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The Effect of STEM Integrated Curriculum on Design Thinking Dispositions in Middle School: A Mixed Methods Study

Dina Thomason
University of Texas at El Paso

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THE EFFECT OF STEM INTEGRATED CURRICULUM ON DESIGN THINKING DISPOSITIONS IN MIDDLE SCHOOL STUDENTS: A MIXED METHODS STUDY

DINA THOMASON

Doctoral Program in Teaching Learning and Culture

APPROVED:

Pei-Ling Hsu, Ph. D., Chair

Mourat Tchoshanov, Ph. D.

Penelope Espinoza, Ph. D.

Stephen Crites, Ph. D.
Dean of the Graduate School

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by

DINA THOMASON

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ABSTRACT

There is an ever-increasing need for technologically literate citizens to find creative ways to solve societal problems. STEM, the integration of science, technology, engineering, and mathematics subjects continues to be a popular topic as schools grapple with how to best prepare students for an ever-evolving society. As societal and technological challenges emerge, design thinking has been lauded as a method to enable people to help tackle those challenges. The steps of the design thinking process, *empathize, define, ideate, prototype* and *test* align with engineering design and can be used as a problem-solving method in classrooms to help promote creativity, critical thinking, and collaboration. The purpose of this explanatory sequential mixed methods study was to better understand if a STEM integrated curriculum helps promote design thinking in middle schoolers. The study compared two middle school groups, one that uses an integrated STEM curriculum and one that does not. Quantitative data was collected through the design thinking disposition survey through pre and post testing. Qualitative data was collected through free response questions and student and teacher interviews. There was no difference found in the change of design thinking dispositions between students at the two schools, however students scored lowest on the design thinking disposition of *prototype.* Free response questions showed that seventh grade students at the STEM integrated school perceived an increased ability to design solutions to problems. Student and teacher interviews highlighted benefits of using a STEM integrated curriculum including providing collaborative opportunities to solve hands-on, open-ended problems. How STEM curriculum can develop design thinking should continue to be examined including how to scaffold student understanding of design processes like clearly defining the problem and building prototypes.

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INTRODUCTION

1.1 Background of the Problem

Due to a perceived lack of global competitiveness in the United States in science, technology, engineering, and mathematics (STEM) fields, the National Research Council developed the Next Generation Science Standards (NGSS) to engage students in the practices of science and engineering. The standards are intended to not only make the United States more competitive internationally in technology-related professions but also to enable all citizens to be able to make educated decisions regarding their health and the health of their community (NGSS, 2013). The standards also call for an integration of the teaching and learning of science with engineering processes and technology. Traditionally, schools teach science through distinct subject areas like chemistry, biology, or physics. The National Research Council, however, recognized that technology and engineering principles should be applied to science disciplines to further students' scientific knowledge and solve practical problems (NGSS, 2013).

The NGSS framework explicitly directs students to engage in scientific practice because "students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves" (NGSS, 2013, p. xv). One potential method to address the implementation of scientific practices as well as addressing the need to teach engineering and technology is to use an integrated STEM curriculum. An integrated STEM curriculum generally uses a problem-based or inquiry learning approach as students work collaboratively to solve engineering or science-related problems. Problem-based learning supports the science and engineering practice in the NGSS of asking questions and defining problems (NGSS, 2013). Through problem-based learning, students explore core ideas, and conversely, "core ideas should provide a key tool for understanding or investigating more complex ideas and solving problems" (NGSS, 2013, p. xvi). Additionally, developing critical thinking and communication skills is essential to navigating the modern workplace. Skills central to the development of critical thinking include problem-solving, clarifying information, rejecting hypotheses, and obtaining and evaluating information (Santos, 2017). A STEM-integrated curriculum incorporates the engineering design process to develop, test, and evaluate solutions using core critical thinking skills.

An understanding of how scientists and engineers build knowledge is not only important for economic competitiveness but also for citizens to be scientifically and technologically literate to make informed decisions and create a more techno scientifically just society (Ortiz-Revilla et al., 2020). All citizens should understand STEM disciplines to engage in discussions and policy decisions. A STEM-integrated curriculum should therefore incorporate standards from not just the NGSS, but also the Standards for Technological and Engineering Literacy developed by the International Technology and Engineering Educators Association (ITEEA). A successful STEM integrated curriculum then should be comprised of concepts and skills that are universal to the disciplines of science, technology, mathematics, and engineering and should focus on a student's ability to identify problems, research, develop and evaluate solutions to those problems, and to communicate those solutions to a wider audience. A STEM-integrated curriculum should be effective at developing critical thinking skills that will be valuable to students in their future endeavors enabling them to problem solve and make informed decisions in their daily lives as they analyze and weigh alternative solutions.

In Texas, the Texas Education Agency (TEA) has adopted a STEM framework that includes high-quality indicators as a guide for schools when implementing a STEM program (TEA, 2020). The recommendations for high-quality STEM programs include using project or problem-based learning to solve complex problems and the use of the engineering design process to solve design challenges in creative and innovative ways. The TEA recognizes that besides being technologically and scientifically literate, workplaces are increasingly expecting employees to have the ability to find novel solutions to pressing problems. These skills extend to fields even outside STEM disciplines. Finding innovative solutions to shifting or "wicked problems" requires resourceful and inventive thinking. The central idea behind design thinking is to solve problems using a creative, viable method that meets the needs of the end user (Ideo.com, 2023). Besides promoting creativity, design thinking can encourage better team building and helps designers identify and define problems (Liedtka, 2014). Design thinking, therefore, has become an essential workplace skill throughout different industries because design thinkers are adept at finding creative and fresh solutions to modern challenges (Razzouk, 2012). As industries and technologies rapidly change, design thinking has the potential to address social, political, economic, and technological issues. Governments are promoting design thinking throughout the world to confront these complex issues (Koh et al., 2015). As design thinking becomes an increasingly important skill in the modern workplace and world, schools need to develop design thinking skills within their students to better prepare them for an ever-changing technological and economic landscape.

1.2 Statement of the Problem

The importance of fostering design thinking in students and preparing them for careers in engineering and technology is a critical issue in the United States. Design thinking, however, is not a skill limited to only STEM fields, but is valued by many industries including financial services and health care (Liedtka, 2014). Determining how to develop design thinking skills in students is essential in helping students navigate the complex society they will encounter as adults. Design thinking is related to problem-solving and critical thinking and there is a need to understand how design thinking can be incorporated along with problem-solving and critical thinking skills to best prepare students for those future challenges. Because design thinking "contributes to the educational task of preparing the young to meet the complex global challenges" confronting modern society (Koh et al., 2015, p. 6), schools need to improve the design thinking abilities of their students and foster a design thinking disposition in all students. How to best develop design thinking and critical thinking skills in schools needs to be understood. If schools are to engage students and prepare them for a competitive and ever-changing society, curriculum models that best nurture critical and creative thinking must be further explored and evaluated.

1.3 Purpose of the Study and Research Questions

The purpose of this study was to better understand how an integrated STEM curriculum can prepare students for 21st-century competencies, specifically design thinking through problem-based learning models. This study sought to understand if students attending a school that implements a school-wide STEM curriculum have better design-thinking dispositions and related critical thinking skills than similar students enrolled in a school that does not implement a school-wide STEM curriculum. Additionally, this study attempted to explore through student and teacher interviews how a STEM-integrated curriculum may help develop design thinking.

The overall goal of the study was to determine if there is a significant difference in design thinking disposition between middle school students in an integrated STEM curriculum and similar students who are not participating in a STEM-integrated curriculum. Additionally, through qualitative data collection, this study attempted to identify how students and teachers perceive design thinking and problem-solving in a STEM-integrated classroom.

Because of the increasing prevalence of STEM programs in K-12 education, researchers need a better understanding to determine how students are benefiting from integrated STEM. As the idea of STEM integration gains in popularity, the usefulness of devoting a separate subject to STEM learning needs to be understood. When students and teachers can just focus on STEM activities without the pressures inherent in tested subjects, what are the benefits? Should schools start scheduling dedicated time to a STEM class, not just as an elective or after-school activity but as a required, core class? To better understand how an integrated STEM curriculum can build design thinking and related critical thinking skills in middle school students, this research addressed the following research questions:

1. What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?
2. What are the perceptions of students and teachers on how a STEM-integrated curriculum helps to develop design thinking dispositions?

Research question one was answered through quantitative data collection using design thinking disposition survey of seventh and eighth-grade students at two middle schools, one that employs an integrated STEM curriculum and one that does not. Seventh graders were tested at the beginning and end of the semester to see if there were any differences in design thinking dispositions between students at the two schools. Eighth graders were tested at the end of their eighth-grade year to determine if students who have attended a STEM-integrated school have different design thinking dispositions than students who did not attend a STEM-integrated school.

The hypotheses for the first research question are as follows:

- Null Hypothesis One: There is no statistically significant difference between design thinking dispositions of seventh and eighth-grade students who attended a school with a STEM-integrated curriculum and seventh and eighth-grade students who did not attend a school with a STEM-integrated curriculum.
- Hypothesis One: There is a statistically significant difference between design thinking dispositions of seventh and eighth-grade students who attended a school with a STEM-integrated curriculum and seventh and eighth-grade students who did not attend a school with a STEM-integrated curriculum.

Research question two was answered through qualitative measures, primarily interviews with teachers and students. Qualitative data collection also included free response questions on the post-survey for seventh-grade students and on the survey for eighth-grade students. This question addressed methods that might promote design thinking within an integrated STEM curriculum through problem-based learning and the engineering design process. The data from research question two helped to explain the data from research question one. If there were significant differences in design thinking dispositions between the two schools, then research question two could help to identify what is promoting design thinking in the classroom. If there were no significant differences between the two schools, then research question two can provide insight into other benefits students might gain from a STEM-integrated curriculum like confidence in problem-solving, or interest in STEM careers.

1.4 Significance of the Study

Because design thinking is an essential skill for both industries and governments, understanding how design thinking can be developed in K-12 students needs to be explored. Determining which curricula or practices support the development of design thinking in K-12 students is crucial data that can benefit both students and society. Current education systems have been criticized for being outdated and not adequately preparing students for today's technologically demanding society (Koh et al., 2015), as schools have traditionally taught knowledge as being fixed in isolated subjects. Teaching knowledge out of context is not aligned with the newer NGSS standards or with the push to move schools towards a more interdisciplinary, knowledge-creation focus. If schools are going to change and reflect the needs of society, there must be evidence demonstrating what types of interventions and changes are successful in preparing students for the complexities they will face.

Assessing design thinking and critical thinking in a STEM-integrated curriculum for middle schoolers has not been firmly established in the literature. Distinctive features of STEM learning including scientific literacy, interest in STEM, and self-efficacy have been measured at various grade levels and intensity of STEM intervention (Benjamin et al., 2017; Kier et al., 2014; Luo et al., 2021; Tyler-Wood et al., 2010). How design thinking affects learning has also been studied in various disciplines with post-secondary students and high school students (Aflatoony et al., 2018; Albay & Eisma, 2021). There are limited studies on design thinking at the middle school level which is why researching what happens in the classroom when design thinking takes place and how students are learning design thinking is essential (Lor, 2017). Tsai and Wang (2021) developed a design thinking disposition scale specifically for middle-school students to study the relationship between design thinking and computer programming self-efficacy. This scale can be applied to other middle school students to better understand students' design thinking dispositions after interventions (Tsai & Wang, 2021).

1.5 Overview of Methods

This research study followed an explanatory sequential mixed methods design. The rationale for using an explanatory sequential mixed methods design is to allow for the collection of quantitative data followed by the collection of qualitative data. Qualitative data can then further explain findings from quantitative data in a sequential pattern (Cresswell & Plano Clark, 2018). The study collected data from seventh and eighth-grade students at two different schools from the same school district. Both schools have students of similar demographics made up of predominantly Hispanic students. One school implements a STEM curriculum for all students and the other does not. Quantitative data was collected from students at both schools to answer the first research question through pre- and post-testing using a design thinking disposition survey developed by Tsai and Wang (2021). Additional qualitative data was collected from the STEM integrated curriculum school to address the second research question. Interviews with students and teachers took place near the end of the year at the STEM-integrated school to identify instances of design thinking through key design thinking indicators including problem identification, collaboration, ideation, and prototyping.

Using a sequential mixed-methods design provided insight into any significant changes in design thinking throughout the year for seventh-grade students in both the intervention school and the control school through quantitative data. Eighth-grade student surveys provided additional data on how design thinking differs after students have been through the STEM program throughout their middle school years. Qualitative data then showed information on how experiential learning can potentially provide students with necessary 21st-century skills like problem-solving, creative thinking, and collaboration. The focus of the qualitative interviews was to better understand how STEM integration can impact aspects of design thinking in the classroom including collaboration and problem-solving. Additionally, qualitative data was sought to understand if a STEM-integrated curriculum impacts career preferences.

1.6 Definitions of Key Terms

Integrated STEM Curriculum: STEM stands for science, technology, engineering, and mathematics. An integrated STEM curriculum incorporates two or more of the disciplines to solve a real-world problem. Generally, in STEM-integrated curricula, the focus is on collaboration and problem-solving skills rather than specific disciplinary knowledge.

Critical Thinking: Critical thinking involves understanding, synthesizing, and analyzing information. Critical thinking skills allow individuals to make decisions based on their knowledge and evaluation of a problem. Critical thinking skills, along with creative thinking and problem-solving are considered higher-level thinking skills (Facione, 2000).

Problem-Based Learning: Problem-based learning is a collaborative process in which students are presented with an ill-structured problem. Students identify the problem and then work together to research, design, and test solutions to the problem. The students then generally present their solutions to a larger audience that provides feedback.

The Engineering Design Process: The engineering design process is a systematic, iterative process to design a solution to a problem. Steps generally include defining and researching the problem, setting constraints, brainstorming, and evaluating solutions, developing and testing prototypes, and communicating results.

Design Thinking Disposition: Characteristics of design thinkers include the ability to take risks, being comfortable with open-ended problems, being empathetic, and possessing analysis and synthesis skills (Koh et al., 2015). Other skills that are characteristic of a design thinking disposition include strategies for collecting information and the ability to collaborate (Tsai &

Wang, 2021). Having a design thinking disposition enables an individual to solve problems creatively whilst also considering the needs of the user by being empathetic.

Design Thinking and Critical Thinking: Design thinking has the potential to "support and augment traditional critical thinking practices" (Ericson, 2021). Traditional critical thinking practices that can be mapped with design thinking methods include observing, feeling, imagining, inferring, experimenting, analyzing, judging, and deciding (Ericson, 2021). The design thinking disposition scale measures four stages of the design process: *empathize, define, ideate,* and *prototype*. *Empathy* in design thinking is related to the critical thinking component of feeling. *Define* in design thinking relates to the knowledge and inferring elements in critical thinking. *Ideate* in design thinking can be related to imagining in critical thinking as designers begin to propose potential solutions. *Prototype* in design thinking can be linked to experimenting and analyzing in critical thinking as designers begin to build, test, and evaluate their proposed solutions.

CHAPTER 2
LITERATURE REVIEW

The purpose of the literature review is to better understand how STEM integration is implemented in middle schools using the engineering design process and problem-based learning models. Additionally, this literature review will attempt to better understand how STEM integrated curriculum can help develop design thinking in middle schools. Because society is becoming increasingly technologically complex and students need to be ready for college and the workplace, educators have found a need to include STEM learning in K-12 education. This is evidenced by the revamping of science standards through the Next Generation Science Standards and the incorporation of engineering design processes into the K-12 curriculum. Because design thinking can potentially extend students' learning and prepare them for addressing complex societal issues, it is important to understand how design thinking is integrated into K-12 subjects and how teachers develop design thinking in students pedagogically (Li & Zhan, 2022).

Search engines used for the literature review included ERIC, EBSCOhost, Proquest, and Google Scholar. Search terms included STEM integrated curriculum, design thinking, engineering design process, problem-based learning, and middle school. The literature review concentrated on studies related to STEM integration in middle school and design thinking in middle schools and on empirical studies focusing on students.

2.1 Theoretical Framework

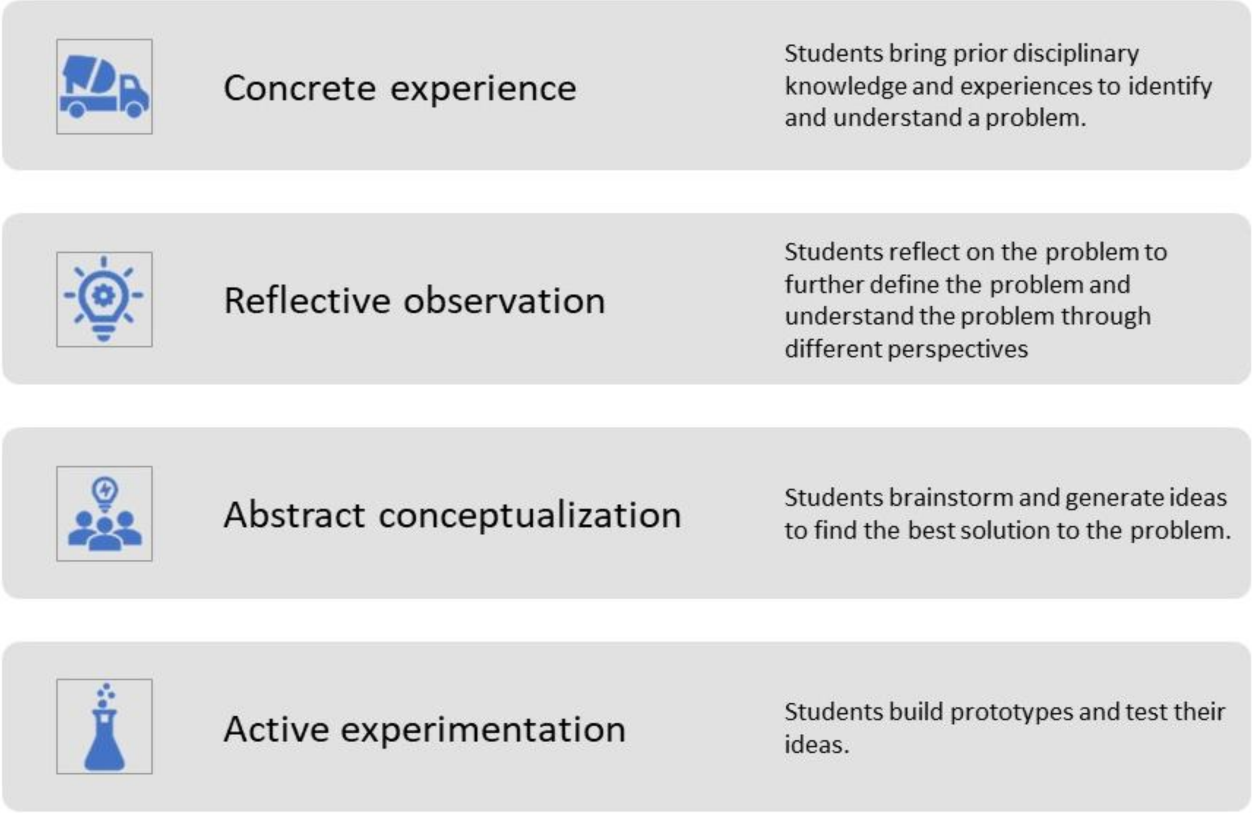
Design thinking encompasses the engineering design process, but it also applies to fields beyond engineering and can be as simple as confronting and solving an everyday problem (Li et al., 2019). Like the engineering design process, design thinking is an iterative process, but not necessarily a linear one. Because design thinking is universal to all STEM disciplines, it is broader than the engineering design process and more applicable to a STEM-integrated curriculum (Hallström & Ankiewicz, 2023). Design thinking does not necessarily adhere to defined methods or logical steps and can often be a chaotic, disordered process albeit a highly iterative one (Razzouk, 2012). Design thinking also considers the needs of humans and the viability of the solution, thus focusing on the end-user when determining the feasibility of a solution (Brown, 2008). Design thinking involves finding solutions to problems, assessing them through prototypes, and refining those solutions until a satisfying final solution is found (Luchs, 2015).

Design thinking is characterized by two basic principles: identifying a problem and developing a solution (Luchs, 2015). A problem must be clearly articulated and defined before successful solutions can be created. Developed solutions are then evaluated and refined as needed in an iterative process that continues to refine and test until a desired solution is found. The engineering design process is more systematic and linear, but both design thinking and the engineering design process include the identification and defining of a problem and designing and evaluating solutions. Additional characteristics of design thinking include the ability to communicate ideas and the ability to work as a team member (Razzouk, 2012). Design thinking constructs also include empathy, risk-taking, a desire to learn, and creative confidence (Dosi et al., 2018). Design thinking is human-centered, and the design-thinking framework includes the following phases: empathize, define, ideate, prototype, and test (Brown & Katz, 2009).

Design thinking is like scientific methods and processes in that they both develop hypotheses and attempt to find potential solutions (Liedtka, 2013). Design thinking, however, differs from the scientific method in that designers are focused on inventing innovative solutions centered around the end user, whereas scientists are discovering solutions or explaining phenomena that already exist. Both, however, are rooted in finding a solution to a problem, and both can be framed by experiential learning theory.

Experiential learning theory is defined as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 23). Experiential learning allows students to collaborate to solve real-world problems using problem-based learning models in STEM settings (Pappas et al., 2018). Kolb's theory of experiential learning has roots in Dewey's observations that knowledge is socially constructed, and children learn through experiencing the world around them (Dewey, 2007). Kolb's theoretical model of experiential learning follows four stages in the learning process: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Concrete experience is the learning experience a student engages in. Reflective observation is then the ability to reflect on those experiences and thoughtfully engage with those experiences through multiple perspectives. Abstract conceptualization is the integration of those reflections into theories, and active experimentation uses those theories to solve problems. Working design thinking into Kolb's model, the concrete experience would be like identifying and understanding a problem. To be able to effectively understand a problem, a person must engage with that problem and have some concrete knowledge about that problem. The reflective observation from Kolb's model would relate to refining and synthesizing the problem and developing a problem statement. To focus on the essential aspects of a problem requires reflection on that problem. Abstract conceptualization then relates to the generation of ideas to solve problems and active experimentation is building prototypes and testing those prototypes to determine if they are viable solutions. As students work together to design solutions, they learn about a problem, reflect on the problem, generate ideas to solve the problem and evaluate their solution to see if it best meets the end user's needs.

This cycle reflects each aspect of Kolb's learning through experience model as shown in Figure 1.



Concrete experience	Students bring prior disciplinary knowledge and experiences to identify and understand a problem.
Reflective observation	Students reflect on the problem to further define the problem and understand the problem through different perspectives
Abstract conceptualization	Students brainstorm and generate ideas to find the best solution to the problem.
Active experimentation	Students build prototypes and test their ideas.

Figure 1: *Relating Kolb's Experiential Learning Theory to Design Processes*

2.2 Design Thinking and STEM Education

Early references to design thinking refer to the ability of designers to use engineering principles to create technological wonders from everyday materials (Goldman & Kabayadondo, 2017). Design thinking moved from industry to education largely through IDEO and the School of Design at Stanford University (Goldman & Kabayadondo, 2017). On its website, IDEO links a "design thinking for educators' toolkit" and the Stanford School of Design website contains a school starter kit for teachers that want to "introduce design to students in their classes" (dschool.stanford.edu. 2023; IDEO.com, 2023). The rationale for moving design thinking into K-12 education is that anyone can participate in and learn design thinking and that design thinking promotes creativity, collaboration, critical thinking, and communication skills (Goldman & Kabayadondo, 2017).

Design, therefore, has played a significant role in developing STEM education in K-12 schools (Li et al., 2019). The engineering design process is a method frequently used in STEM education. Research shows that the use of the engineering design process in STEM integration can help students learn both science and math and develop design thinking (Kelley & Sung, 2017). Using the engineering design process in STEM integration allows students to apply existing knowledge of all four STEM subjects while also gaining further knowledge in those subject areas and developing design thinking skills (Hallström & Ankiewicz, 2023).

2.3 STEM Integrated Curriculum

In 2007 the National Research Council published *Rising above the gathering storm: Energizing and employing America for a brighter future*. The publication was a call to action to make the United States more innovative and globally competitive in technological fields. One recommendation of the council was to improve science and mathematics education in the United States by recruiting and retaining 10,000 teachers to educate ten million minds (NRC, 2007). This led to several STEM education initiatives to both increase science literacy for all Americans and to develop a technically skilled workforce (Barakos et al., 2012). Additionally, the NGSS has increased the call to integrate engineering and technology into mathematics and science education, thus promoting the development of integrated STEM curriculums or a curriculum that uses two or more of the STEM disciplines to solve a problem. How the curriculum is integrated in STEM integration can vary from disciplinary, meaning content is learned in each separate subject and infused with STEM activities that use just one STEM discipline, to transdisciplinary in which multiple content areas are indistinguishable when applied to solving real-world problems (Vasquez et al., 2013).

An integrated STEM curriculum looks different than teaching individual STEM disciplines. In an integrated STEM curriculum, the focus is on the problem rather than individual content areas (Nadelson & Seifert, 2017). Integration of STEM generally follows a model of inquiry learning or problem-based learning rather than direct teacher instruction (Nadelson & Seifer, 2017). The number of STEM subjects incorporated when integrated is less important than the emphasis on using two or more STEM disciplines to solve a real-world problem (Roehrig et al., 2021). The transdisciplinary approach thus emphasizes the problem and the different STEM disciplines are indistinguishable from each other as students collaborate in the problem-solving process. This is contrasted with less integrated models such as multi- or inter-disciplinary approaches (Vasquez et al., 2013). In multidisciplinary learning, students may have a theme connecting the different disciplines as they work on a curricular-aligned project in different classes (Roehrig et al., 2021). For example, for a unit on climate change students in social studies might examine the effects of climate on human populations. In science students could examine the mechanisms influencing climate change and in mathematics students might look at data and make predictions based on that data. Interdisciplinary learning, however, would go further and then integrate the different disciplines into a cohesive synthesis, while still acknowledging the knowledge acquired through the different disciplines. In transdisciplinary learning, students are presented with a problem and then use different STEM disciplines as needed without necessarily identifying which ones they rely on to solve the problem.

One transdisciplinary approach, the engineering design process, is an ideal paradigm to integrate the STEM disciplines in an integrated curriculum, as engineering design applies both math and science content when solving problems using technological tools (Roehrig et al., 2021). Although each of the STEM disciplines has different epistemologies or ways of building knowledge, there are concepts universal to all four STEM disciplines including communication, problem-solving, use of data, using tools, investigating, modeling, and evaluating solutions (Reynante et al., 2020). Practices and how they are related to both the NGSS and the ITEEA are shown in Figure 2. In the diagram, practices from the ITEEA are aligned with how those practices are carried out in the NGSS. For example, in the ITEEA the practice of systems thinking can be shown in the NGSS in developing and making models.

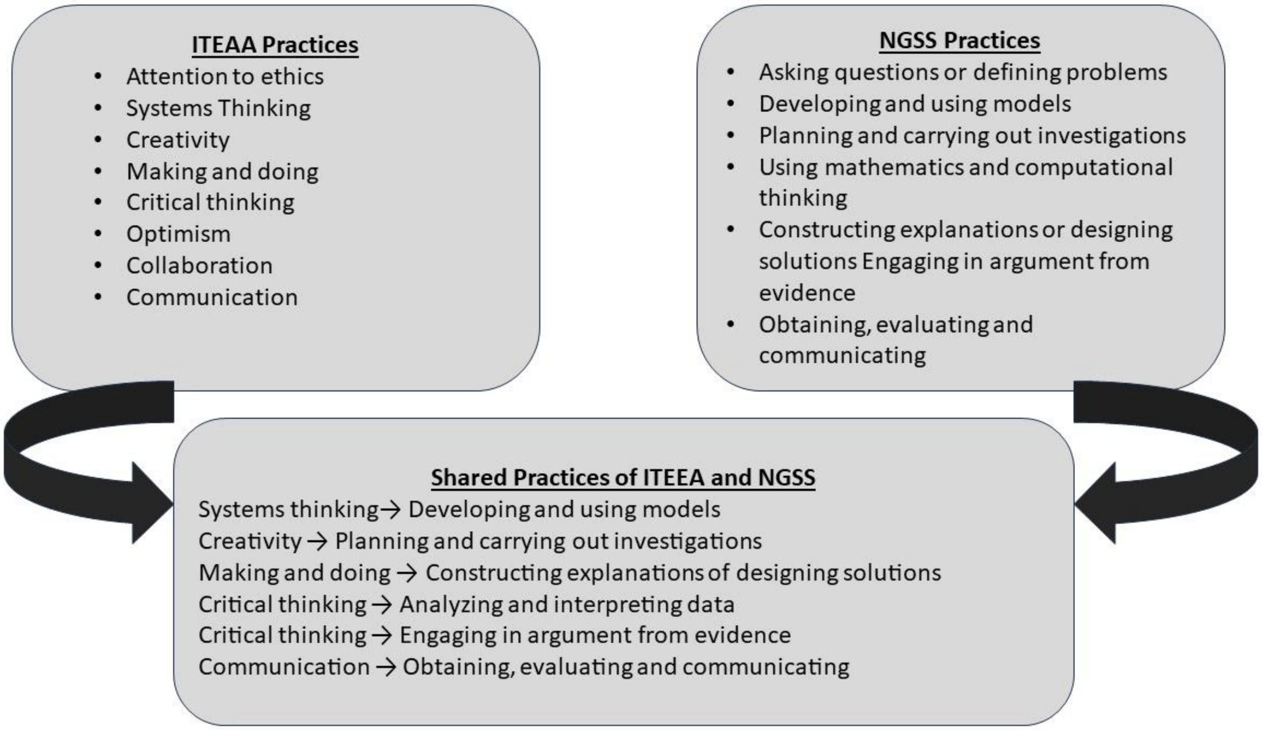


Figure 2: *Shared Practices of the ITEEA and NGSS*

Using an integrated STEM curriculum should not be a replacement for disciplinary learning, particularly in science and math, but rather it should be a method for confronting and developing solutions to societal problems while using skills and content knowledge acquired in specific disciplines. Throughout this process, students are collaborating, researching, and communicating their results. In an integrated STEM curriculum, students are applying knowledge learned in other disciplines while learning specific skills when integrating those disciplines. It is also important that the disciplinary knowledge required of students to solve a problem in STEM integration is aligned with the complexity of the problem. If students do not have the required disciplinary knowledge, they are likely to become frustrated and give up (Nadelson & Seifert, 2017). When STEM problems are of the appropriate complexity, integrated STEM learning encourages students to develop deeper knowledge as they engage in authentic practices. Students can then generalize their knowledge and apply it to new situations (Chiu & Krajcik, 2020).

2.3.1 STEM Integration in Practice

There are numerous studies in the literature supporting the use of a STEM-integrated curriculum. STEM education has been shown to reduce achievement gaps, particularly for limited English proficient (LEP) and Hispanic students (Adams, 2021). STEM integration also situates learning into real-world contexts connecting school learning to students' experiences (Furner & Kumar, 2007). The use of an integrated math and science curriculum that incorporates the engineering design process can increase student motivation and academic achievement (Stohlmann et al., 2012). Additionally, STEM integration can increase students' mathematical spatial abilities (He et al., 2021) and promote a deeper understanding of math and science concepts (Awad, 2023; Frykholm & Glasson, 2010). Wade-Shephard (2016) compared state test scores for math and science for over two thousand middle school students in one school district. Two of the schools implemented a school-wide STEM curriculum and the other two did not. Results showed that students enrolled in schools that used the school-wide STEM curriculum outperformed their peers who did not have a dedicated STEM class. Additionally, the more years the students spent in dedicated STEM classes, the better they did on state-wide math and science tests.

Studies have also shown an increase in collaboration and communication skills while participating in integrated STEM modules (Awad, 2023). Awad (2023), also found that self-efficacy and interest in science increased when seventh-grade students participated in integrated STEM learning modules related to sound, waves, and communication systems. Even young students can benefit from integrated STEM. When compared to a control group, pre-K students in a Head Start program that used a STEM-integrated curriculum had higher gains in number sense, science concepts, and engineering concepts than their peers not exposed to the STEM intervention (Aldemir & Kermani, 2017). The literature supports a STEM curriculum as it improves collaboration, student interest, and student motivation.

Although there is a call to integrate STEM education into K-12 grades, schools still struggle to implement STEM activities effectively. Because STEM integrated curriculum is a recent phenomenon, many current teachers finished college before the concept of STEM became popular, and very few teachers have a thorough understanding of STEM conceptual frameworks (Shernoff et al., 2017). Other challenges include a lack of time for collaborative planning, lack of classroom time for students to fully explore STEM design, and lack of resources (Shernoff et al., 2017).

Besides time and resources, teachers need more extensive professional development in how to effectively integrate STEM activities in the classroom, including how to connect the STEM disciplines and how to integrate technology into the activities. Another perceived barrier to effective STEM education is standardized testing (Shernoff et al., 2017). Because of the need to meet benchmarks on standardized tests, teachers are pressured to spend time teaching to the test and have less time to spend on more creative, student-centered activities. To promote effective STEM education, measures to assess STEM need to be considered as part of statewide assessments, including skills that might extend beyond content-specific knowledge including problem-solving, analysis, inference, and design thinking skills. Problem-based learning through the engineering design process in integrated STEM curriculum is a potential method for meeting the shared practices of the NGSS and the ITEEA as students work to deliver a solution to a proposed problem.

2.4 Problem-Based Learning

Problem-based learning (PBL) was first introduced into medical schools to improve problem-solving and critical-thinking skills and to promote independent and lifelong learning skills (Hung et al., 2007). Rather than follow traditional instruction, in which a teacher imparts knowledge to a student, in problem-based learning, teachers present students with an ill-structured problem, and they then work collaboratively to generate a solution. Ill-structured problems are problems that do not necessarily have one answer and students are not given set guidelines on how to solve the problem (Chin & Chia, 2006). The problems are related to real-life situations and students must determine the best solutions to the problem with scaffolding from the teacher as needed. PBL follows a sequence of steps beginning with students defining the problem, identifying what they already know about the problem, and then determining what they need to find out and assigning responsibilities to group members. Students engage in self-directed study which is shared with the group and as group members share information, they build understanding of the topic. Throughout the process, students participate in a collaborative effort revising their understanding as needed. The problem generally ends with a presentation and the students receive feedback from their peers and teacher, allowing the teacher to identify and address any misunderstandings. (Holthius et al., 2018). If a teacher determines that students have not effectively mastered the material, or the students need further clarification, the teacher can provide further explanations or activities to enhance conceptual understanding.

The idea of using PBL in education is founded in constructivism, or the notion that knowledge is constructed through interactions with the environment. A tenet of constructivism relevant to problem-based learning is that knowledge occurs when there is a dissonance between what is known and what is observed (Marra et al., 2014). By presenting an ill-structured question, the need to know is activated and students are motivated to learn. Knowledge is also constructed through social interactions. By working collaboratively in groups, students rely on the experience and knowledge of peers as they research and build knowledge together (Marra et al., 2014). Although problem-based learning can be used throughout the disciplines including the social sciences, in STEM disciplines, the engineering design process is a valuable model for incorporating problem-based learning into STEM curriculum.

2.4.1 Problem-Based Learning in Practice

Research effectively supports the use of problem-based learning in classrooms. Overall, students participating in PBL had better long-term retention of information, and they also were able to apply knowledge to solving problems in real-world situations (Hung et al., 2007). Additionally, students had better perceptions of their ability to be lifelong learners, and they had increased confidence in their perceptions of problem-solving skills (Hung et al., 2007). In the science classroom, problem-based learning can increase critical thinking skills through indicators like question posing, collaboration, and science process skills. For example, after a problem-based learning curriculum implementation in environmental science, the types of questions students asked became more complex including inquiries related to data analysis and explanations between correlation and causation (Kang et al., 2012). Additionally, in a fourth-grade integrated STEM curriculum Rehmat and Hartley (2020) found a STEM-integrated PBL problem "encouraged students to constantly reflect and apply higher-order thinking skills." Problem-based learning in science was also found to increase communication skills, a key component of critical thinking (Paul & Elder, 2007). When students collaborate during problem-based learning, they build confidence as their language skills develop through posing questions and sharing ideas (Lawrence, et al., 2016).

Besides the types of questions students posed after problem-based learning interventions, other measurements of the effectiveness of problem-based learning include pre- and post-test evaluations compared to a control group which has been shown to increase critical thinking skills (Dakabesi & Louise, 2019). Mixed methods studies show higher student engagement in problem-based learning classrooms through qualitative observations, as well as longer retention of science knowledge through quantitative data collection (Sakir & Kim, 2020). Additionally, comparing student attitudes toward science between a control group and an experimental group demonstrates that problem-based learning increases positive attitudes toward science (Seçgin & Sungur, 2020). Epistemic beliefs have also been measured after a PBL intervention using an epistemic beliefs survey (Belland et al., 2019). Students were found to develop more sophisticated epistemic beliefs and an improvement in the ability to self-regulate their learning.

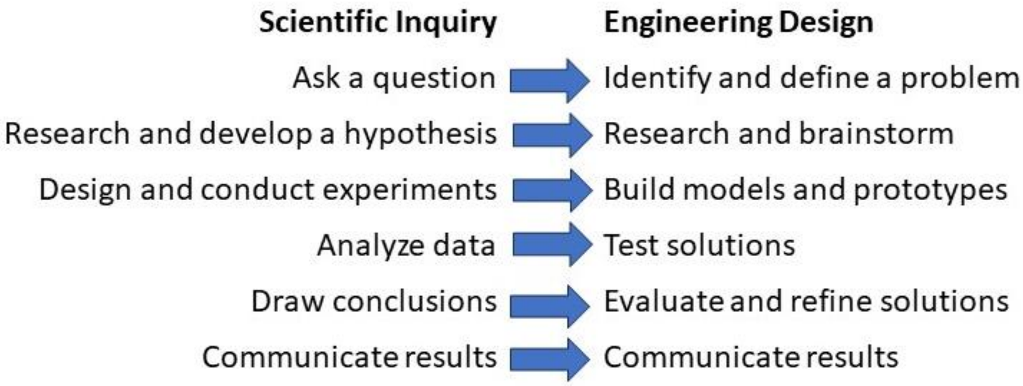
Although problem-based learning has been shown to provide benefits in the classroom, numerous challenges exist for implementing a problem-based learning curriculum. Moving from a teacher-centered pedagogy to one that is learner-centered is difficult for schools and classroom teachers, particularly in the era of high-stakes testing (Dole et al., 2015). To successfully implement problem-based learning, changes in curriculum and assessment are required, as well as comprehensive teacher-staff development in facilitating problem-based learning activities (Dole et al., 2015). Other issues when implementing a problem-based learning curriculum include designing effective problems. In medical schools that implement problem-based learning, problems are oftentimes too simple, not open-ended, or too well-structured and don’t provide the flexibility that students need to fully engage in the process (Dolmans et al., 2005).

Even though teachers are facilitators in problem-based learning, and it would seem the teaching duties are lessened, management responsibilities for teachers tend to be greater in a student-centered classroom rather than in a teacher-centered classroom. Teachers must develop collaboration skills among the students while scaffolding student learning. Students also need to be engaged and invested in the initial problem and that engagement needs to be maintained throughout the process (Ertmer & Simmons, 2006). Teachers are also responsible for identifying and addressing misconceptions in content knowledge as students continue to learn concepts related to the problem and the content area it covers. Managing a class of multiple students working on projects makes problem-based learning a challenging endeavor.

One solution to help teachers with implementing problem-based learning is targeted professional development. Lee and Blanchard (2019) surveyed 156 secondary teachers and found that those teachers successfully implementing problem-based learning had more formal training in PBL practices. Besides gaining the knowledge and skills necessary to effectively implement problem-based learning, successful professional development altered the teachers' beliefs about what constitutes effective pedagogy, convincing them to move towards a more student-centered methodology. When teachers are fully invested and trained in problem-based learning they recognize the benefits that problem-based learning imparts to students.

2.5 The Engineering Design Process

The engineering design process is a systematic method for designing and developing solutions to real-world problems. The steps of the engineering design process are an iterative process that requires reflection throughout. The NGSS recommends including engineering practices in science education and, although engineering design is like scientific inquiry, there are differences. Both scientific inquiry and engineering design, however, use methodical steps, and their similarities are highlighted in Figure 3. The engineering process uses design to solve a problem as opposed to scientific inquiry which answers a question through investigation (NGSS, 2013). Both processes incorporate research, problem-solving, design, analysis, and communication. Integrating engineering processes and principles into science education can better enable students to make connections between the four STEM fields and the real world as practices from engineering design reinforce practices from scientific inquiry (NGSS, 2013).



Scientific Inquiry		Engineering Design
Ask a question	➡	Identify and define a problem
Research and develop a hypothesis	➡	Research and brainstorm
Design and conduct experiments	➡	Build models and prototypes
Analyze data	➡	Test solutions
Draw conclusions	➡	Evaluate and refine solutions
Communicate results	➡	Communicate results

Figure 3: *Relating Scientific Inquiry to the Engineering Design Process*

The engineering design process is an optimum model to use when applying problem-based learning to STEM integration because it encourages teamwork through an open-ended problem-solving process (Long et al., 2020). The engineering design process provides a method of problem-solving that connects the different STEM disciplines by allowing the application of scientific knowledge, scientific inquiry, and mathematical reasoning in an authentic problem-solving design approach (Hallström & Ankiewicz, 2023; Kelley & Knowles, 2016). Technology is infused throughout the process as students use, design, and evaluate technology when working through the problem. The engineering design process supports the idea that knowledge should be situated in relevant contexts and that the application of knowledge is as important as the knowledge itself (Kelley & Knowles, 2016). Learning how to use knowledge and what type of knowledge is relevant to a current problem utilizes the recommendations of the NGSS of using core ideas to apply knowledge through engineering practices (NGSS, 2013). The engineering design process can incorporate the multiple disciplines within the STEM umbrella connecting the subjects as students develop proficiencies in different subjects to solve problems (Shahali et al., 2017). Those proficiencies should include critical-thinking skills throughout the design process like defining the problem, evaluating their solutions, and communicating their results. Students should also learn to think like designers as they engage in the problem-solving process.

2.5.1 Engineering Design in Practice

The use of the engineering design process in middle school can improve spatial abilities (Yildiz & Özdemir, 2020) and students increase their use of higher-order thinking skills when they evaluate and justify their designs during the engineering design process (Aranda et al., 2020). Using engineering design can also increase student engagement and academic achievement in math and science when they can apply skills learned in math and science to a distinct engineering course (Alemdar et al., 2018).

There are examples of studies of middle school students that have focused on how problem-based learning has been used successfully in the engineering design process. Gomoll et al. (2020) used a problem-based learning engineering design model in a robotics program for seventh and eighth-grade students and found that students were able to make connections across disciplines including technology and science inquiry. Gale et al. (2019) studied how robotics and the engineering design process could help facilitate physical science content understanding as well as engineering practices in an eighth-grade science class. Results showed that students were able to gain science conceptual knowledge through the design process, but there were limitations to student understanding of the differences between designing for a solution in engineering and relating the physical science processes that lead to that solution. In addition, science teachers were reluctant to devote the amount of class time required by students to undergo multiple iterations of their designs. Incorporating the engineering design process in a tested subject like science can prevent the full realization of the design process. Having dedicated classes to engineering design that incorporate disciplinary knowledge learned in core classes could potentially alleviate some of those issues.

Another challenge of implementing engineering design in middle school is the lack of effective engineering lessons that are engaging and are not too overly broad (Judson et al., 2016). Standards for engineering in the NGSS like "define criteria and constraints of a design problem" or "develop a model to generate data" do not necessarily translate into ready-made classroom activities. Time needs to be spent to develop engineering-integrated activities that are age-appropriate and easily implemented in the classroom. Additionally, the engineering activities need to be carefully aligned to discipline-based standards particularly in mathematics and science so that students can apply their content-specific knowledge to their engineering design (Mathis et al., 2018). Also, many of the engineering activities found in middle school classrooms tend to be focused on mechanical or civil engineering like building and testing model bridges which integrate well into physics classes (Judson et al., 2016). There is a lack of engineering activities that utilize other science disciplines like life science and chemistry in middle school. Until states fully adopt recommended NGSS standards by creating curricula and assessments that promote engineering design throughout the disciplines, it will be difficult for teachers to justify devoting significant amounts of class time to engineering projects (Gale et al., 2019).

2.6 Research Gaps and Research Purpose

Due to the perceived importance of technological skills, schools are beginning to integrate STEM into disciplines at an early age, including early childhood activities like basic programming and design problems (Wan et al., 2021). In early childhood, disciplinary knowledge is limited for young children and teachers do not necessarily need to have comprehensive pedagogical content knowledge in each of the STEM disciplines. Even so, integrating STEM into activities at the early childhood stage can be challenging (Wan et al., 2021). As students advance into middle and high school, subject areas require even more specialized knowledge. In any discipline, integrating STEM into subject areas requires some discipline-specific scaffolding from teachers. Mathematics teachers or science teachers may not have the content knowledge to appropriately help students integrate disciplines. In a STEM-integrated class, however, teachers receive specific content knowledge in the different disciplines as well as training in facilitating problem-based learning or engineering design projects to help scaffold students' understanding. Additionally, the use of the engineering design process can further develop design thinking while applying content-specific knowledge (Hallström & Ankiewicz, 2023). Moving forward, it is important to understand if having a class that is dedicated to integrating the STEM disciplines is successful in building the problem-solving, critical thinking and design thinking skills required for integrating different subjects when finding solutions.

2.6.1 Research Gaps in STEM Integrated Curricula in Middle Schools

Although research is catching up to the practices of STEM integration, there is still a lack of understanding of how STEM integration affects learning outcomes throughout K-12 education. A search for articles on “Integrated STEM curriculum” on ERIC yielded only 24 results. A search on EBSCO in journal articles yielded 259 results. Those were then filtered to just “education” to yield 121 results. Twenty-six of those studies were literature reviews or related to STEM curriculum frameworks or school leadership. The majority (35) of the remaining articles were studies examining preservice or in-service teachers and their perceptions of STEM programs, or the effects of professional development on STEM teaching. The remainder of the studies were empirical studies in schools, but only 10 included middle school students.

Studies that focused on middle schools or middle school students looked at STEM curriculum implementation (Gale et al., 2019; Gardner & Tillotson, 2018; Stohlmann et al., 2011) or teacher and student perceptions of an integrated STEM curriculum (Gardner, 2017; Pozarski Connolly, 2017). Perceptions of science and math by students after they had participated in integrated STEM curricula were also examined and shown to increase affinity towards STEM disciplines (Gardner, 2017; Pozarski Connolly, 2017; Sunny, 2018). Two studies looked at the cultural context of STEM curricula on minority or traditionally marginalized students (Keratithamkul et al., 2020; Miller & Roehrig, 2018). Only two studies examined student outcomes in middle school. Ng and Chan (2019) examined the effect of 3D computer modeling on both upper primary and middle school students and found that computer-aided design enhanced students' spatial skills and mathematical understanding. Pozarski Connolly

(2017) also measured content knowledge and found students' content knowledge related to energy efficiency increased during an integrated STEM unit.

As more schools adopt integrated STEM curricular programs, there needs to be a better understanding of how those programs impact student outcomes. How schools are implementing these programs is also important to understand when reviewing STEM-integrated modules. In STEM education, curriculum units can be integrated into discipline-specific areas like math or science, or STEM-integrated curriculum can become an independent course coded as technology or engineering. Schools that do not rely on integration in tested, discipline-specific subjects like math and science may have better outcomes when using a STEM-integrated curriculum in a stand-alone course as there is more time to focus on the methods that a STEM-integrated curriculum recommends.

In a review of the literature on studies of STEM integration, the National Research Council (2014) found many of the studies to be inconsistent and lacking in clear understanding of what STEM integration means, and what the outcomes of a STEM-integrated curriculum should be. The council made several recommendations on what researchers should explore about STEM integrated curricula, including how higher-level thinking can be strengthened through integrative approaches.

2.6.2 Research Gaps in Design Thinking in Middle Schools

How design thinking can be developed in middle school is another area that needs further study. Students need to develop creative and adaptable critical thinking skills to succeed in a continuously changing technological world and the design thinking process can “enhance students’ skills such as creativity, engagement, collaboration, evaluation, refinement, and presentation techniques” (Lord, 2019, p. 60). Although there are numerous studies on design thinking in industry and higher education, fewer studies have been done in K-12 education. A search on ERIC with the terms “design thinking” and “middle school” yielded only 30 results. Of those 30 results, only seven included empirical studies of middle school students. Other search results included teacher training, classroom strategies, instructional design, or studies of post-secondary students. The same search terms on EBSCO yielded 31 results. Of those results, four were not repeated and were empirical studies of middle school students.

In one study, in an area not related to STEM, qualitative research examined how geography students worked to redesign systems in the school and found that design thinking allowed students to "become empowered agents in their own learning" as they developed "creative confidence" (Carroll et al., 2010, p. 50).

Related to STEM subjects, Zhou et al. (2021) studied middle school design modalities during a two-week toy design workshop. Design modalities include conversations (verbal), creating sketches or drawings (visual), and creating prototypes (physical). Findings suggest that students should engage in multiple modalities and should focus more on the visual and physical modalities during the design process rather than verbal modalities. The study, however, did not assess or observe design thinking.

In a four-week summer school program, teachers worked with middle school students to design activities related to energy and environmental sustainability using a curriculum developed by students and researchers from Stanford University (Goldman et al., 2017). Qualitative results showed student improvement in creative confidence, design thinking, and the ability of young students to "learn processes and mindsets of problem-solving with the purpose of transforming the lives of those around them" (Goldman et al., 2017, p. 92). Researchers also recommended further studies on how design thinking can influence middle school students.

Christensen et al. (2019) studied how learning the design process can influence middle school students' stance toward inquiry. Students who were part of a FabLab, or space that combines digital fabrication, design thinking, and collaboration to solve wicked problems, were not found to have a more “designerly” stance toward inquiry than students in a control group. They did, however, report on gaining knowledge in the design process that they could apply to other areas. Researchers concluded that a more sophisticated understanding of design capabilities would require more time and more teacher training. Interestingly, researchers noted how difficult it was to implement effective design teaching in classes that were not compulsory.

In a doctoral dissertation, Goldstein (2018) examined how middle school students made and prioritized trade-offs in their design decisions during a two-week engineering design activity within a science classroom. The study suggested that students may need more support in relating the evaluation of their design to the criteria and constraints of the challenge. The study did find, however, that even young designers can make more advanced design decisions when prioritizing their design trade-offs. This study, however, was only of students who were participating in a two-week activity as opposed to students in a full-year design class.

In areas of design thinking and STEM subjects, Avcu and Er (2020) compared an experimental group with a control group of students taking an information and technologies software course. Students in the experimental group were taught using an instructional design model using an experimental design process. Although students in both groups discussed stages of the design process in follow-up interviews, students in the experimental group were observed to have more sophisticated design thinking skills than those in the control group. The students in both groups, however, were exposed to the same curricular content using different implementation methods.

In a quasi-experimental study, the iterative nature of the design thinking process was taught to an experimental group to determine if teaching specific aspects of the design process is beneficial to middle school students (Marks, 2017). Results showed that students can benefit from learning iterative rapid prototyping by being more adaptable and persistent when confronted with ill-designed problems. The intervention, however, only lasted four weeks and the students in the experimental group had less knowledge gains in STEM areas than students in the experimental group.

One aspect of design thinking, empathy, was studied in another four-week intervention, in which middle school students participated in a “genius hour” for 45 minutes once a week (McCurdy et al., 2020). Students participated in student-centered problem-based, design thinking tasks. Through qualitative observations and interviews, students were found to integrate empathy into their design tasks as they confronted real-world scenarios like reducing trash in oceans and tackling malnutrition in underdeveloped countries. Empathy can be a tool to connect design thinking to STEM topics and is a core component of design thinking. Seventh-grade students were able to adopt different perspectives as shown through critical reflections. This study, however, studied STEM integration within a science classroom over a limited period.

2.6.3 Research Gaps of Design Thinking within STEM Integrated Curriculum

When searching specifically for studies that looked at design thinking in a STEM-integrated curriculum, a search on ERIC using the terms "design thinking" and "STEM integration" yielded only five results. Of those five results, only one study was of middle school students, a study previously mentioned (McCurdy et al., 2020).

To broaden the search, integration was removed leaving just “design thinking” and “STEM” which showed a total of 81 results. Of those 81 results, 70 were journal articles. Of those 70 articles, 29 articles related to curriculum/policy recommendations or technology reviews. Two were literature reviews. Seventeen empirical studies were related to preservice teachers, in-service teachers, or librarians and six studies took place in colleges or community colleges. Three studies were of preschool children and the remaining thirteen studies were related to STEM and design thinking for K-12 aged students.

Of those remaining studies, seven were studies done in after-school or summer programs with STEM activities. Enrichment programs can increase content knowledge in after-school and summer programs (Galoyan et al., 2022; Simeon et al., 2022). STEM summer programs also showed increases in design thinking skills like empathy, creativity, communication, and collaboration (Ng & Fergusson, 2020; Pattison, 2021). STEM activities can also increase confidence in STEM subjects and help develop a STEM identity (Ng & Fergusson, 2020; Pattison et al., 2018).

Only six studies took place during a regular school day. In elementary schools, STEM activities and the engineering design process were shown to increase disciplinary knowledge (English & King, 2015) and critical thinking skills like communication, collaboration, and design thinking (Forbes et al., 2021). In high schools, a STEM-integrated course focused on both design thinking and entrepreneurial thinking showed positive results in both types of thinking (Solodikhina & Solodikhina, 2022). During the STEM activities, students demonstrated gains in creativity and innovation, and during the business phase activities, students showed gains in analysis skills (Solodikhina & Solodikhina, 2022). In another high school study implementing STEM integration for one hour per week, students were taught mechanical design and then completed design challenges to assess the relationship between mechanical knowledge and design complexity (Fan et al., 2018). Researchers concluded that students need careful facilitation of the engineering design process to apply their disciplinary STEM knowledge when working on design challenges (Fan et al., 2018).

Only one study took place in middle school. In a middle school physical science classroom, students worked on design and technology projects to develop an understanding of physics principles (Amir, 2020). The integrated STEM activities promoted creative thinking and increased understanding of mechanical principles (Amir, 2020). Like most of the studies found on design thinking and STEM curriculum the STEM activities were incorporated into an existing class, rather than a class dedicated to just STEM. There is a dearth of studies that focus on classes that are specifically for STEM integration and the impact those classes have on design thinking.

2.7 Summary of Literature Review

Although design thinking is starting to become more prevalent in middle school, there continues to be a lack of research on how design thinking is implemented within classes and particularly how integrated STEM classes can impact design thinking. Researchers recommend further studies on outcomes of engineering design and design thinking in middle school classrooms, and studies need to determine how STEM curriculum can meet the standards of the NGSS to clearly define a design problem, evaluate design solutions, and develop and assess design solution models (NGSS, 2013). Although problem-based learning and the engineering design process can have a positive impact on students, there is little research on how they impact design thinking, particularly for middle schoolers.

CHAPTER 3
RESEARCH METHODS

3.1 Research Questions

Because there is a lack of research supporting STEM integrated curriculum in middle schools and how that impacts design thinking, this study investigated the value of devoting part of the school day to a curriculum that promotes collaboration, design thinking, communication, problem-solving, and critical thinking skills. The need to better prepare students for modern workplaces and provide them with adaptable, flexible, problem-solving skills is a universal sentiment throughout the literature. Design thinking provides a mechanism by which individuals can help tackle some of the difficult technological and societal problems that will need to be addressed in the coming years. For this reason, this research explored the following questions:

1. What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?
2. What are the perceptions of students and teachers on how a STEM-integrated curriculum helps to develop design thinking dispositions?

3.2 Researcher Positionality

I first began teaching in the mid-1990s in a troubled school in the Bronx, New York. Students were disenfranchised with the education system and teachers were not equipped to make school relatable to them. This was partly due to the age of the students, middle schoolers are notoriously disengaged, but also because the school was not addressing the needs of their most important clients- the students. Since that time, I have taught multiple grade levels and subjects in different public and private schools. I also have embarked on a mission to obtain a doctoral degree. Both my teaching experience and my experience in the doctoral program have convinced me that student-centered pedagogies that are relevant to both students’ experiences and the needs of society are what is best for students and schools.

For the last several years I have taught an integrated STEM curriculum in a biomedical pathway to high school students. The content in the curriculum is challenging, but it is also student-centered and relies heavily on problem-based learning and engineering design processes. This has led to my interest in exploring this type of curriculum in middle school to better understand what skills students can gain from an integrated STEM curriculum that uses problem-based learning and engineering design. I also have taught middle school science and am frustrated with its reliance on the scientific method as a rigid linear process, when in fact, science inquiry in real-world settings is more similar to the engineering design process in its iterative nature. As industries and job opportunities are constantly evolving, schools should begin to move away from a content-heavy, strict curriculum to one that is more adaptable and encourages students to draw on multiple disciplines providing them with transferable skills because they develop problem-solving, analysis, and collaboration. My interest is focused on providing students with the necessary analytical skills that allow them to make educated, rational decisions and enable them to make positive contributions to a global economy.

3.3 Description of Methods

This study followed an explanatory sequential mixed-methods design and collected quantitative data from a pre and post-survey, and qualitative data from student and teacher interviews as shown in Figure 4. The justification for using a mixed methods approach is to understand the research questions more thoroughly by using qualitative data to better understand quantitative results (Cresswell & Guetterman, 2019). Both qualitative data and quantitative data have their strengths and weaknesses. Quantitative data generally uses a large sample size allowing it to be more generalizable to a wider audience. Quantitative data is also numerical which can then be analyzed through statistical measures showing the strength of relationships. Quantitative data, however, does not necessarily provide explanations for the whys of the data. Qualitative data, on the other hand, can provide insight into the experiences of individuals while attempting to understand why certain patterns or behaviors exist. Qualitative data, however, relies on fewer subjects and is not generalizable to a larger audience.

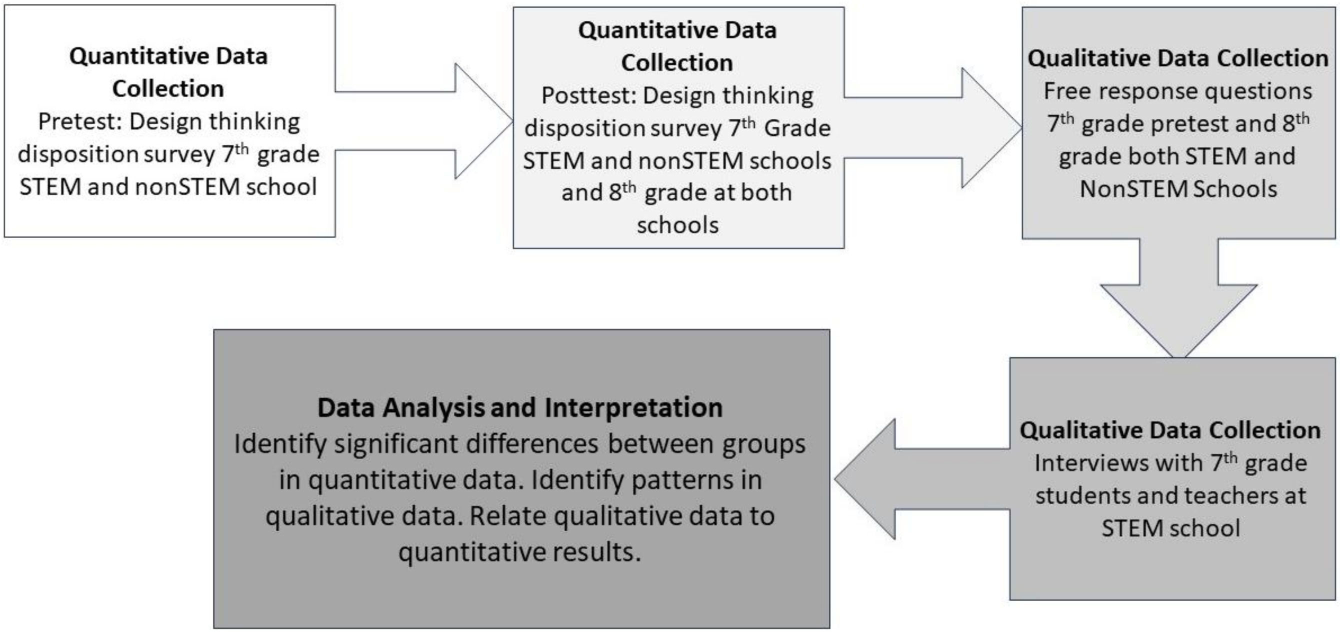


Figure 4: *Explanatory Sequential Mixed Methods Study Design*

A mixed-methods research study takes a pragmatic approach towards a curriculum to evaluate not just gains in a particular area like design thinking disposition, but also impacts on students’ collaboration, communication, and creativity. A pragmatic paradigm allows for the use of different methods of data collection to answer research questions, thus shifting focus to the research questions rather than the methods (Cresswell & Plano Clark, 2018). A pragmatic view provides for more than one reality or more than one perspective (Cresswell & Plano Clark, 2018). This may mean that quantitative data may provide one answer to a question, but that conclusion may be contradicted by qualitative data. Realities are not black and white, and a pragmatic mixed methods study allows for a more in-depth look at a research question. For example, schools are driven by standardized testing, but test scores do not always provide a complete picture of a student's experience. Students may not necessarily do well on standardized tests due to numerous factors like test bias, test anxiety, or lack of test sophistication even if they excel in coursework (Bond, 2007). By analyzing a question using multiple data sources, a better understanding of a student's experience can be obtained.

The purpose of using an explanatory sequential mixed methods design for this study was to answer the two research questions to gain a greater understanding of how a STEM-integrated curriculum might impact student design thinking dispositions and related critical thinking skills. Research question one was answered through quantitative data collection using a design thinking disposition survey. Quantitative data collection used a quasi-experimental design. A quasi-experimental design is used when groups are already intact, and the researcher cannot artificially create random groups (Cresswell & Guetterman, 2019). The survey was administered twice during the year to a sample of seventh-grade students at a school that implements a school-wide integrated STEM curriculum and to a school that does not. Through pre and post testing the data addressed the question of if there is a difference in design thinking dispositions for students in an integrated STEM curriculum school when compared to students that are not enrolled in a school with integrated STEM, and if there are any changes for students after they have been exposed to a STEM integrated curriculum. Additionally, the design thinking disposition survey was administered to eighth-grade students in both schools at the end of the eighth-grade year. The rationale for giving the survey to eighth-grade students was to see if there was a difference in design thinking dispositions between students in a school using a STEM-integrated curriculum and one that does not employ a STEM-integrated curriculum at the end of their middle school years.

Qualitative data was collected through two different sources: interviews of students and teachers at the STEM-integrated school and free-response questions on the design thinking disposition survey. This data can inform the quantitative results by providing evidence of design thinking to support data that might show if students are strengthening their design thinking disposition. Knowing the specifics of how design thinking might occur in classroom interactions, or what activities might develop design thinking dispositions in middle school could potentially help curriculum developers and administrators apply that knowledge to their schools. If, however, there is no significant difference found between the STEM-integrated school and the control school, then qualitative data could identify other benefits of a STEM-integrated school like collaboration, question posing, or communication skills. Qualitative data also can attempt to explain why the STEM integration may not be developing design thinking dispositions.

3.4 Participants and Setting

Table 1

Demographics of Participating Schools

	School 1 (With STEM)	School 2 (NonSTEM)
Student Population	696	656
% Hispanic	94.5	94.4
% Economically Disadvantaged	61.4	68.6
% English Learners	27.3	37.7
Seventh Graders	245	235
Eighth graders	250	237

This study took place in a large, metropolitan area in the southwestern United States near the U.S.-Mexico border in a school district with a little over 6000 students. The school district has two middle schools with similar demographics and populations as shown in Table 1. Both schools employ similar curriculums with required courses including math, science, English, Texas history, physical education, and health. The STEM-integrated school, however, uses a curriculum developed by Project Lead the Way (PLTW). The school that employs the PLTW curriculum has a required STEM course in seventh and eighth grade for all students. In the seventh grade students learn design processes through one of the following classes: green architecture, design and modeling, or automation and robotics. Throughout the units, students learn how to represent design through sketches and then build and evaluate their designs. For example, in design and modeling, students learn how to use computer-aided design software (CAD) and subsequently build a puzzle cube from their models. In the final lesson, the design challenge, students create a solid model of a therapeutic toy for a child with cerebral palsy. Eighth-grade students take an app design and drone course. In this course, students design technology applications and use computer programming to build their designs.

Curriculum at the school that does not employ an integrated curriculum, does include classes in technology as electives but they are not required classes for all students. All seventh-grade students at the non-STEM integrated school are required to take English, mathematics, physical education, science, Texas history, exploring careers, and health. Available electives are art, robotics, band, choir, theater arts, Spanish, piano, and business. Additionally, the nonSTEM school has a magnet medical academy program. 30 students are enrolled in the medical academy. Students in the medical academy take upper-level math and science courses to promote entrance into healthcare professions.

3.5 Quantitative Research Methods

The quantitative portion of the study followed a quasi-experimental design, as there was no randomization of the groups. Using a quasi-experimental design introduces threats to validity that would not necessarily be present in a true experimental design with random grouping (Cresswell & Guetterman, 2019). Although the two groups of students from the two schools share similar characteristics and educational backgrounds, particularly as they are in the same district and area, they are not identical. The school that does not use an integrated STEM curriculum has a slightly higher percentage of English language learners and economically disadvantaged students than the school that does use an integrated STEM curriculum. Using a pre/post-test design can help identify if changes are attributable to the intervention, in this case, the STEM integrated curriculum.

3.5.1 Addressing the Validity of Experimental Results

Any time conclusions or inferences are made from experimental results, the validity of those conclusions can be threatened. Threats to validity include construct validity, internal validity, and external validity (Cresswell & Guetterman, 2019). Construct validity, in this case, if the instrument is accurately measuring design thinking dispositions, is addressed through reliability testing. Internal validity includes threats related to participants, threats related to the treatment, and threats related to the procedures (Cresswell & Guetterman, 2019). By selecting schools with similar demographics, threats related to participants were reduced including maturation, history, and selection. Both schools have similar students and other than the required STEM integrated curriculum at the treatment school both schools have similar curricula. Also, testing occurred at both schools at similar times. To ensure honest and valid answers, the researcher was present during test administration to answer questions or clarify misunderstandings. Students were encouraged to answer honestly and were told that there was no penalty for not participating and that there were no wrong answers. To encourage participation, after the survey, students were given a snack.

Threats related to the treatment were addressed through the treatment taking place at two different schools within the same district. Because there is little interaction among students at the different schools, this limits the compensatory rivalry or diffusion of the treatments. The students at both schools did not receive any additional treatment from their normal school schedule and classes.

Another potential threat to internal validity is the implementation of the test. Because the same test was administered twice during the year, there is the potential that participants will become familiar with the test and recall their responses (Cresswell & Guetterman, 2019). Because the test was administered several months apart, this reduces the likelihood that students will recall the questions. Additionally, both groups took the same test twice and had equal time between the two tests.

Threats to external validity are related to the generalizability of the research results (Cresswell & Guetterman, 2019). This study relates to seventh and eighth-grade students of a particular demographic and their design thinking dispositions. Although conclusions may not transfer to all seventh and eighth graders in all settings, comparing normative groups helps to make the results applicable to similar groups. Additionally, the instrument, the design thinking disposition scale was deemed reliable for measuring design thinking dispositions in multiple contexts.

3.5.2 Design Thinking Disposition Survey

Tsai and Wang (2021) developed the design thinking disposition scale (see Appendix A) to assess middle school students' design thinking dispositions in a computer programming course. The instrument uses a five-point Likert scale rating items from "very much like me" to "not like me at all." Tsai and Wang (2021) developed the scale based on Stanford University's design thinking process of empathize, define, ideate, prototype, and test. The scale has items measuring all the stages of design thinking except for test, as the developers posited that formal testing may not be age appropriate. The initial scale contained twenty items, five for each assessed stage of the design process. After analyzing responses from 350 students, the final scale contained eighteen items and was found to have a Cronbach's α reliability of 0.90, meaning the items were consistent in measuring what they intended to measure. The composite reliability for each factor ranged from 0.79-0.90 and the average variance extracted for each factor was greater than 0.36. The scale was determined to be a reliable scale for measuring "design thinking dispositions in all learning contexts relating to design thinking, such as Maker, STEAM, Robotics, and computer literacy curricula" (Tsai & Wang, 2021).

3.5.3 Quantitative Data Analysis

Quantitative data was collected using the design thinking disposition scale through pre- and post-testing of seventh-grade students who returned a signed consent form. The scale was administered to participating seventh-grade students in both schools at the beginning of the semester and the end of the semester. The rationale for pre- and post-testing was to see if students at the STEM-integrated school showed greater gains in design thinking than students at the nonSTEM-integrated school after they had participated in a STEM-integrated class. Before test administration, students received consent forms and privacy information. No identifying information was used in data collection or data results. To encourage full participation, teachers were given $10 gift cards for encouraging their students to return consent forms. Because the administration of the pre-and post-tests took place several months apart, it reduced the chances that students would recall scale questions. The scale was also administered to eighth-grade students at the end of the school year. The rationale for administering the test to eighth graders was to determine if there was a significant difference between design thinking dispositions between students at the STEM-integrated school and students at the non-STEM integrated school after their three years of middle school.

The analysis included descriptive statistics comparing changes in disposition scales for both groups and sub-groups. Statistical measures used included a two-sample t-test and the reliability-corrected ANCOVA to account for nonequivalent groups (Trochim & Donnelly, 2001). The analysis attempted to understand if there was a significant difference between the design thinking dispositions of students enrolled in an integrated STEM class compared to students who were not.

3.6 Qualitative Research Methods

Qualitative data was obtained through student and teacher interviews at the STEM-integrated school. The purpose of the interviews was to better understand participants' engagement and attitudes towards an integrated STEM curriculum. Questions were related to the participants' experience within the program and what they perceived the benefits of the program to be (see Appendix B). Interviews lasted 20-30 minutes and were conducted securely on campus. Interviews were audio-recorded and transcribed by the researcher. Interviews were coded initially using an inductive method of thematic analysis outlined by Lester et al. (2020). This included organizing and transcribing the data, initial analysis of the data through reading and memoing, coding the data, and finally developing themes. Dedoose software was used to help organize the data and develop codes. Qualitative data was analyzed using constant comparison analysis. Constant comparison analysis, or coding, is used when researchers want to answer questions by identifying themes in qualitative data (Leech & Onwuegbuzie, 2007). The researcher reads through the data and then begins to break down the data into smaller pieces, coding those pieces with a description (Leech & Onwuegbuzie, 2007). As the coding continues, each small section of text is compared to previously identified codes to enable similar pieces of data to have the same code (Leech & Onwuegbuzie, 2007).

To verify the reliability of the coding schemata, qualitative analysis followed a methodological process outlined by Davey et al., (2010). Confirmability and credibility of qualitative data can be increased by using multiple researchers, transparency of how data is collected and interpreted, and rich descriptions of data (Davey et al., 2010). To increase the reliability of researcher interpretations, the primary researcher established a coding rubric. A common coding rubric reduces "variability in research findings attributed solely to researcher variability" (Davey et al., 2010, p. 145). A rubric was developed for both the student interviews and the teacher interviews after initial coding. During rubric development, initial codes were unified and clarified to identify applicable categories through axial coding (Davey et al., 2010). A second researcher then evaluated the codes and code definitions to develop a unified coding rubric for each set of interviews that could be applied to the data. That coding rubric was then applied to code the interviews. The primary researcher and the secondary researcher both independently coded the interviews using the coding rubric. The Cohen's Kappa (*k)* statistic was used to evaluate the interrater level of agreement. The *k* statistic determines the agreement between two variables. The Kappa statistic is calculated by comparing the observed agreement with the possible chance agreement. Because research can never be 100% certain, an acceptable *k* statistic of over 80% agreement is considered the lowest acceptable interrater agreement (McHugh, 2012). 80% agreement means that 20% of the data is coded inaccurately (McHugh, 2012). For the student interviews, both coders coded 58 passages the same, and 8 passages differently or were left uncoded for an interrater reliability of 87.87%. For the teacher interviews, both coders coded 33 passages the same, and 3 passages were coded differently or not coded, for interrater reliability of 91.67%.

Additional qualitative data was obtained from free-response questions at the end of the design thinking disposition survey (see Appendix C). These questions were included in the post-survey the seventh-grade students took and the survey the eighth-grade students took. The purpose of the post-survey free-response questions was to accumulate more qualitative data on student perceptions for a larger group of students than interview data, particularly what careers students were considering. Survey responses were then analyzed using inductive coding like the process used for the interview transcripts.

3.7 Mixed-Methods Analysis

Any mixed methods study intends to use two different methodologies, quantitative and qualitative, to provide a comprehensive understanding of a research question. The combining or integration of different types of data in mixed methods studies can be used to triangulate or corroborate findings, elaborate understandings, uncover contradictions or expand the range of the study (Cresswell & Plano Clark, 2018). Research question one “What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?" was answered through the administration of the design thinking disposition survey to eighth-grade students at both middle schools. Research question two "What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design thinking dispositions?” was answered using qualitative data collection through interviews and free response questions. Data from both portions of the study was then examined to better understand the mechanisms by which design thinking dispositions may be enhanced.

3.8 Summary of Methods

This study followed an explanatory sequential mixed methods design to answer the two research questions:

1. What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?
2. What are the perceptions of students and teachers on how a STEM-integrated curriculum helps to develop design thinking dispositions?

The quantitative portion of the study addressed question one using the design disposition scale. The scale was administered at the beginning and end of the semester to seventh graders and at the end of the year to eighth graders at two schools within the same school district to determine if there was a change in design thinking dispositions between students at a school with an integrated STEM curriculum and students that are not in a school with integrated STEM.

The qualitative portion of the study addressed question two. Through free response questions and interviews, qualitative data was collected to support quantitative findings or to determine if there are other benefits to an integrated STEM curriculum not measured on the design thinking disposition scale. Design thinking and related critical thinking skills are essential to navigate the complexities and challenges facing students. Determining how to best develop those skills is critical to ensuring students are prepared to face those challenges.

CHAPTER 4
RESULTS

The purpose of this explanatory sequential mixed methods study was to determine if an integrated STEM curriculum affects design thinking dispositions in middle school students. Results from both quantitative data and qualitative data will be discussed in this section.
Both quantitative and qualitative data were used to answer research question one: “What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?” Quantitative data was obtained from two groups. A sample of seventh grade students were given the design disposition survey at the beginning and end of the semester to students from each school, a STEM integrated school and one that did not use a STEM integrated curriculum. Students that returned a completed parental consent/student assent form participated. The purpose of pre and post testing was to determine if design thinking dispositions changed after students were exposed to the STEM integrated curriculum and if there was a significant difference between the two groups. The other group that was administered the survey were eighth grade students from both schools at the end of their eighth-grade year. These students were given the survey to see if there was a significant difference in design thinking dispositions between students that had attended a STEM integrated school throughout their middle school years and those that did not.

Qualitative data was obtained through student and teacher interviews. Free response questions were also included on the post-survey for the seventh graders and the survey given to the eighth graders. The purpose of collecting qualitative data was to answer research question two: “What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design thinking dispositions?” Notes from interview transcripts were analyzed and coded as well as responses from the surveys. The purpose of collecting qualitative data was to provide a better understanding of any results obtained from quantitative data and to gain insight into how differences in design thinking dispositions could be identified through student and teacher reflections on their teaching and learning in a STEM integrated class. A summary of the research questions and data collection is shown in Table 2.

Table 2

Research Questions, Data Collection Methods, and Participants

	Research Question One *What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?*		**Research Question Two** *What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design thinking dispositions?*
Data Collection Tool	Design thinking Disposition Survey	Free Response Questions	Teacher and Student Interviews
Participants	7th and 8th Graders STEM and NonSTEM Schools	7th and 8th Graders STEM and NonSTEM schools	7th grade students and teachers from STEM school
Data Analysis Method	Quantitative	Qualitative and Quantitative	Qualitative

4.1 Quantitative Findings

To determine whether the survey was appropriate, a pilot study was conducted. During the summer prior to the administration of the survey, the survey was given to a small sample of students in a summer bridge program. The students had recently graduated from eighth grade at the schools at which the study was going to take place. Students were asked to answer the survey and comment if there were any questions that were unclear or were confusing. Twenty students participated and commented that the survey was easy to understand and did not need clarification.

Before the administration of the survey, parental consent/student assent forms in English and Spanish were distributed to seventh grade students at both schools at the beginning of the semester and to eighth grade students at both schools near the end of the semester (see Appendix D) at each of the two schools. Surveys were distributed to seventh graders during an advisory period. 38 seventh graders from the STEM integrated school agreed to participate in the survey and 42 seventh graders from the non-STEM integrated school returned yes consent forms. A total of 26 seventh graders from the STEM school were present and participated in both the pre and posttest. 33 seventh graders from the non-STEM school were present and able to take both the pre and posttest. Consent/assent forms were also distributed to eighth graders at each of the two schools near the end of the semester. A total of 37 eighth grade students from the STEM school returned consent forms and 36 eighth grade students were present to participate in the end of year survey. A total of 34 eighth grade students from the non-STEM school returned consent forms and 32 were present and participated in the survey. Table 3 shows the number of participants from each school.

Table 3

Participants in the Design Thinking Disposition Survey

School	Seventh Grade Returned Yes	Seventh Grade Participants	Eighth Grade Returned Yes	Eighth grade Participants
STEM School	38	26	37	36
Non-STEM School	42	33	34	32

Because the survey used Likert Scale data, in which multiple items are used to calculate a composite score, descriptive statistics were analyzed at the interval measurement scale (Boone & Boone, 2012). The interval measurement scale combines related items into groups for analysis. Therefore, responses were grouped by area of design thinking disposition: *define* - articulating a problem statement, *empathize* – understanding the users' needs, *ideate* – generating multiple solutions, and *prototype* – building models or visual representations. There was a total of three questions for the *define* area and five questions for each of the other areas: *empathize, ideate,* and *prototype.* Questions for each of the four measured design thinking dispositions areas are shown in Table 4.

Table 4

Design Thinking Disposition Survey Items by Area

Area of Design Thinking	Survey Items
Define	• I usually try to understand the problem that must be solved. • I usually try to simplify or rethink the problem that must be solved. • Before I solve the problem, I try to understand what is required for a solution
Empathize	• I usually see the need to solve the problem. • I usually try to understand the reason the problem needs to be solved. • I usually try to imagine the feelings of the people that need the problem solved. • I usually try to feel the needs of the users. • I usually try to see the problem from the users' point of view.
Ideate	• I usually try to come up with solutions by brainstorming. • I usually come up with many different solutions to the problem. • I usually come up with innovative or unique solutions. • I usually come up with new solutions. • I usually think of different ways to solve the problem
Prototype	• I usually like to draw a picture of the solution design. • I usually like to make a model of the solution design • I usually provide an example for showing an idea. • I usually present an idea by putting together objects to show my idea. • I usually try to make a model to test my solution to see if it works.

Each item on the scale was rated from one to five as follows: ***1****–never like me,* ***2****-rarely like me,* ***3****–sometimes like me,* ***4****-usually like me* and ***5****-always like me.*

4.1.1 Results of Pre and Post Survey for Seventh Grade

For the seventh-grade students, the hypotheses were as follows:

- Null Hypothesis: There is no statistically significant difference in the change in design thinking dispositions throughout the year between students that are in a STEM integrated school and students that are not in a STEM integrated school.
- Hypothesis: There is a statistically significant difference in the change of design thinking dispositions throughout the year between students that are in a STEM integrated school and students that are not in a STEM integrated school.

Statistical analysis was performed using IBM SPSS Statistics 28. The means and standard deviations from both the STEM school and the nonSTEM school are shown below in Table 5.

Table 5

Seventh Grade Means (M) and Standard Deviations (SD) of Pre and Posttest

			Seventh Pretest		**Seventh Posttest**	
	School	***N***	***M***	***SD***	***M***	***SD***
Define	STEM	26	10.65	2.19	11.46	2.02
	NonSTEM	33	10.39	2.42	11.00	2.70
Empathize	STEM	26	17.85	4.16	18.38	3.66
	NonSTEM	33	15.70	3.50	17.41	3.88
Ideate	STEM	26	17.23	4.74	17.62	3.38
	NonSTEM	33	16.21	4.21	17.78	4.47
Prototype	STEM	26	15.08	5.27	16.04	4.24
	NonSTEM	33	14.64	4.16	14.53	4.68

When accounting for the number of items in each area, i.e., define had three questions and each of the others had five, average scores for each measured area of design thinking disposition are shown in Table 6.

Table 6

Difference Between Pre and Post Test by Area

	School	Pretest	Posttest	Gain
Define	STEM	3.55	3.82	0.27
	NonSTEM	3.46	3.67	0.21
Empathize	STEM	3.47	3.52	0.11
	NonSTEM	3.14	3.48	0.34
Ideate	STEM	3.47	3.52	0.05
	NonSTEM	3.24	3.56	0.32
Prototype	STEM	3.02	3.21	0.19
	NonSTEM	2.92	2.91	-0.01

As shown in Figure 5, the STEM seventh graders had greater gains between pre and post-test in both *define* and *prototype.* Although the STEM school had higher scores overall, the nonSTEM school had greater gains in both *empathize* and *ideate.*

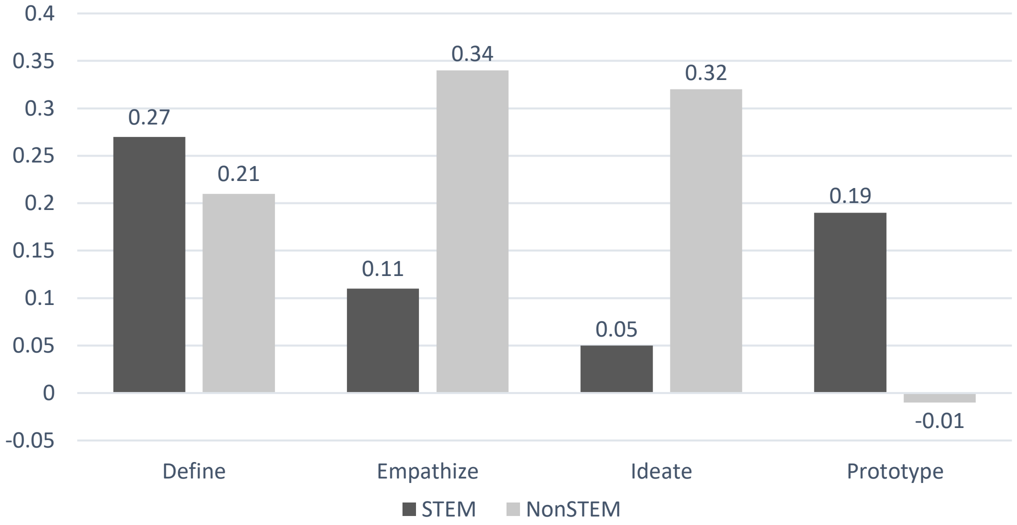


Figure 5: *Gains in Seventh Grade Pre and Post Test Results by Area for STEM and NonSTEM schools*

ANCOVA (analysis of covariance) was calculated for each of the primary areas of design thinking dispositions between pre and posttest based on school using the average sums of each domain. ANCOVA allows the use of a covariant to adjust for any between group differences. Using the pretest as the covariant allows for results of the post-test to be more conclusive. Table 7 shows the results.

Table 7

Results of Analysis of Covariance Seventh Grade

	Sig Pre	**HR**	**f**	**Sig**
Define	0.05	0.95	0.30	0.58
Empathize	0.05	0.34	0.00	0.99
Ideate	0.48	0.83	0.22	0.64
Prototype	0.70	0.14	1.68	0.20

To analyze using ANCOVA, two assumptions were satisfied. First, data was analyzed to ensure that there was not a statistically significant difference between the groups in the pretest. Those results are shown in the sig Pre column which are all at or above 0.05. The second assumption is the homogeneity of regression shown in the HR column. Homogeneity of regression shows that the regression slopes for the pretest and the posttest are parallel. All areas had numbers greater than a p value of 0.05 showing no significant differences between the regression slopes. However, the difference between schools for each of the tested areas was all greater than 0.05 showing that there was no significant difference between design thinking dispositions among seventh grade students that were at a STEM integrated school and those that were not at a STEM integrated school and the null hypothesis cannot be rejected.

4.1.2 Results from Eighth Grade Survey

The hypotheses for the eighth grade were as follows:

- Null Hypothesis One: There is no statistically significant difference between design thinking dispositions of eighth grade students that attended a school with a STEM integrated curriculum and eighth grade students that did not attend a school with a STEM integrated curriculum.
- Hypothesis One: There is a statistically significant difference between design thinking dispositions of eighth grade students that attended a school with a STEM integrated curriculum and eighth grade students that did not attend a school with a STEM integrated curriculum.

Eighth grade results are shown below in Table 8.

Table 8

Analysis of Eighth Grade Survey Results

	STEM School			NonSTEM School			Levene's EQ Variances					
	N	***M***	***SD***	***N***	***M***	***SD***	***F***	***Sig***	***t***	***df***	***p***	***d***
Define	36	10.69	2.86	32	10.53	2.34	1.109	0.296	0.256	66	0.400	0.163
Empathize	36	17.81	3.43	32	16.50	3.62	0.061	0.805	1.527	66	0.066	1.306
Ideate	36	17.58	3.57	32	16.25	3.95	0.006	0.937	1.461	66	0.074	1.333
Prototype	36	15.03	4.31	32	14.16	4.67	0.144	0.705	0.801	66	0.213	0.872

Figure 6 shows the difference between the two schools in each design thinking disposition area. The STEM school had higher averages in all areas of design thinking dispositions. The greatest difference between the two schools was in the areas of *empathize* and *ideate* with an average difference of 0.26 between the STEM and nonSTEM *school*. *Prototype* had a difference of 0.17 and *define* had the smallest difference of 0.05.

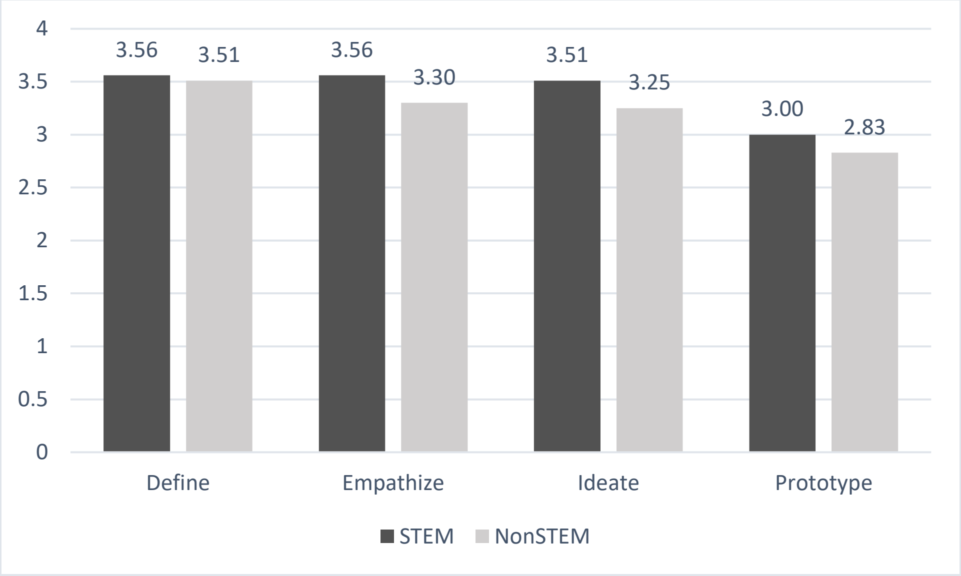


Figure 6: *End of Year Eighth Grade Survey Results STEM and Non-STEM school by Area*

Because all areas had a p value greater than 0.05 in Levene's test of equality the variances of the two groups are not significantly different from each other and thus effect size of each area was calculated using Cohen's *d*. Effect size was 0.062 for the *define* area, 0.371 for the *empathize* area. For Cohen's *d*, the range of effect varies from 0.2 (small), 0.5 (medium) and 0.8 (large). For a Cohen's *d* of 0.8, or a large effect, there is an overlap of about 69% of the scores. For a small effect, 0.2, there is an overlap of approximately 92% of the scores. eighth grade test data show the effect of both define and prototype are small, meaning that there is little expectation that a sample from the STEM school will be any different than a sample from the nonSTEM school. Both *empathize* and *ideate*, however showed an effect size between low and medium. Although the effect is low, there is a greater chance that the effect on the STEM school will be higher.

An independent t-test was conducted on the two groups for each design thinking disposition area. An independent t-test makes the following assumptions:

1. Independence of the observation: each subject was in only one group. STEM school students were in group 1 and non-STEM students were in group 2.
2. The data for each group is normally distributed. This was true as shown in Table 9. The Shapiro Wilk test of normality shows a significance above 0.001 for all question groups, although the define group is shown to be the least significant at 0.002.

Table 9

Shapiro Wilk Test of Normality

Area	Statistic	Df	Sig
Define	.938	68	.002
Empathize	.975	68	.191
Ideate	.977	68	.255
Prototype	.979	68	.304

3. There are no significant outliers in the groups.
4. The variances between the two groups are equal shown through the Levene's test of significance.

Levene's test of significance in the sig column shows a p value of each area greater than 0.05 allowing the assumption that the variances are equal. T values are lower in both *define* and *prototype* areas, 0.256 and 0.801, respectively. Both *empathize* and *ideate* had higher t values of 1.527 and 1.461. T values for *empathize, ideate* and *prototype* are all above the mean difference. Using a significance value of 5% in the *empathize* category a t value of 1.527 is 20% higher than the mean difference of 1.306. *Ideate* has a t value of 1.461 which is 8.7% higher than the mean difference of 1.333. The *define* category has a t value of 0.256 which is 33% higher than the mean difference of 0.163.

Calculated p values for each area are *define*: 0.40, *empathize* 0.066, *ideate* 0.074 and *prototype* 0.213. Because all p values are greater than 0.05, results are not statistically significant, and the null hypothesis is not rejected. Although the mean for each category is higher at the STEM school than the non-STEM school showing some evidence that STEM school students have a higher design thinking dispositions when they leave the school than students at a non-STEM school, the results are not significant enough to reject the null hypothesis that students at a STEM school and students at a non-STEM school will have the same design thinking dispositions.

4.1.3 Free Response Questions

Included on the post survey for seventh grade students and the survey for eighth grade students were four free-response questions. The free response questions were:

1. Thinking back to the beginning of the year, do you think you have changed the way that you solve problems? Explain.
2. Thinking back to the beginning of the year, do you think you are better at designing solutions to problems now than you were before? Explain.
3. What type of career are you interested in?
4. What do you like best about that career?

The purpose of free response questions one and two was to better understand if the student had any perception of growth or change. Literature suggests that students engaging in STEM activities revise and evaluate their work and using this metacognitive process can help students develop a growth mindset (Stohlmann, 2022). Focusing on process rather than performance can develop a growth mindset in students (Haimovitz & Dweck, 2017). Students in STEM classes should learn from their failures as they revise and evaluate their designs. Questions three and four were asked to better understand if students were considering STEM related careers. Participating in STEM activities has been shown to influence STEM identity for middle school girls, (Kang et al., 2019) and to increase interest in STEM careers (Baran et al., 2019; Mohr-Schroeder, 2014; Wingard et al., 2022). Increasing interest in and preparation for

STEM careers helps to fulfill the goals of the NGSS in preparing students for a competitive, technological economy (NGSS, 2013).

The results for questions one and two are shown below in Table 10. In the table, STEM 7 and STEM 8 refers to seventh grade and eighth grade students from the STEM integrated school. NonSTEM 7 and NonSTEM 8 refers to seventh and eighth grade students from the non-STEM integrated school. The percentage of each group is shown along with the number of students from each group. There is a difference between the number of students that answered the free response questions and the number of students that took the survey as not all students chose to answer the free response questions.

Table 10

Answers to Free Response Questions for Seventh and Eighth Graders

		Changed Problem Solving		**Better at Designing Solutions**	
	N	**Yes**	**No**	**Yes**	**No**
STEM 7	26	65% *(N=17)*	35% *(N=9)*	81% *(N=21)*	19% *(N= 5)*
NONSTEM 7	31	60% *(N=20)*	40% *(N=13)*	43% (*N=13)*	57% (*N=18)*
STEM 8	29	79% *(N=23)*	21% *(N=6)*	72% (*N=21)*	28% (*N=8)*
NONSTEM 8	30	67% *(N=20)*	33% *(N=10)*	63% (*N=19)*	37% (*N=11)*

Results were tabulated based on a positive or negative response. For example, some students simply responded "*Yes*" or "*No*" without further explanation. Other responses did not explicitly say yes or no but were considered *"Yes"* or *"No"* based on if their response was positive or negative. Examples of positive responses that were classified "*Yes"* were answers like "*I have gotten better about thinking about the outcomes*," "*I have a desire to look for more solutions*" and "*I am more confident and have a positive approach to solving them*." Responses that were categorized as "*No*" or negative were responses like "*I never really designed anything this year*" "*About the same*" and "*I'm not entirely sure. Personally, I haven't seen that sort of change*."

Because responses could be classified as "*Yes*" or "*No*" the instances of each could be quantified. This data was then analyzed using SPSS statistical software. A Fisher's Exact test was used to determine if there was a difference between student perceptions of both changes in problem solving ability and changes in design thinking at the two schools. A Fisher's Exact test is similar to a Chi-squared test but is recommended when sample sizes are less than fifty. The Fisher's Exact test measures the association between the variables at the two schools. If there is no association, then there would be no differences in the perception of changes in problem solving and design thinking between the STEM school and the non-STEM school. Results of the Fisher's Exact test is shown in Table 11.

Table 11

Fisher's Exact Two-Sided Test

Group	Fisher's	Cramer's V	Significance
Seventh Problem Solving	.785	.055	.678
Seventh Design Thinking	.006	.382	.004
Eighth Problem Solving	.272	.144	.249
Eighth Design Thinking	.600	.077	.537

In the above table, the Fisher's Exact statistic determines whether the variables are related. Using a *p-value* < 0.05, the only area that is significant is design thinking for the seventh graders. Cramer's V determines the strength of that significance. A Cramer's V value of 0.382 in the seventh-grade design thinking is considered a large effect. This indicates that there is a difference in design thinking over the course of the year between seventh grade students at the STEM integrated school and the non-STEM integrated school. Seventh grade students at the STEM integrated school perceived themselves as better at design thinking by the end of the year.

The last two questions on the free response section were “What type of career are you interested in?” and “Why are you interested in that career?” Results were then categorized as a *“STEM”* career or a *“nonSTEM”* career. *“STEM”* careers included careers in the following categories: computer and information sciences, engineering and engineering technology, biology, physical sciences, science technology, math and agriculture, and all health care careers (Salzman et al., 2013). Examples of careers classified as *“STEM”* were “engineer,” “programmer,” and “labor and delivery nurse.” Careers classified as *“no-STEM”* included careers in law enforcement, the service-related careers, welding, teaching, athlete and “I don’t know.” Examples of careers classified as *“non-STEM”* were “FBI,” “firefighting,” “border patrol,” “barber,” and “basketball.” Results are shown in Table 12.

Table 12

Career Choices of Seventh and Eighth Graders at STEM and NonSTEM Schools

	Number	**STEM Careers**	**NonSTEM Careers**
STEM 7	26	54% *(N=14)*	46% *(N=12)*
NONSTEM 7	31	52% *(N=16)*	48% *(N=15)*
STEM 8	29	45% *(N=13)*	55% *(N=16)*
NONSTEM 8	30	27% *(N=8)*	73% *(N=22)*

Results were analyzed using the same process as for the other free response questions. Table 13 shows the results of statistical analysis using SPSS software.

Table 13

Fisher's Exact Two-Sided Test STEM/NonSTEM Careers

Group	Fisher's	Cramer's V	Significance
Seventh Graders	.796	.050	.703
Eighth Graders	.426	.123	.325

The Fisher's exact test is measuring whether there is a significance between STEM and NonSTEM careers between the two schools in each of the two schools. Because numbers for both seventh graders and eighth graders have a *p-value* greater than $p<.05$, results for both seventh and eighth graders were not statistically significant, and a student is not more likely to choose a STEM career based on the school that they attended.

Besides asking what career students were interested in, question four asked why they were interested in that career. Table 14 shows the career choice and the reason for each choice for all students that chose a career that was classified as a *"STEM"* career.

Table 14

STEM Career Preferences of Seventh and Eighth Grade Students at STEM and Non-STEM Schools

Seventh STEM		Seventh NonSTEM	
Career	**Reason**	**Career**	**Reason**
The medical field or space engineer	"I like the science"	Rocket science	"Changing the future and money"
Doctor	"The money"	Meteorologist	"I like weather and the earth and learning about different places"
Physical therapist	"My mom's dream job"	Civil engineer	"I like that I can see construction come together and make something great"
Animation career	"Create how I want and watch what I created"	Labor and delivery nurse	"I want to take care of mother and child"
Fortnite designer/player	"The money"	Architecture	"I like to make models and show what I can do"

Science or art	“I love exploring nature and learning new things”	Health care	“Help people”
Medical field	“I like the money and it seems fun”	Mechanical Engineering	“To build and design”
Astronomer	“I like that I can discover the unknown”	Science	“Because I like thinking and inventing”
Engineer	“The way they solve problems and make things by just being curious”	Architecture	“I get to design buildings”
Doctor	“I love to help people”	Engineering	“Multiple designs you can do”
Pediatric neurosurgeon	“I've always wanted to be a doctor and I like the challenge”	Programming	“I like coding”
Tech	“I like to design”	Engineering	“To make things”
Electrical engineer	“I like math and I like the pay”	Neurosurgeon	“To help people and make their lives better”
Anesthesiology	“Helps people and gets paid well”	Engineering	“The innovation”
		Nurse	“To help people”

Eighth STEM		**Eighth NonSTEM**	
Career	Reason	Career	Reason
Anesthesiology	“Money”	Engineering	“Relaxing and the money”
Biomedical scientist	“They find cures to diseases”	Mechanical Engineer	“Building”
Doctor	“To help people”	Physical therapist	“To help”
Health science	“It's cool”	Robotics	(none)
Engineering	“It's fun and there's money”	Surgeon	“Saving lives”
Engineering	“The people you meet and the problems you solve”	Tech	“Money and opportunities”
Engineering	“Working with tech”	Engineer	“Building”
Engineering	“It includes math”	Aerospace engineering	“Designing and testing airplanes”
Veterinary medicine	“I like animals and caring for them”		
Animation	“Art and technology”		
Engineer/programmer	“I find it interesting and want to expand the field”		

Anything math or science related	“I'm good in anything that includes that”
Engineer	“Making and building stuff”

Reasons given for entering a STEM field were classified as *helping others, good salary, create/design/discover, math/science/tech,* and *miscellaneous.* Although the percentage of seventh grade students interested in STEM careers and their reasons for doing so was similar in both schools there were more eighth graders that were interested in STEM careers at the STEM integrated school, and they also had reasons including an interest in math, science, and technology that was not apparent at the non-STEM school.

4.1.4 Summary of Survey Findings

The design thinking disposition survey was conducted to determine if there was a difference in design thinking dispositions between students at a school that uses an integrated STEM curriculum and students at a school that does not use an integrated STEM curriculum. The design thinking disposition survey examined four categories of design thinking: *define, ideate, empathize, and prototype.* Based on the findings there is no significant difference in pre and post testing for seventh grade students. Although the seventh graders at the STEM school did have a larger change in the *prototype* category, it was not statistically significant.

Although all four category averages were higher for the STEM school than the nonSTEM school in eighth grade, differences in eighth grade students were also not statistically significant. The largest differences between the two schools in eighth grade were in the categories *empathize* and *ideate*. Overall students from the STEM school scored higher in the design thinking disposition survey in all categories in both grades, except for seventh graders on the posttest in the *ideate* category. The average for STEM seventh graders was 3.52 compared to 3.56 for

NonSTEM seventh graders. Although there may be evidence that students that participate in an integrated STEM curriculum may have higher design-thinking dispositions, the results are not significant enough to reject the null hypothesis.

Free response questions on the survey, however, did indicate that there was a difference between students from the STEM school and the nonSTEM school. Students from the STEM school had a statistically significant difference in their own perception of their ability to design solutions to problems. Additionally, a larger percentage of eighth grade students from the STEM school were interested in STEM careers.

4.2 Qualitative Findings

Research question two "What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design thinking dispositions" was answered through qualitative data collection in primarily narrative form. Individual interviews were conducted with students and teachers at the STEM school. A total of thirteen seventh grade students, seven males and six females, participated in face-to-face interviews with the researcher. Interviews lasted between ten to fifteen minutes and were audio recorded. Three teachers participated in face-to-face interviews with the researcher, one from each of the three grade levels at the STEM integrated middle school. Interviews were conducted at the end of the school year on campus and lasted approximately twenty minutes. The interviews were audio recorded.

4.2.1 Interviews

Consent forms distributed to students at the seventh grade STEM school included an option to volunteer to be interviewed. On the returned consent forms 23 students volunteered to be interviewed. Individual interviews were conducted by the researcher at school during the school day near the end of the year. At the time the interviews took place, 13 students that had consented were available to be interviewed. Four students that had previously consented opted out and the other six students had either unenrolled from the school or were on a school trip. Interviews lasted ten to fifteen minutes for each student. One interview was conducted with two students at the same time as they felt more comfortable being with another student. There were seven boys interviewed and six girls. Interview questions were chosen to determine student perceptions of their STEM class and how they may use the problem-solving process to design solutions in the STEM class. Interview questions also explored what types of careers students may be interested in. Participating in science related activities both in and out of school can help middle schoolers develop a STEM identity and interest in STEM careers (Kang et al., 2018). Initial interview questions included the following:

1. What do you like/dislike about your STEM class?
2. How has your STEM class helped you solve problems? What activities have helped you learn how to solve problems?
3. What are the steps you take when you come up/design a solution to a problem?
4. How do you know when you have found the best solution to a problem?
5. What do you like/dislike about working in groups?
6. Why might it be important to understand the user when designing a product?
7. When you think of yourself as an adult, what do you see yourself doing?

Interview questions were chosen to determine student perceptions of their STEM class and how they may use the problem-solving process to design solutions in the STEM class. Specifically interview questions two, three and four were related to the design thinking dispositions of *define, ideate,* and *prototype.* Interview question six was related to the design thinking disposition of *empathize.* Interview question seven explored what types of careers students may be interested in. Participating in science related activities both in and out of school can help middle schoolers develop a STEM identity and interest in STEM careers (Kang et al., 2019).

Teacher interviews took place at the end of the year. Three teachers from the STEM school were interviewed. A STEM teacher from sixth grade, seventh grade, and eighth grade agreed to participate. Mr. Sandoval, the sixth-grade teacher, had six years of teaching experience. The seventh-grade teacher, Mr. Apodaca, had four years of experience, and the eighth-grade teacher, Ms. Clark had twenty-four years of experience.

Initial interview questions included the following:

1. What are the core ideas of STEM?
2. How do you convey those core ideas to your students?
3. What is your understanding of design thinking?
4. How do activities in your class promote design thinking?
5. What methods can students use to solve open-ended problems?
6. What are the challenges in teaching students in a STEM curriculum?
7. What are the benefits to having a class dedicated to STEM integration?

The questions were asked to help identify what teachers perceive as potential benefits to having an integrated STEM curriculum. Questions one and two were asked to better identify what STEM means to the teachers implementing a STEM integrated curriculum and how they communicate those ideas to their students. Questions three, four, and five were asked to understand how design thinking is perceived by teachers at the middle school level and if aspects of design thinking are incorporated into activities in a STEM integrated curriculum. Questions six and seven were meant to better identify specific difficulties in STEM integration and potential benefits of STEM integration.

Interviews were recorded and transcribed by the researcher using Microsoft office dictation tool through a virtual audio cable obtained from VB-Audio. Transcriptions were then edited for clarity by the researcher and uploaded into Dedoose coding software. The primary researcher initially read through interviews to start to develop descriptive codes. Descriptive coding categorizes data at a basic level of topics that can then be grouped into categories for further analysis (Saldaña, 2022). Descriptive codes are short phrases or words that identify the topic of a particular section of qualitative data (Saldaña, 2022). During the coding process, memos were created along with codes and coded data in Dedoose to delineate the thought process of why particular passages were assigned certain codes. After initial descriptive coding, codes were clarified to combine similar codes and eliminate unnecessary codes through axial coding. For example, questions two, three and four were related to solving problems and designing solutions. During initial coding of these question codes of *ideas, fix a problem, test solutions, evaluate solutions, design,* and *different ways to do something* were identified. During axial coding those codes were combined into one code, *solving a problem.* A second researcher independently coded the data and codes were clarified into seven distinct codes before a second round of coding at which point an interrater reliability of 88% was reached.

The final coding rubric for student interviews is shown in Table 15 with the number of times each code was identified in the student interview transcripts.

Table 15

Final Coding Rubric for Student Responses to Interview Questions

Code	Definition	Example	Number of Instances	Number of Students	% of Students
Finding a Solution	Solving a problem by generating ideas, testing ideas, or revising a plan	"Just look at the resources you have around. And if it doesn't work just try to modify it."	24	13	100%
Choice	The ability to make creative choices by choosing projects, designs, or groups	"And we do whatever we want – like we get to be creative in that class."	5	4	31%
Collaboration	Working with classmates to share ideas, help in understanding or divide up work	"There's more minds, to think of better ideas to help with the project."	26	13	100%

Impact on others	Understanding how designs or solutions will affect the user	"You have to think how they will use it and if it will work for that specific person."	8	8	62%
Hands-On	Manipulating materials or turning abstract concepts into physical manifestations	"I like when we get to build things and program it."	27	13	100%
Satisfaction	Enjoying or gaining fulfillment from one's experience	"We do a lot of stuff in there that I really enjoy."	12	12	92%
Job Stability	To have a career that will provide for one's needs and family	"Now my parents are struggling, so I kind of want to like help them."	13	12	92%

All thirteen students mentioned the codes *finding a solution* and *hands-on.* Twelve of the thirteen students spoke about *job stability* and *satisfaction.* Eleven of the thirteen talked about ideas related to *collaboration.* Eight out of thirteen had excerpts coded *impact on others*. The least frequent code found was *choice* with only five of the thirteen students mentioning having the ability to choose projects or groups when responding to interview questions. The following sections will discuss general interview questions and how responses were coded. Student interview questions and answers will be discussed along with teacher interview responses that support identified codes. All responses use pseudonyms to protect the identity of the students and teachers.

4.2.1.1 Question One: What do you like/dislike about your STEM class? Responses to this question were related to the codes of satisfaction, choice, and hands-on. For example, Elian said about his STEM class, "*We just do stuff in there that I really enjoy."* When asked if he could provide an example, his response was "*We just finished building a robot and we could make it* *drive so it could race, and I thought that was really fun*." When asked if there was something he didn't like about his STEM class, his response was "*Not really. It's fun*." Eight of the thirteen students mentioned the word "fun" when asked about their STEM class. STEM classes provide an engaging environment to explore STEM disciplines as Mr. Sandoval said, "*In our class, we get the freedom of applying that same knowledge but in a fun environment and they get to see it in a real-world setting. So, they can use what they learned in math to do this when they use fractions because of gear ratios. They learn how to do the scientific method because of the engineering design process*." Students are engaged in the class, participating in "fun" activities, but they are applying knowledge they have learned in their other classes. Integrated STEM gives them the opportunity to have more freedom in applying knowledge.

Choice was also identified as a reason for liking STEM class. Caleb said he liked STEM because "*we get to choose who we work with, how we work and what and like we choose what we do*." Twelve of the thirteen students said they liked their STEM class because of the activities. The code *hands-on* was also mentioned when students were asked about their STEM class. For example, when asked what she liked about her STEM class, Sandra said she liked "*building stuff*" and she's "*kind of like into building stuff and like helping [her] dad fix things*." Only one student, Jose, said he didn't really like his STEM class because "*I don't really like building robots and stuff*" and "*it's simple for me. I don't really enjoy it*."

Only three other students had anything negative to say about their STEM class, but when they did it was related to the code of *collaboration.* For example, Caleb said that what he didn't like about his STEM class was when "*someone doesn't do their work*" or are "*just goofing off*." Both Jen and Ally also didn't like how some of the kids in their classes were disruptive and "the boys are crazy in that class." The other nine students, when asked what they disliked about their STEM class, said nothing or that they liked everything about it.

4.2.1.2 Questions Two, Three and Four: Problem Solving. When relating STEM class to solving problems, codes that were found were *finding a solution, hands-on* and *collaboration*. When asked "Has your STEM class helped you in solving problems?" ten of the thirteen students interviewed said yes that it had helped them. Excerpts coded as finding a solution include Chloe when she said that the class had helped her by "*working together and a lot of problem solving*." When asked for an example of how the class had helped Ally with problem solving, she replied "*one time when we were building something, and it broke and we had to like figure a way to tape it and fix it and solve it*" another excerpt coded finding a solution. This reveals the intended purpose of an integrated STEM curriculum: learning problem solving skills. As Mr. Sandoval said the main idea of STEM is "*problem solving skills. Just being able to break down information into problems and properly solve them*."

When asked "What method or steps do you take when solving a problem?" excerpts were also coded *finding a solution*, although most students did not have a clear step-by-step problem-solving method. When asked how she goes about solving a problem, Iliana replied, "*Just look for clues I guess*." To the follow up question, "Would you brainstorm?" her reply was "*No I wouldn't brainstorm*." Similarly, when asked if there were steps he takes when designing a solution to a problem, Cristos replied, "*No. We just play it by ear*." Chloe also did not use a particular problem-solving method saying "*Just look at all your resources you have around you. Try to come up with some solution. Test it and if it doesn't work, modify it*." Sandra responded to the question by saying "*I'm just going to come up with extra ideas in case something doesn't work out*." Although none of the students described a methodological problem-solving method, Fabio said he "*would maybe look at my older work and get stuff from there or from a different class, like old notes*." Relating to the process of trial and error, Mr. Apodaca noted, "*You have a problem you can figure out the solution. You design your solution and then you fix it. You find your solution, and if it doesn't work you redo it again so it's a fluid process.*"

When asked "How do you decide on the best solution?" answers were generally coded *collaboration*. Again, students did not have a clear method for decision making when working in groups and most replied similarly to Cristos who responded, "When it works the best out of all the ones we have tried." A similar answer was found in this exchange with Iliana:

> Researcher*: If you're working in a group, how do you decide what the best solution is?*
>
> Iliana*: You see which one works better.*
>
> Researcher*: Ok. And how do you do that?*
>
> Iliana*: I don't know*
>
> Researcher*: Do you test them?*
>
> Iliana*: Well, yeah.*
>
> Researcher*: Do you vote as a group?*
>
> Iliana*: Oh no. We just usually find out which one is better and just put that one on.*
>
> Researcher*: By testing it.*
>
> Iliana*: Yeah*

Jose did have more of an evaluative stance saying, *"I'd respond with logic to see which one is best and if they are equally best, I'd maybe make something that like takes up assets from each and every one and make one super plan."*

4.2.1.3 Question Five: What do you like/dislike about working in groups? The code identified with question five was obviously *collaboration*. Most students had positive associations with group work. One reason found for the preference for working in groups was students could get help from their classmates when they didn't understand something. Steven said groups were good because "*you could ask for help*." Iliana also thought working in groups was helpful because "*your team members can help you because they know how to do it*." Ms. Clark noticed that as students "*were going through the modules they were sticking with the same partners because they built that rapport*." Students are building working relationships as they learn each other's strengths and weaknesses, or as Mr. Sandoval said, "*They learn roles and then if they don't understand what they're doing then they change roles, and you see that adaptation which is really cool in a group collaborative effort because they realize their strengths and weaknesses, and they're not scared to be vulnerable*."

Besides getting help from group members, students liked working in groups because they could generate more ideas. Elian said, *"it feels better to work with a team that can help, and they also know some stuff to bring to the table."* Cristos also liked sharing ideas and when responding to the question of what he liked about working in groups he said, "*We get to share ideas with each other. We get to express our thinking. We get to be creative*." Chloe liked working in groups "*Because you have more brains. So, you might have an idea and then someone else might have more ideas, OK."*

Working with groups also helped students work more efficiently. Sandra said she liked working in groups because *"In case you make a mistake, other people can probably spot that, and they help you out."* Ally also liked sharing the workload saying, "*There's more help and everyone can do their own part and then get finished faster."* Fabio had a similar response saying, "*One person does the other part and the other one does the other part, and another person does the programming, and we can finish faster and all work together."*

Students also liked the social aspect of working in groups. When asked if there was a benefit to working in groups Jose responded, *"The social skills. Learning how to work together and bond with people you don't like."* Aaron said he liked group work because he *"got to talk to people."* Erick also liked groups because he *"could like socialize with [his] friends and talk."*

Only two students mentioned any negative aspects of working in a group. Iliana said, *"Some people don't work. They just talk and talk, and they don't contribute."* When asked what she didn't like about working in groups Chloe said, *"Sometimes people just want to be in charge of everything. Like you want to do your idea but now you have to listen to other people's ideas.*

4.2.1.4 Question Six: Understanding the User.

The code that was associated with question six "*Why might it be important to understand the user when designing a product*" was *impact on others*. All students said thinking about the user was important or very important when designing a solution. When asked if it is important to consider the user, Jose said, "*All the time. Yeah, that's the number one thing when designing something is to think of the user*." Valeria said it was "*important because you want the person to like what you have done in your work, so I think that's an important part*." Ally said, "*You have to think how they will use it and if it will work for that specific person.*" When asked about designing a house for someone else, Aaron also said, "*It's more important what they think than what you think because it's for them, right*?" Mr. Apodaca reinforced this idea saying, "*They always want to design something that they feel they like and that's not what we're doing. We are trying to design something for clients. Part of the design process is to make sure you break down the exact problem that that client needs*."

4.2.1.5 Question Seven: What do you see yourself doing as an adult?

The codes associated with question six were *job stability* and *satisfaction*. Job stability was mentioned in relation to being able to provide for and support one's family or to make money. When asked what he wanted to do as an adult, Erick said he wanted to be a neurosurgeon "*because right now my parents are struggling so I kind of want to help them*." Chloe said that she wanted to be a "*doctor of the ICU or a scientist because I really love science*." STEM provides opportunities for students to explore a wide range of career opportunities, as Mr. Sandoval said when discussing the benefits of STEM, "*We're here to bridge the gap for you. Here's what we can show you. Here's what we have to offer and what you can do with it. It's really cool to see kids open their eyes to what they can do. Kids are amazed at the possibilities of how they can make a living*."

4.2.2 Summary of Qualitative Findings

Although the design thinking disposition survey did not produce significant results in the quantitative analysis of the survey, interviewing students provides some insight into their perceived benefits of a STEM integrated curriculum. Students enjoyed their STEM class because it brought them satisfaction and it was hands-on. Students were engaged in collaborative activities as they refined their ideas to come up with solutions to problems and they expressed positive feelings towards working in groups. Collaboration not only made projects more manageable, but students were also able to get help from their group members when needed. Teacher interviews reinforced the idea that students are building collaborative skills as they work together. Students also were aware of how their design would affect the user, relating to the *empathy* category of design thinking. Additionally, on the free response questions on the survey, seventh grade students had a statistically significant difference in their perceived ability to design solutions. In response to the question "Thinking back to the beginning of the year, do you think you are better at designing solutions to problems now than you were then?" 81% of students from the STEM school responded "Yes" as opposed to only 43% from the nonSTEM school.

CHAPTER 5
IMPLICATIONS, RECOMMENDATIONS AND CONCLUSIONS

The purpose of this explanatory sequential mixed methods study was to determine if middle school students in a school with an integrated STEM curriculum have higher design thinking dispositions than students in a school that does not employ an integrated STEM curriculum. STEM education and the use of the engineering design process has been purported as a method to better prepare students to confront the challenges of an increasingly technological society and equip them with the skills to confront those challenges (NGSS, 2013). STEM education employs the engineering design process, and design thinking is promoted as a solution to help solve complex societal and technological issues (Koh et al., 2015). This study used a mix of quantitative and qualitative data to better understand if an integrated STEM curriculum increased students' perception of their own design thinking abilities. Quantitative data was collected through the design thinking disposition survey developed by Tsai and Wang (2021) using a Likert scale questionnaire to determine students' dispositions in four key areas of design thinking: *define*, *empathize*, *ideate*, and *prototype.* Qualitative data was collected through free response questions on the design thinking disposition survey and through interviews from students and teachers at the STEM integrated school.

The first research question, ''What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?" used both quantitative and qualitative data from the design thinking disposition scale. Seventh grade students completed a pre/post survey at the beginning and end of the semester at both the STEM integrated school and the nonSTEM integrated school. After quantitative analysis, there was insufficient evidence to reject the null hypothesis. All seventh-grade students showed gains between pre and posttest except in the *prototype* domain for the nonSTEM students. There was not a large enough difference in the gains between the two schools to attribute to having a STEM integrated curriculum. This was true for all four of the design thinking dimensions surveyed: *define, empathize, ideate,* and *prototype.* Seventh grade students from the STEM school scored higher than students from the nonSTEM integrated school in the categories of *define, empathize,* and *prototype* in both the pretest and the posttest. The only category the nonSTEM school scored higher was in the posttest for the *ideate* category, 3.56 for the nonSTEM school and 3.52 for the STEM integrated school.

Eighth grade students from both schools completed the design thinking disposition scale at the end of the year, and again there was insufficient evidence to reject the null hypothesis. Eighth grade students from the STEM school did score higher in all four areas of the design thinking disposition survey. The closest categories to having significance were the *empathize* and *ideate* dimension with both having *p values* of 0.07. Although the null hypothesis cannot be rejected, there is some indication that students from the STEM school may have better dispositions in the *empathize* and *ideate* areas.

Qualitative data from the design thinking disposition scale included four free response questions. Because the questions required nominal responses, they could be analyzed quantitatively. Results showed that there was a significant difference between seventh grade students at the STEM integrated school and students at the nonSTEM integrated school in designing solutions. Seventh grade students at the STEM integrated school thought that they were better at designing solutions than students at the nonSTEM integrated school. 81% of STEM seventh graders thought they were better at designing solutions at the end of the year than at the beginning of the year compared to 42% of nonSTEM seventh graders for a *p value* of 0.004 which is less than the accepted $p<0.05$. For the other free response questions on problem solving and career choices results were not statistically significant, and the null hypothesis cannot be rejected. There were higher percentages for both seventh and eighth graders from the STEM school in both categories, “changed problem solving” and “better at designing solutions” but the difference was not great enough to state that these results were not due to chance.

Research question two, “What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design-thinking dispositions?” was answered by collecting qualitative data through interviews with students and teachers at the STEM integrated school. Interview data was coded, and the codes that all thirteen students identified in a STEM integrated class were *finding a solution,* through problem-solving, *collaboration* by working with classmates, and *hands-on* through the manipulation of materials. Additional codes obtained through interviews included *impact on others*, *job stability, satisfaction,* and *choice.*

5.1 Results Discussions and Implications

Research questions and their implications will be discussed in this section. Discussion will include student and teacher perceptions of a STEM integrated curriculum and how their perceptions align with results of the design thinking disposition scale. Factors that may affect the results of the survey are also considered.

5.1.1 Design Thinking Disposition Survey

Research question one “What is the impact of an integrated STEM curriculum in developing design thinking dispositions in middle school students?” sought to discover if there was a difference between the design thinking dispositions between students at a school that employs a STEM integrated curriculum and students at a school that does not employ a STEM integrated curriculum. For the purposes of this discussion, groups are differentiated by “STEM” students and “nonSTEM” students. The initial plan was to determine through pre- and post-testing if STEM students had greater gains in design thinking dispositions than nonSTEM students. Data collected from seventh grade students was not statistically significant. It should be noted, however, that seventh grade STEM students scored higher in all the design thinking domains on both the pre and posttest than nonSTEM students except for the *ideate* domain.

Eighth grade students were surveyed at the end of their eighth-grade year using the design thinking disposition survey. Again, the results were not significant. There was, however, a difference between the two schools. Eighth graders from the STEM integrated school did score higher in every category, and in particular both *empathize* and *ideate* had the largest difference with p values of 0.066 and 0.074, respectively.

Although research has shown STEM integrated classes can improve student outcomes including communication and collaboration for seventh grade students (Awad, 2023), seventh grade students surveyed from the STEM school in this study did not show significantly larger gains in design thinking dispositions. Eighth grade students at the STEM school also did not show a significantly greater design thinking disposition than students at the nonSTEM school.

5.1.1.1 Discussion of Non-Significance. There are several factors that can affect how a STEM integrated curriculum impacts students. How a STEM integrated curriculum is implemented can influence student experiences and thus the students in this study may not have fully experienced the intended benefits of the STEM curriculum. Teachers implementing STEM may choose to focus on different aspects of the STEM experience. When students first begin to learn problem-solving, for example, they need to have scaffolding in collaboration to learn how to work together. This is a process that takes time and may require a teacher to focus less on problem solving processes or steps of the engineering design process. For example, Sikka (1991) found that teachers may be spending time teaching basic skills rather than focusing on more creative, independent problem-solving. Depending on what skills they bring into the classroom, students may also require more specific disciplinary instruction that may reduce the amount of time required to allow students to systematically design, test and refine solutions. It is very likely that students in this study were not fully prepared to engage in independent problem solving and teachers spent more time on developing collaboration skills or teaching specific disciplinary knowledge. Students may also need even further integration to benefit from the STEM experience. Integrating STEM and technology courses with science and math in interdisciplinary units may potentially increase students engineering design skills (Hiğde & Aktamış, 2022). If students in this study were not engaging in disciplinary knowledge in their science and math courses that was supporting engineering design units, then the STEM teachers must take time to teach that knowledge.

Although student demographics were similar in both schools, language proficiency can also impact survey results. Language ability can influence content learning and student interactions when collaborating with peers (Hou & Lien, 2022). Student language abilities were not assessed in this study and student samples may not have equally represented students' language abilities and prior problem-solving experience. Additionally, seventh grade students at the STEM integrated school scored higher in the pre-test in all four design thinking dimensions. Sixth grade students at the STEM integrated school take a foundational course related to technology and problem solving. This provides a foundation for STEM learning as they move into middle school and STEM integrated courses. This background may enable them to have higher initial design thinking dispositions. Because they initially scored higher than the nonSTEM integrated seventh graders, they may show less growth overall. Students that score initially higher or lower during pre-test can move closer to the mean during post-testing moving the entire sample (Marsden & Torgerson, 2012). This regression to the mean (RTM) can cause extremes on both the high and low end to move more central during post-testing (Marsden & Torgerson, 2012).

Another reason the survey data may have had limited significance in design thinking dispositions is simply time. The benefits of educational interventions may not always be readily apparent, or students may also need more time in STEM integrated programs to fully realize the benefits. Students may have different outcomes in design thinking as they move into high school and post-secondary education programs, particularly if they continue to pursue STEM programs in high school. It is very possible that students that were part of the STEM integrated school will continue to pursue STEM and will show greater gains as they move into college. Chan et al. (2020) found that eighth grade students that participated in STEM programs were more likely to choose a STEM major in college. Longitudinal data of both groups of students could provide more insight into the effects of a STEM integrated curriculum particularly for students that elect engineering or technology pathways in high school.

5.1.1.2 Promoting Design Thinking. There are specific recommendations for how to better implement design thinking processes in the classroom that could benefit students in this study while in their STEM classes. For example, teaching students design sketching techniques and then having students sketch their designs during the brainstorming phase can help communicate ideas and assess the viability of the design (Kelley & Sung, 2017). From interviews, it was found that students were brainstorming but they were not spending a great deal of time on sketching those ideas and then evaluating them as a group. Additionally, how teachers apply engineering instruction can impact student results (Guzey & Li, 2023). Teachers must ensure that they are providing instructional support for all students including framing problems around students’ unique cultural and educational experiences (Guzey & Li, 2023). Some modifications to lessons connect problems to students’ own experiences could have made a greater impact on students’ design thinking skills.

One potential method that can help promote design thinking in a STEM curriculum is the use of reverse engineering (Ladachart et al., 2022). Reverse engineering can build aspects of design thinking including human-centeredness and collaboration (Ladachart et al., 2022). Other ways to develop design thinking in middle schoolers is to use scaffolding tools, integrate specific discipline knowledge, and to use real-world problems that connect to student experiences (Lin et al., 2020). Overall, this study did not find significant differences in design thinking dispositions between the STEM and nonSTEM integrated school, but the lack of significance could be due to the implementation of the curriculum in the classroom, the classroom environment, differences in students’ prior knowledge, or regression to the mean (RTM).

Although the differences in design thinking dispositions between the STEM school and the nonSTEM school were not statistically significant for either the seventh grade or the eighth grade, it does not mean that there are not benefits to incorporating STEM integrated curriculum into schools. Students can still have positive experiences and gain both collaboration and communication skills. Although large differences in gains in design thinking dispositions were not observed in this study, there were other benefits found to providing students with a problem-based learning STEM experience**.** Student and teacher interviews provided insight into the importance of collaboration in the classroom. Collaboration is clearly an important 21st skill, but this was not measured on the survey. Students liked working with their peers because it helped them generate more and better ideas. The survey, however, focused solely on individual assessments, rather than group contributions. For example, questions related to *ideate* were items like “I usually come up with many different solutions to the problem.” Seventh grade students from the STEM school did not have large gains in the *ideate* category. They did, though, speak about the benefits of getting multiple ideas from their peers when working in groups. Having a survey that considers the impact of collaborative efforts in the design process could show greater benefits.

5.1.2 Free Response Questions

On the free response questions, there was a significant difference found in seventh graders between the two schools in self-perceived design thinking. In response to the question “Thinking back to the beginning of the year, do you think you are better at designing solutions to problems now than you were before?” 81% of respondents from the STEM school replied “Yes” as opposed to 43% of students from the nonSTEM school. In science classes, self-efficacy, or the belief in one’s ability, has been linked to motivation and a desire to pursue science related fields (Lofgran et al., 2015). Students that think they can succeed in school are more engaged in learning, and self-efficacy in STEM is a predictor of students pursuing a career in STEM fields (Falco, 2020). STEM students showed more confidence in their design thinking abilities which in turn could contribute to greater student engagement in STEM classes and a likelihood that the student will pursue STEM subjects in the future. Additionally, thirteen out of the twenty-nine (45%) eighth grade students from the STEM school choose STEM careers as a future option than students at the nonSTEM integrated school where eight out of thirty (27%) chose a STEM career.

5.1.3 Student and Teacher Interviews

Research question two, “What are the perceptions of students and teachers on how a STEM integrated curriculum helps to develop design thinking dispositions?” was answered through qualitative data. Interviews with thirteen seventh grade students and three teachers at the STEM integrated school were coded. Predominant codes included *hands-on* with twenty-seven instances, *collaboration* with twenty-six instances and *solving a problem* with twenty-four instances. These were considered predominant because of the high frequency of the codes and because all thirteen students mentioned them in the interview. Additional codes included *impact on others, job stability, satisfaction,* and *choice.* The following sections discuss codes related to design thinking and how an integrated STEM curriculum might impact categories of design thinking related to the design thinking disposition survey: *define, empathize, ideate,* and *prototype*.

5.1.3.1 Hands-On When asked what they liked about their STEM class, students mentioned activities related to the code hands-on twenty-seven times. All thirteen interviewed students mentioned the code hands-on when discussing what they liked about their STEM class. Based on Dewey's (2007) model of active engagement, students learn when they are actively engaged in the learning process and can relate that learning to real world experiences. Students are better able to understand abstract concepts in STEM when they participate in hands-on activities through the manipulation of materials rather than just through observations (Hayes & Kraemer, 2017).

Participating in a STEM integrated curriculum provides students with the opportunity to manipulate materials to make prototypes of their designs and then test their solutions. Excerpts from interviews included descriptions of building dream homes, designing, and programming robots and creating products like orthopedic boots and skimmers. Students were actively engaged in designing, building, and testing their projects and they were able to apply content learned in other subjects. For example, through building, students were able to see how gear ratios worked, an abstract concept learned in math that they were able to apply to the building of their robots. The hands-on model helps develop design thinking capabilities through the iterative process of ideation and problem solving (Gwangwava, 2021). As students work on manipulating materials through a problem-solving process, they are relating to the design thinking dispositions of *ideate* and *prototype.*

5.1.3.2 Collaboration When interviewed the code *collaboration* was mentioned by students 26 times and all 13 interviewed students discussed the benefits of working in groups. During STEM integrated activities, students work in groups to solve problems. Collaborative learning follows the socio-cultural models of knowledge construction proposed by Vygotsky (1978). Students build off each other's prior knowledge to create new understandings. In a STEM integrated class, artifacts are the products of that knowledge construction. Besides collaborative communication, artifacts are a shared manifestation of group knowledge that provide evidence of each members' contributions (Kress & Kimmerle, 2018). Benefits of collaboration include prompting group members' prior knowledge, sharing complementary knowledge, and error correcting each other's mistakes (Nokes-Malach et al., 2015). Interviewed students liked working in groups because they could produce more ideas and learn from their group members. Collaboration seems to help the design thinking dimension *ideate* as group members share ideas and benefit from having multiple individuals contribute to the brainstorming process. This contributes to the design-thinking disposition of *ideate* as students generate new ideas.

Although collaboration can help students' cognitive development, there are impediments to collaboration as evidenced through student interviews. Students mentioned the problem of group members that did not contribute or were off task. Group members that do not take responsibility for their individual roles can contribute to group failure (Nokes-Malach et al., 2015). Improvement in collaboration can be achieved by careful monitoring and facilitation by the teacher and by providing extended time to develop relationships (Crawford et al., 1999). Interviewed teachers provided insight into how they implemented that facilitation to encourage individual responsibility by creating new groups or offering alternative assignments.

5.1.3.3 Finding a Solution The code *finding a solution* was identified twenty-four times in student interviews by all thirteen interviewed students. Students mentioned how they produced the best solution by generating ideas, testing their ideas, and then revising their solutions when they didn’t work. A STEM integrated curriculum provides opportunities for students to engage in problem-based learning activities using engineering design processes with fewer time and curriculum constraints than in a single subject classroom like math or science. Having a class that integrates knowledge from different STEM subjects allows students the time to work on design processes through brainstorming and building prototypes. Open-ended problems, however, may not always provide an in-depth understanding of STEM disciplinary concepts (Bartholomew & Strimel, 2019). Tan et al. (2019) recommends designing problems that focus on using data and evidence to support scientific findings, and framing problems to better promote understanding of STEM disciplinary knowledge. When interviewing students in this study, there was a lack of coding in the *define* category. Students did not mention steps like identifying criteria or constraints. When students begin to design solutions, they may not be fully identifying STEM concepts that could further their disciplinary knowledge. Before students begin to brainstorm solutions, they should be encouraged to develop a design brief listing all criteria and constraints as recommended by the NGSS (2013). Designing without identifying all aspects of the problem can limit content understanding (Arık & Topçu, 2022).

Additionally, when asked about what methods they used to generate ideas, or decide on a solution, students that were interviewed did not discuss using a methodological, systematic approach to problem solving or using data to justify their solutions. When students found that something did not work, they would just alter their design without necessarily identifying what exactly was not working. Teachers should emphasize the use of critical thinking processes when analyzing solutions and help students use data to justify their analyses (Dare et al., 2021). Although teachers mentioned using the engineering design process, students did not clearly identify the steps they took to generate ideas and evaluate their solutions in the design process. Spending time to define and identify problems and then use data to determine the viability of their solutions could better develop critical thinking skills in a STEM integrated class. As recommended by Siverling et al. (2019) teachers should incorporate evidenced-based reasoning scaffolding to encourage students to justify design decisions.

5.1.3.4 Additional Codes: Impact on others, Job Stability, Satisfaction, and Choice

Another code identified that relates to the design thinking disposition survey was impact on others. One of the key dimensions of the design thinking process is empathy. Designers need to understand the needs of the end user, and designers need to be able to find solutions that best meet those needs. Students surveyed were aware of the need to meet clients' needs and were cognizant of the importance of considering the end user when creating a product. Interviewed teachers also emphasized the importance of the user and related creating a product in school to the real world where if they did not meet a clients' needs then they could lose income or positions. Highlighting empathy in a STEM integrated curriculum can enable students to deepen their understanding of STEM topics and encourage them to find alternate solutions (McCurdy et al., 2020). In this way, a STEM integrated curriculum can allow students to think more broadly about societal challenges as they consider how solutions can positively or negatively affect other people. When asked about career choices, students mentioned job stability. Students were concerned about being able to provide for their families and generating income. Although job stability does not relate directly to design thinking dimensions, per se, STEM learning experiences have been shown to influence students to select STEM careers (Maiorca et al., 2021). Additional codes of *satisfaction* and *choice* also may not be linked directly to design thinking dispositions. However, the promotion of a student-centered approach in STEM integrated classes can increase student engagement (Struyf et al., 2019). STEM integration promotes student choice throughout the problem-solving process as students decide on the best solutions, materials, and methods. Student engagement can increase when students have autonomy in a supported environment that fosters collaboration (Guzey & Li, 2023).

5.1.4 Qualitative Summary

Free response questions and interviews with both teachers and students highlighted advantages of a STEM integrated curriculum. Both teachers and students thought the STEM class promoted collaboration and hands-on problem solving. Teachers also spoke of the benefits of exposing students to different types of careers in STEM and more eighth graders at the STEM school expressed an interest in STEM careers. Although the purpose of this study was not to analyze data from different demographics, teachers spoke of the ability of STEM to engage all learners. For example, Mr. Apodaca mentioned a struggling special education student who liked to draw "*and he really liked CAD and he started designing stuff on CAD and transitioning his art into the CAD software which is really cool. I really think stem or CTE courses in general are a great outlet for kids."* Although there were not significant differences found in the quantitative data analysis, both teachers and students involved in STEM integration believed it was well worth the time to include a STEM class in the curriculum. Qualitative data also provided some insight into how STEM integration could be strengthened, including more systematic problem-solving processes and more explicit analysis and evaluations of ideas and prototypes. This data can help to explain why design thinking dispositions in the STEM school may not have significantly increased. Qualitative data showed that the design thinking dimensions of *define, ideate,* and *prototype* may not have been fully developed in the classroom during the problem-solving process. Teachers were spending some time on facilitating group work and collaboration skills and may not have had the time to be able to fully implement the systematic problem-solving processes that promote design thinking dispositions.

5.2 Recommendations

Quantitative findings from this study found that an integrated STEM curriculum can help students develop a greater belief in their perceived ability to design solutions to open-ended problems. Based on the results from free response questions, seventh grade students from a STEM integrated school had better perceptions in their ability to design solutions to problems. Integrated STEM education can help students develop a growth mindset by participating in challenging design tasks, evaluating their solutions, and refining those solutions as needed (Stohlmann, 2022). This metacognitive process provides opportunities for students to reflect on their designs and learn from their failures. This study also found instances of dimensions of design thinking including *ideate, empathize,* and *prototype* within an integrated STEM curriculum through student interviews. The following section will discuss recommendations for design thinking integrated STEM for both practitioners and researchers.

5.2.1 Recommendations for Practice

Prototyping In quantitative data collection, the lowest scoring design thinking disposition domain for both seventh and eighth graders was *prototype.* This was true for both the STEM and the nonSTEM school. Post test seventh grade averages in the *prototype* domain at the STEM school were 3.2 and at the nonSTEM school were 2.9. Eighth grade averages at the STEM school were 3.0 and at the nonSTEM school were 2.8. Students should be encouraged to make drawings and prototypes of their designs early and often in the design process. Early iterative prototyping can lead to the creation of more successful designs and lead to less frustration from failed designs (Marks & Chase, 2017). Additionally, teachers can scaffold understanding of the design process and include design activities that highlight design processes like prototyping (Zhou et al., 2017). Having students learn to properly sketch their initial designs before they prototype can also help them better visualize and assess their designs (Kelley & Sung, 2017).

Defining the Problem One aspect missing from qualitative data obtained through student interviews was the *define* dimension of design thinking. Although students were explicitly asked in interviews how they followed problem solving processes, there were no codes found associated with defining the problem, a crucial step in both engineering design and design thinking. Defining the problem is a crucial step in the design process as it allows a reframing of the problem that is unique to the designer and the intended user. Through a more focused, narrower problem statement, better, more fruitful ideas can be generated (Shanks, 2012). Educators should be cognizant of the importance of having students restate problems and identify the intended users. When students can define the problem and identify the criteria and constraints using available resources and prior knowledge, their designs will have greater success (NGSS, 2013). One recommendation is to use a point of view statement in which students break down the problem statement into a description of what the object needs to do and why (Isabell & Mentzer, 2022).

Problem Solving Methods Another aspect that could lead to better outcomes in STEM integration is employing a methodological process to solve design problems. When asked how they went about the problem-solving process, students oftentimes were unclear on the methods they used to generate a solution. Responses were oftentimes things like “I do whatever works” or when asked what they do if their design solution does not work, they replied with answers like, “I just try to modify it.” Students were not able to explicitly state what methods they used to brainstorm, evaluate their solutions, or determine how to refine them. Students should be encouraged to employ a specific process when developing ideas and determining which ideas best meet the requirements of their problem statement. Systematic processes should be used to evaluate designs and determine how well they meet criteria and constraints (NGSS, 2013). Teachers can employ decision matrices and incorporate more data collection into their design activities to better determine the feasibility of the solution and how the designs might need refinement. Students should use data to justify their design decisions and how they did or did not meet design criteria. A process that includes written documentation of each step can help students reflect on their decision-making process and ensure their designs are meeting criteria. In an alarm-system design activity for eighth graders, Mehalik et al. (2008) outlines a seven-step design system process that includes a decision matrix that rates each design on a scale of 1-5. As students document their process they engage in analytical thinking because they must justify their decisions while using science content knowledge to do so (Mehalik et al., 2008).

5.2.2 Recommendations for Research

Future research should continue to consider how STEM integration can impact middle school students' design thinking dispositions and their interest in STEM careers. One area research should concentrate on is how teachers can effectively target the *define* dimension of design thinking. This study did not generate any codes that were related to the *define* dimension of design thinking. Although the code *finding a solution,* relating to the codes of *ideate* and *prototype*, was apparent, there was little evidence that students were defining the problem and clearly making a problem statement. Potential future research could include the design of an instrument that can specifically measure how students are determining criteria, constraints, evaluating available resources, and activating prior knowledge. Also, future instruments should incorporate collaboration and how each dimension is impacted through working with peers. Interviews with students showed that working in groups helped them generate more and better ideas. Additionally, classroom observations could record interactions that are specific to distinct aspects of design thinking like *define* and *prototype* to better understand how students are engaging with designing thinking dimensions as they work in groups. Additional research could also focus on curriculum implementation and how to develop scaffolding tools to support teachers in the classroom.

Longitudinal research should also follow students as they move into secondary school and beyond. Do the students that feel they are more confident in designing solutions retain that confidence over time? What would be the results of the same survey if it were given when the students are in high school? The effects of interventions are not always evident immediately and tracking students' future study and career choices would provide data into long term effects of STEM programs.

Future research should also look at how STEM integration affects different demographic groups. How does the collaborative nature of STEM programs impact students of limited English proficiency? Do STEM integrated curricula increase marginalized students' interest in STEM careers?

5.3 Research Limitations

One limitation to this study is the small sample size. Having greater participation in the design thinking disposition survey could have yielded more fruitful data and possibly shown more significance in differences between the STEM integrated school and the nonSTEM integrated school. Having a larger sample size could have provided more insight into the differences between the two groups. Additionally, having more time between the pre and post-test might have shown greater changes in the STEM group. Seventh grade students were tested at the end of the first semester and at the end of the year. Longitudinal data that tests students before they enter middle school and after they leave middle school might provide more insightful data. Additional interviews could also have provided more evidence to reinforce coding schemata.

Another limitation to this study is the duration of the study. Although seventh grade students did show some differences in design thinking dispositions from pre and post testing, following students into their curricular and career choices after middle school could provide further insight into the longitudinal effects of a STEM integrated curriculum.

Additional limitations are related to the schools and participants, including the school environment, teachers, and students. Although demographics at both schools are similar, teacher experience and knowledge can affect student performance and knowledge. Quasi-experimental design does not allow for the random selection of students or for controlling the school environment. Ideally students from both schools would have similar classroom experiences except for the STEM class. Students also are subject to both central tendency and response bias when using a Likert scale survey. Although the survey was validated for middle schoolers, any self-reported data is subjective. Having greater participation would increase the validity of the responses.

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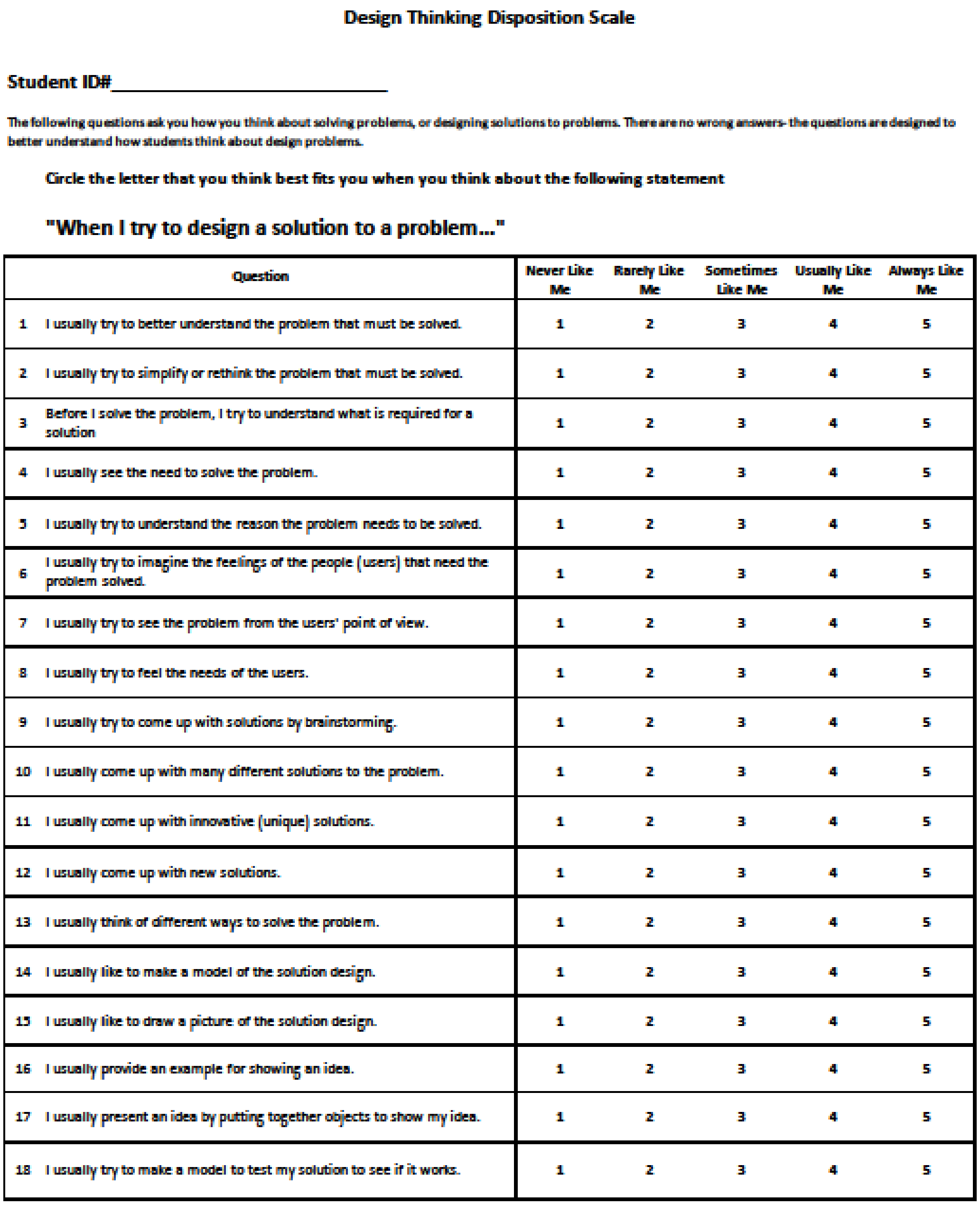
APPENDIX A
The Design Thinking Disposition Scale



Design Thinking Disposition Scale

Student ID#____________________________

The following questions ask you how you think about solving problems, or designing solutions to problems. There are no wrong answers- the questions are designed to better understand how students think about design problems.

Circle the letter that you think best fits you when you think about the following statement

"When I try to design a solution to a problem..."

	Question	Never Like Me	Rarely Like Me	Sometimes Like Me	Usually Like Me	Always Like Me
1	I usually try to better understand the problem that must be solved.	1	2	3	4	5
2	I usually try to simplify or rethink the problem that must be solved.	1	2	3	4	5
3	Before I solve the problem, I try to understand what is required for a solution	1	2	3	4	5
4	I usually see the need to solve the problem.	1	2	3	4	5
5	I usually try to understand the reason the problem needs to be solved.	1	2	3	4	5
6	I usually try to imagine the feelings of the people (users) that need the problem solved.	1	2	3	4	5
7	I usually try to see the problem from the users' point of view.	1	2	3	4	5
8	I usually try to feel the needs of the users.	1	2	3	4	5
9	I usually try to come up with solutions by brainstorming.	1	2	3	4	5
10	I usually come up with many different solutions to the problem.	1	2	3	4	5
11	I usually come up with innovative (unique) solutions.	1	2	3	4	5
12	I usually come up with new solutions.	1	2	3	4	5
13	I usually think of different ways to solve the problem.	1	2	3	4	5
14	I usually like to make a model of the solution design.	1	2	3	4	5
15	I usually like to draw a picture of the solution design.	1	2	3	4	5
16	I usually provide an example for showing an idea.	1	2	3	4	5
17	I usually present an idea by putting together objects to show my idea.	1	2	3	4	5
18	I usually try to make a model to test my solution to see if it works.	1	2	3	4	5

APPENDIX B

Student and Teacher Interview Questions

Semi-structured Student Interview Questions Sample

1. What do you like about your STEM class?
2. What do you dislike about your STEM class?
3. How has your STEM class helped you learn to solve problems? What activities are helpful in teaching you about how to solve problems?
4. When you design a solution to a problem, what are the steps you take?
5. How do you decide on the best solution to a problem?
6. How do you know when you've found the best solution?
7. Why do you think it might be important to understand other peoples' points of view when designing solutions?
8. When you think of yourself as an adult, what do you see yourself doing?

Semi-structured Teacher Interview Questions Sample

1. What are the core ideas of STEM?
2. How do you convey the core ideas of STEM to your student??
3. What is your understanding of design thinking?
4. Describe the best methods students can use to solve open-ended problems.
5. How do the activities in your classroom promote design thinking?
6. What are the challenges in teaching students to think creatively?
7. What are the benefits of having a class dedicated to STEM integration?

APPENDIX C

Free Response Questions on Student Surveys

1. Thinking back to the beginning of the year, do you think you have changed the way you have solved problems? Explain.

2. Thinking back to the beginning of this year, do you think you are better at designing solutions to problems now than you were before? Explain.

3. What type of career are you interested in?

4. What do you like best about that career?

APPENDIX D

Parent/Student Assent Forms (English and Spanish)

University of Texas at El Paso (UTEP) Institutional Review Board

Parental Permission Form/Child Assent Form for Research Involving Human Subjects

Protocol Title: The effect of a STEM integrated curriculum on design thinking dispositions in middle school students: A mixed methods study.
Principal Investigator: Dina Thomason
UTEP: Department of Education

Introduction

You are being asked to allow your child to take part in the research project described below. You are encouraged to take your time in making your decision. The purpose of this form is to clearly inform you of the purpose of the study and to obtain your permission and your child's assent to participate in this study. It is important that you read the information that describes the study. Please ask the study researcher or the study staff to explain any words or information that you do not clearly understand.

Why is this study being done?

The purpose of this study is to better understand how an integrated STEM curriculum can prepare students for 21st century competencies, specifically design thinking through problem-based learning models. This study seeks to understand if students attending a school that implements a school-wide STEM curriculum have better design-thinking dispositions and related critical thinking skills than similar students that are enrolled in a school that does not implement a school-wide STEM curriculum.

Approximately 300 7th graders, will be asked to participate in this study from both Canutillo Middle School and Alderete Middle School. Students at both schools will be asked to voluntarily complete a brief survey on design thinking dispositions at two times during the school year. Once during the first semester and once during the second semester.

Further studies will include classroom observations and interviews only at Canutillo Middle School to better understand how students might be acquiring skills to further their design thinking dispositions in a STEM integrated curriculum. You are being asked to provide permission for your child because he or she attends 7th grade at a middle school in the Canutillo School District. Besides taking part in the survey at two times during the school year, your child might be part of a classroom observation or asked to participate in a brief interview if your child attends Canutillo Middle School.

What is involved in the study?

As part of this study, the researcher will be conducting a pre and post survey during the school year to see if there are any differences in design thinking dispositions for children enrolled in 7th grade classes between STEM integrated schools and non-STEM integrated schools. The survey will take no longer than 15 minutes and will be conducted during the school day. Researcher may also access student demographic information from school databases including student schedules to analyze data for different student groups to see if other factors might influence design thinking dispositions. Additionally, classroom observations of STEM integrated classrooms will be conducted at Canutillo Middle School. The researcher is specifically looking for evidence of design thinking during these class periods. During classroom observations, detailed notes on student and teacher interactions will take place. Observations may occur at three times during the school year and will last the duration of the class period. Observation notes will not include student names or identifiable information about students. Notes will only use terms like "student 1" etc. Research papers and reports will use pseudonyms for students. 10-15 students will be selected to participate in a brief interview. The interviewer will ask questions of the student regarding their perception of the STEM integrated class and how they may go about solving design problems. The interview will last no longer than 30 minutes and will take place during the school day. The interview will be audio recorded and detailed notes will be taken. If your child participates in an interview, no identifiable information including name or student ID will be collected. Students will be given a pseudonym if any of their interview is used as part of a research paper or presentation. During the research project, interview recordings and transcriptions and observation notes will be kept in a locked closet at the researcher's residence. Three years after the conclusion of the project, all notes and recordings from interviews and observations will be destroyed. If you do not want your child to participate in this study, no information about your child will be collected during classroom observations, and your child will not be selected participate in any interview.

What are the risks and discomforts of the study?

The risks associated with this research are no greater than those involved in daily activities. There are no known or anticipated risks or discomforts associated with participation.
The researcher may decide to stop your child's participation without your permission, if he or she thinks that being in the study may cause them harm, or if your child is no longer attending schools within the Canutillo Independent School District.

Are there benefits to taking part in this study?

Your child is not likely to benefit by taking part in this study. This research may help us to understand curriculum that best benefits students' design thinking and problem-solving abilities.

What are my costs?

There are no direct costs to you or your child.

Will my child be paid to participate in this study?

Your child will not be compensated for taking part in this research study. However, your child will receive a small snack after their participation in the design thinking disposition survey.

Who do I call if I have questions or problems?

You may ask any questions you have now. If you have questions later, you may email or call Dina Thomason at dthomason@miners.utep.edu or 1-915-217-6211

If you have questions or concerns about your child's participation as a research subject, please contact the UTEP Institutional Review Board (IRB) at (915-747-6590) or irb.orsp@utep.edu.

What about confidentiality?

Your child's part in this study is confidential. The following procedures will be implemented to keep their personal information confidential: Students will be identified by participant number and identifying information will only be used in data analysis for subgroups. Any personally identifiable information connecting to the student participant number to student ID# or name will only be accessed by the researcher, and all information will be kept on a password protected computer. Notes from interviews or classroom observations will be kept in a locked closet at the researchers place of residence.

The results of this research study may be presented at meetings or in publications; however, your child's name will not be disclosed in those presentations. All participants that are included in observations or interviews will only be identified by a pseudonym. Additionally, participating schools, district and region will not be mentioned by name.

Organizations that may inspect and/or copy research records for quality assurance and data analysis include, but are not necessarily limited to:
- Office of Human Research Protections
- UTEP Institutional Review Board

Because of the need to release information to these parties, absolute confidentiality cannot be guaranteed.

All records including surveys, and notes from observations and recordings from interviews will be stored for three years after the conclusion of the researcher project in a locked cabinet in the researchers place of residence and will then be destroyed. Any files linking student participant number to school ID number or name will be deleted three years after the conclusion of the research project.

Authorization Statement

You will be given a copy of this Parental Permission form to keep. By signing below, you agree to the following:

I have read each page of this paper about the study (or it was read to me).
I understand my child's participation is voluntary. He/she does not have to participate in this study if they do not want to.
If he/she decides not to participate, they will not be enrolled even if you have agreed that he/she may.

I understand I have the right to change my mind and remove my child from the study at any time, there will be no penalty.

Parent Permission:
If you would like your child to participate in this study, please indicate by circling the appropriate boxes.

I would like for my child participate in the survey portion of this study.	YES	NO
If your child attends Canutillo Middle School, please complete the following:		
I would like for my child participate in the observation portion of this study	YES	NO
I would like for my child participate in the interview portion of this study.	YES	NO

____
Child's Name (printed)

____
Child's School

____
Parent/Guardian's Name (printed)

______________________________________ ____________
Parent/Guardian's Signature Date

______________________________________ ____________
Signature of Person Obtaining Consent Date

Student Assent:

If you have had all your questions answered and would like to participate in this study, sign on the lines below. Remember, your participation is completely voluntary, and you're free to withdraw from the study at any time.

I know that only the people who work on this research study will know my name. They will also know my student ID#. They will not use my name or my ID number in any papers or presentations. As part of the study, I will only be identified as a participant and given a participant number.

____

Name of Participant (print)

____ _______

Signature of Participant Date

PARTICIPANT NUMBER: ____________________

Junta de Revisión Institucional de la Universidad de Texas en El Paso (UTEP)

Formulario de Permiso de los Padres/ Formulario de Consentimiento del hijo/a para Investigaciones de Seres Humanos

Título del Protocolo: El efecto de un plan de estudios integrando un currículo de STEM en las disposiciones de pensamiento en base a diseño, en estudiantes de secundaria: Un estudio de métodos mixtos.
Investigador Principal: Dina Thomason
UTEP: Departamento de Educación

Introducción

Se le pide que permita a su hijo/a que participe en el proyecto de investigación que se describe a continuación. Le pedimos que tome su tiempo para tomar una decisión. El propósito de este formulario es informarle claramente el propósito del estudio y obtener su permiso y el consentimiento de su hijo/a para participar en el mismo. Es importante que lea la información que describe el estudio. Pídale al investigador del estudio que le explique cualquier palabra o parte de la información que no entienda claramente.

¿Por qué se realiza este estudio?

El propósito de este estudio es comprender mejor cómo un currículo STEM integrado puede preparar a los estudiantes para las habilidades del siglo XXI, específicamente el pensar en base a diseño a través de modelos de aprendizaje en basados a problemas. Este estudio busca comprender si los estudiantes que asisten a una escuela que implementa un plan de estudios STEM en toda la escuela tienen mejores disposiciones de pensamiento en base a diseño y habilidades de pensamiento crítico relacionadas a estudiantes similares que están inscritos en una escuela que no implementa un plan de estudios STEM en toda la escuela.

Aproximadamente a trecientos (300) estudiantes del séptimo grado, se les pedirá que participen en este estudio, tanto de la Escuela Intermedia Canutillo como de la Escuela Intermedia Alderete. A los estudiantes de ambas escuelas se les pedirá que llenen voluntariamente una breve encuesta sobre las disposiciones de pensamiento en base a diseño dos ocasiones durante el año escolar. Una vez durante el primer semestre y una vez durante el segundo semestre.

Otros estudios incluirán observaciones en el aula y entrevistas solamente en la Escuela Intermedia de Canutillo para comprender mejor cómo los estudiantes pueden adquirir habilidades para mejorar sus disposiciones de pensamiento en base a diseño en un plan de estudios integrado STEM. Se le pide de permiso a su hijo/a porque asiste al 7 ° grado en una escuela intermedia en el Distrito Escolar de Canutillo. Además de participar en la encuesta en dos ocasiones durante el año escolar, su hijo/a puede ser parte de una observación en el salón de clases o se le puede pedir que participe en una breve entrevista si su hijo/a asiste a la Escuela Intermedia Canutillo.

¿Qué implica el estudio?

Como parte de este estudio, el investigador realizará una encuesta previa y posterior durante el año escolar para ver si hay alguna diferencia en las disposiciones de pensamiento en base a diseño para los niños matriculados en clases de séptimo grado entre las escuelas integradas STEM y las escuelas no integradas STEM. La encuesta no tomará más de 15 minutos y se llevará a cabo durante el día escolar. El investigador también puede acceder a la información demográfica de los estudiantes de las bases de datos escolares, incluidos los horarios de los estudiantes, para analizar los datos de diferentes grupos de estudiantes y ver si otros factores pueden influir en las disposiciones del pensamiento en base a diseño. Además, se llevarán a cabo observaciones de los salones de clase integrados STEM en la Escuela Intermedia Canutillo. El investigador está buscando específicamente evidencia de pensamiento en base a diseño durante estos períodos de clase. Durante las observaciones en el aula, se tomarán notas detalladas sobre las interacciones entre estudiantes y maestros. Las observaciones pueden ocurrir tres veces durante el año escolar y durarán la duración del período de clase. Las notas de observación no incluirán los nombres de los estudiantes o información identificable sobre los estudiantes. Las notas solo usarán términos como "estudiante 1", etc. Los trabajos de investigación y los informes usarán seudónimos para los estudiantes. Se seleccionarán de 3 a 5 estudiantes para participar en una breve entrevista. La entrevistadora le hará preguntas al estudiante sobre su percepción de la clase integrada STEM y cómo pueden resolver problemas de diseño. La entrevista no durará más de 30 minutos y se llevará a cabo durante la jornada escolar. Se tomarán notas detalladas. Si su hijo/a participa en una entrevista, no se recopilará información identificable, incluido el nombre o la identificación del estudiante. Los estudiantes recibirán un seudónimo si parte de su entrevista se utiliza como parte de un trabajo de investigación o una presentación. Durante el proyecto de investigación, las notas de la entrevista y la observación se guardarán en un armario cerrado con llave en la residencia del investigador. Todas las notas de las entrevistas y observaciones serán destruidas tres años después de la conclusión del proyecto. Si no desea que su hijo/a participe en este estudio, no se recopilará información sobre su hijo/a durante las observaciones en el aula, y su hijo/a no será seleccionado para participar en ninguna entrevista.

¿Cuáles son los riesgos y las molestias del estudio?

Los riesgos asociados con esta investigación no son mayores que los que implican las actividades diarias.
No existen riesgos o molestias conocidos o anticipados asociados con la participación.
El investigador puede decidir detener la participación de su hijo/a sin su permiso, si cree que participar en el estudio puede causar daño a su hijo/a o si su hijo/a ya no asiste a escuelas dentro del Distrito Escolar Independiente de Canutillo.

¿Hay beneficios por participar en este estudio?

No es probable que su hijo/a se beneficie al participar en este estudio. Esta investigación puede ayudarnos a comprender el plan de estudios que mejor beneficie el pensamiento en base a diseño y las habilidades de resolución de problemas de los estudiantes en general.

¿Cuáles son mis costos?

No hay costos directos para usted o su hijo/a.

¿Se le pagará a mi hijo por participar en este estudio?

Su hijo/a no será compensado por participar en este estudio de investigación. Sin embargo, su hijo/a recibirá un pequeño refrigerio después de su participación en la encuesta de disposición de pensamiento de diseño.

¿A quién llamo si tengo preguntas o problemas?

Puede hacer cualquier pregunta que tenga ahora. Si tiene preguntas más adelante, puede enviar un correo electrónico o llamar a la maestra Dina Thomason a dthomason@miners.utep.edu o al 1-915-217-6211

Si tiene preguntas o inquietudes sobre la participación de su hijo como sujeto de investigación, comuníquese con la Junta de Revisión Institucional (IRB) de UTEP al (915-747-6590) o irb.orsp@utep.edu.

¿Qué pasa con la confidencialidad?

La participación de su hijo/a en este estudio es confidencial. Se seguirán los siguientes linimientos para mantener la confidencialidad de información personal: Los estudiantes serán identificados por número de participante y la información de identificación solo se utilizará en el análisis de datos de subgrupos. Solo el investigador tendrá acceso a cualquier información de identificación personal que se conecte al número de del estudiante participante con el número de identificación o el nombre del estudiante, y toda la información se mantendrá en una computadora protegida con contraseña. Las notas de las entrevistas o de las observaciones en el aula se mantendrán en un armario cerrado con llave en el lugar de residencia del investigador.

Los resultados del estudio de investigación podrán ser presentados en reuniones o en publicaciones; sin embargo, el nombre de su hijo/a no se divulgará en esas presentaciones. Todos los participantes que sean incluidos en observaciones o entrevistas serán identificados únicamente con un seudónimo. Además, las escuelas, el distrito y la región participantes no se mencionarán por nombre.

Las organizaciones que pueden inspeccionar y/o copiar registros de investigación para garantizar la calidad y el análisis de datos incluyen, entre otras, las siguientes:

- Oficina de Protecciones de Investigación Humana
- Junta de Revisión Institucional de UTEP

Debido a la necesidad de divulgar información a estas partes, no se puede garantizar la confidencialidad absoluta.

Todos los registros, incluidas las encuestas y las notas de las observaciones y entrevistas, se almacenarán durante tres años después de la conclusión del proyecto del investigador en un gabinete cerrado con llave en el lugar de residencia de la investigadora y después serán destruidas. Cualquier archivo que vincule el número de participante del estudiante con el número de identificación o el nombre de la escuela se eliminará tres años después de la conclusión del proyecto de investigación.

Declaración de autorización

Se le dará una copia de este formulario de permiso de padres para que la conserve. Al firmar a continuación, usted acepta lo siguiente:

He leído cada página de este documento sobre el estudio (o me lo leyeron).
Entiendo que la participación de mi hijo/a es voluntaria. Su hijo/a no tiene que participar en este estudio si no quiere.

Si su hijo/a decide no participar, no se inscribirá incluso si usted ha aceptado que lo haga.
Entiendo que tengo derecho a cambiar de opinión y retirar a mi hijo/a del estudio en cualquier momento, y no habrá penalización.

Permiso de los padres:
Si desea que su hijo/a participe en este estudio, indíquelo marcando con un círculo las casillas correspondientes.

Me gustaría que mi hijo/a participe en la parte de la encuesta de este estudio.	SÍ	NO
Si su hijo asiste a la Escuela Intermedia Canutillo, complete lo siguiente:		
Me gustaría que mi hijo/a participe en la parte de observación de este estudio.	SÍ	NO
Me gustaría que mi hijo/a participe en la parte de la entrevista de este estudio.	SÍ	NO

____
Nombre del Niño (impreso)

____
Escuela del Niño/a

____
Nombre del padre/tutor (en letra de imprenta)

____ ______________
Firma del padre/tutor Fecha

____ ______________
Firma de la persona que obtiene el consentimiento Fecha

Asentimiento del estudiante:

Si le respondieron todas sus preguntas y le gustaría participar en este estudio, firme en las líneas a continuación. Recuerde, su participación es completamente voluntaria y puede retirarse del estudio en cualquier momento.

Sé que solo las personas que trabajan en este estudio de investigación sabrán mi nombre. También sabrán mi número de identificación de estudiante. No usarán mi nombre o mi número de identificación en ningún documento o presentación. Como parte del estudio, solo se me identificará como participante y se me dará un número de participante.

____
Nombre del participante (letra de imprenta)

____ ______
Firma del Participante Fecha

NÚMERO DE PARTICIPANTE: ________________

CURRICULUM VITAE

Dina Thomason is from El Paso, Texas. She graduated high school from Las Cruces, New Mexico and went on to receive an undergraduate degree under a music scholarship from the University of Arizona in Interdisciplinary Studies. After freelancing as a French horn player in New York and receiving graduate education credits from City College in New York, she began teaching science in both public and private schools in New York City. She returned to El Paso to raise her kids and teach in the El Paso area and has experience teaching in multiple subject areas and grade levels. Dina has a master’s degree in educational leadership from the University of Texas at Tyler and currently works as a biomedical science teacher for a high school in the El Paso area.