGSS, 2013) recommended learning about the natural and manufactured worlds (Cunningham et al., 2020). Students' scientific understanding deepened by applying this knowledge to community-based STEM problems (Cunningham et al., 2020). Educators are transitioning instruction from *what* we need to know toward *how* we can empower learners during an inquiry process (Quigley et al., 2020) and how to use innovative technology to facilitate the process. A lesson designed around community-based problems connects to students’ lived experiences, deepening the learning and drawing out the underlying value of solving problems to help others. Adding the human experience to science, technology, engineering, and mathematics (STEM) recognizes the impact of STEM in improving the human condition (Johnson et al., 2021). Connecting STEM projects to the local community requires more information for teachers to address in STEM classrooms. Next, a description of the problem and purpose, supported by constructionism and pragmatism learning theories, clarifies the direction of research.

Background of the Problem

The Pew Research Center (2018) surveyed public school parents in the United States about perceived problems in K-12 STEM education. The results showed 62% of parents perceived too much emphasis on standards, while 53% felt there was not enough emphasis on the practical use of STEM education in everyday life. In addition, 49% of parents thought K-12 STEM education had an insufficient focus on critical thinking and problem solving, 48% felt inadequate time was spent teaching STEM at the elementary school level, and 46% perceived a lack of up-to-date curriculum. The goal of community-based, or place-based, learning was to reimagine standards and curriculum through a more connected pedagogy to students' and teachers' lived experiences (Gruenewald, 2003) and utilize innovative technology to identify and design solutions. Teachers who are interested in localizing STEM through community-based problem-solving benefit from analyzing how current STEM teachers use innovative technology to facilitate community-based problems and design challenges in Grades K-8.

Statement of the Problem

The problem was a lack of connection between community-based problems with current standards and pedagogy designed to develop a globally competitive workforce. The situation continues to grow as technology use increases, community involvement decreases, and artificial intelligence (AI) grows daily (Miles, 2021). Lack of accountability to communities and increased focus on global competition create a disconnect between schools and life outside of school and the need to think critically about and shape what happens there (Gruenewald, 2003).

Students now in K-8 schools were born after the introduction of the smartphone. Nearly half the planet owns a smartphone just 14 years later, and no one could have predicted how reliant people have become on smartphones (Anderson & Rainie, 2021). STEM teachers have the opportunity to harness the power of technology for the greater good, empowering students to innovate creative solutions to solve problems for others. According to Gunckel and Tolbert (2018), most research on teaching STEM rests on technical skills, with little attention paid to research on care and social empathy in students' project designs. A gap in the literature expressed by Gunckel and Tolbert (2018) and Sias et al. (2017) justified a focus on STEM teacher lesson plans and evidence of how teachers facilitated innovative design solutions.

Purpose of the Study

The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems.

Students considered the problems of the school's community and addressed possible solutions from the perspectives of people impacted by the designs (Gunckel & Tolbert, 2018). According to Calabrese Barton et al. (2021), there was a lack of consensus in the field on how to incorporate students' experiences authentically when designing STEM challenges. If the goal was to prepare students to solve real-world problems, then an element of care contextualizing the design process was required (Gunckel & Tolbert, 2018). Students who received exposure to instructional design were more reflective of innovation, cultural structures, and the community's needs throughout school (Sias et al., 2017). Sias et al. (2017) claimed the prevalence of STEM-related problems found in all communities was an opportunity for students and teachers to address problems through educational technology innovations. Understanding the significance of the purpose of the study clarifies the need for additional research.

Significance of the Study

Researchers in STEM education are examining the possibility of preparing students to become active, empathic citizens by focusing on local problem solving (Bush & Cook, 2019; Holmes et al., 2021). To fill this need, researchers are exploring ways to use technology and problem-solving strategies in the context of local communities. Students grow into creative problem solvers when given access to state-of-the-art technology (Ellis et al., 2020). The literature establishes a relationship between technological advancements and acts of compassion and care within local communities.

According to Suters et al. (2021), the Fourth Industrial Revolution (4IR), characterized by emerging technologies like artificial intelligence, biotechnology, and autonomous vehicles, including how humans interact with these technologies, was resulting in rapid changes in society and the workplace. Jobs continued to grow in emerging technology. The U.S. Bureau of Labor

Statistics (2022) cited the increasing need for STEM-related jobs, showing a growth rate of 10.8% from 2022 until 2031, versus non-STEM careers at 4.9%. According to O'Rourke (2021), the increase in jobs went hand-in-hand with the need for curious, creative people who could help solve the world's most pressing problems.

This study may contribute to the knowledge base of K-8 STEM teachers looking for ways to integrate technology into the design process to connect students with real-world, community-based problems. STEM teachers in Grades K-8 in the Midwest United States were the target population for this project. The results of this study offer an overview of emergent themes surrounding the innovative use of technology to solve community-based STEM problems for application in the professional development of K-8 STEM teachers. Growing the knowledge base for teachers may provide support, ideas, and research to bolster the need for STEM education, beginning with elementary-age students.

Research Questions

The central ideas this study addressed were a lack of community-based problem solving in elementary STEM classrooms and an understanding of how students can solve community-based problems with innovative technology. According to Calabrese Barton et al. (2021), there needed to be more consensus in the field on how to incorporate students' authentic experiences when designing STEM challenges. The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. The following questions drove the study:

Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?

Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?

Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?

Theoretical Framework

A theoretical framework established the learning theories supporting the purpose of the study: constructionism and pragmatism. Using models to solve problems and visible learning with students bolstered constructionism as a theory for STEM education (Noss & Clayson, 2015). Constructionism, developed by Seymour Papert (1986), built on the constructivism theory of Vygotsky (1978). Pragmatism, described as learning by doing (Niiranen, 2021), is a theory with deep connections to John Dewey (1916) and influenced by William James and Charles Peirce (1899). Constructionism and pragmatism support the study of community-based problem solving using innovative technology through hands-on learning (Papert, 1986), designing and modeling solutions collaboratively (Noss & Clayson, 2015), and connecting with the people and community and the local environment (Webber, 2021). The literature review addresses additional themes of community-based problem solving, solving problems for others, and using innovative technology to design, model, and solve problems.

Definitions of Terms

Community-based learning is defined as real-world, hands-on learning experience connecting students to the world outside the classroom (Webber, 2021).

Constructionism is a form of learning that involves developing internal knowledge through building, reflecting, and iterating (Noss & Clayson, 2015).

Design thinking is the blending of empathy with creative thinking to solve problems (Cook & Bush, 2018).

Empathy is defined as an emotional response while taking others' perspectives and expressing a desire to help (Letourneau & Bennett, 2020).

Innovative technology is dually defined as both tools for teaching and tools for learning content (Johnson et al., 2021). The definition of innovative technology is subjective. For the purposes of this study, it means both new technology and technology used in a new way to solve a problem.

Interdisciplinary STEM is defined as two or more closely linked disciplines (Bush & Cook, 2019).

Place-based learning is an interdisciplinary approach to using the local environment to connect humans to the place (Gruenewald, 2003).

Pragmatism is defined as learning by doing based on experiences (Dewey, 1916).

STEAM education is STEM with the inclusion of the *A* for Arts to focus on the creative design process for cross-disciplinary integration (Bush & Cook, 2019).

STEM education is defined as integrated science, technology, engineering, and math applied to solve a problem (Bybee, 2010).

Transdisciplinary STEM is defined as two or more disciplines applied to real-world problems (Bush & Cook, 2019).

Assumptions

Assumptions in research are the general beliefs about a study presumed to be true (Hancock & Algozzine, 2017). According to Bantjes and Swartz (2017), the assumptions made about knowledge and information limit the types of data we might gather and the techniques we use to evaluate and interpret our findings. Bantjes and Swartz claimed assumptions were made when individuals were aware of what to do, could correctly remember and explain actions, and could tell an accurate picture of reality. Teachers invited to participate in this study were presumed to be willing participants who would share their honest and forthright perceptions and experiences of elementary or middle school STEM education. The perceptions and experiences of the teachers were assumed to be free of bias. The interview instrument was assumed to be free of bias and was modified according to field testing feedback from subject matter experts.

Scope and Delimitations

The scope of a research study includes the criteria used to establish the boundaries of a study (Newsome, 2016). Boundaries, as described by Newsome, included the number of participants, the description of the participants, and the geographical location. Creswell (2009) argued that the scope, delimitations, and limitations increased the validity and reliability of a study. The study provided an opportunity to gather teachers' perspectives on facilitating community-based problem solving with students using innovative technology. The scope limited participants to fifteen STEM teachers in grades K-8 from the Midwest United States. Age, gender, and ethnicity were not considered in the description of the participants. Requests for participation were sent through professional listservs and online forums for professional organizations. Participants who completed the screening survey and fit the scope of the study were invited to participate in semi-structured interviews conducted using online video conferencing in April and May 2023, Due to the definition of participants as STEM teachers in grades K-8, transferability of results to other grade levels or other educational situations is limited. The scope of the study increases validity and reliability while also informing future researchers about the problem, setting, time frame, and participants when reviewing or recreating the study.

Delimitations are the research boundaries that include characteristics of the case (Hancock & Algozzine, 2017). According to McGregor (2018), delimitations are the pre-defined items within the researcher's control based on decisions made around the boundaries determined by the scope of the research. Delimitations were conscious choices regarding what to include or exclude from the study. Delimitations for this study included a minimum number of 15 participants with a maximum number of 20 participants in order to maintain a manageable size. The study maintained a focus on teachers located in the Midwest United States. This choice was made to facilitate identifying regional similarities in the participants based on school sites. Online video conferencing was used to facilitate face-to-face interviews with teachers and maintain a timeframe of two months. The technology used for interviews limited interaction to the screen’s viewing area rather than the context of a site location visit might contribute to understanding instructional choices.

Defining STEM education was a delimitation of the study designed to be inclusive of the transdisciplinary nature of STEM and STEAM programs. A transdisciplinary approach to STEM education incorporates multiple disciplines both within the STEM acronym of Science, Technology, Engineering, and Math, and from all disciplines with real-world problem solving characteristics. Examples from other disciplines incorporated in STEM might include Social Studies, social emotional, and art and design education. Ideal participants came from STEM programs with a dedicated teacher or STEM integrated into a classroom rather than a makerspace-type program. This study did not include teachers of STEM or STEAM programs for Grades 9-12, after-school, enrichment, or off-site programs. Due to the subjective nature of technology definitions, all technologies described by the participants in the interviews were included in the data analysis, regardless of whether they aligned with conventional ideas of technology. Unconventional examples included in the delimitations are students using cardboard or LEGO® to create models.

Limitations

Creswell (2009) defined limitations as internal factors identified during a study as weaknesses or challenges. Limitations may also include issues with data collection, biases or sampling. During the study, participant selection proved a challenge. STEM and STEAM programs are continuously evolving and are defined in various ways according to the teacher responsible for designing instruction. The use of purposeful sampling was intended to attract teachers with desired characteristics for the study, however few participants responded to the initial recruitment requests. Snowball sampling, or identifying participants through referrals, was the sampling method that provided participants who may not participate in Professional Learning Networks (PLNs). Using snowball sampling increases potential bias because the population may not have enough variation to provide unique experiences.

Researcher bias can come from a conscious or unintentional tendency to collect or interpret data, leading to wrong conclusions or supporting certain beliefs or experiences (Bloor & Wood, 2006). During this study, a concern arose around the unintentional inconsistency in asking interview questions, providing alternate explanations, or variations in answering participants' questions. Furthermore, enthusiasm and passion for the subject might introduce bias in the data analysis, influencing the findings. To maintain transparency in the data analysis process, an audit trail was established, as described by Bloor and Wood (2006). This involved careful justification during the data analysis, especially when describing themes from the data.

The scope, delimitations, and limitations were part of the audit trail explaining choices made about the study upfront.

Chapter Summary

Teachers in K-8 STEM programs have a unique opportunity to allow students to be creative and develop new ways to solve problems. This study aimed to capture the stories of successful STEM projects involving community-based problems. Identifying the problem, purpose, and significance of the study provided a foundation for the rationale and decisions made through the work. A theoretical framework of constructionism and pragmatism supported the objective of learning how students used technology to solve problems—learning by doing. Interviews of teachers in STEM-related programs told the story of how teachers generate ideas, the planning it takes to implement a project, and the creativity found in the clever ideas of the teachers and students.

A list of definitions clarified relevant terms in the field and reduced the risk of misunderstandings or misinterpretations. Identifying the assumptions, scope, delimitations, and limitations of the study increased the likelihood of transferability to other contexts. Bias was always a risk, but thick descriptions, adherence to interview protocol, and careful data analysis minimized the impact. The delimitations clarified the boundaries of the study and provided a description of what aspects are included or excluded from consideration.

Understanding the background of STEM education requires a deeper dive into the theoretical underpinnings and the very meaning of transdisciplinary STEM education. The literature review, presented next, synthesized past trends and current work in connecting community-based problem solving, solving problems for others, and innovative technology solutions, which were lacking in the literature. Making this connection provided a pathway for

K-8 STEM teachers to bring fresh ideas to students by using local issues to spark students to solve problems for others with the innovative use of technology.

Chapter 2: Literature Review

Teachers in STEM programs have a unique opportunity to harness the power of technology to benefit society as a whole, enabling their students to innovate and create new ways to address existing challenges. According to Gunckel and Tolbert (2018), most research on teaching STEM subjects focused on teaching technical skills, while only a small amount of attention was paid to research on caring about project designs and having social empathy. The problem was a lack of connection between community-based problems with current standards and pedagogy designed to develop a globally competitive workforce. The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems.

The theoretical framework supported research on learning by doing, including theories of constructionism (Bower et al., 2020; Burrows et al., 2021; Hatzigianni et al., 2020; Papert, 1986) and pragmatism (Dewey, 1916; Hatzigianni et al., 2020; James, 1899; Öhman & Sund, 2021; Poeck & Östman, 2020). Constructionism and pragmatism supported the study of community-based problem solving using innovative technology through hands-on learning (Papert, 1986), designing and modeling solutions collaboratively (Noss & Clayson, 2015), and connecting with the people and community and the local environment (Webber, 2021). The following sections of the literature review focused on community-based problem solving, problem solving for others, and the application of innovative technology to design, model, and solve problems.

Literature Search Strategy

Peer-reviewed journals and other publications established the literature review on community-based problem solving and innovative technology. A literature review determined a need through gaps in the research and a theoretical foundation for experiential learning through community-based problems. The American College of Education ACE OneSearch search engine searched for peer-reviewed articles across multiple databases. Databases such as Education Source by EBSCO, ERIC, ProQuest Education Database, ProQuest Dissertations, and Theses Global were searched for relevant research. The vast majority of the analyzed literature was published between 2018 and 2021. Key search terms included: *place-based learning, hands-on learning, problem-based learning, community-based problem solving, constructionism, design thinking, empathy, technology education, pragmatism learning-by-doing, STEAM education, and STEM education.*

Theoretical Framework

This study addressed a lack of community-based problem solving in elementary STEM classrooms and teachers' perceptions of how students can solve community-based problems with innovative technology. A theoretical framework established the learning theories that supported the purpose of the study as constructionism and pragmatism. Constructionism is an epistemological theory (Noss & Clayson, 2015) that describes a form of learning involving developing internal knowledge through building, reflecting, and iterating. Seymour Papert (1986) built constructionism from the ideas of constructivism theory (Vygotsky, 1978), particularly the notion of students learning by doing.

Noss and Clayson (2015) argued that a watered-down version of Vygotsky's theory of learning by doing now described nearly every area of education. Constructionism, therefore, was a way to focus on the learning developed through the *design process* not addressed in constructivism. Noss and Clayson (2015) described constructionism learning theory as incorporating six tenets: a) using models to solve problems, b) shaping actions based on models, c) layering mathematics and science principles, d) creating an engaging learning environment for students, e) giving students opportunities to make their learning visible, and f) collaborating with others on projects. Current research supported constructionism as a theoretical framework for the study found in educational technology (Lærke Weitze, 2019; Trust & Maloy, 2017), STEM (Burrows et al., 2021) and makerspaces (Bower et al., 2020; Hatzigianni et al., 2020).

Pragmatism is a theory of learning based on experiences or learning by doing (Dewey, 1916). James and Peirce influenced John Dewey, who was recognized as the founder of experiential learning in education and considered a leader in pragmatism in education, or learning by doing (Niiranen, 2021). With the book, *Talks to Teachers on Psychology* (1899), William James made significant contributions to teaching, and James is now regarded as one of the founders of pragmatism (Liszka, 2013) along with Charles Peirce. Niiranen summarized four stances of pragmatism based on Roberts' work (2012). The first viewpoint held that people learn about a problem by proposing solutions. Second, learning was strongly linked to the environment and its people. The third point emphasized the significance of context in the learning environment, stating contextual learning provided an authentic and relevant experience. Fourth, mistakes were a natural part of the learning process. Through experience, the learner gained tacit knowledge, and that experience included making mistakes.

Niiranen’s (2021) interpretation of Roberts' (2012) four stances aligned with Poeck and Östman's (2020) understanding of modern educational pragmatism theory, which provided opportunities for students to engage in real-world and authentic problem solving and seek answers through creative, hands-on learning experiences. According to Hatzigianni et al. (2020), pragmatic theory-based learning necessitated critical reflection. It implied learning was not an intangible process of the mind but, rather, something that occurred when students were involved, and they responded with initiative (Öhman & Sund, 2021). In pragmatic learning theory, as discussed in Öhman and Sund (2021), the teacher had to choose the situations where this interaction occurred and consider the entire learning environment to adapt to the student group's needs.

Constructionism and pragmatism had in common the philosophy of children learning best by doing. Learning centered around the student's knowledge construction through unique experiences in their local environment. Both theories supported teachers who sought community-based problem-solving projects for STEM learning. Building, designing, creating, iterating, reflecting, and taking the initiative to solve problems were essential skills for meaningful learning. Community-based problem solving in STEM education found the teachers acting as facilitators of experiences (Öhman & Sund, 2021), while the students were at the heart of the design process (Noss & Clayson, 2015).

Researchers in STEM and STEAM education looked more closely at the possibility of preparing students to become engaged, empathetic citizens by focusing first on the local level (Bush & Cook, 2019; Holmes et al., 2021). Examining established literature for STEM and STEAM education identified areas for future research. One gap recognized was investigating a combination of community-based problem solving and innovative technology to design solutions to help others in our society. Students were transformed into inventive designers of solutions when using cutting-edge technology as a problem-solving tool (Ellis et al., 2020). The literature review was drawn together by threads of design thinking, the differences and similarities between STEM and STEAM education, and what it meant to teachers in the classroom.
An examination of community-based problem solving incorporated an older perspective of placed-based learning (Gruenewald, 2003) into a modern model centered on the school community (Webber, 2021). The literature review connected community-based problem solving

to empathy and care for others through innovative technology solutions. Theories of constructionism and pragmatism supported this view as students learned from the experiences of designing and creating solutions through hands-on learning. The literature synthesis built a purpose for STEM and STEAM learning, tying together the concepts of community-based problem solving, solving problems for others, and designing solutions using innovative technology.

STEM and STEAM Education

The STEM/STEAM education literature suggested researchers and practitioners wrestle with differing views of STEM education (MacDonald et al., 2020). Develaki (2020) described multiple definitions of integrated STEM education resulting in ambiguity and uncertainty. A firm understanding of integrated STEM education was needed but has yet to emerge.

The battle between STEM and STEAM was further complicated by pushback between leaders in the disciplines, which diverted attention from the real issue, the transdisciplinary space found within, between, and outside of the STEM disciplines (MacDonald et al., 2020). Turning to Bybee (2010), one of the leaders in early STEM education, STEM was primarily associated with science and mathematics, even though technology and engineering greatly influence everyday life. Johnson et al. (2021) supported this interpretation of STEM as a science-and-math-first framework supported by engineering and technology.

Bybee (2010) moved beyond the science-and-math-first definition by stating true STEM education should improve students' understanding of how things work and their ability to use technology and include more engineering concepts. Engineering was directly involved in problem solving and innovation, as described by Bybee. Dalvi and Wendell (2015) and Dalvi et al. (2016) proposed an engineering-centered STEM framework, giving younger students a strong start in STEM through engineering to solve problems. Students should learn about engineering, given its economic importance to society, and they should develop some of the skills and abilities associated with the design process.

The design process itself is what the STEAM leaders argued should be of paramount importance (Bush & Cook, 2019; Cook et al.). Bybee addressed the design process in the definition of STEM from 2010. Bybee stated that students must integrate the needed STEM disciplines and apply their knowledge to solve problems. Students' skills and knowledge should come from various sources, including other disciplines' standards not defined in the acronym STEM. With this broader understanding of STEM as an interdisciplinary or transdisciplinary framework to solve problems by designing solutions using all available knowledge and skills, it seemed STEM was a complete discipline for any problem-solving event.

Many authors agreed with the interdisciplinary and transdisciplinary nature of integrated STEM instruction (Bybee, 2010; Cunningham et al., 2020; Jackson et al., 2021; Johnson et al., 2020; Lo, 2021). Bush and Cook (2019) and Lo (2021) distinguished between interdisciplinary STEM, or two or more disciplines closely linked by concepts, and transdisciplinary STEM, which was two or more disciplines applied to real-world problems. While Johnson et al. (2020) and Aguilera and Ortiz-Revilla (2021) made the case that there was no single definition of STEM education, Johnson et al. stated it was one of the many challenges facing teachers because the purpose of STEM was based on the person talking about STEM. Aguilera and Ortiz-Revilla claimed STEM and STEAM education did not have a defined conceptual model that was widely accepted.

Bush and Cook (2019) argued that a STEAM definition including the arts allowed for more cross-disciplinary integration and focus on design thinking and problem solving rather than on mathematics and science. While mathematics and science content should still be taught, technology and the arts should be used to enhance the engineering process. Chung et al. (2022) added *i* for imagination, creating iSTEAM as a framework. This framework centered around students using their imagination and design thinking to solve engineering problems. The diversity of teachers' understandings and implementation of STEM integration was highlighted by issues related to the variety of conceptions surrounding the nature of STEM integration (Dare et al., 2021).

Jackson et al. (2021) asserted the most critical components of STEM education were access to high-quality integrated STEM instruction and learning experiences with opportunities for critical thinking, problem solving, and empathy. Jackson et al. explained that the acronym was not essential to STEM education. Instead, STEM education was about high-quality learning experiences for students. Each teacher would bring to STEM education a focus relevant to the local community, school, and areas of interest and need.

Design Thinking

As the debate between STEM and STEAM continued in academic literature, a pedagogical approach known as design thinking (DT) was added to the transdisciplinary discussion. Design thinking was found in the works of Bush et al. (2020), Cook and Bush (2018), Ladachart et al. (2022), and Reddy et al. (2021). Design thinking originated in the design world as early as the late 1960s (Cook & Bush, 2018). Since then, the term has been used to describe knowledge acquisition, a method of self-reflection, artifact production, and activity. DT could be used in an educational context of interdisciplinary or even transdisciplinary STEAM. Cook and Bush described DT as a blend of empathy, creative thinking, and rationality used to analyze and solve problems. Since DT incorporated the arts through creativity and imagination, Cook and Bush found DT complemented STEAM instruction.

Reddy et al. (2021) discussed the integration of design thinking into STEM education resulting in an increased awareness of the design aspect often missing in traditional STEM integration. Reddy et al. noticed creativity of more visual thinkers offered different solutions to problems. Ladachart et al. (2022) expanded on this idea by investigating where the problem-solving process through design thinking had the most significant impact. The authors concluded learning about science through the design-thinking approach to solving a problem was more beneficial to students than learning about science first and then designing solutions found in traditional STEM or separate science coursework. To incorporate DT into STEM was to embrace the transdisciplinary nature of truly integrated STEM education.

Community-Based Problem Solving

Community-based problem solving was grounded in the theory of place-based learning by Gruenewald (2003), who described it as an interdisciplinary approach to using the local environment to connect humans and place, grounded in the theory of place-based learning. Webber (2021) described place-based education as connecting youth to their natural and human environments. A place-based educational approach aimed to connect students to the greater community outside the classroom. Critical place-based learning was a version of place-based learning designed to challenge existing sociopolitical structures and disrupt colonial attitudes and beliefs (Logan, 2021). Logan added many well-meaning teachers implementing place-based learning was problematic and perpetuated assumptions about a Eurocentric approach. When students learned about the natural world and their relationships with the land without the lens of Indigenous people, it perpetuated colonial privilege. Critical place-based learning was admirable and worthy of more research, but it was beyond the purpose of this research study and was not part of the definition of community or place-based learning used here.

Sociocultural place-based learning was another view appearing in place-based literature. Unlike critical place-based learning, which was focused on decolonization and the support of Indigenous and marginalized people in place (Gruenewald, 2003; Logan, 2021), a sociocultural approach taken by Reid (2019) argued for place-based education extending learning into the local landscape using a hands-on approach to solve real-world problems to bring all students into the learning community of place. Jackson et al. (2021) saw an equity issue; the role of STEM learning should provide access for every student. Delivering high-quality, integrated STEM learning and connecting students with a community-based approach meant more students saw STEM learning as a place where they belonged. (Webber, 2021).

The Evolution of Place-Based Learning

Place-based learning evolved into a community-based learning model to connect students to the world outside their classroom (Campbell & Speldewinde, 2022; Merritt & Bowers, 2020; Roberts et al., 2021; Webber, 2021). Smith and Sobel's book on place-based education (2010) described a reconceptualization of place-based learning as a way of connecting classrooms and communities. Smith and Sobel contended an approach to learning offering real-world, hands-on learning experiences helped students commit to serving as actively engaged citizens, making communities a better place to live for everyone. Understanding the history of place-based and community-based learning guided this research through community-based learning based on Webber's model, which connected students to the world outside their classroom.

Community-Based Learning and STEM Education

According to Dewey (1916), alongside its scientific purpose, experience gained outside the school has a geographical, artistic, and literary element. “All studies arise from aspects of one earth, and the one life lived upon it” (p. 91). As in the work of Holmes et al. (2021), Garibay and Teasdale (2019), and Dewey (1916), the definition of community-based learning included a teaching approach for addressing local issues through transdisciplinary education; in this case, STEM education. Community-based problems tied to STEM instruction through multiple methods, including capitalizing on relationships with adult experts in the community and linking them to real-world careers. However, Holmes et al. recognized a lack of research in the literature despite the potential benefits of using community-based problems for STEM education.

Garibay and Teasdale (2019) noted the increasingly important view of community partnerships with schools. They encouraged amplifying successful programs and projects incorporating community and STEM education partnerships to reach more schools and communities. McLean et al. (2020) discussed elementary school students’ attitudes toward engineering design when local college engineering students volunteered as role models for a STEM program. While many studies focused on sustainability as the purpose of place-based learning (Häggström & Schmidt, 2020; Ritter et al., 2019), this lens did not address student-led problem solving and designing solutions in hands-on STEM education.

The current literature on STEM-related, community-based learning was either becoming dated (Dalvi & Wendell, 2015; Dalvi et al., 2016) or was informative rather than research-based (Lamb, 2020). Dalvi and Wendell and Dalvi et al. connected community-based learning and STEM engineering called community-based engineering, or CBE. Community-based engineering originated in an urban school setting where students identified a problem in the school and designed solutions to address the problem. Dalvi and Wendell purposefully chose an urban school setting to address an environment rarely seen as a focus for STEM instruction. The research team discussed how focusing on the local community provided an everyday lens through which students and teachers could view cultural and linguistic diversity as a resource rather than a barrier. Looking closer at this idea in 2023 based on teachers' perceptions of current community-based STEM projects might reignite this topic for additional study.

Connecting to Real-World Problems

Solving real-world problems was referenced in the literature to integrate STEM education across multiple disciplines (Gunckel & Tolbert, 2018; Johnson et al., 2020; Ortiz-Revilla et al., 2020; Rehmat & Hartley, 2020; Roehrig et al., 2021). Roehrig et al. described the importance of engaging students in real-world problems to connect STEM with their lived experiences in their framework for integrated STEM instruction. Rehmat and Hartley found a positive influence on personal and academic development. The classroom became more student centered with critical thinking as students explored solutions to real-world problems. Rehmat and Hartley argued STEM integration combined with problem-based learning ignited curiosity and creativity in students, especially younger students. Real-world problems could be found in the school community (Holmes et al., 2021), addressing issues in the school building, the playground, and the greater community, circling outward as needed. Drawing on students' personal and community interests and their lived experiences would be more motivating for them.

Dalvi and Wendell (2015) used an urban school setting as a place to identify and solve a real-world problem. When solving real-world problems, students recognized how STEM related to the world and how skills learned in STEM were helpful when dealing with real-world issues, meaning STEM was valuable for solving problems in their lives (Jackson et al., 2021). Roehrig et al. (2021) stated many students struggled to relate to traditional STEM approaches and were not focused on developing solutions to real-world problems. Ortiz-Revilla et al. (2020) recognized the need for a set of epistemological views shaping how students view, act, and understand their world. Prioritizing social and cultural meaning through integrated STEM achieves this goal.

Community-Based Problem Solving and Its Impact on Learning

When applied to local problems, project-based learning could effectively reframe STEM education (Bascopé & Reiss, 2021; Roehrig et al., 2021). Nava and Park (2021) described a version of community-based learning as Community-STEM-Project Based Learning (C-STEM-PBL), a pedagogical tool teachers could use to challenge students to think critically about their community and respond with solutions to provide a greater good for others. According to Nava and Park, content knowledge, collaboration skills, and autonomous learning were benefits of C-STEM-PBL.

Holmes et al. (2021) described how localized learning accelerated STEM achievement by increasing critical thinking, creative thinking, flexible thinking, and problem solving. Students established themselves as contributors to their community when they addressed an authentic need and investigated a design to improve the conditions for others (Cook & Bush, 2018). Applying their knowledge of science and mathematics to solve a problem for someone else built soft skills necessary for a healthy society, such as empathy (Letourneau et al., 2021; Shek & Chung, 2018). Combining content areas provided a transdisciplinary experience building students and the community's capacity for resilience when combined with a local purpose (Bascopé & Reiss, 2021).

Holmes et al. (2021) mentioned other advantages of localized learning, such as increased enjoyment and interest by students, career interests, and skills transferred to other areas. Webber

(2021) described the benefits to individuals beginning to learn through local explorations and expanding outward, including love for their place and a social and ecological sense of justice. Cook and Bush (2018) described many benefits of learning, including transferring knowledge between subjects, collaborating, ideating, and reflecting on learning. Nava and Park (2021) found C-STEM-PBL challenged students to think critically and act in community-related contexts, contributing to the greater good.

Local learning was not without its limitations. Holmes et al. (2021) reported lessons based on community problems could be time-consuming, and organizing trips outside the school grounds could pose a significant challenge. Managing behavior was another issue once students left the school grounds. Negative behavior had an impact on the timeframe and quality of community-based learning. Logan (2021) found teachers had frustrations stemming from a lack of support from administrators for taking students outside the classroom to learn. Teacher planning was another issue, as was gaining participation from community members (Holmes et al., 2021). Holmes et al. suggested teachers consider partnerships less obvious and suggested using creative ways to collaborate with others.

Connecting to standards and place-based or community-based learning was a challenge addressed by Semken and García (2021), Merritt and Bowers (2020), and Engels et al. (2019). Semken and García addressed the philosophical compatibility of Next Generation Science Standards (NGSS, 2013) with place-based learning. Through their discussion, Semken and García made a case for universal and global NGSS standards with little mention of local study and interaction. Engels et al. proposed a confluence approach to align NGSS standards with project-based learning and place-based education. This confluence approach improved students' critical thinking and problem-solving skills. Tying authentic learning and solving problems in the local community with a confluence approach to aligning NGSS standards addressed teachers' need to maintain curriculum relevance with assessments and scientific practices. Furthermore, Semken and García recommended teachers utilize a backward-design process (Wiggins & McTighe, 2011) to develop curriculum-bundling standards with place-based education.

Solving Problems for Others

In the 21st century, success in the workplace requires cognitive skills such as communication skills and social-emotional skills such as empathy (Garner et al., 2018). Garner et al. described children who were curious and actively engaged in learning as better able to regulate emotions, thus performing better in school. Cook and Bush (2018), Nava and Park (2021), and Webber (2021) all mentioned the benefit of community-based learning for students in learning to solve problems for others. Other research supports this finding, including Edelen et al. (2019a), who described buy-in from and engagement of students established through a lens of empathy when developing the problem statement. Facilitating an empathetic response while solving authentic problems introduced students to the possibility of becoming the engineers of tomorrow who will solve our world's many multifaceted, complicated, and transdisciplinary problems as described by Edelen et al.

A review of the literature on empathy in STEM revealed that very little research in this area of K-12 education was published before 2017 (Burns, 2021). Previous research on empathy in STEM was conducted at the college level to incorporate empathy into professional engineering (Burns, 2021; Burns & Lesseig, 2017). Between 2013 and 2018, the American Society of Engineering in Education (ASEE) saw a 400% increase in papers on empathy in engineering (Burns, 2021). Interest in empathy and engineering was spreading to K-12 research in higher education.

The importance of empathy in engineering design practices was a crucial tenet to the success of girls and women in STEM classes and STEM fields identified by Burns (2021), Calabrese Barton et al. (2021), Letourneau and Bennett (2020), and Lottero-Perdue and Settlage (2021). Students experienced what it was like to be in a specific situation or environment, increasing excitement for solving the problem which lasted throughout the investigation (Cook & Bush, 2018; Shek & Chung, 2018). According to Letourneau and Bennett, additional research would provide techniques for incorporating empathy into STEM instruction.

Garner et al. (2018) acknowledged the first step toward becoming a global citizen was demonstrating an awareness of others and a sense of social responsibility by participating in community-based solutions. Gunckel and Tolbert (2018) supported this by adding caring, compassion, and empathy to engineering. They questioned whether technical knowledge was enough to solve the increasingly complex problems of the world and whether students should be able to take multiple perspectives of the people impacted by design solutions. Gunckel and Tolbert argued that without adding care and concern for others to design solutions, the STEM curriculum ran the risk of a utilitarian technocracy without regard for the impact on people or the environment. A utilitarian technocracy ran counter to the goals of community-based learning, where people and the environment were considered first, and solutions considered second.

Defining Care

Understanding the human element of engineering was necessary for tackling complex problems in the real world. Engineers were responsible for considering the needs and priorities of the people who would use their designs and their work's societal and ethical implications (Letourneau & Bennett, 2020). Empathy was connectedness, self-reflection, and perspective-taking as defined by McCurdy et al. (2020) and Hess et al. (2017). A behavioral expression of empathy defined by Letourneau and Bennett included having an emotional response, taking others' perspectives, and expressing a desire to help. Building awareness of empathy and care meant understanding how others feel and acting on it with internalized understanding (Lottero-Perdue & Settlage, 2021). A look at the literature on adding care in STEM education found a variety of descriptors, including an ethic of care (Lottero-Perdue & Settlage, 2021), social-emotional learning (Garner et al., 2018) and empathy (McCurdy et al., 2020).

McCurdy et al. (2020) found empathy to be a concept that was not new, but rather a characteristic often left out of STEM instruction. McCurdy et al. (2020) and Cook and Bush (2018) found the transdisciplinary nature of excellent STEM education, infused with design thinking pedagogies, was a crucial place to include empathy while solving problems for others. Gunckel and Tolbert (2018) and Calabrese Barton et al. (2021) added the combination of empathy with problem-based learning and design thinking was a pathway to improve interest in science through an emotional connectedness.

Gunckel and Tolbert (2018) made a case for adding a dimension of care to engineering education and attempted to reframe design challenges in sociopolitical issues. Roehrig et al. (2021) picked up this line of thinking and included it in a framework for integrated STEM education. Shek and Chung (2018) added that empathy promoted positive development in adolescents, showed a decrease in anxiety and distress, and increased leadership and confidence. Real-world problems such as community-based problems provided students with experiences of increased engagement.

Roehrig et al. (2021) and Jackson et al. (2021) suggested STEM teachers should explicitly address how students' solutions addressed a broader context, including sociopolitical issues. Sociopolitical and socioscientific issues are humanitarian issues or the greater good for all

(Gunckel & Tolbert, 2018). Gunckel and Tolbert addressed this by discussing power and inequality and developing student empathy. They concluded humanitarian approaches incorporated many of these issues, and empathy in engineering should address how problems were defined and the impact of the solutions. Jackson et al. identified empathy as a disposition necessary in high-quality, integrated STEM experiences to create equitable access to STEM learning for all students.

Humanizing STEM

Addressing sociopolitical or socioscientific issues in STEM education also involved an epistemological view that STEM fields have a role in a full range of skills required for students to participate as citizens in society (Ortiz-Revilla et al., 2020). The C-STEM-PBL framework described by Nava and Park (2021) aligned community-based teaching and learning with culturally responsive and humanistic pedagogy. Nava and Park proposed C-STEM-PBL connected teachers and students to the wealth of resources available in a community's people and organizations. STEM taught in a community-based model such as the one described in Nava and Park challenged students to use community-based problems to think critically and act in a human-centered way. Teachers interested in humanizing STEM through community problem solving would benefit from an analysis of how current STEM teachers used innovative technology to facilitate community-based problems and design challenges in Grades K-8.

Benefits of Integrated Learning Through Care and Empathy in STEM

When integrated, community-based STEM projects challenged students to create solutions for others, students learned STEM skills that contributed to the greater good of humanity (Edelen et al., 2021). Empathy helped students see themselves as having a role in finding solutions to problems (Calabrese Barton et al., 2021; Jackson et al., 2021). According to

Jackson et al., empathy was an access point for students to identify how STEM impacted their own life and the lives of others. This made the learning experience more meaningful to students. Bush et al. (2020) described students' perceptions after participating in empathy-based STEAM projects. Students showed a strong desire to solve problems for others, and their perceptions expanded because they could connect and feel for someone in a situation that did not apply to them directly.

The work of McCurdy et al. (2020), which supported the empathetic approach to designing solutions, found this combination of integrated STEM learning and solving problems for others was transformative and addressed the concerns Gunckel and Tolbert (2018) had about a lack of empathy and care in engineering practices. Paying attention to the human element connected the dots between community-based problem solving and solving problems for others with care and empathy.

Calabrese Barton et al. (2021), Lottero-Perdue and Settlage (2021), Letourneau and Bennett (2020), and Burns and Lesseig (2017) found the importance of empathy in engineering design practices was a crucial component to the success of girls and women in STEM classes as well as STEM fields. The students experienced what it was like to be in a unique learning environment, capturing their attention. Their interest in finding a solution to the issue kept students interested and motivated throughout the investigation (Bush & Cook, 2019).

Students unable to participate in STEM education due to various obstacles could now do so with the help of an equity-oriented framework for STEM literacy in Grades K-12 (Jackson et al., 2021). When empathy was part of a STEM education curriculum, students developed a deeper comprehension of their function as stakeholders in finding solutions to other people's problems. Engagement increased as students solved problems for others and participated in discussions and collaboration among students (Bush & Cook, 2019). Learners gained access to a new level of understanding through the development of empathic understanding, which also increased their sense of agency and participation (Jackson et al., 2021).

Empathy Through Perspective Taking and Narratives

Perspective taking in STEM involved internalizing another's thoughts and feelings (Hess et al., 2017). Perspective taking could be transformative as students reflected on their ability to feel or understand what another was feeling (Nelems & Theo, 2018). Engineers rarely interacted with the people for whom design decisions were made. Therefore, the ability to imagine their needs required perspective taking. In their research, Hess et al. (2017) found taking perspectives most dissimilar to their own sparked a shift in students' decision-making and solutions. In addition, Hess et al. found several different perspective-taking themes, including sharing diverse perspectives, imagining oneself in a situation, and experiencing cognitive dissonance.

Letourneau and Bennett (2020) used storytelling narratives to elicit empathy and engage adolescent girls in the engineering design process by having them imagine themselves in a situation. They discovered narratives increased analytic problem solving and solution designs by promoting emotional connections to the problem. Empathizing through a narrative was found in very young students in Lottero-Perdue and Settlage (2021). Kindergarten students used empathy to solve a problem in a narrative without instruction, rejecting formal instructions in favor of helping and easing suffering. The results found not only empathy through perspective taking, but an individual call to action in kindergartners.

Edelen et al. (2019a) discussed using problem statements to spark buy-in and elicit an empathetic response from students. Carefully developed problem statement narratives allowed for multiple approaches to solving a problem, whole-class discussions, and solving a problem for someone in need. Using a narrative approach with a community-based problem set up a scenario for students to solve problems for others, role-playing stakeholders, and experts in the field (Letourneau & Bennett, 2020).

Cheek et al. (2022) sometimes noticed teachers with the best intentions inadvertently caused a limitation on students' creativity by providing them with models or adding empathetic characters to the narrative. Students' concerns for the characters impacted their creativity out of fear or pressure to solve a significant problem. Their research also showed once students had a solution in their minds, they had great difficulty visualizing other possibilities. Addressing issues as they appeared and being aware of potential drawbacks left room for students to be creative, research, and design solutions without overdone scaffolding and models or real-life interactions (Cheek et al., 2022).

Innovative Technology Solutions

Using innovative technology in STEM required students to learn new technology skills to solve a problem. Ellis et al. (2020) asserted the lack of a definition of technology in STEM often meant it was left out or underrepresented in the STEM curriculum. Defining technology in STEM was complicated because it was rarely described in the literature (Roehrig et al., 2021). Leinonen et al. (2020) distinguished between learning technical skills and applying those skills creatively to solve a problem. Ellis et al. asserted that the education community needed a clearer idea of how technology worked in STEM education.

Quigley et al. (2020) discussed technology integration in STEM as connected closely to the maker movement. Makerspaces took on an informal atmosphere, blending technology with playful or creative problem solving. Quigley et al. implied making should be integrated into the problem-solving technology integration of STEM learning every day. A relaxed approach to technology integration allowed teachers to connect with technology options for students they already used in life outside of school, such as video production, robotics, game design, and digital drawing. One definition of innovative technology was tools for teaching and learning content (Johnson et al., 2021). By using innovative technology, students connected to real-world applications of STEM, and technology became part of learning. Jackson et al. (2021) maintained participation in society, enhancing education in other subject areas, and obtaining future jobs necessitated technological literacy. Innovative technology was constantly changing and was described herein as general categories rather than specific applications.

Ellis et al. (2020) distinguished between instructional tools, technology resulting from engineering, computational thinking tools, and tools used in STEM careers. McCurdy et al. (2020) differentiated between technology presentation and specialized tools as part of the problem-solving process. This distinction informed the definition used for this study. Innovative technology was defined as new technology tools or technology tools used in a new way in the problem-solving process.

Gunckel and Tolbert (2018) cautioned against a technocratic perspective employing technology solutions without addressing the humanistic and sociocultural aspects. They contended a belief in technology as fundamentally sound without considering what was good or whom it benefited often favored the majority culture. Ellis et al. (2020) found only some STEM teachers were fully ready to use technology in innovative ways. Many teachers thought of technology as digital tools (Dare et al., 2021) and no other forms of technology, such as the product of engineering. Dare et al. also found teachers were concerned about an overreliance on technology when students had ample screen time in their personal lives. Because of misconceptions surrounding technology in STEM education, teachers needed to keep growing their technology skills and support technology instruction before it was integrated into STEM instruction in a transformative way (Ellis et al., 2020).

Examples of Innovative Technology in STEM

Building on the definition of innovative technology as tools for problem solving or the product of engineering, examples of innovative technology included coding and robotics, creative media, 3D fabrication and modeling, simulations, augmented reality (AR), virtual reality (VR), data collection and analysis, and communication. Modeling, designing, and building solutions to community-based problems could take any form and was, according to Ellis et al. (2020), dependent on how teachers chose to use technology in the classroom.

Coding and Computational Thinking. Scherer et al. (2021) claimed coding was becoming an increasingly important skill for solving complex scientific problems quickly and consistently. Many countries worldwide were starting coding initiatives and incorporating computational thinking into their curricula at all levels of education, from higher education to secondary school to elementary school and kindergarten. Ellis et al. (2020) included coding and computational thinking as one of the leading perspectives of technology in STEM education.

Coding and computational thinking were increasingly necessary skills to successfully work with many different forms of technology in integrated STEM education (Ellis et al., 2020). Teaching coding and robotics using an integrated STEM approach improved students' attitudes, interests, and work habits. It also increased teachers' knowledge of their students' needs, increased collaboration among teachers, and promoted substantive and critical learning as described by García-Carrillo et al. (2021). Yepes et al. (2021) pointed to coding as an essential skill in drone technology. Scherer et al. discussed the cognitive benefits of systematic problem solving in coding concepts. Coding and computational thinking tied well to the mathematical discipline in STEM. Mathematical modeling required decomposing a problem into parts, understanding relationships, using symbols to represent relationships, and applying algorithms to a solution. Artificial intelligence (AI) was another form of computational thinking and coding (Sung & Kim, 2021) growing in use in STEM classrooms but still emerging in the literature. For many people, artificial intelligence meant a machine could think like a human. Artificial intelligence was built on the idea machines could learn new things independently. This meant that devices could be programmed to learn rules and parameters independently, just like humans.

Drones and Robotics. Lamb (2020) described how drone technology crossed into community-based learning when aerial photography solved local problems such as water run-off, flooding, erosion, and permeable ground cover. Providing different perspectives from drone photography encouraged creativity and integration of other technology, such as 3D printing and coding. Yepes et al. (2021) described how drones could reinforce content and integrate it into learning when properly applied. Lamb (2020) explained how incorporating drone technology into hands-on, location-based activities connecting students to real-world global projects was an effective way to engage students. Yepes et al. said using educational robotics like drones in the classroom allowed students to take an active role in the learning process. An active role in learning enabled students to participate in creating and interpreting their knowledge rather than simply memorizing facts and taking tests. Drones connected students to real-world careers in archaeology, law enforcement, wildlife tracking, and medicine. Finding community-based professionals willing to share their experiences with drone technology connected students to local communities, creative problem solving, innovative technology, and STEM careers.

3D Printing and Fabrication. According to Alexander et al. (2019), digital fabrication and design improved students' self-efficacy and self-identity in STEM education. For the first time, students received hands-on experience with cutting-edge technological tools previously reserved for research and development facilities. Alexander et al. discovered several practical classroom applications from their research. Teacher support was required for the successful implementation of digital fabrication activities. A supportive community of practice was essential for teachers to discuss the many issues cropping up during digital fabrication activities. Trust and Maloy (2017) described how 3D printers provided a constructionist experience for students, encouraging play, discovery, and design while solving problems. Trust and Maloy explored how teachers' perceptions of 3D printing technology developed students' creative thinking and design skills.

Cook and Bush (2018) described a 3D printing project involving creating a tool to allow a keyboard stroke combination for a student with a hand disability. Printed designs in 3D were coupled with an inquiry project surrounding the problem of homelessness in Edelen et al. (2021), bringing empathy and sociocultural issues to STEM inquiry. Another study by Edelen et al. (2019b) combined a narrative storyline to engage students in developing a solution requiring robotic prototypes to transport a student in a wheelchair. Other creative technology solutions included digital fabrication found in Alexander et al. (2019) and those described by Quigley et al. (2020), including paper circuits, programmable robots, Little Bits programmable blocks, and Hummingbird robotics kits.

Creative Media. Quigley et al. (2020) revealed students today know how to use various technological tools to solve problems, including video production, game design, and digital drawing or sketching. Very little research has been done to identify ways students could use creative media in STEM education to solve problems. Students could use creative media to communicate findings to the community or the world. Creative media tools could also gather data through video capture tools. Hackett-Hill (2022) discussed the value of podcasts as a tool for nonfiction narrative writing. Podcasts took the place of other forms of assessment, such as essays or presentations, and were a tool that could relay information to stakeholders. Giving students a voice through audio and video recordings empowered them and gave them the possibility of creating a global platform (Miller, 2020). Game-based learning was frequently used to synthesize technology skills, including coding, digital drawing, virtual reality, and simulations (Lærke Weitze, 2019). Through game development, students tapped into their creativity and critical thinking skills to create digital content to solve problems.

Augmented Reality and Virtual Reality. Augmented reality (AR) and virtual reality (VR) allowed students to explore virtual worlds and create virtual worlds of their own (Miller, 2020). By overlaying computer-generated imagery on top of a real-world environment, augmented reality (AR) merged physical and digital realities in real time (Trust et al., 2021). Virtual reality (VR) allowed a person to explore or become a part of a virtual world. Within a virtual world, a person could interact with and manipulate objects. Research on AR and VR in STEM education was still emerging, but promising uses included controlling a prototype before 3D printing and exploring a remote location for study.

Data Collection. It was common in science classes to use probes and sensors, such as those created by Vernier LabQuest® (Ellis et al., 2020). Probes and sensors allowed students to collect data in many different ways, analyze the data, and design a solution to solve a problem. Yepes et al. (2021) also used drones to gather data for analysis. This combination of technology led to a connection between technology and scientific inquiry for students.

Communication, Communication technology had various tools students could use to share their learning and solutions with a global audience (Miller, 2020). Blogs, email, social media posts, video conferencing, podcasting, and video sharing were just a few ways students could communicate their STEM learning. The 21st Century Skills (Battelle for Kids, 2019) listed 12 essential skills students would need to participate successfully in tomorrow's careers. While not entirely technology related, the 4 Cs of communication, collaboration, creativity, and critical thinking were ubiquitous in describing students' technology skills. Communication skills were essential skills for students to develop. Integrated, transdisciplinary STEM education was where communication skills could develop naturally as part of learning (Jackson et al., 2021).

Benefits of Learning Through Innovative Technology

According to Quigley et al. (2020), technology in STEAM instruction was closely linked to the maker movement, as it encouraged students to think creatively, explore ideas, and innovate. The Department of Education, Office of Educational Technology, and Digital Promise (DOE, OET & DP, 2019) outlined nine ways STEM learning benefited from technology. From this study, several benefits were found connecting directly to the idea of innovative technology used as a solution for problem solving. Dimension 4 involved the use of technology to promote scientific argumentation. By collecting evidence with digital tools and probes and taking digital photographs at different times of the year, students could effectively capture, organize, and display evidence. Benek and Akçay (2022) argued socioscientific issues did not have clear solutions as one way to have students develop scientific argumentation as found in Dimension 4. Socioscientific inquiry (SSI) benefits included increased scientific knowledge; gains in emotional responses, values, and beliefs; and improved leadership and communication skills combined with an engaging narrative and the engineering design process (Kinslow et al., 2019). Kinslow et al. suggested including alternative fuel, recycling, and environmental issues, while Benek and Akçay (2022) suggested biotechnology and global warming topics.

Dimension 5 involved engineering design, where students tested problems and solutions using appropriate technology. Through this process, students gained higher-order thinking skills and problem-solving skills. In Edelen et al. (2019b), students learned to program robots to solve problems involving students who needed help. Authentic problem solving took students through many task iterations to solve the problem. Dimension 6 applied computational thinking to solve problems through algorithms, data, and simulations, where students gained skills in computational thinking and showed gains in logical thinking, algorithms, and analysis. Dimension 7 involved students using digital technology in the context of a challenge during interdisciplinary project-based learning. Technology communicated ideas and facilitated collaboration for learning how to apply technology skills to other content areas. Students who used technology during authentic STEM learning showed lasting self-efficacy and self-concept toward STEM instruction and careers (Alexander et al., 2019).

According to Quigley et al. (2020), STEAM instruction provided technology options such as video production, game design, robotics, digital drawing or sketching, and connecting with peers to share creative problem-solving solutions. Quigley et al. discovered teachers who let students direct their own learning provided more inquiry and opportunities for students to create authentic tasks. While technology played a role in STEM education, teachers made instructional decisions based on evidence that a particular approach would improve students' learning outcomes. Students had to access learning experiences enhanced by technology to prepare them for life and work (DOE, OET & DP, 2019).

Chapter Summary

Taking a local approach first to prepare students to become engaged, empathetic citizens was receiving closer examination by researchers in STEM education (Holmes et al., 2021).

Community-based problem-solving STEM challenges taught students soft skills such as care and empathy (Edelen et al., 2019b, 2021; Gunckel & Tolbert, 2018; McCurdy et al., 2020) while connecting students to events outside their classroom doors. Cook and Bush (2018), Nava and Park (2021), and Webber (2021) all made a case for positive learning benefits when students integrated multiple disciplines while solving problems based on the needs observed around them—using innovative technology as problem-solving tools transformed students into creative designers of solutions, emulating the real-world careers of scientists and engineers. (Ellis et al., 2020). Education had the potential for social good (Hacker et al., 2017) by identifying societal problems and designing solutions using innovative technology and engineering.

One issue facing community-based STEM learning was teachers' lack of a curriculum. With community-based STEM learning, teachers had to design learning outcomes specific to the needs identified in the community (Holmes et al., 2021). Many teachers had yet to receive training in this form of STEM curriculum design. A gap existed in the literature tying all three themes of community-based problem solving, solving problems for others, and using innovative technology to solve problems. This research study aimed to find and amplify exemplary STEM projects created by students and teachers in K-8 schools, seeking to understand how teachers found local problems, built care for helping others, and used innovative technology integrated into STEM learning. Next, the methodology section outlined the planning and procedures for this qualitative case study. Included were the research questions, research design, methodology, and procedures.

Chapter 3: Methodology

Educators have shifted their focus from what students need to know to how to empower learners in the inquiry process and use innovative technology in the process (Quigley et al., 2020). Lessons centered on community-based issues connect to students' lived experiences, deepening learning and highlighting the underlying value of solving problems to help others. Including the human experience in science, technology, engineering, and mathematics (STEM) acknowledges STEM's impact on improving the human condition (Johnson et al., 2021).

The problem was a lack of connection between community-based problems with standards and pedagogy designed to develop a globally competitive workforce. Lack of community accountability and an increased emphasis on global competition create a disconnect between what is taught in school and life outside of school, as well as the need to think critically and shape what happens there (Gruenewald, 2003). The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. In STEM classes, students must consider community problems and potential solutions from the perspectives of those impacted by the designs (Gunckel & Tolbert, 2018). The following questions drove this study:

Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?

Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?

Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?

The following sections describe the research methods, design, and the problem addressed through the research, purpose, and research questions. A discussion of the study's design includes information about the population and sample of the study, data collection methods, reliability, validity, coding, data analysis methods, and ethical procedures. Lastly, a summary of the study's methodology is provided.

Research Methodology, Design, and Rationale

Qualitative research as a methodological approach is used to explore how individuals perceive an idea or problem (Creswell & Creswell, 2018). To effectively capture the rich experiences and insights of participants, the research design choices become crucial to the outcomes of the study. The selected research design must align with the overall goal of the study, which explores teachers' perceptions of how students can solve community-based problems with innovative technology.

Methodology

A qualitative approach allows for a comprehensive exploration of the lived experiences of the participants. Qualitative research is the best choice when exploring a central phenomenon from the perspective of the participants (Creswell & Creswell, 2018). In qualitative research, the exploration and description of the phenomenon does not lend itself to quantifiable measures. A quantitative methodology was considered to measure the growth of empathy in children but was rejected because the research questions required an in-depth exploration of the insights and experiences of teachers. A qualitative approach permitted the exploration of actual responses from teacher participants, listening and understanding to what was said, and then using that knowledge to provide insight into the trends in STEM education.

Design

According to Creswell (2009), case studies serve as a method for conducting in-depth investigations on human-related events, activities, or processes. In the context of this study, teachers were asked to reflect on the experiences and perceptions they felt influenced their practices in a STEM classroom. Creswell (2009) emphasized that cases in a case study are bounded by time and activity, allowing researchers to use a variety of data collection. Greig et al. (2013) highlighted that this design allows for the in-depth exploration of a case using multiple forms of data collection, such as interviews and lesson plan documents. In this research, the case study design served a dual role, both descriptive and instrumental. Not only did the study provide the perceptions of K-8 teachers in planning community-based STEM projects, but it also was instrumental in providing understanding and insights into their specific instructional practices aimed at STEM learning.

Role of the Researcher

I served as an interviewer, data collector, and analyst in this qualitative case study. As the aim of the study was to explore teachers' perceptions of how students use technology to solve community-based problems, it required essential skills for case-study research as described by Yin, 2018. Yin explained how having good questions, listening well, remaining adaptable to new situations and information, deeply understanding the content of the study, and conducting the research ethically and professionally were necessary skills for case study research. One of the ethical concerns for a researcher includes being aware of bias and preconceived notions. Before becoming a researcher, my experience as a STEM teacher spanned 8 years. Any relationships with participants were strictly professional and limited to professional learning networks (PLNs). I had no supervisory or influential power with any participants.

Research Procedures

This study addressed a lack of community-based problem solving in elementary STEM classrooms and teachers' perceptions of how students could solve community-based problems with innovative technology. An instrumental, descriptive case study design as recommended by Yin (2013) and Hancock and Algozzine (2017) captured the perceptions of K-8 STEM teachers in planning community-based STEM projects. The primary goal of this study was instrumental – to better understand teachers' involvement in planning and facilitating community-based STEM problems. The following research procedures, including population and sample selection, data instruments, and interview protocol are provided in the sections that follow. All research procedures were approved by the Institutional Review Board (IRB) before the research began (see Appendix A).

Population and Sample Selection

Deciding on a target population requires consideration of the research objectives (Guest et al., 2017). The target population required expertise and experience in STEM education in grades K-8. According to Guest et al. (2017) being able to compare between and among groups requires a smaller target population of teachers within a similar geographic location, The target population for the research was K-8 STEM teachers in the Midwest United States. The population was decided to facilitate sampling from local professional communities. According to Guest et al. (2017), sampling is an important part of research design, and the degree of generalizability to the larger population is impacted by sampling choices.

Participants were recruited by three methods: social media posts, professional organization forums or communication materials, and participant referrals, or snowball sampling. The gatekeepers included organization sponsors and administrators. An email or direct message was sent to the individuals in charge of sharing research studies with the group members. This email or message introduced the project and explained the purpose and overview of the case study (see Appendix B). Site permission documents for participant recruitment are recorded in Appendix C.

According to Emmel (2013), purposeful sampling, also called judgment sampling or purposive sampling, is planned before the research begins and might change as the investigation continues. Emmel (2013) elaborated on how the purpose of the study, its context, and consideration of the research's target audience impact sampling decisions. Purposeful sampling included posting or sending an invitation to potential participants (see Appendix D) with a link to a screening survey on the Qualtrics website (see Appendix E). The initial purposeful sampling did not return a minimum of 15 participants, therefore snowball sampling asked participants to please share with colleagues who were not part of the social media or email lists but might be interested in participating.

Social media also had the potential for coverage bias, where some potential participants were excluded from the sample due to their lack of participation in social media groups—contacting state-level professional teaching organizations for permission to contact members of the target population addressed this issue.

The screening survey opened with an informed consent box for participants to approve before being able to complete the electronic questionnaire. The questionnaire assessed their STEM teaching experience with community-based projects or innovative technology solutions (see Appendix E). The target population for the screening survey was 20 participants. This purposeful screening of participants helped identify prospective participants for a semi-structured interview. Fifteen participants comprised the sample.

Demographic information from the survey was handwritten in a notebook and kept in a locked cabinet. Each subject received a five-digit identification number for data collection. Once participants submitted the screening questionnaire, a determination was made if they met the selection criteria. Inclusion criteria included teachers who had experience with community-based STEM projects, teachers who used innovative technology with students in STEM classrooms, and teachers who used STEM to solve problems for others. Teachers were excluded if their experience was limited to simple challenges requiring only minor problem-solving skills and which were completed in 1 or 2 days.

Participants who met the selection criteria received a follow-up email from an ACE account asking to schedule a time for a 30-minute interview. Prior to the interview, potential participants received an additional informed consent document to sign and return (see Appendix F). The informed consent explained the study's purpose, voluntariness, and how to withdraw from the study.

Yin (2018) argued each case was a holistic, individual case study in a multiple-case design and should be treated as such. Because the sample size was 15 participants, multiple-case designs needed to follow a replication logic rather than a sampling logic. Yin identified a flaw when generalizing from case studies to the larger population. Instead of the cases being a sample of the population, they were considered lessons learned from the participants, shining a light on their lived experiences.

Data Instruments

The data collection sources comprised semi-structured interviews and lesson plan documents. The study began with a screening questionnaire to find K-8 STEM teachers with experience in areas relevant to the study, community-based problems, innovative technology, and solving problems for others. From the screening tool, 15 participants were invited for interviews. From the interview participants, a selection of teachers was asked to share a lesson plan document showcasing a STEM project relevant to the research questions.

Participant Screening Questionnaire

Consistent with Longhurst (2016), recruiting participants for semi-structured interviews might take a variety of approaches. A brief screening questionnaire was used in this research to collect basic information and asked participants whether they were willing to engage in a follow-up interview at the survey's conclusion. Yin (2018) described the purpose of screening to select individuals for interviews who fit the inclusion criteria before any data collection. In addition to this method, Longhurst claimed researchers increasingly used social media to recruit new subjects. With the approval of group administrators, a link to the screening questionnaire was distributed to target social media groups. Using professional organizations to locate participants narrowed the range of interview candidates to those who most closely fit the study's aim.

Interview Protocol

Participants took part in 30-minute semi-structured interviews using an interview protocol. The interview protocol created some standardization during the process as described by Billups (2021). The interview protocol (see Appendix G) was strictly followed with planned follow-up and probing questions to minimize the introduction of bias. The interview protocol consisted of semi-structured, open-ended questions that allowed the collection of information relevant to the research questions, with follow-up questions drawing out individual experiences. The questions moved from introductory items to establish rapport, introduce the research to the participant, and move into the key questions. Follow-up questions and probes were included to provide some structure to the interview while still allowing the participants to answer with their perspectives and stories. Billups stated qualitative interviews captured an individual's stories, experiences, perspectives, and feelings.

The instrument designed for the semi-structured interviews required original questions aligned to the research questions and the purpose of the study. Billups (2021) provided a semi-structured interview protocol template to guide question development. Based on Yin's recommendations, bias-prone areas were avoided through subject matter expert review of the interview questions. The instrument was sent to three separate subject matter experts (SMEs) for item validation and feedback. The SMEs were all current teachers in STEM-related disciplines. Feedback was used to modify and improve the questions. Screenshots of subject matter expert email and feedback are included in Appendix G.

Document Review

Lesson plan documents provided physical evidence associated with the research investigation. Lesson plan documents supported the data from the interviews with real-world examples (Hancock & Algozzine, 2017). Written lesson plans showed evidence of teacher planning in action. Three to five lesson plans were the target goal for this research. Participants contributed four lesson plan documents by emailing them to an ACE email account. Lesson plan documents were stripped of identifiable information and saved on the removable drive designated with the participant’s code identifier.

The lesson plan documents were used to compare what was said in the interviews with evidence of the experience as described by Billups (2021). Billips explained how documents and artifacts were frequently used in qualitative studies to triangulate data. Documents, according to Billups, provided context and created confidence in the research interpretations. Yin (2018) cautioned that documents might not be bias-free and should not be taken as literal transcripts of events. However, Yin added, documents could corroborate evidence from other sources. Reviewing lesson plans sent in by participants provided additional evidence and context of STEM education in action. The review involved matching the lesson plan with the interview transcript to corroborate the participants' experiences with the lesson planning documents.

Data Collection

Data were collected in two ways, a semi-structured interview provided perspectives and descriptions of teachers in the field, and lesson plan documents provided an additional look at evidence of how teachers planned for STEM instruction aligned with the research questions.

With site administrator approval (see Appendix C), a link to a screening questionnaire as posted with permission on Facebook groups, professional community forums, and listserv groups with STEM teachers. Qualtrics was used to collect and store the questionnaire data. The screening questionnaire used six questions to identify participants who matched some or all of the inclusion criteria. Brenkert-Smith et al. (2018) recommended Qualtrics as an electronic survey tool to define the study population and recruit participants. The screening questionnaire ensured prospective participants met the inclusion criteria.

Once the questionnaire data were collected and inclusion criteria verified, 20 participants were contacted through the email provided in the survey and invited to share more in an interview. Each participant received an email with interview scheduling information. Interviews took place over video conferencing via Zoom and lasted 30 minutes. Archibald et al. (2019) found Zoom technology was easy to use, secure, interactive, and could help users connect personally. Zoom was a good place to conduct qualitative interviews compared to other commonly used VoIP technologies. Zoom Video Communications, Inc. (2021) addressed concerns regarding security through cloud recording storage. Recordings were processed and stored in Zoom's cloud. A passcode protected the cloud recordings. Cloud recording and audio transcripts were encrypted for storage. Only the account owner could see encrypted content stored in Zoom Cloud.

During the interviews, if a participant shared a compelling lesson idea, a copy of the lesson plan was requested and received via ACE student email account. Sharing lesson plans was completely optional for the participants. Consent for the lesson plan documents was included in the informed consent documentation (see Appendix F). Data were organized according to the numerical identification code for each participant. Transcriptions and other documents were saved and archived on a removable drive, which used numerical codes to identify the participants. The drive will be stored in a locked cabinet for 3 years. Recordings of the interviews will be held in encrypted cloud storage for 3 years. After 3 years, the removable drive and all data will be destroyed.

Data Analysis

Both a content analysis and a thematic analysis were used for the study, providing a comprehensive understanding of the results. Heracleous and Fernandes (2019) recommended using content analysis to identify keywords or phrases to capture the essence of the content. A grounded, bottom-up thematic analysis recommended by Terry et al. (2017) generated meaningful themes from the data collected.

Lesson Plan Content Analysis

Content analysis was used to connect lesson plan documents with the transcripts. A content data analysis model was recommended by Billups (2021b) when analyzing documents for comparison. A content data analysis of the lesson plan documents contents emphasized matching the interview transcripts with the lesson plan documents. The analysis of the lesson plan documents determined similarities between the key terms from both documents, corroborating the experiences shared in the interviews. The lesson plan documents served as evidence of the planning and preparation of lessons described by participants.

Transcript Thematic Analysis

A six-phase thematic analysis was employed to generate themes and report the final themes using a process recommended by Terry et al. (2017). Terry et al. cautioned that this is not a linear process, but is iterative and recursive. A thematic analysis was selected in part because it is flexible in the sense that Terry et al. described it as useful within most theoretical frameworks. An inductive coding model was employed from the bottom up rather than the top down.

Phase 1 Familiarization

Familiarization with the transcript data provided an initial perspective. Familiarization was described by Terry et al. (2017) as an immersion in the data and involves reading with deep engagement. Reading with a questioning mindset, thinking about how the data connects to the research questions, and making notes in the margins were part of the process for familiarization. Re-reading through the transcripts a second time and highlighting key terms allowed for deeper engagement with the text. The highlighted sections generated an entry point for initial coding.

Phase 2 Generating Codes

As connections and generalizations surfaced from the familiarization phase, initial codes appeared. Note cards captured ideas and concepts that stood out in the familiarization process. Hundreds of note cards were labeled with anything of relevance from the transcript data. The coding process was iterative and flexible, and codes were revised and refined throughout the process. As stacks of note cards were sorted and organized, similar or connected concepts were stacked together. Terry et al. (2017) described this stacking and sorting as collating data in preparation for generating themes.

Phase 3 Generating Themes

Generating themes began with collated data, identifying stacks of sorted note cards by relevant content. Combining and collapsing, codes as described by Terry et al. (2017), produced provisional themes. Patterns were identified and compared with the research questions to maintain alignment. Each stack of note cards became a possible theme, and eventually, a visual map with a theme for a title identified crossover ideas and weak themes. The results were discussed with colleagues who asked probing and reflective questions about connections, and relationships between ideas and connected each theme back to the research questions. The questioning and reflection of the provisional themes helped define and name the themes,

Phases 4 and 5 Reviewing and Defining Themes

According to Terry et al. (2017) reviewing and defining themes once the provisional themes were created was a critical part of the process. Reviewing led to adjustments in the themes, making sure each concept in the code stack matched the theme and the research question addressed. Following the process outlined by Terry et al. each theme had to be independent yet related to the others. Creating thematic mind maps in NVivo software provided a visualization of the theme development. The thematic mind maps were shared with colleagues who asked questions and helped further refine the themes.

Defining and naming themes was an iterative process, and followed the steps of phase five defined by Terry et al. (2017). Finally, the themes needed to address the research questions. The printed thematic mind maps were physically sorted into research questions for a final check.

Final themes, according to Terry et al. were given a name that clearly expressed the content, built interest in the theme, and connected to the research questions.

Phase 6 Reporting

The sixth phase involved reporting data results. Terry et al. (2017) included reporting as a phase of thematic analysis to indicate a final moment for refining the data, analysis, and aligning all items back to the research questions. Selecting powerful quotes, and illustrating the examples from the stories of participants brought data to life, and told the story of STEM teachers lived experiences.

Reliability and Validity

In qualitative research, trustworthiness is the term used to describe the quantitative research concepts of validity and reliability (Given, 2008b). As mentioned by Given, the commonly used terms to describe trustworthiness included credibility, transferability, dependability, and confirmability. Although qualitative research does not conform to the same standards of reliability and validity as quantitative research, attending to elements of trustworthiness increases confidence in the findings.

Credibility

In qualitative research, credibility was equated with validity by Neuendorf (2017). Neuendorf (2017) defined credibility as measuring what one intended to measure. Several measures were described by Billups (2021b) to ensure credibility. Documented in this study are the use of peer feedback, member-checking, and triangulation. Subject Matter Experts (SMEs) served as peer feedback and addressed potential bias in the interview questions and improved the validity of the interview questions. SMEs provided feedback on the interview questions, and the interview protocol was updated to include the changes. Member-checking by participants was used to confirm what was said during the interview by asking participants to approve the interview transcripts. Data triangulation involved the use of interview transcripts and lesson plan documents to align the data with the research questions and corroborate findings.

Transferability

The primary goal of transferability is to provide results that other researchers can apply to similar settings and other contexts (Bielenia-Grajewska, 2018). Detailed procedural documentation was used for this study as described by Bielenia-Grajewska (2018). Carefully describing the research procedures and participant selection, providing detailed descriptions of the data collection, and describing the results of the data with rich narratives allow others to follow the documentation and apply the results in different contexts and locations.

Dependability

Dependability is the qualitative version of reliability, as defined by Given (2008b), and ensures consistent outcomes are achieved when using the same data collection procedures. To enhance dependability, the use of an audit trail of the research procedures and research instruments, as recommended by Billups (2021b), was used. The audit trail included an interview protocol documented in Appendix G and the validation of the interview protocol by subject matter experts as described in Appendix H.

Confirmability

The confirmability of a study, as defined by Billups (2021b) refers to the accuracy of the findings. Providing an audit trail of research procedures allows another researcher to replicate the study with similar results. The research procedures and data analysis were checked for accuracy and are included in the study with detailed descriptions. Corroborating results with triangulation was recommended by Billups (2021b) to increase credibility, the interview data and lesson plans were matched as described in the content analysis to increase accuracy in the final reporting.

Ethical Procedures

Protecting human subjects is the highest priority in dissertation research (Durdella, 2019). Basic human dignity and a right to self-determination are the focus of ethical considerations because the participants' safety is of the utmost importance. Durdella (2019) mentioned the interpersonal nature of qualitative research, requiring the proper steps to ensure subjects understand their participation. Following the guidelines of The Belmont Report (Department of Health, Education, and Welfare, 1979), the Common Rule, and institutional policies, the research strictly adhered to the ethical treatment of human subjects. The Belmont Report established three guiding principles for human subject research: respect for persons, beneficence, and justice.

Respect for persons includes voluntariness, which protects participants' freedom to participate and withdraw from the study. This principle accompanies informed consent. Informed consent was included in the questionnaire sent to all potential participants to screen for inclusion criteria and preceded the interviews (see Appendix E). Data from the questionnaire were encrypted and stored on the Qualtrics platform (Qualtrics, 2022). Participants recruited from social media sites, such as a Facebook group, a membership forum, or a listserv, were granted permission from the site or organization administrators (see Appendix C).

Participants who met the inclusion criteria for the screening were sent an additional informed consent letter through ACE student email account (see Appendix F) with more details about the research. The second consent document explained the purpose of the research, the research design, and procedures, how the participant was selected, and voluntary research participation. Participation could end at any time without repercussions. Next, the data collection was explained, including the interview process and lesson plan submission. Lesson plans were submitted to an ACE student email account, where they were stripped of any identifiable information and saved with the participants' numerical code. Confidentiality was explained, including the procedures for keeping data completely anonymous by removing any identifying information and storing it in a separate, locked location. Only a numerical code identified the participant on any data stored.

The informed consent (see Appendix F) included the technology required to participate in the interview and requested permission to record and store the interview encrypted on the Zoom Cloud (Zoom Video Communications, Inc., 2021) for 3 years. Participants signed the document with an electronic signature using a tool of their choice and sent it back via email. After 3 years, all data will be destroyed. Paper copies will be shredded and external storage devices will be smashed and disassembled, and all cloud data will be deleted.

Throughout the research study, confidentiality and anonymity were strictly maintained. All ethical human research guidelines set forth by the Belmont Report (Department of Health, Education, and Welfare, 1979), were followed. IRB approved the research protocol on January 19, 2023 (see Appendix A). Participants' privacy and confidentiality were protected during and after the research process through protocols such as numerical codes in place of participant names and storing all data in locked cabinets or encrypted in cloud storage. At no point during the research process was deception involved. Subjects were fully informed of what was expected of them and could withdraw their participation at any point in the research.

Chapter Summary

The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. A case study described the process teachers followed to identify, plan, facilitate, and innovate with students as one goal of this study. Through purposive and snowball sampling, teachers were recruited using social media, professional organizations for STEM education teachers, and email listservs. A screening questionnaire narrowed the potential participants to those who met the inclusion criteria.

Case studies explain, investigate, characterize, and comprehend a phenomenon within a particular context (Schoch, 2020). A semi-structured interview protocol invited teachers to tell the stories of their STEM classrooms with children in Grades K-8 in schools across the Midwest United States. Lesson plans of exemplary projects provided rich details to corroborate the stories shared in the interviews. The goal was to identify and describe innovative ideas and characteristics of STEM programs serving as models for future STEM educators. In the next chapter, data collection and analysis related to STEM education teachers' experiences are described.

Chapter 4: Research Findings and Data Analysis Results

Reimagining the STEM curriculum by centering real-world experiences and community connections required attention to how successful STEM teachers facilitated classroom learning. Teachers interested in localizing STEM through community-based problem solving benefit from learning how current STEM teachers use innovative technology to facilitate community-based problems and design challenges in Grades K-8. Students considered both the problems of the school's community and the global community, designing possible solutions from the perspectives of people impacted by the designs (Gunckel & Tolbert, 2018).

Incorporating new ways to design and facilitate STEM projects for students in Grades K-8 addressed a need identified by the Pew Research Center. Public school parents in the United States were surveyed about the perceived problems in K-12 STEM education (Pew Research Center, 2018). The results showed 62% of parents perceived too much emphasis on standards, while 53% felt there was not enough emphasis on the practical use of STEM education in everyday life. In addition, 49% of parents thought K-12 STEM education had an insufficient focus on critical thinking and problem solving, 48% felt inadequate time was spent teaching STEM at the elementary school level, and 46% perceived a lack of up-to-date curriculum.

The problem was a lack of connection between community-based problems with current standards and pedagogy designed to develop a globally competitive workforce. The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. The following questions drove this study:

Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?

Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?

Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?

The gathering and analysis of qualitative data were described in the sections that follow. The analysis findings were based on the actual experiences described by the participants. Dependability and validity were reviewed in the final section followed by a summary of the answers to the research questions.

Data Collection

K-8 STEM teachers in the Midwest were invited to participate in the qualitative case study through social media networks and professional learning communities, including Facebook STEM teacher groups, International Society for Technology in Education (ISTE) STEM teacher forum, the National Science Teachers Association STEM forum, and the Illinois Digital Educators Alliance (IDEA) (see Appendix D). Beginning in spring 2023, teachers were invited to complete a screening questionnaire, which included a preliminary informed consent form for the survey data alone (see Appendix E). Twenty-six teachers completed the survey, with 23 teachers leaving an email for follow-up contact information. From the 23 complete survey responses, three participants were eliminated due to location or teaching role, and two responded to the survey after data analysis was completed.

Eighteen participants were invited for an interview. Fifteen teachers who met the inclusion criteria of teachers in the Midwest with experience with community-based STEM projects, teachers who used innovative technology with students in STEM classrooms, and teachers who used STEM to solve problems for others were invited for interviews. In addition, three participants were randomly selected to share lesson plans to assist in data triangulation. This invitation to share lesson plans was optional for the participants. Table 1 identifies the characteristics of the participants included in the study.

Table 1

Participant Demographic Information

Demographic characteristics	*f*
Years of STEM teaching experience	
0-5	5
6-12	8
More than 12 years	2
Grade level	
K-2	7
3-5	10
6-8	6
Previous experience using a problem from the community in STEM	
Yes	11
No	1
Maybe	3
Facilitated the innovative use of technology to solve a problem	
Yes	8
Maybe	1
No	2
Probably yes	4

Note. Data show the characteristics of interview participants. Participants could choose more than one grade-level band.

Participants received an invitation through the American College of Education's Microsoft Outlook Calendar for a Zoom video call that lasted about 30 minutes. The interviews were conducted via Zoom Cloud videoconferencing software and transcribed by Otter.ai. The data collection plan was changed in one way from Zoom transcription to Otter.ai transcription. This change was necessary because Zoom only provided transcription within the video and not as a separate document. Transcriptions were exported into Word documents and sent to each participant for member checking and approval. Fourteen participants replied to the request to review their transcripts, and 14 transcripts were approved. Participants were invited to share a lesson plan, resulting in four lesson plan documents included as data.

Data Analysis and Results

A content analysis and a thematic analysis were used to analyze the data. The content analysis recommended by Heracleous and Fernandes (2019) captured the essence of the content of the lesson plans and compared it with the interview transcripts. A comprehensive look at transcript data involved a thematic analysis which followed the six-phase thematic analysis recommended by Terry et al. (2017).

Lesson Plan Content Analysis and Results

The content analysis of the lesson plan documents employed matching concepts and phrases of the document to the transcript to corroborate what the participants described. Four lesson plans collected from participants were used to triangulate data, which corroborated how teachers planned for STEM instruction. The lesson plans were used to confirm the project descriptions from the interviews. Billups (2021a) and Yin (2018) explained that documents were evidence of the experiences shared in interviews and could tell more than what was captured in the interview. A final match of the lesson plan documents to the research questions maintained alignment with the goals of the study. The content analysis of the lesson plans is found in Table 2. The analysis corroborated the lesson plans matched the description of activities described by participants in the interviews.

Table 2

Lesson Plan Content Analysis

Participant	Lesson plan content	Matching with transcript

Participant 12	City design, designing for others, 3D city design, 3D printers	"City X project gave us that next layer of now we're designing for humans" "The kids designed in Tinkercad, so they design in 3D."
Participant 12	Problem solving to help a character from a story.	"To help get kids to that first layer of thinking about others' needs, and paying close attention. So that we learn not only how to, well how to design for someone else."
Participant 15	Snowy footprint investigation	"We are currently writing a grant for an animal camera and bird watching station supplies."
Participant 6	Australia wild fire environmental impact	"For the Australian animal project we had, I found a map from National Geographic that showed destroyed habitats of koalas, kangaroos and wombats." "We found kid interviews (online) to provide context for the fires, then were able to design from there."

Note. Table 2 represents a content analysis matching concepts from the lesson plan with quotes from the participant found in the transcript. Participant 12 submitted two lesson plans used in the analysis.

Transcript Analysis and Results

Phase 1 involved interacting with the data, and becoming familiar with it, as Terry et al. (2017) described. Transcripts were highlighted, identifying words and patterns of importance relating to the research questions. Highlighted transcripts generated a familiarization with the data and an initial perspective for an entry point into coding. In Phase 2 of the six-phase analysis, notecards were used to move ideas from the transcript into a tangible form, literally stacking, grouping, and regrouping codes into related topics. The first stacks generated initial data codes tied directly to the research questions and included familiar STEM topics mentioned by participants such as technology tools, problem solving behaviors, and STEM thinking and project ideas. Each individual word or phrase was indicated on a note card and the note card was identified with the participants identification number for reference.

As coding expanded, Phase 3 initiated the collapse of similar codes, and stacking relevant content into provisional themes. The provisional themes included *technology, community-based problems, facilitating projects, problem solving language,* and *benefits.* At this point, a visual map of the initial theme title and the note cards were laid out and discussed with colleagues. Connections and relationships were discussed, and colleagues asked questions to refine and determine theme names. Bazeley (2009) identified the benefits of using colleagues to facilitate data analysis in a relaxed setting, generating new meaning through questioning and conversations about data features.

In Phase 4, the themes changed again to recognize broader ideas that are more reflective of analytical thinking rather than direct summaries. Themes developed to include *problem solving for others, finding ideas,* and *positive outcomes.* Three work colleagues helped review potential themes, asking questions, and generating reflective discussions to make connections and related potential themes to the research questions. From here, the analysis moved into NVivo software (QSR International, 2022) to create thematic mind maps. Terry et al. (2017) recommended thematic maps as a visual aid during theme refinement. Through the thematic mind-mapping process, sets of codes began to collapse into significant themes. Codes evolved through several themes, including Engineering Design and Design Learning which eventually became the theme STEM Habits of Mind. Figure 1 is the mind map created while developing the theme of STEM Habits of Mind.

Figure 1

Thematic Mind Map of STEM Habits of Mind

Note. Thematic mind map example created from collapsed codes in NVivo.

Once themes developed in mind maps, the printed maps were presented to the three colleagues again, who asked questions and continued to assist in refining the themes, making new connections, collapsing codes and themes, and connecting all ideas back to the research questions. Stacking the printed mind maps around the research questions provided a visual relationship between the data, themes, and research questions. In this process, the research questions were labeled with additional descriptions drilling into the questions and describing them in pedagogical terms as a teacher planning and preparing for instruction. This process is represented in Table 3

Table 3

Drilling into Research Questions for Meaning

Research question	What does this mean to a teacher?
Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?	Identified as describing the *what* of teaching. What are we going to teach, and how to we find ideas?
Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?	Identified the how and why of teaching. How does the planning and preparation bring purposeful learning to the classroom? What planning considerations facilitate learning for students?
Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?	Addressed the solutions used by students to solve problems or address issues.

Note. Table 3 represents an analytical process used to connect themes to the research questions.

The mind maps were placed around the research questions, and additional changes became apparent. Two original themes of Developing Ideas and Purposeful Learning collapsed into one theme of Developing Purposeful Learning. This theme represented the thinking, planning, connecting, and idea generating teachers used when creating student learning opportunities. Some of the codes from Purposeful Learning moved to other themes, such as moving forward thinking and future careers to STEM Habits of Mind, as they connected to the *why* of designing STEM projects. Table 4 highlights the significant codes and themes with supporting evidence from the data analysis.

Table 4

Thematic Analysis and Emergent Themes

Collapsed codes	Themes	Description	Supporting evidence
Area attractions, community organizations and foundations, experts in the field, families, global connections, local businesses, school community	Connecting Beyond the Classroom	Community can be described from the classroom level to town, area, and global level.	"STEM opens up students' minds to problems out there they may not know exist, whether that they be in their community, or whether that be worldwide." (Participant 4)
Collaborating with classroom teachers, experts in the field, books, national standards, social media, student generated ideas, community members, conferences, real-world learning, interdisciplinary, engaging, student centered	Developing Purposeful Learning	Facilitating innovative projects requires resourcefulness for acquiring new ideas. How did teachers make it purposeful and meaningful?	"I love crowdsourcing and sharing ideas with other teachers." (Participant 8) "I have developed great relationships with other people who share this passion." (Participant 2) "Kids can't be what they can't see." (Participant 8)

Collapsed codes	Themes	Description	Supporting evidence
Laser cutters, QR codes, video production, design software, drones, 3D printing, robotics, podcasting, vinyl cutting, video conferencing, virtual reality, simulation software, micro bits, sewing machines	Innovative Solutions	The technology tools, materials, and resources students use to design solutions.	"I am a big proponent of using technology in a way that is part of the process and not something that just gives you a product." (Participant 4)
Compassion, helping others, think beyond themselves, greater good, awareness, global citizen, problem solving for others	Lens of Empathy	Problem solving for others requires students to step out of their own life and view the world through someone else's needs.	"So, looking at those needs through that lens, and then, for, you know, the students to kind of start that way and then build and generate ideas from there." (Participant 5)
Collaborate, design thinking, creativity, vulnerability, iterate, test, evaluate, reflect, engage, explore, critical thinking, problem-based, prototype, plan, imagine, present, inquiry	STEM Habits of Mind	Habits of mind are behaviors and process for creative problem solving, building skills for a successful life.	"We approach STEM education as the STEM habits of mind. I'm talking to them about collaboration and critical thinking, and how these skills are really important. And we're building them through our STEM content." (Participant 5)

Note. Collapsed codes were a sampling of the final codes. Quotes were verbatim from the transcripts.

Connecting the themes to the research questions created a visual hierarchy of themes. Phase 5 of the six-phase thematic analysis (Terry et al., 2017), named the final themes. Terry et al.

mentioned the final themes should tell the story of the research, answering the research questions. The connection between themes to the research question is represented in Table 5.

Table 5

Connecting Themes to Research Questions

Research question	Theme	Participants addressing the theme
Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?	STEM Habits of Mind Lens of Empathy Connecting Beyond the Classroom	15/15 14/15 15/15
Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?	STEM Habits of Mind Lens of Empathy Developing Purposeful Learning Connecting Beyond the Classroom	15/15 15/15 15/15 15/15
Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest	STEM Habits of Mind Lens of Empathy Innovative Solutions	15/15 15/15 15/15

Note. STEM Habits of Mind and Lens of Empathy informed all three research questions. One participant did not describe anything of significance that impacted others.

During the thematic data analysis, all participants described some information that corresponded to each theme, except the theme Lens of Empathy. In this case, the participant described student projects more tied to curriculum-driven learning. Although ideas were found outside the classroom walls, they took a more entrepreneurial approach than helping others.

Entrepreneurial codes also appeared in other interviews but served a different purpose with the outcome of helping others.

Several participants were unaware of how learning in the classroom served to help others but became aware through the examples they shared in the interview. Bazeley (2009) addressed the divergent views that appeared in qualitative data. Divergent views, or outliers, were an opportunity to understand the data deeper while searching for an explanation. Returning to the transcripts for deeper analysis, the word empathy was found in eight transcripts, with six other transcripts describing empathy in other terms, such as “compassion” or “thinking beyond themselves.”

Using curriculum and pre-made kits and supplies was a foundational approach to teaching STEM. One participant described how curriculum served as a base, a way to start and then grow ideas from there. “But everything, that sort of baseline, you have to get some baseline knowledge of the different technologies and systems.” (Participant 9)

Five participants used the purchased curriculum with four creating projects autonomously after students learned baseline skills. Only one teacher followed the provided curriculum closely. This participant was the outlier in the Lens of Empathy responses, leading to further questions about following the curriculum so closely as to eliminate the autonomous and spontaneous decisions that created meaningful, relevant, and interdisciplinary projects that connected students outside the classroom walls.

Phase 6 of the six-phase thematic analysis (Terry et al., 2017) required a report of the final analysis, supporting themes with quotes from the participants. Terry et al. described this reporting process as returning to the big picture of the project, connecting the analysis with the research questions. A narrative description described how the five themes addressed the research questions.

Ways in Which Teachers Identify STEM-Related Community-Based Problems

Research Question 1 asked, “How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?” This research question attempted to determine how teachers found what they would teach in their classrooms. Teachers with the autonomy to deviate from purchased curricula and search for real-world ideas were likely to engage their students with relevant and meaningful projects. Three themes emerged from talking to teachers about where they found ideas: STEM Habits of Mind, Lens of Empathy, and Connecting Beyond the Classroom.

STEM Habits of Mind

Participant 5 used the term “STEM habits of mind” when describing the purpose of STEM education. However, the STEM habits of mind also informed the search for STEM-related, community-based problems. STEM habits of mind were described in work done by Asunda and Weitlauf (2018) when they started a conversation about what STEM habits of mind might look like at the high school level and were based on the work of Costa (2008). According to Asunda and Weitlauf (2018), STEM habits of mind were the ways of thinking, process, and problem-solving strategies used to solve real-world problems. It included the engineering design processes adopted by STEM teachers or the design thinking teachers encouraged students to use when creating solutions.

All 15 participants discussed ideas coded as STEM Habits of Mind when asked to describe what STEM means to them. Figure 1 in the Data Analysis section shows the many words used by participants to describe the STEM Habits of Mind. As Asunda and Weitlauf

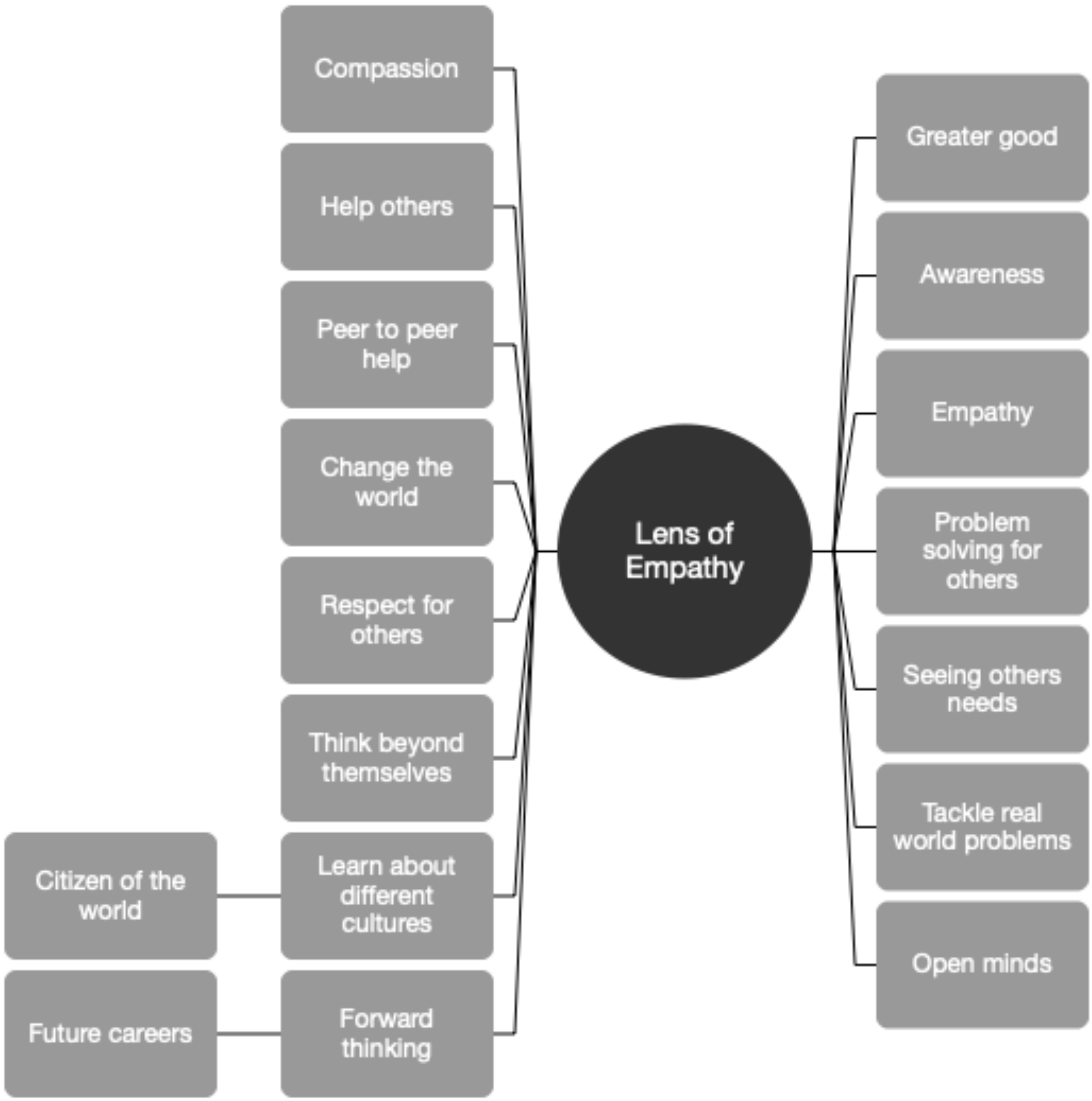
(2018) concluded, the STEM Habits of Mind were all the opportunities students had to deepen their thinking and solve problems in the global challenges of the 21st century. This research supported the idea that STEM Habits of Mind informed all of the research questions and the idea generating, design, facilitation, and solution creation done by teachers and students in K-8 STEM education.

Lens of Empathy

Using a lens of empathy came from the idea of problem solving for others. When we look outside of ourselves at the needs of others and attempt to provide solutions, we make our world a better place. Eight of the 15 participants mentioned empathy specifically, and all participants mentioned a form of the word. Participant 14 mentioned empathy 13 times, and Participant 9 mentioned it six times. The conversations around empathy were the most passionate and emotional when teachers described projects' impact on students. Participant 14 said, “These are 9- and 10-year-olds changing the world and, in our community, but the impact was felt beyond our community.” Figure 2 features the Lens of Empathy mind map.

Figure 2

Lens of Empathy Thematic Mind Map



Note. An analysis of comments made by participants about problem solving for others.

Like the STEM Habits of Mind, it was determined that the Lens of Empathy informed all research questions. Keeping the idea of empathy centered in planning, preparation, and solutions supported the idea that STEM education could "impact our world," as Participant 2 said. When we start to look for problems around us, a whole world of opportunity opens, then we see students move from 3D printing trinkets to 3D printing solutions to help others, even if they are imaginary solutions.

Participant 14 described a project that was inspired by a student in the classroom with Down Syndrome:

> So, to me, like, empathy was just one of the best character traits that you can have from kid to adult, like just truly understanding other humans and putting them before yourself. And so, I just, we had a huge like celebration day, and they made videos for her for World Down Syndrome Day. And they surprised her, and they printed off their little QR codes. So, when I think about impacting other people with technology, like, so easy to film a video for someone, attach a QR code, put it in a card, and they have that video forever. You know, they can watch it 100 times, and her mom told me that before bed most nights, she'll ask to watch some of those videos that the kids made for her. So, I know I cried.

Launching into projects with a Lens of Empathy creates relevance, purpose, and real-world connections to STEM classes wherever they are. According to Szalavitz and Perry (2011), empathy is a teachable trait. Further, exposing students to designing solutions with an empathetic lens enabled them to problem-solve for others in all areas of their lives.

Connecting Beyond the Classroom

In addressing Research Question 1, the prominent themes were STEM Habits of Mind and Lens of Empathy. However, upon summarizing the data analysis for the chapter summary, Connecting Beyond the Classroom became a focus as a smaller theme. Teachers used connections with experts to build ideas.

Designing and Facilitating Community-Based STEM Projects

The two themes of STEM Habits of Mind and Lens of Empathy continued to inform the design and facilitation of community-based STEM projects, but the focus was on the other two themes emerging from the data, which described the *how* and *why* of teacher planning, preparation, and facilitation of STEM projects. Connecting Beyond the Classroom explores how teachers found ideas and why connections were essential. Developing Purposeful Learning addressed the many resources teachers used for inspiration, ideas, and new knowledge while designing and facilitating interdisciplinary projects that were not part of a standard curriculum.

Connecting Beyond the Classroom

The word community took on a definition of the micro-community of the classroom through to the macro-global community. Participant 5 explained, “You can define community as a classroom within a school, your town, or more global, too.” Participant 2 connected two communities of fourth-grade students and made them one community of problem solvers. Participant 2 described the experience of a 4th-grade STEM project working collaboratively with students in Zimbabwe:

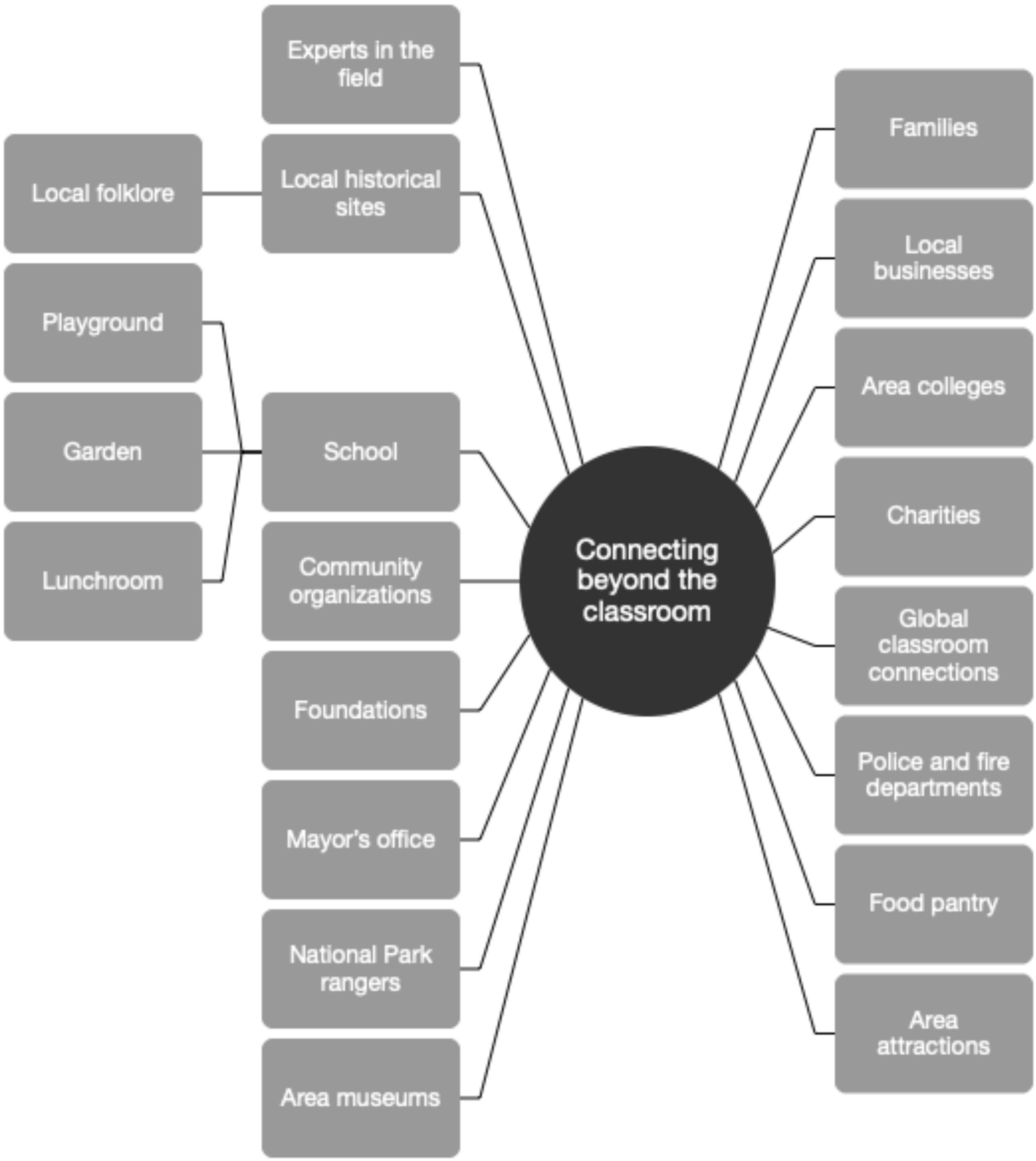
> They would record themselves working on a project where they were creating a 3D printed flashlight and so we received kits for the internal pieces of the flashlight, but the kids actually designed the external case that was going to be holding the flashlight, and they did that through video conferencing and video recordings with their partners in Zimbabwe. And the facilitator down there had received all of the materials that they needed through Level Up Village. And so, they were both learning Tinkercad both classes, and they would talk about their designs in Tinkercad. And they would share their designs so that they were making flashlights together that were eventually for the

children in Zimbabwe because they didn't have electricity at certain times of the day, especially in the evenings.

Bringing the problems of the students in Zimbabwe to the students in the United States to help solve came from an organization called Level Up Village. Working with organizations to generate ideas was mentioned by 12 out of 15 participants. Connecting beyond the classroom also meant connecting with experts in the field. Seven participants used the word expert in their interview to make connections. Connecting beyond the classroom was the awareness teachers had of the opportunities outside the classroom walls. Participant 6 said it best, “Just ask, and then your impact can be so much greater than what you thought, beyond the walls of your school.” Teachers were creative in how they connected with others outside of their classrooms. Figure 3 showcases how teachers connected beyond the classroom.

Figure 3

Connecting Beyond the Classroom Thematic Mind Map



Note. Analysis of comments made by participants when describing ideas and resources for planning.

Developing Purposeful Learning

Among the 15 participants of the study, six used a purchased curriculum, and nine did not. The curriculum mentioned came from two organizations: Project Lead the Way and Creative Learning Systems. Only Participant 3 described staying true to the curriculum for students' projects and was previously identified as the outlier when describing solving problems for others. The other five curriculum-based participants used the curriculum for foundational skills, adding other projects as an identified need arose.

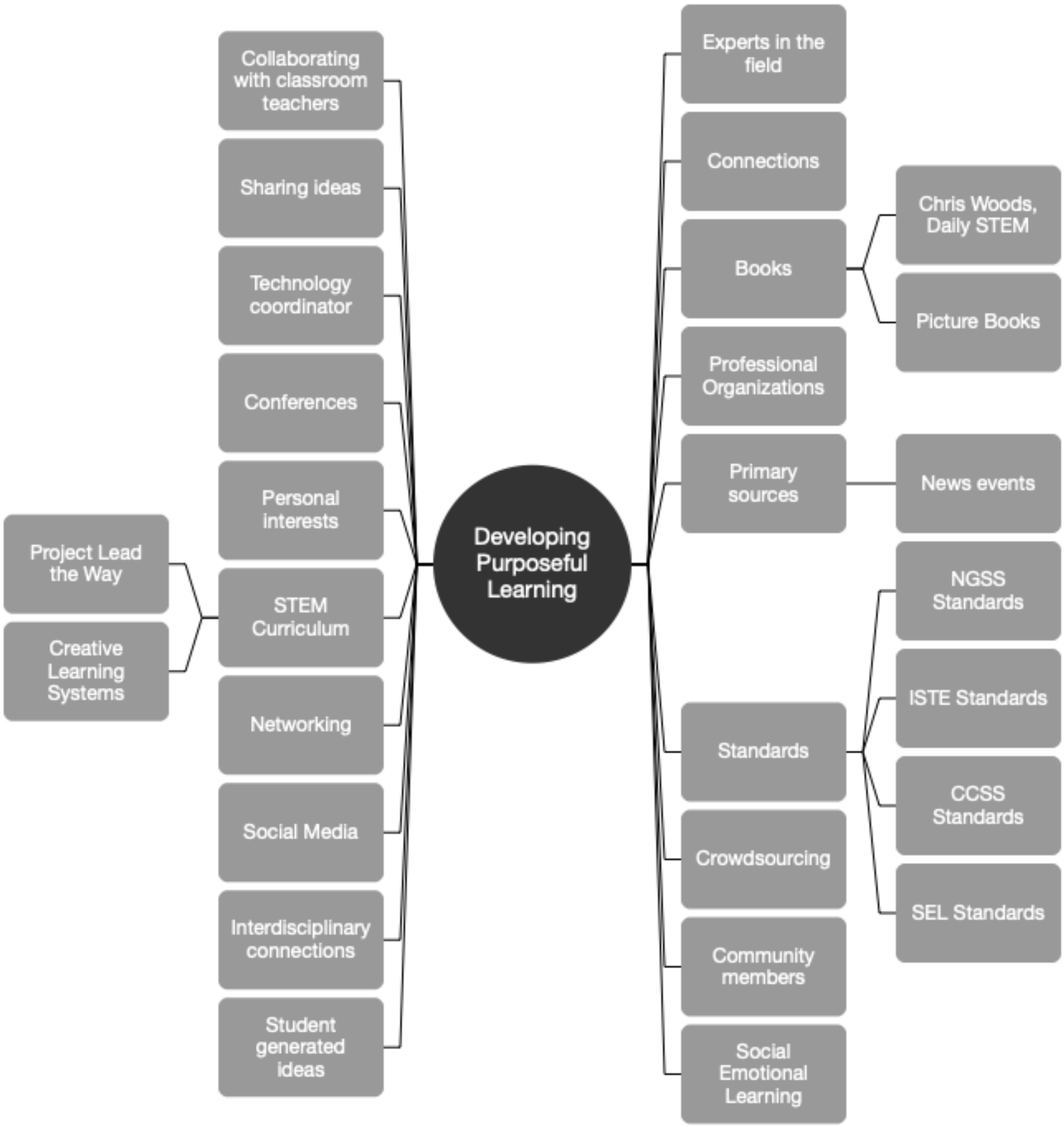
Nine participants approached the design and facilitation of STEM projects from the view of building foundational skills, followed by more involved projects. Participant 12 described this approach:

> So, the way that I approach design thinking, and using innovative tech to solve community problems, is kind of like a scaffolded approach. So, I feel like students need some simulation-type problem solving first, where it's safer, where it's creative, out of the sandbox fun. And then we work our way towards helping real people.

Looking at the Developing Purposeful Learning mind map in Figure 4, the many resources served as a road map for teachers looking to design and facilitate any interdisciplinary program, including STEM education.

Figure 4

Developing Purposeful Learning Thematic Mind Map



Note. Analysis of comments participants made about resources used in planning and preparation.

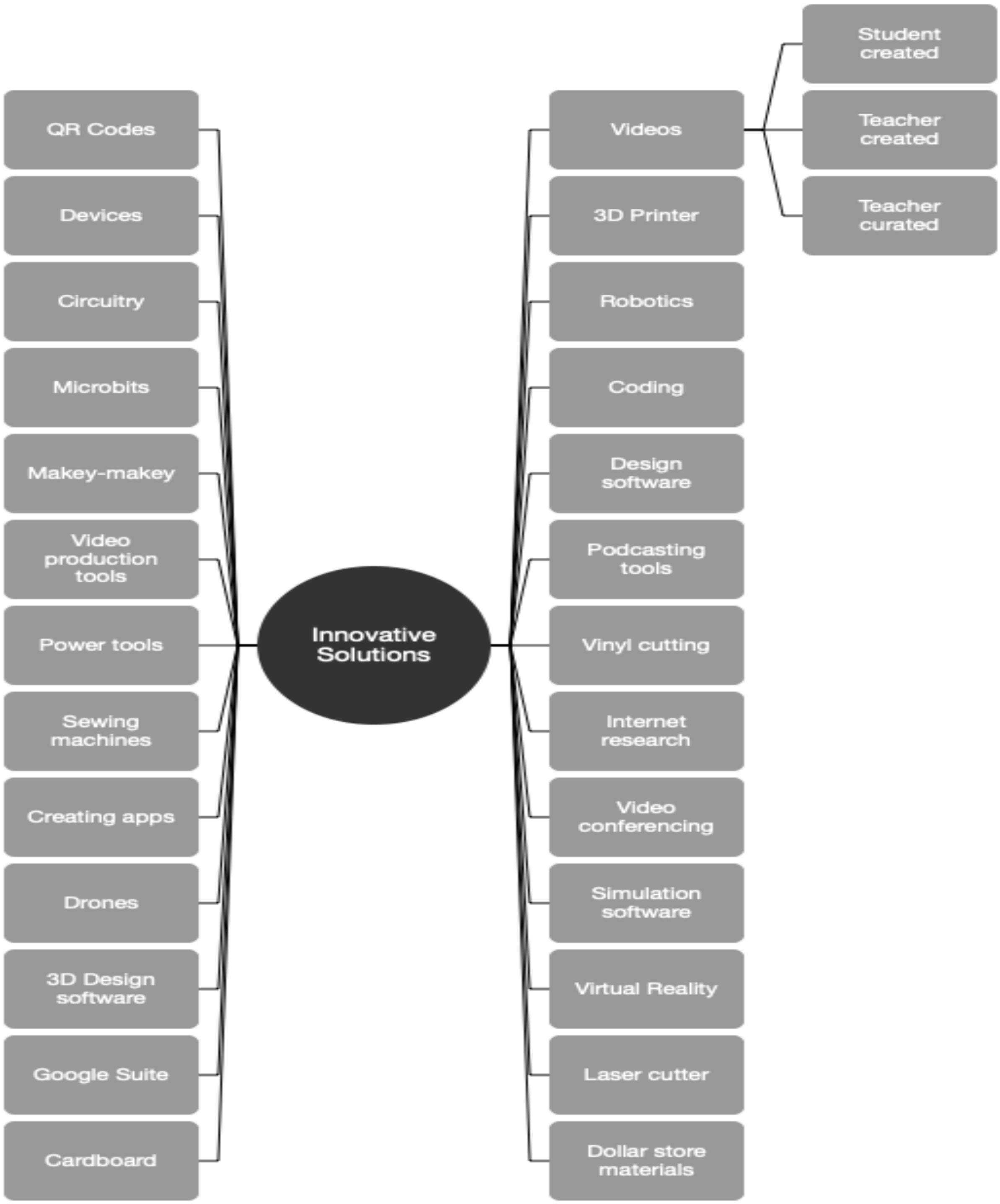
The final idea from the participants was centering purposeful learning around student-led ideas. Letting the students lead project designs situated the teacher as a facilitator. In this student-centered model, the teacher assisted in finding resources and making connections. However, the students did the heavy lifting, spoke with experts, researched, and sought background knowledge from primary sources in an inquiry-driven process. In an ideal STEM classroom, the students identified the problem using a lens of empathy, design and produce solutions with guidance from the teacher.

Use of Technology by Students to Design Innovative Solutions

The final theme was directly tied to the use of technology, but when listening to the interviews, we saw that technology took on a broader scope. Students used many things in innovative ways to design solutions. After analyzing the responses and trying multiple themes, the theme that addressed this question best was Innovative Solutions, as shown in the mind map in Figure 5.

Figure 5

Innovative Solutions Thematic Mind Map



Note. Analysis of comments made by participants when addressing the question about the innovative technology students used in STEM.

Three participants mentioned QR codes as solutions to communicating information to others in a video format. Participant 4 described how students met with local businesses to create video explanations of favorite foods or menu items. QR codes were displayed outside the businesses so potential customers could listen to and watch the students' videos. QR codes were a free tool available to all teachers. They are now embedded in other free programs, like Flip or Canva, allowing students to present information to an outside audience at no cost to the school. Adding other resources like greenscreen effects and video production software, as described by Participant 4, increased the complexity of technology skills, integrating multiple tools and skills across solutions.

Five participants mentioned students utilizing 3D printers to design solutions. Participant 2 described the flashlight project in collaboration with a classroom in Zimbabwe. Students worked in Tinkercad to design a solution together that was 3D printed and sent to Zimbabwe. Drones were used as an innovative solution by Participant 2. After erosion damaged the area around the school building, students used drones to document the damage and developed a response plan.

Robotics was mentioned by 80% of participants as a technology tool used by students as an innovative solution to a problem. Robots were a large part of many STEM programs. Participants mentioned Bee-bots, LEGO® robotics, and VEX IQ robots. Robots served as a means to an end in projects. Participant 6 said this about using robots:

> It just kind of inspired me to look for real-world problems to find. Because I mean, I even think down to like kindergarten, like they're just so capable, and they feel it's so much better. To me, a robot, for a robot's sake is just, it just doesn't do it for me. I mean, I think

they get bored with it after a minute. And then it's just really expensive to keep that program up.

In analyzing the Innovative Solutions and the role of technology, it became apparent that participants had an unexpected view of technology as described by Participant 4, “I’m a big proponent of using technology in a way that is part of a process and not something that just gives you a product.” This viewpoint created choice among the students to use 3D printing as one possible solution, not the only solution.

As participants described innovative technology solutions created by students, it was evident that this question carried the least enthusiasm and weight, and participants gave shorter answers. Many participants had trouble naming technology, even though it was embedded throughout their programs. This was attributed to the idea that technology had become truly embedded in students' everyday learning, particularly in STEM, moving it from a novelty to a common learning tool or school supply. One possible explanation was that STEM teachers have entered the Redefinition stage of the SAMR model described by Puentedura (2014). Puentedura made the SAMR model to show how technology was used in the classroom at four levels. SAMR stands for Substitution, Augmentation, Modification, and Redefinition. Pacheco-Guffrey (2022) described the role of SAMR in STEM classrooms, and it fully aligned with the themes described in this study. If STEM teachers used technology at the SAMR model's redefinition level, students integrated technology into learning seamlessly. Pacheco-Guffrey expressed the potential benefit to student learning, such as breaking down barriers and building powerful learning opportunities for everyone.

Reliability and Validity

In qualitative research, reliability and validity are known as trustworthiness and are described by Given (2008b) as credibility, transferability, dependability, and confirmability. Attending to these elements in a qualitative study increases confidence in the findings. A description of the steps taken to ensure trustworthiness allows future researchers to assess the applicability of the results in other contexts.

Credibility

Subject Matter Experts (SMEs) provided feedback on the interview questions (see Appendix H), which addressed potential bias in the questions and increased validity. Member-checking was employed to verify what was said in the interview transcripts. Data triangulation aligned the lesson plan content with the interview transcripts to corroborate findings. The credibility measures documented in this study conform to those recommended by Billups (2021b).

Transferability

A detailed description of the data collection, data analysis, and results supported by the rich narratives of participants increased transferability. The transferability documentation is supported in the description of transferability provided by Bielenia-Grajewska (2018). The detailed descriptions allow other researchers to apply the process to similar settings or contexts.

Dependability

Dependability ensures the outcome of the study can be achieved again using the same data collection procedures. The data collection procedures were documented in the interview protocol found in Appendix G. Data collection procedures followed the audit trail of the research procedures as recommended by Billups (2021b).

Confirmability

The audit trail of research procedures provides a roadmap for other researchers to replicate the study with similar results. The accuracy of the findings supported the confirmability of the study. Triangulation of the interview data and lesson plans corroborated what the participants reported with evidence from their teaching materials. Triangulation increased accuracy in the reporting and matched the description of confirmability by Billups (2021b).

Chapter Summary

This study explored how K-8 STEM teachers in the Midwest utilized innovative technologies to solve community problems through project-based learning. The study involved 15 participants who shared their experiences and insights through a questionnaire, semi-structured interviews, and lesson plans. The collected data addressed the three research questions that guided the study.

Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?

Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?

Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?

A ground-up thematic analysis, partnered with a content analysis, uncovered STEM teachers' lived experiences and perceptions in their classrooms. Mind maps and colleague conversations centered the data around the research questions as primary themes emerged. Two themes stood out as prominent and informing all three research questions: STEM Habits of Mind and Lens of Empathy. When teachers considered the two themes in idea gathering, planning, preparation, and guiding student work, the results, using words from the participants, were described as relevant, meaningful, engaging, and memorable. The other themes, Connecting Beyond the Classroom, addressed Research Question 1 and Research Question 2; Developing Purposeful Learning, Research Question 2; and Innovative Solutions, addressed Research Question 3.

The first question looked for evidence that related to what teachers were going to teach and how they found ideas for STEM projects. The themes of STEM Habits of Mind and the Lens of Empathy informed this research question. After reflecting on how participants used expert help, it was determined while summarizing the analysis that sometimes Connecting Beyond the Classroom helped teachers identify community-based problems to solve. Teachers sometimes sought expert help to locate problems, not just experts supporting the development of solutions.

Research Question 2 was designed to identify the planning and preparation, resources, and considerations of teachers when bringing purposeful learning to the STEM classroom. It included standards, curriculum, community connections, people, resources, and teachers' pedagogical choices when designing learning. The themes of Connecting Beyond the Classroom and Developing Purposeful Learning addressed this question, while STEM Habits of Mind and Lens of Empathy influenced teachers' decisions. STEM teachers were interdisciplinary experts, and most participants deviated from or did not use a published curriculum to guide instruction. Instead, they pulled from real-world problems and students’ interests, finding problems in the world around them to use for inquiry-driven learning. The ability to construct meaningful learning came from experience and close connections to other STEM teachers through professional learning networks and social media groups. Identifying this skill among STEM teachers would help other STEM teachers see the value in reaching out to each other for ideas.

Research Question 3 addressed the solutions found in the STEM classroom using innovative technology. An unexpected outcome of this question generated a different theme than just technology alone. The theme became Innovative Solutions after the analysis showed teachers did not see computers or computer-aided tools as the only innovative tools to problems as students designed solutions. Instead, technology tools in the traditional sense fell under a broader umbrella of the innovative use of materials to create solutions. According to participants, student-generated solutions included sewing, cardboard designs, Play-Doh®, and LEGO® models, among many other ideas. By applying the STEM Habits of Mind and a Lens of Empathy, students could explore innovative solutions beyond just technology for problem solving, imagining various solutions using resources such as sewing, cardboard, Play-Doh®, and LEGO®.

Data analyses provided a deeper understanding of how K-8 STEM teachers approached community problems, developed STEM projects, and encouraged students to design innovative solutions using technology. A thorough analysis uncovered the themes, Lens of Empathy and STEM Habits of Mind, significantly shaped teacher strategies. Compelling stories from K-8 STEM teachers identified such critical themes such as Connecting Beyond the Classroom, Developing Purposeful Learning, and Innovative Solutions. Moving forward, the next section delves into the findings and implications of the research, highlighting the broader impact of the findings on STEM instruction in elementary and middle schools. Additionally, recommendations are made for K-8 STEM teachers looking to add to their instructional ideas, sharing the best lesson ideas from the participants in the field.

Chapter 5: Discussion and Conclusions

The lived experiences and stories of STEM teachers drew a bigger picture of how technology empowers students to become active, empathetic, and creative problem solvers. The valuable insight teachers shared described how combining community-based problem solving, perspective-taking, and innovative technology fostered a sense of care for others. The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitate projects utilizing innovative technologies to solve community-based problems.

The problem was a lack of connection between community-based problems with current standards and pedagogy designed to develop a globally competitive workforce. Projects designed around community-based problems promoted students' connections to their lived experiences and helped them understand the value of solving problems to help others. Teachers who want to connect STEM projects with their local community need more information to achieve this goal successfully in their classrooms. This research aimed to share the knowledge and experiences of STEM teachers to inform leadership, teaching practices, curriculum development, and teacher training in K-8 STEM education.

A literature review found that using community-based problems in STEM education while connecting them to the world outside the classroom was highly beneficial. Incorporating innovative technology could sometimes lead to a focus on learning specific technology skills rather than solving problems. Many teachers needed STEM curriculum or training to combine community-based problems and innovative technology in their teaching effectively. STEM teachers were often alone in their role in their building or even their district, leading to a need for more guidance and support while designing curricula. The literature review highlighted the need for studies investigating the use of these two approaches together to provide the best possible student outcomes.

A data analysis delivered insight into the strategies by which K-8 STEM educators identified community-based problems and designed and facilitated STEM projects that encouraged students to use technology for innovative solutions. A ground-up thematic analysis revealed two key components that heavily influenced the teachers' approaches: the STEM Habits of Mind and the Lens of Empathy. Three other themes identified included Connecting Beyond the Classroom, Developing Purposeful Learning, and Innovative Solutions. These themes were critical in addressing all three research questions.

Research Question 1: How did teachers identify STEM-related, community-based problems in an elementary or middle school in the Midwest?

Research Question 2: How did teachers design and facilitate community-based STEM projects in an elementary or middle school in the Midwest?

Research Question 3: How did students use technology to design innovative solutions to address community-based problems in an elementary or middle school in the Midwest?

This study offered valuable insights for teachers hoping to integrate STEM projects with innovative technology and community-based learning. Educational leaders could utilize these findings to provide teachers with professional development opportunities that enhanced their teaching practices and informed decision-making, staffing, curriculum choices, and budget decisions for K-8 STEM education. The following section delves deeper into the research findings, interpretations, and conclusions. Lastly, the results described the potential of using technology in community-based STEM education.

Findings, Interpretations, and Conclusions

This study revealed the role of K-8 STEM teachers in the Midwest in creating and guiding community-based projects that promote empathy, developing problem-solving skills, and utilizing technology to create unique solutions. The projects shared by the participants prepared students to tackle real-world challenges through the lens of helping others. STEM teachers incorporated problem solving for others, community connections, and cutting-edge technology into their classrooms to provide a transdisciplinary educational experience for students that took them beyond the walls of their classrooms.

The five themes that emerged from the data included STEM Habits of Mind, Lens of Empathy, Connecting Beyond the Classroom, Developing Purposeful Learning, and Innovative Solutions. Tying the findings back to the research questions, existing literature, and theoretical framework required careful consideration of the scope of the study. Interpretations were made regarding the experiences of K-8 STEM teachers in the Midwest and should be considered applicable to this population of educators. A theoretical framework guided the research, and the findings aligned with the existing literature.

Research Question 1

Research Question 1 analyzed how STEM teachers identified community-based problems. The data showed three themes that supported this concept: STEM Habits of Mind, Lens of Empathy, and Connecting Beyond the Classroom. From a pedagogical perspective, Research Question 1 described the *what* of teaching and how teachers found ideas and decided what would be addressed in the classroom. STEM Habits of Mind was a central theme for Research Question 1.

STEM Habits of Mind

Design thinking (DT) connected directly to the literature's STEM Habits of Mind theme. This type of thinking involves acquiring knowledge through self-reflection, creative thinking, problem solving, and imagination (Cook & Bush, 2018). Design thinking is often missing from traditional STEM integration (Reddy et al., 2021); therefore, incorporating STEM Habits of Mind and DT brought a problem-solving approach to STEM education, which had a more significant impact on learning (Ladachart et al., 2022).

The teachers in this study repeatedly mentioned the importance of providing students with opportunities to use STEM Habits of Mind in a problem-solving-centered approach to STEM. Continuing to expand on this idea is a possible area for future research, an area that could be highlighted in conference presentations and professional development for STEM teachers and leaders. Schools offered very few problem-centered learning opportunities for students, missing an area where many students excelled who may not have done so in more traditional academic settings.

Lens of Empathy

One of the powerful themes from the research, the Lens of Empathy, was connected to all three research questions. Solving problems for others was mentioned by Cook and Bush (2018), Edelen et al. (2019a), Nava and Park (2021), and Webber (2021) as a meaningful way to build social-emotional skills in children. When students learned to solve real-world problems that impacted the lives of others, they understood the role scientists, designers, and engineers play in solving tomorrow's problems. Empathy was described by Lottero-Perdue and Settlage (2021), Letourneau and Bennett (2020), Calabrese Barton et al. (2021), and Burns and Lesseig (2017) as a critical component of the success of girls and women in STEM education.

Adding an element of care and empathy is a simple change in the planning and facilitation of STEM projects that could have a long-lasting impact. Solving problems for others might involve reframing a problem, adding a hypothetical narrative, or asking who or what was impacted by students' choices. By adding an element of care for others, teachers could widen their view of STEM to include all of the skills necessary for students to impact society positively (Ortiz-Revilla et al., 2020).

This curricular modification was only sometimes found in pre-packaged curricula. Even a standardized curriculum could benefit from small changes that got to the heart of helping students solve problems for others. Teachers could benefit from understanding how small changes to their approach, from building challenges and problem-solving projects to solving problems for others, could build an awareness of the problems of others throughout the community.

Connecting Beyond the Classroom

The theme Connecting Beyond the Classroom addressed two research questions in different capacities. Related to Research Question 1, Connecting Beyond the Classroom described how teachers identified STEM-Related problems in the community. STEM teachers pulled from many forms of creative community connections, from the micro-community of their classrooms to the macro community, which included global connections, to find and design relevant and engaging problems for their students to solve.

Tapping into local resources could also grow the transdisciplinary impact, connecting students to standards outside of the STEM disciplines, such as social studies standards, geography, and social-emotional learning. Even though all participants mentioned using connections beyond the classroom, many teachers may not have considered looking outside the classroom for additional ideas and support. Holmes et al. (2021) recognized a need for more research on the benefits of using community-based problems for STEM education despite the potential benefits of learning. The research showed that teachers used experts to help develop ideas before students were presented with a problem to solve, as well as using expertise to support students while designing solutions to problems. Parents, community organizations, government educational programs, local colleges, and local experts were just a few resources participants used to connect beyond the classroom.

Research Question 2

Research Question 2 addressed how teachers designed and facilitated community-based STEM projects. Teachers in the study addressed the *how* and *why* of community-based STEM in the planning and preparation for learning in the STEM classroom. Four themes covered participants' information about planning and preparation: STEM Habits of Mind, Lens of Empathy, Connecting Beyond the Classroom, and Developing Purposeful Learning.

STEM Habits of Mind

According to Asunda and Weitlauf (2018), STEM Habits of Mind are the ways of thinking, problem solving, and processing information students used to solve real-world problems. STEM teachers who used STEM Habits of Mind found in this study (see Figure 1) encouraged behaviors in students that resulted in creative problem solving. The various engineering design processes and design thinking adopted by STEM teachers were considered part of the STEM Habits of Mind teachers emphasized as students worked to design solutions.

Built on the work of Costa (2008), STEM Habits of Mind were discussed by Asunda and Weitlauf (2018) as the idea applied to Grades 9-12. There was room in the literature for additional research on STEM Habits of Mind for Grades K-8. Future researchers could address the consolidation of how teachers apply problem-solving strategies in STEM classrooms.

Lens of Empathy

Solving problems for others was mentioned by Cook and Bush (2018), Edelen et al. (2019a), Nava and Park (2021), and Webber (2021) as a meaningful way to build social-emotional skills in children. When students learned to solve real-world problems that impacted the lives of others, they understood the role scientists, designers, and engineers played in solving tomorrow's problems. Moreover, empathy was described by Lottero-Perdue and Settlage (2021), Letourneau and Bennett (2020), Calabrese Barton et al. (2021), and Burns and Lesseig (2017) as a critical component of the success of girls and women in STEM education.

Hess et al. (2017) described perspective taking in STEM by imagining the needs of others and taking their perspective. Adding an element of care and empathy was a simple change in the planning and facilitation of STEM projects that could have a long-lasting impact.
Solving problems for others might involve reframing a problem, adding a hypothetical narrative, or asking who or what was impacted by students' choices (Letourneau & Bennett, 2020).

By adding an element of care for others, teachers could widen their view of STEM to include all of the skills necessary for students to impact our society positively (Ortiz-Revilla et al., 2020). This curricular modification was only sometimes found in the pre-packaged curriculum. Even a standardized curriculum could benefit from small changes that got to the heart of helping students solve problems for others.

Connecting Beyond the Classroom

Community-based problem solving built on Gruenewald's (2003) older view of place-based learning by focusing on the school community as Webber (2021) described. Gunckel and Tolbert (2018) explained the benefit of students thinking about both the problems in the school community and possible solutions from the point of view of people whom the designs would impact. Calabrese Barton et al. (2021) noted the need for more agreement about how to use students' experiences when making real STEM challenges.

If the goal was to prepare students to solve problems in the real world, the design process needed real-world context (Gunckel & Tolbert, 2018). Breen et al. (2023) confirmed this notion with recent research that centered STEM around community problems and engaged students in real-world problem solving, transforming learning through increased awareness of the needs of others. Sharing community-based STEM projects on social media, conference presentations, and content journals spreads the message to teachers who may need to consider the benefits of looking for problems in the community to solve in STEM classrooms.

Developing Purposeful Learning

Developing Purposeful Learning involved the thoughtful integration of real-world problems with STEM projects. Purposeful learning extended beyond curriculum kits and boxed technology tools. Teachers had to be intentional about how new materials and curricula engaged students in real-world problem solving. Solving real-world problems was referenced in the literature by Gunckel and Tolbert (2018), Johnson et al. (2020), Ortiz-Revilla et al. (2020), Rehmat and Hartley (2020), and Roehrig et al. (2021). With guidance and inspiration, teachers might find it easier to think beyond the materials in the room and connect to real-world problems for more purposeful learning experiences.

Developing Purposeful Learning connected to the transdisciplinary approach to STEM described by many authors (Bush & Cook, 2019; Bybee, 2010; Cunningham et al., 2020; Jackson et al., 2021; Johnson et al., 2020; Lo, 2021) and was supported by the descriptions of K-8 STEM projects by participants in the study. Pulling from all STEM disciplines and incorporating other disciplines such as literacy, social studies, art, and social-emotional learning was a consistent discussion across participants. Jackson et al. (2021) asserted that the most critical aspects of STEM education were the opportunity to think critically, problem solve, and respond with empathy.

Teachers who considered the transdisciplinary nature of STEM education moved past the boundaries of traditional science, technology, engineering, and mathematics to provide profound, engaging experiences for students (Jackson et al., 2021). Additional research in the understanding and benefit of transdisciplinary STEM education at the K-8 level would provide insight into how teachers integrated multiple disciplines to design engaging, relevant learning.

Research Question 3

Research Question 3 addressed how students used technology to design innovative solutions for community-based problems. The themes STEM Habits of Mind and Lens of Empathy continued to inform Research Question 3. The new theme that grew out of the data were represented as Innovative Solutions. This theme considered the multiple definitions of technology in STEM described by the participants. Innovative solutions could include sewing, LEGO® construction, cardboard construction, robotics, and 3D printing, to name a few examples. Roehrig et al. (2021) asserted that defining technology in STEM was complicated because it was rarely described in the literature. Each theme emerged as a serious consideration STEM teachers used to facilitate students' decisions to design solutions.

STEM Habits of Mind

According to Quigley et al. (2020), technology in STEM encourages students to think creatively, explore ideas, and design innovative solutions. The Department of Education, Office of Educational Technology, & Digital Promise (DOE, OET & DP, 2019) outlined nine ways students benefited when using technology during STEM learning. Three of the dimensions outlined in the DOE report aligned with the results of this study. First was the idea of engineering design, part of Dimension 5. Students gained critical thinking skills and problem-solving skills when designing, testing, and creating solutions using technology.

Dimension 6 described the benefit of technology for problem solving using algorithms and data. Teachers in the study explained how students used robotics and coding to build logical thinking skills. Dimension 9 discussed using technology to build and test models. Building STEM Habits of Mind through technology required teachers in the study to take the stance that technology alone was not enough.

STEM learning in the study used innovative technology to encourage students to use STEM Habits of Mind to solve real-world problems. Ellis et al. (2020) supported this idea; modeling, designing, and building solutions could take any form, depending on how teachers used technology in the classroom.

Lens of Empathy

Using a lens of empathy with technology was supported by the work of Bush and Cook (2019), Holmes et al. (2021), and Ellis et al. (2020). A primary benefit of localized problem solving was preparing students to be engaged and empathetic learners in STEM education. Ellis et al. (2020) claimed innovative technology transformed students into solution-driven problem solvers. Suters et al. (2021) described the emerging technologies of the Fourth Industrial

Revolution, including the rise of artificial intelligence, as a reason to think about how humans interact with technology.

Korhonen et al. (2023) highlighted the positive effects of empathy in students who learned in a supportive, engaging, and innovative environment. They found that when students were encouraged to take different perspectives and tackle real-world challenges, they became more creative with technology and less reliant on step-by-step instructions. These findings aligned with the results of this study, which showed that community-based challenges helped students develop problem-solving skills while designing innovative solutions with technology.

STEM teachers described how problem solving from a localized perspective ignited an empathetic response from students, who showed care and concern for others. Utilizing a broad definition of innovative technology, STEM teachers described how students worked to solve problems with both real and imaginary solutions. The findings revealed how design thinking inspired students to solve problems through an iterative process.

Innovative Solutions

Korhonen et al. (2023) described technology as a tool and a way to learn. In innovative project designs, the technology depends on the students' design plans, but teachers can limit the project's goals by giving the students certain technologies. Quigley et al. (2020) described an informal approach to technology integration in STEM similar to that found in the maker movement and the work of Korhonen et al. (2023). A less-formal approach implied the use of problem-solving technology students used in all areas of their life, including how they used technology outside of school. Ellis et al. (2020) found that only some STEM teachers used technology in innovative ways, relying instead on technology as a digital tool, which is aligned with the work of Dare et al. (2021).

Teachers needed to keep growing their technology skills and how technology could transform STEM learning for students. The results of this study supported the use of technology as a solution for problem solving rather than for isolated technology skills. Further analysis of this distinction would benefit the integrated instructional technology field.

Findings Related to the Theoretical Framework

The purpose of this qualitative case study was to explore how K-8 STEM teachers facilitated projects utilizing innovative technologies to solve community-based problems. Learning theories underpinned the goals of the study and were grounded in the constructionist and pragmatist theoretical frameworks. The pedagogies of constructionism and pragmatism supported the belief that children learn best through direct experience. In a classroom setting, students built their understanding of the world through their observations and interactions.

Constructionism

The theory of constructionism describes learning based on building, reflecting, and iterating (Noss & Clayson, 2015). Seymour Papert (1986) used principles of constructivism theory (Vygotsky, 1978) to focus more intentionally on students' learning by constructing new knowledge through hands-on activities. This study supported the intentions of current constructionism theory through the descriptions teachers gave of students designing and building innovative solutions with technology. Students learned through doing: designing, building, iterating, and reflecting on their work.

Pragmatism

Pragmatism is another theory that supports learning by doing (Dewey, 1916). Niiranen (2021) expounded on Dewey’s theory by summarizing four principles that were fully supported by this study: a) proposing solutions generated new learning about a problem, b) learning was linked to the environment, c) contextual learning provided an authentic and relevant experience, and d) mistakes were part of the learning process. All participants described elements of pragmatic learning students experienced through designing solutions to solve problems. STEM education was one of the few areas in schools where students were encouraged to learn by solving problems from the environment around them.

Conclusions From the Study

Five themes from the qualitative case study informed the theoretical framework of constructionism and pragmatism and answered three research questions. The two overarching themes of STEM Habits of Mind and Lens of Empathy informed all three research questions. They showed the strong connection between STEM-related behaviors and the social-emotional impact of those behaviors when teachers intentionally led students to solve problems for others. Connecting Beyond the Classroom, Developing Purposeful Learning, and Innovative Technology completed the analysis related to the research questions. Understanding how teachers reached out to experts and organizations beyond the classroom to find and design projects for students to solve and develop those ideas into purposeful learning using technology solutions completed the picture and addressed the research questions.

Asking students to step outside their perspective and connect to the world around them increased engagement and had a lasting impact on both students and teachers. Moving forward, shifting the focus in STEM away from a heavily technology-based conceptualization and toward a problem-solving focus would allow room for technology skills to be learned by accomplishing a needed function. The problem-solving focus would use a comprehensive understanding of technology as a solution-driven tool.

A technology model designed to build skills by solving problems aligns with the theoretical framework grounded in constructionism and pragmatism. Supported by the theoretical framework, allowing students to solve problems by building and designing innovative solutions, either real or imaginary, was attained through the regular practice of looking outside the classroom for ideas. The connections drew students away from their perspectives to see how problem solving could help others.

Limitations

Yin (2018) cautioned that qualitative case studies inherently limit the transferability of their results due to factors such as sample size, reliance on personal experiences and perspectives, and the unique characteristics of the participants required for inclusion. This qualitative case study explored the perceptions of 15 K-8 STEM teachers in the Midwest United States. As Yin (2018) suggested, the findings were constrained in transferability to a broader population of STEM teachers. Future researchers should give transferability careful consideration when applying the results of this study to other contexts.

Using social media for participant recruitment posed a limitation, as not all teachers use these platforms. To address this limitation purposive sampling and snowball sampling identified participants who closely matched the study's scope. Blair and Blair (2015) noted issues with social media sampling bias, but found it appropriate for academic research where numerical estimates were not needed for generalization. Further limitations on the population sample are found in the impact of snowball sampling. Participants recommended other teachers they know, often in similar educational settings. The homogeneity of the participants is a limitation.

A limitation that was reported by potential participants who declined to participate related to time constraints and scheduling. The data collection window was April and May. In a typical school year, those months are very busy for teachers. Recruiting teachers during the summer months when they have flexibility might increase the responses.

Another limitation was researcher bias evident in the enthusiasm and interest in the topics discussed by the participants. Data triangulation and member checking were employed to mitigate potential credibility issues. Conducting a quantitative study with similar questions may yield reliable and measurable data. While the results of the research have limited transferability, its strength lies in providing in-depth insights that can enhance understanding in related settings, or inspire future research on similar topics.

Recommendations

The implications for STEM education showed the value of community-based problem solving to engage students in learning by designing innovative solutions that solve real-world problems for others. Teachers and education leaders should use the learning theories outlined to support the inclusion of STEM education in K-8 learning environments, providing students with theoretically supported learning experiences that are engaging and designed to provide a transdisciplinary experience for learning.

Recommendations for Professional Development

Recommendations for professional development included in-person professional development sessions at the district level, content area publications, and conference presentations, sharing with teachers the idea of using a lens of empathy when selecting STEM projects for students. STEM teachers and leaders needed support and examples of changing the perspective from an internal personal view to an outward, community-based perspective (Bush & Cook, 2019; Holmes et al., 2021).

Sharing ideas through professional learning networks of STEM educators for community connections built teachers' capacity to seek their ideas and grow new connections to the community. As educators looked outward for ideas, they could continue to build purposeful learning around community-based learning. Building a STEM program could look like a spiral of learning. Even in the youngest grades, students could learn essential STEM Habits of Mind to solve imaginary problems for others, such as their family, classmates, or pets. The STEM teachers in this research used curriculum-based instruction to provide foundational skills and build STEM habits of mind.

Recommendations for Future Research

The lessons learned along the way revealed several ideas for future research. One idea evolved from the theme STEM Habits of Mind. Built on the work of Costa (2008), STEM Habits of Mind was discussed by Asunda and Weitlauf (2018) as it applied to Grades 9-12. Exploring this idea further with a quantitative methodology would add to the literature a new way of looking at students' thinking and behaviors when engaging in problem solving in STEM education. Breaking it down further into K-5, 6-8, and 9-12, STEM education classes would create an interesting picture of the most important or most-used habits of mind in STEM classrooms.

Additional research could further identify students' perceptions of the use of localized problem solving, technology used for problem solving, and a deeper dive into the benefits of using a lens of empathy in STEM. Compiling an understanding of students' perceptions through a quantitative or mixed methods approach could expound on pedagogical decisions' impact on students' learning. Gathering perceptions and experiences from STEM teachers in other countries and other parts of the United States beyond the Midwest would add to the knowledge.

Research on similar ideas, such as that done by Korhonen et al. (2023) in Finland, would generate an interesting comparison between STEM education in the United States and STEM education in other countries.

Implications for Leadership

School leaders ensured the best access to instruction for student learning. Staying current on research-driven best practices was how leaders served their teachers. Professional development opportunities for teachers involved finding and designing community-based problem-solving projects for students. Bringing awareness of solving problems for others to teachers' pedagogical choices could improve STEM programs. Connecting to students' interests and making a real connection to a problem outside the classroom built an empathetic understanding of problem solving and learners' propensity to see and solve problems independently.

Recommendations for innovative technology use included informing educational leaders of using technology as a problem-solving tool. Reframing the purpose of technology could add an element of *why* purchasing decisions were often made unilaterally at a district level. Allowing STEM teachers to request specific technology that met the needs of their problem-solving classroom scenarios capitalized on the budgeting decisions at the classroom level, ensuring good stewardship of local resources.

Social Change

This study has the potential to impact social change by promoting a shift in K-8 STEM education towards a focus on community-based problems and fostering a lens of empathy. The study results could encourage teachers and students to become active contributors to their communities. Findings could also positively impact change by involving students in identifying and solving local problems, empowering them with a sense of social responsibility and the idea that they could impact their surroundings positively.

Conclusion

This qualitative case study research explored the design and facilitation of community-based K-8 STEM projects utilizing innovative technology. The themes generated from the data guided the recommendations for professional development, stakeholder decision-making, and future research. The findings highlighted the significance of integrating STEM Habits of Mind and a Lens of Empathy in identifying community-based problems and designing engaging and relevant STEM projects. Bolstered by the additional themes of Connecting Beyond the Classroom, Developing Purposeful Learning, and Innovative Solutions, these findings pointed to the critical role teachers play in connecting beyond the classroom.

By collaborating with community partners and experts in the field to establish real-world contexts for learning and integrating innovative technology, such as 3D printers, robotics, and coding, teachers utilized a solution-based approach. This approach could also provide students with opportunities to use such tools as 3D printers, robotics, and coding to solve problems in real-world contexts. Emphasizing the importance of community connections could inspire social change, empowering students to become leaders and change agents in their communities.

The implications of this study extended to teachers, curriculum developers, professional development providers, and educational leaders. Educational leaders could use this information to decide funding, staffing, training, and curriculum development in K-8 schools. Many schools in the K-8 grade range do not offer STEM classes. Typically, stand-alone science and mathematics classes present content in traditional formats. The study recommendations did not look to eliminate those programs, but to realize a problem-solving-based STEM class could move student learning to a new level, capturing the creativity, critical thinking, and innovation of a technology generation that has yet been seen in our schools.

To move beyond a pre-designed curriculum, K-8 STEM teachers needed guidance on meaningful ways to incorporate real-world experiences for their students. Using community-based problems as inspiration for problem solving shows many possible benefits to student learning. Integrating technology as a solution-generating tool rather than a whole-class, skills-based tool took technology to a deeper and more meaningful level, potentially moving students' view of technology to a problem-solving, solution-driven tool.

This study contributed to understanding K-8 STEM education by highlighting the significance of implementing community-based learning, utilizing empathy to find solutions that benefit others, and using innovative technology to produce solutions beyond standard skill-based learning. The outcomes of this research could encourage social transformation by enabling students to become agents of positive change in their communities. Teachers have the power to influence the greater good for all, and one step forward is empowering students to value helping others in their communities.

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Appendix A

IRB Approval Letter

AMERICAN COLLEGE of EDUCATION

January 19, 2023

To: Kathy Garneau
Melissa Ortega, Dissertation Committee Chair

From: Institutional Review Board American College of Education

Re: IRB Approval
"Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education"

The American College of Education IRB has reviewed your application, proposal, and any related materials. We have determined that your research provides sufficient protection of human subjects.

Your research is therefore approved to proceed. The expiration date for this IRB approval is one year from the date of review completed on, January 19, 2024. If you would like to continue your research beyond this point, including data collection and/or analysis of private data, you must submit a renewal request to the IRB.

Candidates are prohibited from collecting data or interacting with participants if they are not actively enrolled in a dissertation sequence course (RES6521, RES6531, RES6541, RES6551, RES6561, RES6302) and under the supervision of their dissertation chair.

Our best to you as you continue your studies. Sincerely,

Tiffany Hamlett
Chair, Institutional Review Board American College of Education

Appendix B Site

Permission Request Documentation

IDEA Permission Request

AMERICAN COLLEGE of EDUCATION

8/14/2022

[redacted]

My name is Kathy Garneau and I am a doctoral candidate at American College of Education (ACE) writing to request permission to interview K-8 STEM teachers in the Midwest United States. This information will be used for my dissertation research related to **Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.**
This qualitative case-study research aims to discover how STEM teachers use problems in their community for STEM projects their students attempt to solve. Solutions can be real or imaginary models of possible solutions.
I will start with screening questionnaire to find teachers who fit the inclusion criteria for my study. Once the questionnaire is sent, I need 15 participants for interviews that will last 30-45 minutes.

Important Contacts for this study include:

Principal Investigator: Kathy Garneau
E-mail: Kathy.garneau8371@my.ace.edu
Phone: 847.372.9841

Dissertation Chair: Dr.
Melissa Ortega
E-mail: Melissa.Ortega@ace.edu.

Thank you for your attention to this issue and prompt response. I appreciate your time and consideration of my request.

Regards,

Kathy Garneau

ISTE Permission Request

AMERICAN COLLEGE of EDUCATION

10/25/2022

[redacted]

[redacted]

My name is Kathy Garneau, and I am a doctoral candidate at the American College of Education (ACE) writing to request permission to interview K-8 STEM teachers in the Midwest United States. This information will be used for my dissertation research on **Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.**

This qualitative case-study research aims to discover how STEM teachers use problems in their community for STEM projects their students attempt to solve. Solutions can be real or imaginary models of possible solutions.

I will start with a screening questionnaire to find teachers who fit the inclusion criteria for my study. Once the questionnaire is sent, I need 15 participants for interviews that will last 30-45 minutes.

Important Contacts for this study include:

Principal Investigator: Kathy Garneau
E-mail: Kathy.garneau8371@my.ace.edu
Phone: 847.372.9841

Dissertation Chair: Dr. Melissa Ortega
E-mail: Melissa.Ortega@ace.edu.

Thank you for your attention to this issue and prompt response. I appreciate your time and consideration of my request.

Regards,

Kathy Garneau

Facebook Group: Elementary STEM Specials Teachers Permission Request

AMERICAN COLLEGE *of* EDUCATION

12/04/2022

[redacted]
Facebook Administrator: Elementary STEM Specials Teachers

Dear Emma Smith;

My name is Kathy Garneau and I am a doctoral candidate at American College of Education (ACE) writing to request permission to interview K-8 STEM teachers in the Midwest United States. This information will be used for my dissertation research related to **Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.**
This qualitative case-study research aims to discover how STEM teachers use problems in their community for STEM projects their students attempt to solve. Solutions can be real, or imaginary models of possible solutions.
I will start with screening questionnaire to find teachers who fit the inclusion criteria for my study. Once the questionnaire is sent, I need 15 participants for interviews that will last 30-45 minutes.

Important Contacts for this study include:

Principal Investigator: Kathy Garneau
E-mail: Kathy.garneau8371@my.ace.edu
Phone: 847.372.9841

Dissertation Chair: Dr. Melissa Ortega
E-mail: Melissa.Ortega@ace.edu.

Thank you for your attention to this issue and prompt response. I appreciate your time and consideration of my request.

Regards,

Kathy Garneau

Appendix C

Permission from Site Administrators

IDEA Permission

ILLINOIS DIGITAL EDUCATORS alliance

2735 Hassert Blvd Ste 135 PMB 304 | Naperville, IL 60564 | www.ideaillinois.org

Dear Ms. Garneau,

IDEA would be honored to assist you with your dissertation research. We are happy to send an email on your behalf to our membership. Information can be sent to Heather Woomer at either hwoomer@ideaillinois.org or info@ideaillinois.org.

Sincerely,

[redacted]

[redacted]

Event Coordinator
Illinois Digital Educators Alliance

ISTE Permission

LK [redacted]

To: Kathy Garneau Tue 11/8/2022 11:21 AM

Please be cautious
This email originated from outside of ACE organization

Hi Kathy,

Yes of course! You have permission to share about your doctoral research and recruit volunteers to participating by posting in the STEM forum in ISTE Connect.

[redacted]
Director of Membership and Community
ISTE

...

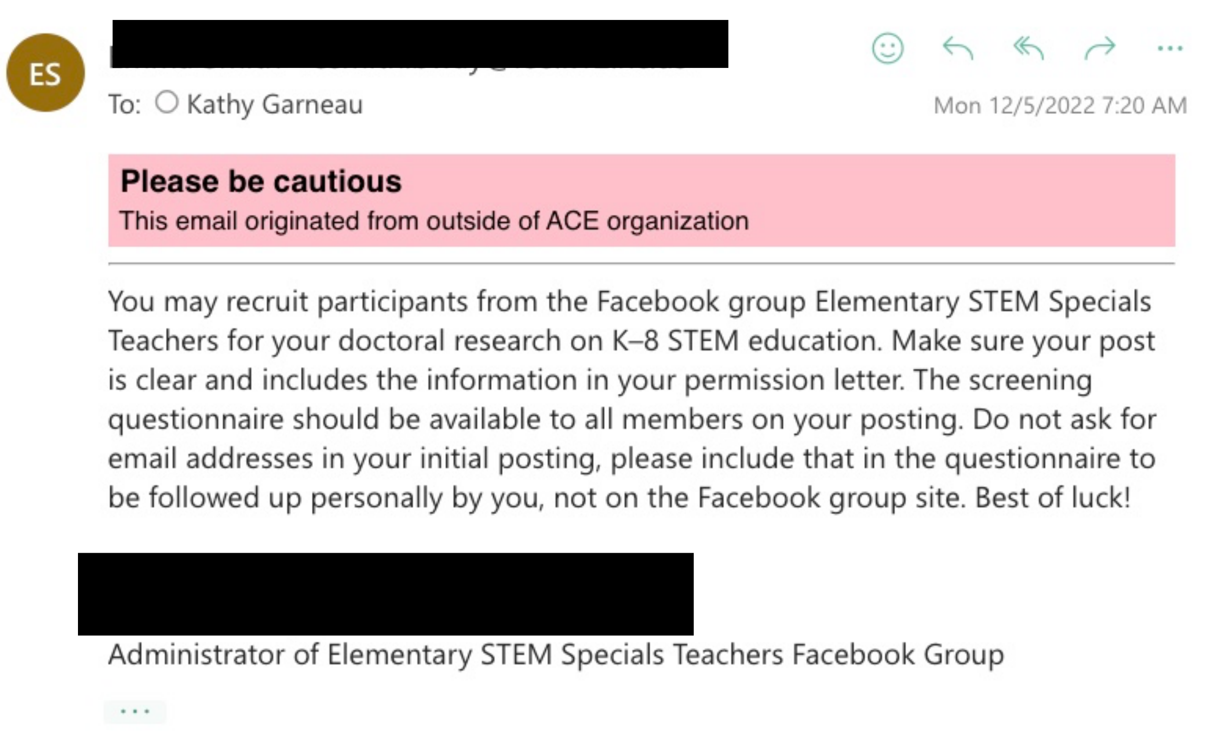
NSTA Forum Posting Rules

nsta Search for anything Bookstore My Library Log Out Menu

also agree to reserve list discussions for topics best suited to the medium.

- As with any community, there are guidelines governing behavior on the list servers. For instance, violating antitrust regulations, libeling others, selling, and marketing are not permissible.
- Do not challenge or attack others. The discussions on the lists are meant to stimulate conversation not to create contention. Let others have their say, just as you may.
- Do not forward, copy, or paste all or portions of e-mails sent off-list to you or from you to any NSTA list e-mail address.
- Do not post commercial messages. The cyberspace term for this is spamming.
- When recommending a commercial product or service in response to a request for suggestions from another listserv poster, please share your personal experience with that product or service. Recommendations of a product or service from individuals with a vested interest in the product or service will be viewed as commercial messages.
- Please do not contact people directly with products and services that you believe would help them.
- Please try not to include attachments. Attachments of any malware will result in immediate suspension of your list subscription privileges until such time as credible proof of the complete repair and "disinfection" of your system can be provided to NSTA. If you wish to share large or multiple files, please click to NSTA's Community Forums, where you can upload and download resources of any file type in groups similar in taxonomy to the listservs.
- Use caution when discussing products. Information posted on the lists is available for all to see, and comments are subject to libel, slander, and antitrust laws.
- All defamatory, abusive, profane, threatening, offensive, or illegal materials are strictly prohibited. Do not post anything in a list server message that you would not want the world to see or that you would not want anyone to know came from you.
- Please note carefully all items listed in the disclaimer and legal rules below, particularly regarding the copyright ownership of information posted to the list.
- Remember that NSTA and other e-mail list participants have the right to reproduce postings to this list server. Any message sent via the lists should not be considered private. For your own security, please do not include any confidential information.
- The NSTA E-Mail Lists are limited to use by NSTA members. Please do not post messages on behalf of a friend, student, or colleague.
- Do not send the same message to multiple NSTA lists. You may send your message to only the most appropriate list. Cross-posting of messages is not allowed.
- Harvesting contact information of participants in list server discussions is not allowed.
- Self-promotion for commercial gain is not permitted.
- If you share a survey request, you must state the purpose of the study and who is sponsoring it, show your methods, and offer to share the results. All of this information must appear in your listserv post.

Elementary STEM Specials Teachers Facebook Group



ES [redacted]

To: Kathy Garneau

Mon 12/5/2022 7:20 AM

Please be cautious

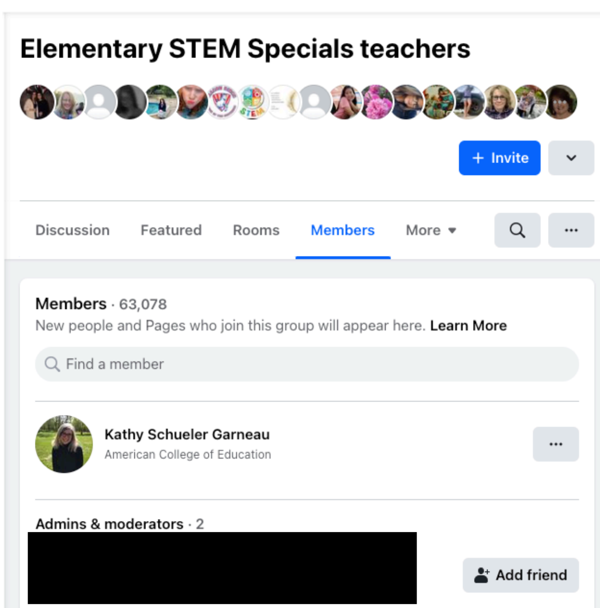
This email originated from outside of ACE organization

You may recruit participants from the Facebook group Elementary STEM Specials Teachers for your doctoral research on K–8 STEM education. Make sure your post is clear and includes the information in your permission letter. The screening questionnaire should be available to all members on your posting. Do not ask for email addresses in your initial posting, please include that in the questionnaire to be followed up personally by you, not on the Facebook group site. Best of luck!

[redacted]

Administrator of Elementary STEM Specials Teachers Facebook Group

Administrator Verification



Appendix D

Recruitment Information

Recruitment Email

Attention all K-8 STEM teachers!

Do you have experience integrating technology into STEM education? Do your students design innovative solutions to real or imaginary problems? I would love to interview you about your experiences.

Who is invited to participate? Any STEM or STEAM teachers in grades K-8 from a midwestern state.

How do you get started? Respond to a short questionnaire that should take no more than 10 minutes to complete: http://bit.ly/3XtiU3M
All answers to the screening questionnaire are confidential.

If selected for the second part of the study, I will contact you through the email you provided in the questionnaire. I will interview via Zoom for up to 30 minutes.
Your participation is entirely voluntary, and you may withdraw at any time.

Why is this research necessary?
As STEM and STEAM education continues to grow in Grades K-8, sharing teachers' experiences will help other STEM/STEAM teachers create exciting new opportunities for their students. Your stories are essential to growing our field!

If you have any questions, please contact me by my email. Please do not respond in the comments with any personal information.

Do you have any friends or colleagues who are also STEM/STEAM teachers? Please share this link with them!

Thank you,
Kathy Garneau
Doctor of Education Candidate in Instructional Technology-STEM
American College of Education

IDEA Listserv Email

KG Kathy Garneau
To: Illinois Digital Educators Alliance <info@ideaillinois.org>
Sun 2/12/2023 7:36 AM

Hello everyone,

My name is Kathy Garneau, and I am looking for K-8 STEM/STEAM teachers to interview for my doctoral research study. If you are interested, you can click the link below for additional information.

For questions, don't hesitate to get in touch with me at kathy.garneau8371@my.ace.edu

https://bit.ly/3XtiU3M

This study has been approved by the American College of Education.

ISTE Forum Post

1. Doctoral research participants needed in K-8 STEM/STEAM Education

Kathy Garneau

Posted 01-25-2023 21:19

Reply More

Attention all K-8 STEM/STEAM teachers!
Do you have experience integrating technology into STEM education? Do your students design innovative solutions to real or imaginary problems? I would love to interview you about your experiences for my dissertation research on STEM/STEAM education.
Who is invited to participate? Any STEM or STEAM teacher in grades K-8 from a midwestern state.
How do you get started? Respond to a short questionnaire that should take no more than 10 minutes to complete:
http://bit.ly/3XtiU3M
All answers to the screening questionnaire are confidential.
If selected for the second part of the study, I will contact you through the email you provided in the questionnaire. I will schedule an interview with you via Zoom for no more than 30 minutes.
Your participation is entirely voluntary, and you may withdraw at any time.
Why is this research necessary?
As STEM and STEAM education continues to grow in grades K-8, sharing teachers' experiences will help other STEM/STEAM teachers create exciting new opportunities for their students. Your stories are essential to growing our field!
If you have any questions, don't hesitate to get in touch with me by email.
kathy.garneau8371@my.ace.edu
Do you have any friends or colleagues who are also STEM/STEAM teachers? Please share this link with them!
Thank you.
Kathy Garneau
Doctor of Education Candidate in Instructional Technology-STEM
American College of Education

NSTA Forum Post

Author Post

Jan 25, 2023 at 8:22 PM Reply to this post Report Edit

Kathy Garneau
40 Points

Attention all K-8 STEM/STEAM teachers!
Do you have experience integrating technology into STEM education? Do your students design innovative solutions to real or imaginary problems? I would love to interview you about your experiences for my dissertation research on STEM/STEAM education.
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If you have any questions, don't hesitate to get in touch with me by email.
kathy.garneau8371@my.ace.edu
Please do not respond in the comments with any personal information.
Do you have any friends or colleagues who are also STEM/STEAM teachers? Please share this link with them!
Thank you.
Kathy Garneau
Doctor of Education Candidate in Instructional Technology-STEM
American College of Education

Appendix E

Screening Questionnaire with Informed Consent

[Preview link.]

Thanks for using a Qualtrics Survey Template! To get started, follow the instructions below. When you're ready to go, make sure to delete this question so that your respondents don't see it!

1. Read through this survey and make sure to update or replace text when applicable. (You can also remove any questions that you don't need - just click on the question, then click on the little red minus button to the left of the question to put it into the trash.)

2. Click the "Preview" button at the top right of the editor page to take a look at what your respondents will see when they take your survey.

3. When your survey is ready, go to the "Distributions" tab above to see how you can send your survey to your respondents.

Remember to delete this question, and happy surveying!

Welcome to the research study!

We are interested in understanding [STUDY TOPIC]. For this study, you will be presented with information relevant to [STUDY TOPIC]. Then, you will be asked to answer some questions about it. Your responses will be kept completely confidential.

The study should take you around [SURVEY DURATION IN MINUTES] to complete. You will receive [INCENTIVE] for your participation. Your participation in this research is voluntary. You have the right to withdraw at any point during the study. The Principal Investigator of this study can be contacted at [NAME/ EMAIL ADDRESS].

By clicking the button below, you acknowledge:

Your participation in the study is voluntary. You are 18 years of age. You are aware that you may choose to terminate your participation at any time for any reason.

I consent, begin the study

I do not consent, I do not wish to participate

>>

Total number of years experience teaching STEM/STEAM.

- 0-5 years
- 6-12 years
- More than 12 years

Grades taught in STEM/STEAM. Select all that apply.

- K-2
- 3-5
- 6-8
- 9-12

Have you used a problem from your community as inspiration for a STEM/STEAM project? The project can be a real-life solution, or a model or scenario mimicking a solution.

- Yes
- Maybe
- No

Have you facilitated an innovative use of technology to solve a problem?

- Yes
- Maybe
- No
- Probably yes

If yes, or probably yes, please give a brief description.

Do you encourage your students to solve problems **for others**?

- Yes
- Maybe
- No
- Probably yes

Q10. Would you be willing to participate in a semi-structured interview over Zoom to gather additional information?

- Yes
- Maybe, I have additional questions
- No

Q11. If you are willing to participate further, please provide your email address below.

>>

Appendix F

Informed Consent

Prospective Research Participant: Please read this consent form carefully and ask as many questions as possible before deciding whether you want to participate in this research study. You are free to ask questions before, during, or after participating in this research.

Project Information

Project Title: Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.
Researcher: Kathy Garneau
Organization: American College of Education
Email: kathy.garneau8371@my.ace.edu Telephone: 847-372-9841

Date of IRB Approval:
Please note that the American College has approved this research study by the Education Institutional Review Board. The IRB approved this study on January 19, 2023. A copy of the approval letter will be provided upon request.

Researcher's Dissertation Chair: Dr. Melissa Ortega

Organization: American College of Education

Email: Melissa.Ortega@ace.edu
My name is Kathy Garneau, and I am doing research under the guidance and supervision of Dr. Melissa Ortega, my dissertation chair at the American College of Education (ACE). This research is part of the requirements for a Doctor of Education degree in Instructional Technology. Before deciding to participate, you can talk to anyone you feel comfortable with about the research. I will give you some information about the project and invite you to be part of this research. Please ask me to stop as we go through the information, and I will provide you with additional explanations. If you have questions later, you can ask them then.

Purpose of the Research
The title of this research is **Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.** This research aims to discover how STEM teachers use problems in their community for STEM projects their students attempt to solve. Solutions can be real or imaginary models of possible solutions. I am interested in teachers' opinions of how students feel when solving problems for others and how they use technology to solve them.

Research Design and Procedures
This qualitative case study research will involve your participation in a semi-structured interview that should last about 30-45 minutes. Semi-structured means I will ask validated questions and follow-up questions based on your answers. The interview will be recorded and transcribed for analysis purposes. Additionally, some participants may be invited to submit a lesson plan documenting a STEM project discussed in the interview. I will not share information about you

with anyone outside my research team. The information I collect will be kept confidential. I will use a numerical code to identify you, with your identifying information held in a separate locked cabinet. I will save all electronic recordings, and transcripts will be held in a secure cloud-based location. During the defense of the doctoral dissertation, the data collected will be presented to the dissertation committee. The data will be kept in a locked cabinet and destroyed in three years.

You are invited to participate in this research because your experience as a STEM teacher can contribute much to our understanding of STEM education. The benefits of participating include sharing your wealth of knowledge and experiences with other STEM teachers, further enriching our understanding of STEM education. I will include research findings in my final dissertation, which will be electronically available through dissertation databases for dissemination. Presentations at conferences or sharing more broadly through publications can also share the results with other people interested in this research.

If you have questions, you may contact Dr. Melissa Ortega at melissa.ortega@ace.edu. This research plan has been reviewed and approved by the Institutional Review Board of the American College of Education. This committee's role is to ensure research participants are protected from harm. If you wish to ask questions of this group, email IRB@ace.edu.

Certificate of Consent

I have read the information about this study, or it has been read to me. I acknowledge why I have been asked to participate in the research study consisting of an interview and possible lesson plan documents. I have been allowed to ask questions about the study, and any questions have been answered to my satisfaction. I certify that I am at least 18 years of age. I consent voluntarily to be a participant in this study.

Print or type Name of Participant:

Signature of Participant:

Date:

I confirm that the participant was allowed to ask questions about the study, and all the questions were answered to the best of my knowledge. I confirm that the participant has not been coerced into giving consent, and the consent has been given freely and voluntarily. A copy of this consent form has been provided to the participant.

Lead Researcher: Kathy Garneau

Signature:
Date:

Appendix G

Interview Protocol

Hello, my name is Kathy Garneau, and I want to express my gratitude for your willingness to participate in this research study. I know you have already returned your consent form to me; do you have any questions? I'll be recording this session. Is that still ok with you?
[If the participant answers yes, turn on recording.]
Ok, I've started recording. To capture it on the recording, is it ok that I record this session? Remember, you can stop the interview anytime if you feel uncomfortable. You may also skip any question you prefer not to answer. I expect this interview to last between 30 and 45 minutes.
Let me tell you a little about my study:
As you know, this research looks at your facilitation of STEM projects based on community problems and innovative technology. I want to collect the stories of experienced STEM teachers to share their knowledge with others.
Before we jump into specific questions, please tell me a little about yourself.

Interview Questions

Tell me about your job. What does STEM or STEAM mean to you?

[FOLLOW-UP]: How long have you taught STEM?

[FOLLOW-UP]: What grade levels do you teach?

[FOLLOW-UP]: Where is your school located?

1) Describe your STEM curriculum.
   a) [FOLLOW-UP]: Where do you find your project ideas?
   b) [FOLLOW-UP]: Does your district provide any curriculum?
   c) [FOLLOW-UP]: Do you have autonomy over what you teach?
   d) [FOLLOW-UP]: Describe any standards you use, such as NGSS, ISTE, or other standards, when planning.
   e) [FOLLOW-UP]: What additional resources do you use when planning?
2) Describe how you find community-based problems or issues to work with.
   a) [FOLLOW-UP]: Describe a project that you would consider community-based.
   b) [FOLLOW-UP]: What inspired the idea?
   c) [FOLLOW-UP]: Describe the planning process.
   d) [FOLLOW-UP]: Describe a community partnership involved with the project.
3) Describe how your students use technology to solve problems.
   a) [FOLLOW-UP]: What are some specific examples of how students use technology to solve problems
   b) [FOLLOW-UP]: How do students find ideas?
   c) [FOLLOW-UP]: How do students learn to use the technology?
   d) [FOLLOW-UP]: Describe the design process.
   e) [FOLLOW-UP]: What is your role in the classroom?
   f) [PROBES]: Can you tell me more about it? What else do the students do?
4) What does *problem solving for others* mean to you?
5) Describe how you facilitate *problem solving for others* in STEM.
6) Please describe a STEM project that positively impacted your students, school community, or others. This could be a real solution or a hypothetical model of a solution.
   a) [FOLLOW-UP]: Describe any specialized training the students need.

   b) [FOLLOW-UP]: How do you think the students felt?
   c) [FOLLOW-UP]: How could you tell?
   d) [FOLLOW-UP]: Looking back, what made this project feel special?
7) What would your “perfect” community-based STEM project look like?
   a) [FOLLOW-UP]: What technology would you need to make it happen?
   b) [FOLLOW-UP]: What other resources or training would you need?
8) Is there anything else you would like to share about your STEM classroom?
9) Do you have any comments or questions for me?
   a) [FOLLOW-UP]: Is there anything you would like me to explain further?

Thank you for taking the time to participate in this interview with me. Before I turn off the recording, do you have any additional information that might be helpful to me? Do you have any questions you would like to ask me about the study?
Again, thank you. You have my contact information if you need to reach me later. I will email you a copy of our interview transcript for your review in the next few days. You will be able to correct any errors in the transcript you see.
[End Recording]

Appendix H

Subject Matter Expert Feedback

SME Email request

Subject Matter Expert feedback

1

KG

Kathy Garneau

[redacted]

Thu 8/4/2022 10:59 AM

Interview Questions 8.4.22 M...
15 KB

August 4, 2022

[redacted]

Hello, I am Kathy Garneau, a doctoral student at the American College of Education. I am doing research under the supervision and guidance of my dissertation chair, Dr. Melissa Ortiz.

I am writing to you today to request your help and input regarding the research instrument (See file attached) that I have designed for my dissertation research project.

The study I plan on conducting for my dissertation is **Community-Based Problem-Solving in STEM: A Qualitative Case Study of K-8 STEM Education.**

The study will use a qualitative case study research design to explore teachers' perceptions in K-8 STEM classes that use community-based problems as part of their curriculum. This study will examine the teacher's perceptions of facilitating students' use of innovative technology and how teachers encourage students to solve problems for others.

The research instrument is a semi-structured interview based on the attached questions. The selection of participants will be made through purposive sampling. Participants will reply to a screening questionnaire posted on social media by STEM teacher groups and professional learning communities. Fifteen teachers will be selected for interviews.

Based on your extensive experience in the field, your input on the appropriateness of my research instrument would be invaluable. Would you consider taking a moment to examine the interview questions and offer me some guidance and feedback? Your input would contribute greatly to the validity of the study.

If you have any questions, please do not hesitate to contact me at kathy.garneau8371@my.ace.edu.

Thank you in advance for your collaboration. I look forward to hearing from you.

Sincerely,
Kathy Garneau

SME Feedback 1

Re: Interview questions for subject matter expert feedback

Hi Kathy-

Thank you for sharing your questions with me. Your research study sounds very interesting, I'd love to learn more when you are finished. Here are some initial thoughts regarding your questions:

- Questions 1 and 2 are well worded and follow a clear path with the follow-up questions.
- Question 3 may benefit with an initial question of "What does community-based problem-solving mean to you?" (similar to question 5). I think the first follow-up question would then be " Describe how you find community-based problems or issues to work with."
- Question 4 (along with the follow-up questions) feels like it could be broken down into two different questions focusing on **technology use** in the classroom (4A/4C) and the **design process** (4B/4D/4E).
- Assuming that *problem-solving for others* is connected to community-based problem-solving, maybe questions 5 and 6 would fit within question 3 or immediately after.
- Questions 7-10 have a great flow and are clear/concise.

I hope that this feedback helps you in your research. Please feel free to reach back out with any further questions.

[redacted]

-

[redacted]

SME Feedback 2

Overall Feedback:
I'm thinking this is an in-person interview as opposed to one done over email (written answers) and that the follow up questions are more for you to stay consistent.
My understanding is that student use of technology is a major component of this dissertation. If so, I added some extra follow up questions that I think will give you more of that information from the teachers that you interview.
Does it matter if someone has taught STEM, STEAM, or have done both. Does the distinction matter with your dissertation?

Feedback per question:

1. Straightforward. Maybe add in the STEAM option. If someone has done both, have them describe the difference.
2. Add: Does your school/district provide any curriculum? How is that curriculum chosen?
3. Does it need to be a local project? Add: How do you find community-based issues, projects, or members to work with?
4. Add: Did your students require training for tech?
5. None
6. None
7. Does the project need to have been completed? Could the project have been hypothetical or does it need to have been implemented?
   Follow Up Questions: Was it successful? What type of technology was required? What type of training did your students or you need?
   Alternative question thread: Did you ever have a project that fell apart or was unable to be completed due to technology constraints? What type of technology was needed?
8. Are you looking for the "perfect" project to be community based? If so, add that to the question. Follow up question: How would technology play into this project?
9. None
10. None

SME Feedback 3

Subject Matter Expert feedback

KM [redacted]

Mon 8/8/2022 2:28 AM

Hi Kathy,
Here are my comments. But keep in mind that I don't really know the purpose of your study or the literature you based these on, so my feedback may be off base. I hope it is helpful though. I tried to view the questions through the lens of your audience and identify ambiguities or areas where they may not quite understand what you are asking.

- Q1a: When you ask how long teachers have taught STEM, are you interviewing math teachers, science teachers, engineering teachers, or teachers labelled as generic STEM teachers? How narrow is your audience? Are you going to need some questions that help you clarify this during the interview (e.g. what does teaching STEM mean to them? Is it the same as it means to you?)
- Q2b: I wonder if "autonomy" would be better than the word "control"?
- Q2d: is close ended. Consider making it open ended by asking, "what additional resources do you use when planning?"
- Q2: Would it be helpful to also find out if there are any metrics they are accountable for - for example, if there are common benchmark assessments, school/district/state testing associated with their instruction? As that may influence their planning.
- Q3a: is close ended. Consider "Describe the project."
- Q3b: I don't think you want to use the word "where" here. What is the purpose of this question? Do you mean what inspired the idea? Or what first prompted the idea? Or how did the idea for this project orginate?
- Q3c: Respondents might need a little more structure to this question. What specific planning process are you referring to? Are you referring to the entire process from conception through completion? Are you referring to developing partnerships and establishing an authentic student work output? Are you referring to the lesson planning process that resulted in some sort of unit plan?
- Q3d: is close ended. Consider "Who else have you collaborated with on this project?"
- Q4a: is close ended. Consider "What are some examples of how your students use technology to solve problems?" Except you may need to clarify a bit more. To solve problems when? Where? In the classroom? In their everyday lives?
- Q4b: Where do students find ideas for what? For their projects? For potential solutions for their projects?
- Q4c: Are you just looking for a very open-ended interpretation of this question? When I read it I thought, the engineering design process? The experimental design process? The formal process that we teach in schools, or the more messy real-life process?
- Q4d: How do you help what? Help students come up with ideas for projects? Help students work towards solutions? Help students learn the steps of the engineering design process?
- Q6: There is something about this question that is elusive to me. I think it has something to do with the use of the words "facilitate" and "in STEM." Is this referring facilitating learning experiences where students have the opportunity to solve problems related to STEM? Perhaps if you used quotes around "problem-solving for others" to indicate that it is its own concept?
- Q7a: is it enough if the teacher's STEM project just impacted the students, or are you specifically wanting to hear about projects that solved problems for others? If so, word this as such.
- Q7: You ask about how students felt and how the teacher felt, but you didn't ask about how those impacted (helped) by the project felt - the "others" - is this important data to you as well?

Let me know how it goes.
[redacted]