

**GIRLS' MATHEMATICAL MINDSETS AND GENDERED MATHEMATICAL
BELIEFS IN AN ALL-GIRLS CLASSROOM**

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Abstract

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Over recent decades, education stakeholders have raised significant concerns regarding the underrepresentation of females in science-related professions and academic programs, particularly in mathematics. Existing research in this domain highlights that the social transmission of unfavorable beliefs about mathematics —such as mathematical anxiety, gendered mathematical beliefs, and beliefs about mathematical intelligence — may contribute to gender inequality and a gender gap in mathematics-related majors and occupations. This study was undertaken to investigate the variables influencing the mathematical mindsets and gendered mathematical beliefs of female students within an all-girls educational setting. The research questions were formulated by the researcher with the purpose of examining and exploring the variables that influence the mathematical mindsets and gendered mathematical beliefs of female students in an all-girls environment. By doing so, further insights can be gained into the means of encouraging and enhancing the mathematical mindsets and gendered mathematical beliefs of female students.

The conceptual framework for this study is grounded in growth mindset theory. Data were collected through a combination of interviews, surveys, and classroom observations, and analyzed using a mixed-methods approach, incorporating both quantitative and qualitative methodologies. The specific methodologies employed include (a) qualitative descriptive analysis, (b) Chi-Squared tests, (c) the Mann-Whitney U test, and (d) thematic analysis.

Based on the results of this study, the suggested recommendations aim to foster collaboration among students, educators, and policymakers to build supportive environments that nurture growth-oriented mathematical mindsets and challenge pervasive gendered mathematical beliefs. By addressing these constructs, suggested strategies can be used to empower students, particularly girls, to excel in mathematics and confidently pursue STEM-related careers. Implementing the study's findings and recommendations can promote gender equity in education, ensuring that all learners, particularly females, have the opportunity to achieve their full potential in mathematics and beyond.

Keywords: growth mindset, fixed mindset, gendered mathematical beliefs, cognitive engagement, affective engagement, behavioral engagement, academic achievement.

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Dedication

First, I dedicate this thesis to my honest and hardworking parents, whose unwavering love and sacrifices have been the foundation of all my achievements. Your dedication and perseverance have been my guiding light, and I am forever grateful for the values you ingrained in me.

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Chapter 1: Introduction

Need for the Study

Statement of the Problem

Numerous concerns have been raised by stakeholders in education about the underrepresentation of women in science-related majors and careers, particularly mathematics (Ceci et al., 2009; National Science Board, 2018). As highlighted by researchers, beliefs play an important role in educational contexts, and teachers' and students' beliefs may contribute to gender inequality and gender gap in various contexts (Eble & Hu, 2022; Philipp, 2007). One explanation for this gender gap put forth by researchers is the social transmission of unfavorable beliefs about mathematics, such as mathematical anxiety, gendered mathematical beliefs, and beliefs about mathematical intelligence (Gunderson et al., 2011). Some have pointed that female students may tend to avoid math-related majors and occupations due to these beliefs (Davies et al. 2002).

Background, Context, and Conceptual Framework

By gendered mathematical beliefs, I am referring to the beliefs "that men are inherently better than women at learning mathematics" (Eble & Hu, 2022, p.1). According to related studies, teachers and students continue to subscribe to the belief that mathematics is a domain exclusively for males (Cvencek, Meltzoff, & Greenwald, 2011; Keller, 2001). In contrast to "biologically determined" aspects of male–female differences (sex), gender can be defined as a means of

differentiating “socially constructed aspects” of these differences (Haig, 2004). However, it is common for all-girl schools to use assigned sex at birth as gender, which is how I will use the term for the purposes of this study.

Gendered mathematical beliefs impact both teachers and students in the teaching and learning process. Studies indicate that teachers often overestimate boys' mathematical abilities compared to girls' (Keller, 2001; Philipp, 2007; Tiedemann, 2002). Additionally, teachers tend to attribute girls' failures to a lack of ability, while boys' shortcomings are linked to insufficient effort (Tiedemann, 2000; 2002

Teachers' gendered mathematical beliefs negatively impact female students' math performance (Heyder et al., 2019; 2020) and can indirectly reinforce these beliefs in students (Simpson & Linder, 2016). These gendered mathematical beliefs often lead to performance deficits and lower math outcomes for female students (Inzlicht & Ben-Zeev, 2000; 2003; Lavy & Sand, 2015; Nosek et al., 2009) and reduce engagement, affecting educational and career pathways (Nosek & Smyth, 2011; Wang et al., 2016; Miller et al., 2015; Reschly & Christenson, 2012).

Gendered beliefs may be conveyed explicitly or implicitly, with implicit beliefs influencing behavior even when consciously rejected (Nosek, Banaji, & Greenwald, 2002; Gawronski & Bodenhausen, 2006). Consequently, this study aims to focus on implicit gendered beliefs since implicit cognition can influence behaviors automatically, even when those implicit thoughts are explicitly rejected.

In this study, I use the term engagement to encompass the entire trio of students' cognitive, behavioral, and affective engagement (ex., Fredricks et al., 2004; Wang et al., 2011). This approach aligns with the emphasis placed by researchers on the importance of considering all three dimensions of engagement (Sinatra et al., 2015). Behavioral engagement has been defined as:

“involvement in classroom and school contexts such as attention, participation, and effort; positive conduct; and the absence of disruptive behaviors” (Fredricks et al., 2004). The concept of affective engagement has been defined as: “positive and negative reactions to teachers, classmates, academics, and school and is presumed to create ties to an institution and influence willingness to do the work” (Fredricks et al., 2004). Finally, the definition of cognitive engagement is as follows: “thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills” (Fredricks et al., 2004).

In addition to gendered beliefs, individuals' views on the changeability of mathematical intelligence—growth mindset versus fixed mindset—can also contribute to the gender gap in math-related fields (Yeager & Dweck, 2012; Dweck, 2006; Gunderson et al., 2011). A growth mindset has been linked to improvements in students' academic performance, engagement, and math achievement (Blackwell, Trzesniewski, & Dweck, 2007; Claro et al., 2016; Lin-Siegler et al., 2016; Schmidt et al., 2017). For teachers, their mindset affects teaching strategies, instructional approaches, and curriculum choices (Dweck, 2006; Handal, 2003; Aragon et al., 2018; Rattan et al., 2012). Additionally, students of teachers with growth mindsets showed greater effort, engagement, and academic success (Rattan et al., 2012; Schmidt et al., 2015; Ronkainen et al., 2019; Seals, 2018)

Given the independent nature of domain-specific mindsets (Dweck et al., 1995; Ryan & Mercer, 2012), recent studies highlighted the importance of focusing on domain-specific mindset over general mindset (Costa & Faria, 2018; Lou & Noels, 2019). Thus, this study examines mathematical mindsets specifically. Teachers' mindsets and gendered beliefs shape their instructional actions (Aragon et al., 2018; Keller, 2001; Philipp, 2007; Rattan et al., 2012), which influence students' mindsets (Aragon et al., 2018; Rattan et al., 2012) gendered beliefs (Gunderson

et al., 2012; Tiedemann, 2002) and affecting their engagement levels (Lin-Siegler et al., 2016; Miller et al., 2015). As a result, further exploring—in a specific school context—the relationship between teachers' instructional actions and students' mathematical mindsets and gendered mathematical beliefs is important.

Purpose of the Study

Objective of the research

The purpose of this study is to understand the mathematical mindsets and gendered mathematical beliefs of female students in an all-girl school, and to investigate how some factors including students' and teachers' mathematical mindsets and gendered mathematical beliefs as well as other contextual factors like all-girl schools' special features and teachers' instructional actions are impacting girls' engagement in this specific setting.

Rationale, Relevance, and Significance of the Study

The majority of research on mathematical mindsets and gendered mathematical beliefs have been conducted in co-ed settings (e.g., Good, Aronson, & Inzlicht 2003; Romero et al. 2014; Schmidt et al., 2017). According to researchers single-sex contexts and schools are more advantageous for female students (Eisenkopf et al. 2015; OECD 2009; Riggers-Piehl et al, 2018). As a result, considering an all-girl setting as a unique context for investigating factors influencing mathematical mindsets and gendered mathematical beliefs is essential (Davies et al., 2002; Gunderson et al., 2011).

Certain elements (such as teachers' instructions) in this distinctive environment might shape the mathematical mindsets and gendered mathematical beliefs of female students. Such effects could have repercussions on the mathematical achievements of the students as a whole, given that academic achievement is contingent on factors other than students' backgrounds and systemic fluctuations in human and physical resources (Leder, 2014).

As scholars have pointed out, mathematical mindset and gendered mathematical beliefs have the greatest impact on students at the middle school level (Good, Aronson, & Inzlicht 2003; Romero et al. 2014). However, other similar studies in all-girls settings were not frequently conducted in middle school (e.g., Moore, 2018), and so as a result, it is essential to address these various constructs in an all-girls middle school. It should be noted that in this study, we use the word affordances which means:” the opportunities and resources a school environment provides that shape and support student learning experiences and engagement” (Gibson & Pick, 2013).

Research Questions

Research Questions

The research questions which will guide this study (depicted in Figure 1) are:

- 1) In an all-girl school context, what are the mathematical mindsets, and the gendered mathematical beliefs that middle school girls hold? How do these compare to reports from the literature?
- 2) How do individual girl’s engagements (both self-reported engagement and observed behavioral engagement) relate to their mathematical mindsets and gendered mathematical beliefs?
- 3) In an all-girl mathematics classroom, how does the engagement of a typical student in the class (both self-reported engagement and observed behavioral engagement) relate to the teachers’ mathematical mindsets and gendered mathematical beliefs?

4) What are the perceived affordances [from teachers] of an all-girl school context which are influencing middle school girls' mathematical mindsets, and gendered mathematical beliefs? What instructional actions, in general, do the teachers feel like help improve girls' mathematical mindsets, and gendered mathematical beliefs?

Schematic Representation of the Research Questions

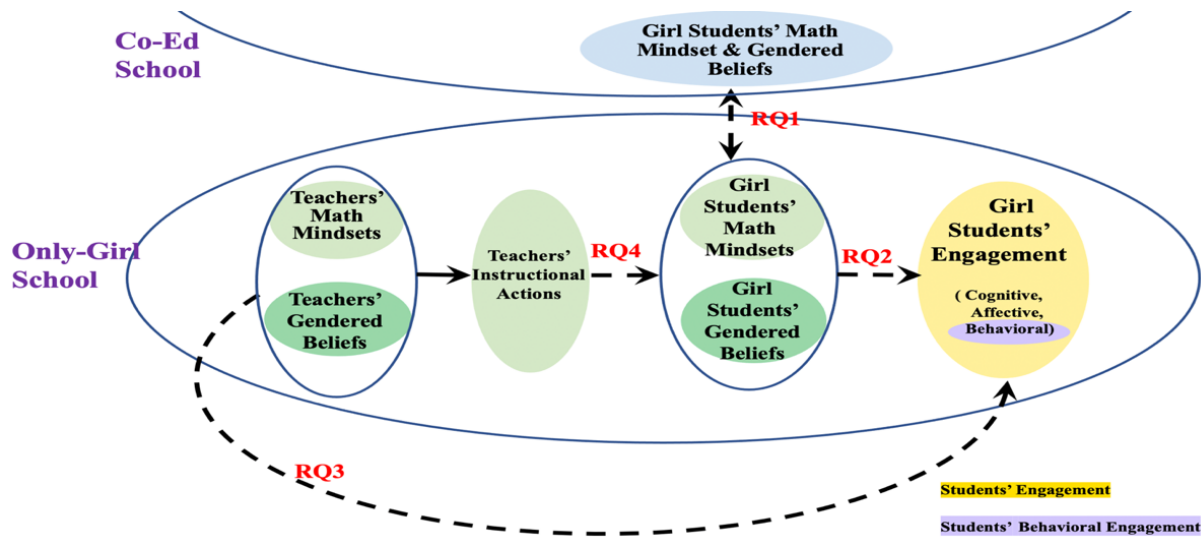


Figure 1. Schematic Representation of the Research Questions

Procedure of the Study

Rationale for methodology

Due to the researcher's "integration of qualitative and quantitative research and data" (Creswell & Creswell, 2018, p. 51) to address the research questions and obtain findings, this study is a mixed-methods study. Additionally, the objective of a mixed-method design is to "build on the synergy and strength that exists between quantitative and qualitative research methods to understand a phenomenon more fully than is possible using either quantitative or qualitative

methods alone" (Gay et al., 2012, p. 481). A convergent mixed-method design was used, amongst other mixed-method designs, because the researcher "converges or merges quantitative and qualitative data to provide a comprehensive analysis of the research problem" (Creswell & Creswell, 2018).

Sampling and Data Collection

The study was conducted at a private all-girl middle school located in a suburban area near a large urban center, in the Midwest, as single-sex middle schools was the preferred setting for the current study. This particular school was selected due to the researcher's affiliation with it and the convenience it offers in terms of conducting the study there. All three middle school mathematics teachers, along with their students, were comprise the potential participants of the investigation. Every participant who provided consent to participate was included.

The researcher collected information from a variety of sources, including survey, interview, and classroom observation. It should be noted that, a modified version of the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998; <https://implicit.harvard.edu/implicit/Study?tid=-1>) was used to measure participants' gendered mathematical beliefs implicitly.

A Dweck (2006; 2007) general mindset scale, consisting of six Likert-scale questions that include both fixed and growth mindset items, was utilized to assess participants' mathematical mindset level (Blackwell et al., 2007). It should be noted that, the researcher employed a version of the mindset scale incorporating both fixed and growth items to reduce acquiescence bias, which occurs when individuals provide affirmative responses based on expected norms. In addition, as

researchers emphasized the need for considering domain-specific mindset, the measures for this construct were developed (e.g., an 8-item mathematical mindset scale; Degol et al., 2018) by simply changing general mindset questions to domain-specific questions. For this study, the author utilized the adaptation of Dweck's (2007) general mindset scale, which is a well-validated and reliable scale, as the math mindset scale (reliability = 0.78).

Moreover, 12 additional items in the students' survey were added to evaluate students' engagement, across the three subdomains of Cognitive, Behavioral, and Affective engagement. This part of the survey was also in Likert-scale format. Accordingly, the survey's answers for each subdomain of engagement could fall into one of three categories: Low, Moderate, and Strong.

Building on the highlighted advantages of observational methods, such as the ability to collect real-time information and ease of administration (Fredricks, 2022), the researcher employed classroom observations to measure students' observable behavioral engagement. This approach involved observing students' behaviors during mathematics instruction using a structured observational protocol. The protocol comprises carefully selected indicators derived from six established observational frameworks (Fredricks et al., 2011; Ocumpaugh et al., 2015; Pianta et al., 2012; Reynolds & Kamphaus, 2015; Shapiro, 2011; Volpe & DiPerna, 2010) to ensure the accurate capture of students' observable behavioral engagement. Students' engagement was categorized into one of three levels of: Low, Medium, High.

The data collection involved observing each class session, lasting approximately 40 to 45 minutes, across two classes from each of the three middle school teachers. All participating students within these classes were observed to encompass a diverse sample, reflecting varying levels of mathematical mindsets and gendered beliefs. The indicators of engagement were assigned point values: 1 point for 1 to 2 occurrences and 2 points for more than 2 occurrences of a given

behavior. Based on these scores, three levels of behavioral engagement were identified: Low, Moderate, and High.

In addition, as researchers have emphasized the need for considering gendered beliefs implicitly (ex., Nosek, Banaji, & Greenwald, 2002; Nosek et al., 2009), a modified version of the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998; <https://implicit.harvard.edu/implicit/Study?tid=-1>) was used as part of the survey instrument to measure students' and teachers' gendered beliefs implicitly. A classification into one of five distinct categories were the outcome, consisting of three groups representing the (Strong, and Moderate) association of males with mathematics and females with liberal arts; one group representing the Little or No preference between gender and academic domains; and two groups representing the (Strong, and Moderate) association of males with liberal arts and females with mathematics.

Finally, semi-structured interviews with the teachers were conducted. Through face-to-face interviews with the teachers, information regarding their perceptions of the affordances of all-girl schools' that would influence girls' mathematical mindsets were collected. Moreover, teachers' perceptions about instructional actions that might impact girl students' mindsets and gendered beliefs were explored. For the trustworthiness of the data from the teachers' interview, different factors (e.g., credibility, transferability, dependability, etc.) were considered. To address the validity issue of this instrument, peer debriefing was applied for the questions.

Data Analysis

After collecting both types of quantitative and qualitative data from students' and teachers' surveys, teachers' interviews, and classroom observations, the raw data were prepared for analysis.

To answer the first research question, the researcher applied a *qualitative descriptive methodology* (Gay et al., 2012), in which the researcher computed the results about mathematical mindsets and gendered beliefs from this study in an all-girl middle school and compared these results with the results of existing literature which were conducted in co-ed setting. To maximize the match-pairing between our study and previous ones, some factors were considered, for example, the level of students (*middle school level*). Then, the researcher described the findings from the existing literature and compared it with the results of this study (*all-girl vs. co-ed*), using a *qualitative descriptive methodology* (Gay et al., 2012).

To answer the second research question, a *correlational analysis* (Gay et al., 2012) was used. To encompass all mathematical mindsets and gendered mathematical beliefs categories, the researcher used result of students' mathematical mindset and gendered beliefs. Then, through classroom observation (which will be also recorded), students' *behavioral engagement* were recorded and evaluated, using the observational protocol. Additionally, students' responses were utilized to analyze their engagement in three subdomains: cognitive, behavioral, and affective. The researcher then employed the Chi-Squared test (Creswell & Creswell, 2018) using the SPSS software to examine the correlation between the level of engagement subdomains (Categorical) and the mathematical mindsets and gendered mathematical beliefs (Categorical) of individual students, as advised as an appropriate analysis by experts (Creswell & Creswell, 2018).

To answer the third research question, a *qualitative descriptive* approach (Gay et al., 2012) as well as a *Mann-Whitney U Test* (Creswell & Creswell, 2018) were used to describe and evaluate the relationship between teachers' mathematical mindset and gendered mathematical beliefs with

the students' engagement subdomains (both the three self-reported engagement subdomains and the observed behavioral engagement). The inclusion of the Mann-Whitney U Test enabled the researcher to both delineate the relationship between the variables and assess "the degree to which they [variables] are related" (Gay et al., 2012), which was an appropriate methodology in this context.

To answer the last research question, the researcher used thematic analysis (Gay et al., 2012), since middle school teachers provided individual perceptions describing the phenomena in everyday real life (all-girl school's affordances and instructional actions which are influencing girl students' mathematical mindsets and gendered mathematical beliefs). As highlighted by Kim et al., (2016) the goal and focus of the researcher in *qualitative descriptive* methodology is describing or summarizing an event, not interpreting an event, which was the case here. The teachers' responses to interview questions were used to identify how aspects of an all-girl classroom influence middle school girls' mathematical mindsets and gendered mathematical beliefs and enabled the researcher to identify teachers' instructional strategies that enhance girls' mathematical mindsets and challenge their gendered mathematical beliefs in this specific setting of all-girl environment.

Chapter 2: Literature Review

2.1 Introduction

Chapter two will include a discussion of the *background to the problem*, the *identification of the gap in the literature*, the *conceptual framework* which guides this study, and the *review of relevant literature*. The majority of the chapter is dedicated to the examination of relevant literature. Throughout the literature review, the researcher performed numerous queries across various databases by employing the designated key terms. The databases that were employed comprised ProQuest, Google Scholar, ERIC, Education Database, Sage, among others.

The primary focus of the literature review procedure was devoted to previous studies that pertained to the subject matter of the current study. The review segment encompasses a variety of subjects, including but not limited to those that are related to the themes that have surfaced in the most pertinent studies. The emerged topics are *Presence of Gender Gap in Mathematics and STEM*, *Students' Mindset*, *Teachers' Mindset*, *Students' Gendered Mathematical Beliefs*, *Teachers' Gendered Mathematical Beliefs*, *Students' engagement*, and *single-sex education*.

Overall, the proposed research study has the potential to augment the current literature regarding female students' engagement in mathematics classes, which has ramifications for their representation in STEM domains, especially in mathematics disciplines and careers. Moreover, it will scrutinize the beliefs of both students and teachers regarding gendered mathematical beliefs and mathematical mindsets, as two main factors impacting female students' engagement. This research study may also reveal how various contextual factors, such as all-girl environments and teaching methodologies utilized by educators, influence engagement levels of female students.

2.2 Background to the Problem

In recent decades, stakeholders in education have voiced their concerns regarding the underrepresentation of women in science-related degrees and careers, particularly in mathematics. Recent research has brought attention to the persistent underrepresentation of women in STEM (science, technology, engineering, and mathematics) disciplines, which heavily rely on mathematical expertise and proficiency (National Science Foundation, 2011).

Female representation in the undergraduate (43, 19, 18, and 38%) and doctoral (29, 19, 23, and 34%) student populations for mathematics and statistics, computer and information sciences, engineering, and physical and technological sciences, respectively, has been comparatively low, according to recent statistical data (U.S. Department of Education, NCES 2014, as cited in Wang & Degol, 2017).

This persistent underrepresentation of women in math-intensive fields has drawn significant attention in the USA, with researchers putting forth and disputing theories (ex., expectancy-value theory, mindset theory, etc.) to explain and mitigate the problem. Despite previous research indicating that boys and girls achieve comparable academic success in mathematics (e.g., Hyde et al., 2008), significant gender inequalities continue to exist and, in certain instances, have even intensified with regard to the selection of careers in mathematics (Ceci et al. 2009; National Science Board 2018).

In recent decades, researchers have studied a wide range of factors, including students' and teachers' beliefs, in an effort to identify the causes of the gender gap in math-intensive fields (Philipp, 2007). Through these studies, researchers noticed that teachers and students' beliefs can

contribute to gender inequality and gender gap in various contexts (Eble & Hu, 2022; Philipp, 2007), and one explanation for the gender gap in math-related majors and careers proposed by researchers is the social transmission of unfavorable beliefs about mathematics, such as mathematical anxiety, gendered mathematical beliefs, and beliefs about mathematical intelligence (Davies et al. 2002; Gunderson et al., 2011). In light of these investigations, researchers noted that female students may tend to avoid math-related majors and careers due to these negative beliefs about mathematics (Brunye et al., 2013; Davies et al. 2002; Geist, 2015; Huberty, 2009; Meloney & Beilock, 2012; Perry, 2004; Trotter, 2006).

Researchers have identified two primary categories of factors influencing gender differences in mathematical achievement and engagement: student-related and environmental. Student-related factors include elements such as mathematical self-efficacy, mindset, and anxiety (Forgasz, 2014). Environmental factors, including cultural expectations and societal norms regarding gender, also play a complex role in shaping students' mathematical outcomes. A thorough understanding of these factors—particularly beliefs such as mathematical mindsets and gendered mathematical beliefs—is crucial for a comprehensive analysis of the gender gap in mathematical achievement and engagement. Addressing these factors constitutes a central focus of this study.

2.3 Identification of the Gap in the Literature

The underrepresentation of females in math-related careers and majors has prompted numerous studies in recent decades. These studies have been carried out on a range of topics

pertaining to the gender gap, including *mathematical mindsets* (e.g., Blackwell, Trzesniewski, & Dweck, 2007; Boaler et al., 2022; Boaler 2018; Claro et al., 2016; Dweck, 2006; 2007; Lin-Siegler et al., 2016; Schmidt et al., 2017), *gendered mathematical beliefs* (ex., Eble & Hu, 2022; Heyder et al., 2019; 2020; Inzlicht & Ben-Zeev, 2000; Inzlicht & Ben-Zeev, 2003; Lavy & Sand, 2015; Nosek et al., 2009; Tiedemann, 2000; 2002), and the *connection of these two* constructs with *students' engagements* (ex., Lin-Siegler et al., 2016; Miller et al., 2015; Nosek & Smyth, 2011; Rattan et al., 2012; Ronkainen et al., 2019; Schmidt et al., 2015; Wang et al., 2016).

Research has demonstrated that middle school students are profoundly affected by mathematical mindsets and gendered mathematical beliefs (Good, Aronson, & Inzlicht, 2003; Romero et al., 2014); however, there is a major gap in studies that focus specifically on these factors at the middle school level (e.g., Blackwell et al., 2007; Plante et al., 2013; Romero et al., 2014). Research on these subjects has been conducted mainly at other educational levels, including secondary education (e.g., Forgasz, Leder, & Kloosterman, 2004; Moore, 2018) and higher education (e.g., Aronson et al., 2002; Schmader, Johns, & Barquissau, 2004).

Research indicates that all-girl educational environments benefit female students (Eisenkopf et al. 2015; OECD 2009; Riggers-Piehl et al. 2018), yet most studies on gendered beliefs about mathematics and mathematical mindset have been carried out in coeducational contexts (e.g., Good, Aronson, & Inzlicht 2003; Romero et al. 2014; Schmidt et al. 2017). Consequently, a gap exists in the literature concerning the examination of these two variables and their impact on the engagement levels of female students, which subsequently influences their academic and professional paths in a single-sex environment.

2.4 Conceptual Framework

The Growth Mindset Theory

This research will be conducted within the framework of the *Growth Mindset Theory*. Decades of psychological research conducted by Carol Dweck and colleagues led to the formulation of the theoretical framework for the mindset construct presented in this article. The conceptual framework of mindset theory originates from the Implicit Theory. The relationship between an individual's learning and his or her motivation, behavior, and emotions is clarified by the concept of implicit theories of intelligence, which describes how individuals perceive and comprehend their intelligence or abilities as a fixed or malleable capacity (Blackwell et al., 2007; Dweck & Leggett, 1988).

The implicit theory is the foundational presumption regarding the fundamental nature of human characteristics and their susceptibility to modification (Dweck & Leggett, 1988). Individuals possess varying perspectives regarding various human characteristics, in accordance with the implicit theory. For example, based on the implicit theory different viewpoints exist concerning personality traits and IQ, and whether or not these constructs evolve with time (Freedman, Powell, Le, & Williams, 2019).

During the late 1980s and early 1990s, several researchers made significant contributions to the field that shed light on the effects and significance of implicit theories (Dweck et al., 1995). As stated previously, the Implicit Theory classifies individuals into two distinct categories according to their various perspectives on intelligence and personality traits. Although certain

individuals perceive these characteristics as immutable and unalterable over time (fixed or entity), others regard them as malleable and subject to modification and expansion (growth or incremental) (Freedman et al., 2019).

The phrase mindset which has recently become prevalent in mathematics education studies, is defined as a person's belief in the malleability of intelligence (Dweck, 2006). As Dweck highlighted, there are two kinds of mindset, growth, and fixed mindset (Dweck, 2006). Believers of the fixed mindset or entity theory contend that intelligence is predetermined from birth. They believe that throughout their lifetimes, intelligence remains constant and unaffected. There is little or nothing a person can do to improve their IQ beyond what they are born with (Freedman et al., 2019). Additionally, proponents of entity theory believe that although people can learn and acquire more knowledge, their cognitive capacities won't advance over time or might even deteriorate. According to this view, even though people might make an effort to learn new things, it might not have any impact on their intelligence (Yeager and Dweck, 2012).

In contrast, the growth mindset substantiates the notion that intelligence is not a fixed or immutable characteristic but rather is amenable to development (Yeager and Dweck, 2012). The incremental theory of intelligence posits that intelligence is a malleable and controllable characteristic that can be developed (Dweck & Leggett, 1988).

Intelligence may be altered and enhanced, according to proponents of the growth mindset or incremental theory. According to this belief, learning can take on new significance where people are motivated and willing to persevere and if they put in the necessary effort, and the intelligence will be improved over time (Ilhan Beyaztas et al., 2017). Incremental or growth mindset ideas consider intelligence as malleable constructs, not a fixed one.

Individuals' mindsets have profound impacts on perceptions, intentions, and behaviors. For example, on their persistence, while a fixed mindset has been connected with less resilience (Freedman et al., 2019), growth mindset has been linked to empowerment, with individuals putting out more effort in their academic endeavors (Freedman et al., 2019).

Mindset has been a topic of myriad educational studies in recent decades. As Dweck (2006) highlighted, students' mindsets, not their intelligence, are what make them successful in the classroom. She also discovered that challenging children and those classified as "gifted" occasionally experienced pressure to achieve well and keep up good scores. Because of this, when faced with obstacles, high-ability students frequently settle for subpar performance (Dweck, 2000). Consequently, not necessarily the intelligence, but the mindset determines students' success in school.

According to related literature, a growth mindset has been linked to elevated students' academic performances (Blackwell et al., 2007; Claro et al., 2016). The improved academic achievements of students who possess growth mindsets can be explained through their objectives and academic goals, their different perspectives on effort, and their various responses to academic challenges and obstacles (Blackwell et al., 2007; Haimovitz et al., 2011).

In contrast to students who exhibit a growth mindset who seek to acquire knowledge, those who possess a fixed mindset seek to validate their own abilities (Haimovitz, Wormington, & Corpus, 2011). Similarly, students with a growth mindset perceive effort as a constructive phase and demonstrate perseverance, whereas those with a fixed mindset succumb readily to setbacks and undermine their own endeavors (Blackwell et al., 2007). Also, it has been witnessed that students who possess a growth mindset exhibit a distinct response to academic obstacles and challenges, demonstrating a dedication to mastery, while students with fixed mindset display a

sense of helplessness when confronted with academic challenges (Blackwell et al., 2007; Haimovitz et al., 2011). Consequently, the mindset influences students' goal orientation, perseverance, and response to obstacles, all of which have a substantial bearing on the teaching and learning of mathematics.

As noted by researchers, individual goal orientation is related to the person's mindset (Dweck & Leggett, 1988; Haimovitz, Wormington, & Corpus, 2011). Individuals who possess a fixed mindset prioritize attaining performance-oriented objectives and are more concerned with gaining external validation of their intellect. Conversely, those who exhibit a growth mindset are driven by a desire to continuously learn and develop.

The manifestation of an individual's behavior pattern, whether it be adaptive (focused on mastery) or maladaptive (helpless), signifies the complete influence of their mindset and goal orientation (Dweck & Leggett, 1988). A helpless behavior pattern is characterized by the selection of easy-to-complete tasks, the avoidance of challenging situations, and the decision to give up, whereas a mastery-oriented behavior pattern is characterized by perseverance and the pursuit of difficulty (Dweck & Leggett, 1988). Individuals who hold fixed viewpoints and have a low perception of their own capability are more prone to encountering unfavorable events; consequently, they tend to avoid challenges and lack dedication.

In contrast, individuals who possess growth mindsets exhibit the capacity to persist irrespective of their self-perceived competence level (Haimovitz et al., 2011). This is due to the fact that their behavior is less apprehensive of failure, as their objective is to "maximize the growth of ability and the pride and pleasure of mastery" (Dweck & Leggett, 1988). Therefore, those who possess growth perspectives perceive failure not as a sign of diminished capability but rather "as a cue to escalate effort" (Blackwell et al., 2007; Romero et al., 2014).

According to related studies, middle school students who held growth mindsets demonstrated superior academic achievement in challenging subjects such as mathematics. Additionally, these students maintained their determination to improve by enrolling in progressively more difficult mathematics courses during their junior high months (Blackwell et al., 2007; Romero et al., 2014).

As noted by researchers, mindset is an important component of teaching and learning mathematics. More precisely, as Dweck (2008) emphasized, students' performance—particularly women and minorities—in mathematics and science is significantly influenced by their mindsets.

In the middle school level, utilizing a mindset theoretical lens makes it possible to investigate students' mental processes at this important stage, making it perfect for examining and recounting the mathematical experience and achievement of female students in middle school level.

Gendered Mathematical Belief

Although there has been a slight increase in the representation of women in mathematics, as well as gender equality in undergraduate mathematics degrees in recent decades (National Science Foundation 2019), the prevailing belief that men are more capable in the field of mathematics is further supported by the large percentage of men in math-related careers and postsecondary education (Leslie et al. 2015).

Gender has had a significant role in educational settings, particularly in the teaching and learning of mathematics. Gender refers to the socially constructed aspects that differentiate between males and females, as opposed to the biological aspects determined by sex (Haig, 2004).

While studies have found no significant differences between genders in math performance on standardized tests from elementary to high school (Hyde et al., 2008), there are still disparities in gender in math-related fields and professions (Davies et al., 2002; Gunderson et al., 2011), as highlighted in chapter one.

Since gendered mathematical beliefs have been highlighted as a key factor contributing to the gender gap in STEM and math-related fields and careers, it is essential to clarify our understanding of the term "gendered mathematical belief" before proceeding (Gunderson et al., 2011). Feelings, attitudes, beliefs, morals, values, and ethics comprise an internal representational system, also known as the affective domain (DeBellis and Goldin, 2006; Liljedahl, 2014), as articulated by researchers. As one aspect of affective domain, beliefs play an important role in teaching and learning process, specifically teaching and learning mathematics. Belief can be defined as: "Psychologically held understandings, premises, or propositions about the world that are thought to be true" (Philipp, 2007) or can be expressed more succinctly as: "the lenses through which one looks when interpreting the world" (Philipp, 2007).

One of the beliefs people may hold is the *gendered mathematical belief*. One way to characterize gendered mathematical belief is this idea that: "men are inherently better than women at learning mathematics" (Eble & Hu, 2022). In other words, gendered mathematical belief is this idea that men are more likely than women to excel in mathematics, have a greater aptitude toward science and math, and be found in more rigorous academic programs and math-related jobs (Brandell & Staberg, 2008; Wang, Eccles, & Kenny, 2013). Consequently, people who hold this belief considered mathematics as a male domain. These beliefs still persist in spite of research demonstrating minimal, if any, gender disparities in performance measures, a better

comprehension of mathematical ideas, and the ability to solve complicated problems (Vale & Bartholomew, 2008).

According to related studies, gendered mathematical beliefs not only pass on throughout generations, but also impact how well girls exhibit their math skills in comparison to boys (Eble & Hu, 2022). Therefore, this aspect should always be taken into account while investigating any issue in a mathematics education context.

In an educational context, gendered mathematical beliefs hold significant weight. The gendered mathematical beliefs might potentially impact the entire process of teaching and learning, given their impact on both students and teachers. Related research noted that teachers who have strong gendered mathematical beliefs frequently overestimate the mathematical aptitude and potential of male students in comparison to female students (Keller, 2001; Philipp, 2007; Tiedemann, 2002).

Studies indicate that teachers frequently believe that girl students struggle more than boys [who succeed to the same extent] to master mathematics (Riegle-Crumb and Humphries, 2012; Tiedemann, 2002). Teachers can implicitly communicate their gendered mathematical beliefs to their students through their instruction, by establishing a lower standard for female students' learning and not motivating them to fulfil their potentials (Keller, 2001; Levin, 2019).

Beyond that, scholarly literature has indicated that instructors who hold more extreme gendered beliefs regarding mathematics are more likely to ascribe the failures of male students to a lack of effort, while attributing the failures of female students to incapacity (Tiedemann, 2000; 2002). More importantly, researchers noted that female students' mathematical performances can be adversely affected by the gendered mathematical beliefs of their teachers (Heyder et al., 2019; 2020). The capacity of teachers to indirectly reinforce gendered mathematical ideas in their

students is another significant consequence of their gendered mathematical beliefs (Simpson and Linder, 2016)

Equally important, scholars have noted that the gendered mathematical beliefs of educators [and parents] might influence the self-reported interest of female students for STEM-related subjects and mathematics, their inclination to pursue careers in STEM-related fields, and their academic performance (Kim, Sinatra, & Seyranian, 2018). These factors, in turn, have an effect on the students' long-term engagement in mathematics majors and fields that heavily rely on mathematics (Good, Rattan, & Dweck, 2012; Lavy & Sand, 2015).

Similarly, students are impacted by gendered mathematical beliefs. According to related studies, gendered mathematical beliefs among students can lead to inferior mathematical outcomes and cause performance deficits in mathematics for female students (Inzlicht & Ben-Zeev, 2000; Inzlicht & Ben-Zeev, 2003; Lavy & Sand, 2015; Nosek et al., 2009). Additionally, in compared to male students, female students are more prone to underestimate their own abilities because of the gendered beliefs about mathematics (Eccles, Barber, Jozefowicz, Malenchuk, & Vida, 2000).

Moreover, as prior studies have documented, students who hold more gendered mathematical beliefs exhibit lower levels of engagement (Nosek & Smyth, 2011; Wang et al., 2016; Miller et al., 2015). This is an important issue that needs to be stressed, since the low levels of students' engagement and participation would significantly impact the students' career and educational routes (Reschly & Christenson, 2012).

2.5 Review of Literature

Presence of Gender Gap in Mathematics and STEM

Decades of scholarly investigation have been devoted to examining the origins, consequences, and causes of the gender divide in STEM. Boys and girls begin elementary school and middle school at comparable mathematical proficiency levels, as previous research has demonstrated. However, a gender gap in mathematics achievement begins to manifest during this transition (Fryer Jr & Levitt, 2010; Kersey et al., 2018). The gender gap in mathematics achievement, as reported by researchers, begins in kindergarten, persists through middle school (Fryer Jr & Levitt, 2010; Kersey et al., 2018), and even widens in high school level (Prieto-Rodriguez et al., 2020; Reilly et al., 2015).

Regarding mathematical outcome, male students used to perform better than their female peers (e.g., Hyde et al., 2008). Presently, while a number of studies have detected marginal and diminishing gender disparities (e.g., Hyde et al., 2008), and in certain instances, female students have achieved an equivalent or superior standard of performance (Goulas et al., 2022; Hyde et al., 2008; Hyde & Mertz, 2009), the gender gap is still considerable in key academic metrics like PISA (Program for International Student Assessment; National Center for Education Statistics [NCES], 2016).

When it comes to relevant courses taken in college, students who proceed up to the undergraduate and graduate levels take less math and science courses (Chen, 2013). This substantial dropout rate might be an indication that students are not prepared or feel confident to take college-level courses that need solid grounding in mathematics, and researchers noted that men are more likely than women to pursue degrees in STEM subjects and to enroll in them (e.g., Beede et al., 2011).

Similarly, math-intensive disciplines and majors are among the few STEM fields where women have not yet attained parity with males at both undergraduate and graduate levels,

according to data from the U.S. Department of Education. For example, women received 59% of degrees in the biological and biomedical sciences at the undergraduate level, according to relevant statistics, whereas only 43% of degrees in math-intensive subjects were awarded to women in 2012 (U.S. Department of Education, NCES 2014). In the same vein, there exists a dearth of female representation at the graduate level, as evidenced by the fact that doctorate degrees in computer and information sciences, engineering, physical and technological sciences, and mathematics and statistics are awarded to women at rates of 29, 19, 23, and 34%, respectively (NCES 2014, U.S. Department of Education).

In the professional sphere, women have accounted for the majority of degrees and jobs in medical and health sciences in the United States in recent decades (U.S. Department of Education, NCES 2012). However, according to the National Science Foundation (2011), they are still underrepresented in the STEM fields, which need the greatest amount of mathematical knowledge and skills (National Science Foundation 2011). For example, as per the National Science Foundation (2015), there has been a decline in the percentage of women in some STEM professions such as computer science, which can be simply the translation of the existing educational gap in math-intensive major, indicated above.

The intention of this research was to address the existing gap in math-intensive majors and careers, by considering level of students' engagement in a special setting of all-girl educational environment. To that end, related factors such as students and teachers' mathematical mindset, gendered beliefs about mathematics, as well as the affordances of all-girl setting were taken into account.

Defining Mindset

Since students' mathematical mindsets have been identified as a key determinant of the gender gap in mathematics majors and careers, it is important to first clarify the concept of "mindset." Mindset refers to the belief in the malleability of intelligence (Dweck, 2006), with prior research emphasizing its role in shaping students' academic choices and persistence in mathematics (Dweck, 2006; Gunderson et al., 2011). Beliefs regarding the malleability of intelligence divides individuals into two groups with growth or fixed mindset (Yeager and Dweck 2012). Individuals who possess a growth mindset perceive intelligence as a quality that can be developed and expanded with diligence and time (Dweck, 2006; Yeager and Dweck, 2012). On the other hand, individuals adhering to the fixed mindset regard intelligence as an unchangeable characteristic (Dweck, 2006; Yeager and Dweck 2012).

Similarly, mathematical mindset can be defined as person's belief about malleability of mathematical intelligence (Boaler, 2018). Accordingly, individuals may hold fixed or growth mathematical mindset (Boaler, 2013; Dweck, 2006; Yeager and Dweck 2012). Individuals, and students in particular, in this context, who possess a growth mindset in mathematics hold the belief that their mathematical abilities can be enhanced through diligent practice and persistent effort, as opposed to those who hold a fixed mathematical mindset and consider their mathematical abilities to be inherent and unchangeable (Daly et al., 2019).

It is noteworthy to remark that there exists a correlation between students' mathematical achievement and their mathematical mindsets, as well (Bernardo, 2020; Bostwick et al., 2019; Claro et al., 2016; Good et al. 2012; Kaya & Karokoc, 2022).

As indicated in the first chapter, related research has demonstrated that domain-specific mindsets operate independently (Dweck et al., 1995; Ryan & Mercer, 2012), and individual may hold growth mindset in one area but fixed mindset in another one. Furthermore, the importance of taking domain-specific mindsets into account rather than general mindsets was emphasized by researchers (Costa & Faria, 2018; Lou & Noels, 2019). Consequently, this research will predominantly examine the mathematical mindsets, as opposed to the general mindsets.

The processes of learning and teaching mathematics are impacted by the mindsets of both instructors and learners (Boaler, 2013; Dweck, 2006). Thus, researchers have consistently considered not only students' mindsets, but also teachers' mindsets, when they are investigating mindset and its impacts. In accordance with the researchers' recommendations, the present study will also examine the influence of students' and teachers' mathematical mindsets on students' engagements.

Students' Mindsets

A broad line of research has been focused on students' mindset and its impacts. Previous research in this field has identified a correlation between the mindsets of students and their academic achievements (Blackwell, Trzesniewski, & Dweck, 2007; Claro et al., 2016; Cury et al., 2006 ; Lin-Siegler et al., 2016; Romero et al., 2014; Schmidt et al., 2017), their engagement level (Ln-Siegler et al., 2016; Schmidt et al., 2017), their selection of academic disciplines, and their likelihood of enrolling in additional mathematics courses in the future (Good et al. 2012; Burkley et al. 2010; Leslie et al. 2015; Romero et al. 2014), their mathematical performance (Blackwell et

al., 2007; Claro et al., 2016), and their mathematical achievements (Bernardo, 2020; Bostwick et al., 2017; 2019; Claro et al., 2016; Good et al., 2012; Kaya & Karokoc, 2022).

According to earlier studies, individuals with a fixed mindset frequently enroll in college programs that have minimal math requirements, which restricts their career opportunities in math-intensive disciplines (Leslie et al., 2015). In contrast, students with a growth mindset are willing to invest effort to improve their mathematics skills, believing that success stems from hard work and persistence (Boaler, 2016; Dweck, 2006). The following is a concise summary of pertinent research on student mindset and its impacts.

a) Impact of Mindset on Mathematical Performance

Several studies highlighted the relationship between students' mindset and their mathematical performance. Growth mindsets- belief that abilities can be developed through effort and perseverance- have been positively correlated with higher mathematical achievements. Research by Blackwell et al. (2007) revealed that students who adopted a growth mindset intervention showed improved mathematical performance over time, as evidenced by higher scores on standardized mathematics tests. The study, involving 373 seventh graders, demonstrated that growth mindset not only led to better scores but also fostered persistence and positive behavioral responses to academic challenges.

Similarly, Claro et al. (2016) investigated the relationship between mindset and mathematical performance relationship among 168,203 tenth graders in Chile. Their findings reinforced the notion that a growth mindset is strongly associated with higher academic achievement. Students who believed in the malleability of intelligence demonstrated significantly higher math scores, irrespective of their socioeconomic background. Importantly, students from

lower socioeconomic strata exhibited comparable academic performance to their higher-income peers when a growth mindset intervention was implemented.

In a study involving fourth-grade students in Turkey, Kaya and Karokoc (2022) further corroborated these findings. Their research demonstrated that while a fixed mindset had a direct negative impact on students' math performance, growth mindset positively influenced achievement through the mediating factors of grit, interest consistency, and perseverance. This indirect effect emphasizes the importance of mindset in shaping students' approach to learning, beyond mere performance metrics.

b) Impact of Mindset on Course Selection and Academic Persistence

The influence of mindset extends beyond immediate performance, shaping students' academic trajectories, particularly in course selection and persistence in challenging subjects like mathematics. Students with a growth mindset are more likely to enroll in advanced mathematics courses and persist through academic difficulties. Romero et al. (2014) conducted a study on 115 middle school students, finding that those with a growth mindset not only performed better in core subjects like mathematics but were also more likely to enroll in advanced math courses in subsequent years. This positive correlation between academic ambition and growth mindset emphasizes the mindset's role in promoting long-term educational objectives.

Conversely, students with a fixed mindset tend to shy away from mathematically intensive courses. Leslie et al. (2015) demonstrated that individuals with a fixed mindset are more likely to avoid majors requiring high levels of mathematical proficiency, thereby limiting their future professional opportunities. When confronted with difficulties in math, these students are more likely to change majors, seeking paths with less mathematical rigor. This avoidance behavior

highlights the detrimental effects of a fixed mindset on students' willingness to engage with challenging academic content.

c) Impact of Mindset and students' Engagement

The mindset of students also influences their level of engagement. Mindset interventions, designed to transition students from a fixed to a growth mindset, have demonstrated efficacy in enhancing both academic performance and student engagement levels. Lin-Siegler et al. (2016) examined the role of growth mindset interventions in enhancing student engagement in science. Through story-based instruction that depicted scientists overcoming challenges, the researchers were able to significantly improve students' engagement and learning outcomes compared to a control group. This study emphasizes the importance of mindset interventions in motivating students to embrace challenges and sustain effort in difficult academic tasks.

Additionally, observational research by Fredricks et al. (2011) has demonstrated that students with a growth mindset exhibit higher levels of behavioral engagement in classroom settings. By observing students' responses to instructional challenges, researchers have identified a clear link between growth mindset and active participation, persistence, and effort in the face of difficulty.

d) Mindset impact beyond high school level

Effects of mindset on mathematics-related outcomes have also been examined. Good et al. (2012) explored the relationship between mindset and mathematics enrollment in a sample of college calculus students. Their findings revealed that women with a fixed mindset experienced a diminished sense of belonging in the math domain, negatively affecting their desire to pursue further math courses. This reduced sense of belonging mediated the relationship between mindset

and future math-related ambitions, highlighting the gendered impact of mindset in academic persistence.

Teachers' Mindsets

Teachers' instructions and actions can be also influenced by the types of mindsets that they possess. In particular, the teachers' mindsets influence the instructional approaches they employ (Aragon et al., 2018; Rattan et al., 2012), the mathematical materials they select (Handal, 2003), and the mathematical instructions and strategies they implement (Dweck, 2006). In addition, students whose instructors possessed a growth perspective demonstrated greater diligence and effort (Seals, 2018), along with enhanced engagement and academic success (Rattan et al., 2012; Schmidt et al., 2015; Ronkainen et al., 2019). The subsequent section will provide a concise overview of several pertinent studies in this field.

a) Impact of Teachers' Mindset on Instructional Approaches

Teachers' mindsets significantly influence their instructional methods, especially in relation to their openness to adopting student-centered approaches such as active learning techniques. Aragon et al. (2018) explored this connection in a study involving 620 college-level instructors, who received intensive training in evidence-based active learning practices. The training focused on inclusive instruction, formative evaluation, and active learning. Aragon et al. (2018) findings revealed that educators with a fixed mindset were less inclined to employ active learning techniques and were skeptical of their effectiveness. This research emphasizes the

importance of teachers' beliefs regarding intellect in the development of their instructional strategies.

Rattan et al. (2012) also investigated the influence of teachers' mindsets on their instructional approaches through a series of studies. In one study involving 95 pre-service teachers, Rattan et al. manipulated participants' mindsets by having them read articles emphasizing either a fixed or growth mindset. They found that participants with a fixed mindset were more likely to adopt comfort-oriented strategies, characterized by lowered expectations and reduced academic demands. This instructional approach is intended to be supportive but ultimately discourages student interest and engagement. The study demonstrated that a fixed mindset leads to instructional choices that undermine students' growth and perseverance, contrasting with the more encouraging and effort-focused strategies associated with a growth mindset.

Further, Ronkainen et al. (2019) conducted a qualitative case study on a Finnish elementary school teacher known for her growth mindset. The teacher employed mastery-oriented strategies, constructive feedback (such as the phrase "not yet"), and process-focused praise. The study's findings highlighted that this approach effectively fostered strategic thinking, resilience, and effort among her students. This evidence indicates that a growth mindset leads educators to adopt instructional methods that not only challenge but also support students in achieving their academic goals.

b) *Impact of Teachers' Mindset on Selection of Mathematical Materials*

Handal (2003) explored the influence of teachers' mindsets on the selection of mathematical materials in the classroom. According to Handal (2013), teachers with a fixed mindset tend to prioritize traditional, procedural, and textbook-oriented materials that reinforce rote learning and focus on basic skills. This approach aligns with their belief that mathematical

abilities are fixed, and that mastery can only be achieved through repetitive practice of established methods. Conversely, teachers who adopt a growth mindset are more inclined to choose materials that encourage exploration, conceptual understanding, and problem-solving. These teachers are driven by the belief that students can enhance their mathematical abilities through engagement with challenging tasks, collaborative learning, and open-ended questions. Handal (2003) argues that teachers' mindset not only shapes their instructional approaches but also determines the quality and variety of the resources they bring into the classroom.

c) *Impact of Teachers' Mindset on Students' Goal Orientation*

The influence of teachers' mindsets exceeds instructional decisions and selected resources, affecting students' attitudes, motivation, and orientation towards learning. Seals (2018) conducted a doctoral dissertation study on the effects of an online growth mindset intervention program targeting secondary mathematics teachers. The study used a pre-post experimental design with 1,653 teachers and their students. The findings revealed that while the intervention effect on students' interest and mastery orientation in mathematics. Moreover, teachers' growth mindset beliefs and instructional practices moderated students' inclination towards mastery-oriented learning, indicating that teachers' mindsets can indirectly shape students' academic perspectives.

d) *Impact of Teachers' Mindset on Students' Mindset and Interests*

Rattan et al. (2012) further explored how teachers' mindsets affect students' mindsets and interests. Their series of studies revealed that instructors with a fixed mindset were more likely to attribute students' poor performance to an inherent lack of intelligence, a belief that shaped their

feedback and instructional approaches. In one study involving graduate-level teachers, Rattan et al. found that teachers with a fixed mindset provided "comfort-oriented" feedback that aimed to protect students' self-esteem but inadvertently lowered their academic expectations. This style of feedback reduced students' motivation and sense of support from their teachers, leading to lower expectations of their future performance.

In contrast, teachers with a growth mindset provided feedback that encouraged persistence and resilience, framing difficulties as opportunities for growth rather than indicators of limited ability. This approach helped foster a supportive classroom environment that promoted students' belief in their capacity to improve through effort and perseverance.

Defining Gendered Mathematical Beliefs

Gendered mathematical beliefs influence the gender disparities observed in STEM and mathematics-intensive careers and fields of study (Gunderson et al., 2011). Researchers recognize these beliefs as a contributing factor to the ongoing gender gap in these areas (Gunderson et al., 2011; Wang and Dagol, 2017). More precisely, Wang and Dagol (2017) identified six empirically validated variables in the "Current Evidence-Based Explanations for Gender Gap in STEM" portion of their review paper as reasons behind gender gap in STEM. These six factors highlighted by Wang and Dagol (2017) are:” a) cognitive ability, (b) relative cognitive strengths, (c) career preferences, (d) lifestyle values, (e) field-specific ability beliefs, and (f) gender-related beliefs and biases.

By gendered mathematical beliefs I am referring to these beliefs “that men are inherently better than women at learning mathematics" (Eble & Hu, 2022, p.1), and these beliefs might

influence both educators and learners during teaching and learning of mathematics (ex., Keller, 2001; Kim, Sinatra, & Seyranian, 2018; Nosek et al., 2009). gendered mathematical beliefs may be transmitted either explicitly, when an individual is cognizant of them, or implicitly, through the automated transmission of particular connotations and behaviors. (1995; Strack & Deutsch, 2004). To clarify, implicit beliefs and biases are "relatively unconscious and automatic characteristics of prejudiced judgment and social behavior," while explicit bias is consciously aware prejudiced judgment and social behavior. In summary, "controlled" versus "automatic" distinguishes these two types.(Brownstein, 2015).

Several tools are available to quantify implicit and explicit gendered biases. Explicit measures typically involve self-reported instruments, such as surveys, while implicit measures rely on cognitive tests that evaluate reaction times, delivering responses involuntary and unaffected by intent (Brownstein, 2015; Fazio & Olson, 2003). For example, Cvencek et al. (2014) discovered that there was negligible to no correlation between Singaporean children's implicit and explicit reports of gendered beliefs regarding math ability, and Passolunghi et al. (2014) reported comparable findings among Italian students. It is important to note that implicit and explicit measures may produce varying results. The Implicit Association Test (IAT) is a well-known instrument for determining presence of implicit biases. It utilizes response latencies and error rates in tasks to assess the association between concepts (Greenwald et al., 1998; Brownstein, 2015).

The impact of gendered beliefs regarding mathematics has been investigated by researchers. Scholars have determined that even the most fundamental manifestations of gendered beliefs and biases regarding mathematics—such as the assertion that "Men perform better on math tests than women"(Cadinu et al., 2003; Rosenthal et al., 2007) —can influence students' academic performances negatively.

More importantly, gendered mathematics beliefs held by parents and educators may influence female students' reported interests in STEM subjects and mathematics, their tendency to pursue careers that require significant mathematical skills, and their academic performance (Kim, Sinatra, & Seyranian, 2018). In addition to the negative effects of explicit gendered mathematical beliefs, implicit gendered mathematical beliefs negatively affected female students' performance, engagement, and STEM major choices (Greenwald et al., 2009; Nosek et al., 2002).

According to similar studies, gendered mathematical beliefs still impact educators and students, maintaining the assumption that mathematics is just a male domain. Teachers implicitly and actively demonstrate these gendered mathematical views, as reported by the researchers (Copur-Gencturk, Cimpian, Lubienski, & Thacker, 2020; Keller, 2001; Tiedemann, 2000, 2002; Leedy, LaLonde, & Runk, 2003). The following sections will discuss studies on the Gendered Mathematical Belief and its effects on students, teachers, and teaching and learning of mathematics.

Students' Gendered Mathematical beliefs

As indicated by related literature, students associate mathematics with males, and that girls particularly, considered boys to be more skilled in mathematics than girls (Steele, 2003; see also Heyman & Legare, 2004). Researchers further demonstrated that, as children become older, their gendered beliefs about mathematics become more pronounced (Stake & Nickens, 2005).

According to prior works in this area (Inzlicht & Ben-Zeev, 2000; Inzlicht & Ben-Zeev, 2003; Lavy & Sand, 2015; Nosek et al., 2009), gendered mathematical beliefs may cause performance deficits in mathematics for female students, as well as lower mathematical outcomes

and lower levels of engagement (Nosek & Smyth, 2011; Wang et al., 2016; Miller et al., 2015). Also, as highlighted by related studies, the adverse consequences of gendered mathematical beliefs may extend to students' career and academic trajectories (Good et al., 2012; Lavy & Sand, 2015; Reschly & Christenson, 2012). In the subsequent paragraphs, brief summaries of several studies in this field will be provided.

a) *Impact of Gendered Beliefs on Students' Academic Performance*

Nosek and Smyth (2011) investigated the impact of gendered mathematical beliefs on students' performance, examining data from 5,139 participants who completed the Implicit Association Test (IAT) and self-reported key engagement components such as math attitudes and identity. The study found that women with stronger gendered beliefs reported lower self-ascribed math ability, more negative attitudes, reduced engagement, and lower math achievement, as reflected in their ACT and SAT scores. In contrast, male participants showed weak, opposite associations. These findings highlight the detrimental effects of gendered beliefs on female students, contributing to gender disparities in math-related fields. The study emphasizes the need to address these beliefs early to prevent their negative influence on students' engagement and achievement.

b) *Impact of Gendered Beliefs on Female's Future Career Trajectories*

The impact of gendered beliefs on females' future career choices was studied in a large-scale analysis by Miller et al. (2015), who utilized data from 350,000 participants between 2000 and 2008. These participants, with an average age of 27 years, completed the gender-science IAT

and explicit measures of gendered beliefs through the Project Implicit website. Miller and colleagues measured explicit gender beliefs by asking participants to rate their association between science and gender on a scale ranging from very male to strongly female. The study revealed a consistent association between science and males, with both explicit and implicit measures reflecting gender biases. To understand the broader impact of these beliefs, the researchers analyzed women's representation in science using two key metrics: the proportion of women employed as researchers and the percentage of women enrolled in tertiary-level scientific education.

Their findings showed that an increase in the number of female researchers correlated with a decrease in explicit biases toward science and gender, but not implicit biases. Moreover, a reduction in both explicit and implicit gender biases was associated with higher female enrollment in STEM programs at the tertiary level. Millet et al. (2015) supported these findings using multiple regression models that accounted for 25 national factors, concluding that gendered beliefs significantly shape career trajectories. These results emphasize the deep-rooted nature of implicit biases and their influence on women's representation in scientific careers, highlighting the need for interventions targeting both explicit and implicit beliefs to increase gender parity in STEM fields.

c) *Impact of Gendered Beliefs on Students' Mathematical Performance and Proficiency*

The impact of gendered beliefs on students' mathematical performance and proficiency was investigated in studies by Galdi et al. (2014) and Steffens et al. (2010), which examined how these beliefs influence students' math achievements. Galdi et al. (2014) conducted an experiment with 276 first-grade Italian students to explore how gender biases affect girls' math performance.

Participants were randomly assigned to one of three conditions—consistent, control, or inconsistent—where they were tasked with coloring images that depicted either boys or girls solving math problems correctly. This task was designed to activate gendered beliefs in girls by exposing them to negative in-group associations. Following the task, students completed a Child-IAT to measure implicit biases and were also presented with visual scales to assess explicit biases. Results showed that girls' math performance declined significantly under biased conditions, indicating that gendered beliefs negatively impacted their academic achievements.

Similarly, Steffens et al. (2010) conducted two studies involving 140 students from grades 4, 7, and 9, investigating the implicit biases and their relationship with students' math proficiency. Students were administered the IAT to measure implicit biases and responded to explicit bias statements. The researchers then analyzed students' math outcomes based on their recent exam results. They discovered that implicit gender biases were already present in girls as young as nine years old, while boys did not display these biases. Regression analysis revealed that implicit biases were significant predictors of girls' academic achievement and enrollment choices beyond explicit biases, indicating that gendered beliefs play a crucial role in shaping girls' math proficiency. These findings emphasize the need for addressing implicit gender biases in educational settings to foster equitable academic outcomes and encourage girls' continued engagement in mathematics.

d) Impact of Gendered Mathematical Beliefs on Students' Engagement

The impact of gendered beliefs on students' engagement in mathematics was studied extensively by researchers like Nosek & Smyth (2011), Wang et al. (2016), and Miller et al. (2015). Engagement, which encompasses cognitive, behavioral, and affective dimensions, plays a crucial

role in students' academic outcomes and persistence in math-related subjects. Nosek & Smyth (2011) found that women who held stronger gendered mathematical beliefs reported lower levels of engagement in mathematics, including negative attitudes towards the subject and a weaker sense of math identity. These findings suggest that gendered beliefs can create psychological barriers that hinder female students from fully investing in math learning, leading to reduced self-confidence and disengagement over time.

Wang et al. (2016) further explored how gendered beliefs about mathematics influence students' engagement in classrooms, examining how these beliefs can impact not only individual motivation but also collective classroom dynamics. Their study revealed that girls who internalized these beliefs demonstrated lower participation and reduced willingness to take on challenging tasks in math, which in turn affected their academic outcomes. Similarly, Miller et al. (2015) highlighted the broader implications of gender biases on engagement, finding that implicit and explicit gender biases contribute to shaping students' perceptions of who "belongs" in math-intensive fields, thereby affecting female students' sense of belonging and participation. These studies emphasize the detrimental effects of gendered beliefs on the engagement levels of female students, demonstrating that these beliefs not only influence their attitudes and perceptions but also directly affect their tendency to participate and persist in math-related activities. Addressing these beliefs is therefore crucial to fostering an inclusive and supportive learning environment where all students can thrive academically.

e) *Appearance of Gendered Beliefs in Children*

The appearance of gendered beliefs in children was explored by Cvencek et al. (2011), who investigated when these biases first emerge and their impact on children's math self-concepts.

Cvencek and colleagues conducted a study with 247 students from grades 1 through 5, assessing their explicit and implicit gendered mathematical beliefs using self-report questionnaires and computer-based IATs. They adapted the adult version of the IAT to suit younger participants, following similar modifications made in prior research by Dunham et al. (2006). To capture explicit beliefs, they utilized visual scales inspired by Harter and Pike's (1984) Pictorial Scale, which allowed children to express their self-perceptions and gender associations with mathematics. The study found that gendered mathematical biases were evident as early as the second grade, with male students demonstrating stronger math self-concepts and positive associations with math on both implicit and explicit measures compared to their female peers.

Adding to this understanding, Steffens et al. (2010) examined the early onset of gendered beliefs in a study involving 140 students from grades 4, 7, and 9. They focused on when implicit biases related to math begin to manifest and their potential impact on students' self-concepts and performance. Their results revealed that by age nine, girls already displayed implicit gender biases associating math with boys, while boys at the same age did not exhibit such biases. This finding aligns with Cvencek et al. (2011), further emphasizing that gendered beliefs about math are not only present at a young age but also predominantly affect female students. The study also showed that these biases had a substantial influence on girls' self-concept and math-related attitudes, highlighting the importance of early interventions to counteract these beliefs and promote positive math identities among female students. Together, these studies highlight the significance of addressing gendered beliefs early in education to prevent their negative impact on students' self-concepts and future academic choices.

Teachers' Gendered Mathematical beliefs

As previously highlighted, gendered beliefs about mathematics are widely held in Western countries, and teachers and parents still maintain this view that mathematics is a male domain (Cvencek, Meltzoff, & Greenwald, 2011; Keller, 2001; Riegle-Crumb and Humphries, 2012; Tiedemann, 2002; Nosek et al., 2010). Math-gender biases and beliefs discourage female students from pursuing mathematical careers and lower their motivation, interest, and performance in the subject of mathematics (e.g., Wang & Degol, 2017). As noted by researchers, teachers, who play a significant role as socializers in the classroom, also promote gender biases about mathematics (Gunderson et al., 2012). The following is a summary of pertinent investigations.

Based on studies by Ceci et al. (2009, 2014), researchers emphasized that biases and discriminatory behaviors tend to emerge at early ages when children begin developing career interests. Additionally, Wang and Degol (2017) highlighted the ongoing issue of parents and teachers underestimating girls' mathematical abilities compared to boys, despite similar academic performance, which impact boys' and girls' career trajectories.

Wang and Degol (2017) also noted the pervasive cultural belief in Western societies that math and science are male-dominated fields, which children as young as six internalize, as shown by studies like Miller et al. (2015). These studies highlighted how both implicit and explicit gender-math associations are more likely in males, who often connect mathematics with their gender identity, a trend observed in Cvencek et al. (2011) study involving first and second graders in the United States. As noted by all of these studies, these gendered beliefs about mathematics have a substantial impact on teaching and learning of mathematics.

a) Impact of Teachers' Gendered Beliefs on Their Teaching Practices

The impact of teachers' gendered beliefs on their teaching practices was explored in studies like Nurnberger et al. (2016) and Heyder & Kessels (2017). In Nurnberger et al.'s study, 130 preservice teachers evaluated 12 hypothetical student profiles, each containing a summary of a student's performance in math and language and were asked to recommend students for either a math/science-focused or language-focused secondary school. The study employed the Sorting Paired Features Task (SPF) to measure implicit biases and found that while explicit gender biases did not significantly predict teachers' recommendations, implicit biases did. The results showed a clear tendency for teachers to recommend male students for math/science tracks and female students for language tracks, demonstrating how implicit beliefs influence guidance practices. This aligns with Heyder & Kessels (2017), who found that teachers' gender-stereotyped expectations led to different treatment of male and female students, such as encouraging boys more frequently in math activities, even when girls displayed similar abilities. These practices highlight how implicit biases, though unintentional, shape academic trajectories and can contribute to the gender gap in STEM fields.

b) Impact of Teachers' Gendered Beliefs on Students' Academic Performance

The impact of teachers' gendered beliefs on students' academic performance was investigated in-depth by Lavy and Sand (2015) and further supported by the findings of Beilock et al. (2010), and Lavy and Sand (2015) analyzed the effects of gender biases held by elementary school teachers on students' test scores and course selections as they advanced into middle and

high school. They found that female students' math achievements were negatively affected by teachers' biases, leading to fewer enrollments in advanced math courses compared to their male counterparts. Similarly, Beilock et al. (2010) studied the role of female elementary teachers' math anxieties and gendered beliefs, discovering that female students who were taught by anxious teachers with gendered beliefs performed worse in math by the end of the school year. The teachers' anxiety and beliefs indirectly reinforced gender stereotypes, which discouraged female students from engaging in mathematics and achieving at their potential. These findings collectively emphasize how teachers' biases can result in long-term disparities in students' academic performance and aspirations.

c) Impact of Teachers' Gendered Beliefs on Students' Mathematical Abilities

The negative impact of teachers' gendered beliefs on students' mathematical abilities has been well-documented, with studies by Heyder et al. (2019, 2020) and Cimpian et al. (2016) offering key insights. Heyder et al. found that teachers who believed that boys were inherently better at mathematics tended to set lower expectations for female students, ultimately affecting the girls' perceived self-efficacy and actual math abilities. These biased expectations resulted in teachers providing less encouragement and support to female students, leading to decreased confidence and performance in math-related tasks. This finding is consistent with Cimpian et al. (2016), who demonstrated that young girls often internalize teachers' low expectations, perceiving themselves as less capable in subjects like math. The study showed that even subtle cues from teachers could influence female students' beliefs about their own abilities, thereby reducing their motivation and interest in pursuing math-related activities. Together, these studies underscore the

importance of challenging gendered beliefs in educators to promote a more inclusive learning environment.

d) Impact of Teachers' Gendered Beliefs on Students' Gendered Beliefs

The influence of teachers' gendered beliefs on students' own gendered beliefs was examined in studies by Simpson and Linder (2016) and Eccles et al. (2015). Simpson and Linder (2016) found that teachers often unconsciously transmit gender stereotypes through their actions, communication, and feedback to students. For instance, teachers might provide more praise to boys for succeeding in math while attributing girls' success to effort rather than ability, reinforcing the stereotype that boys are naturally better at math. Eccles et al. (2015) further highlighted how teachers' beliefs about gender and academic abilities can shape students' own beliefs and choices. Their study showed that teachers' biases influenced female students' self-concepts and interests, leading to decreased confidence in their math abilities and lower enrollment in advanced math classes. These findings illustrate how the classroom environment and teachers' beliefs play a critical role in shaping students' perceptions of gender roles in mathematics, ultimately influencing their academic choices and aspirations.

Defining Engagement

Over the past few decades, one of the main areas of interest for educational research has been students' engagement. As highlighted by Reschly & Christenson (2012), numerous engagement-related themes (ex., engagement's types and definition, engagement's measurement,

indicators and facilitators, etc.) have been thoroughly investigated by researchers through recent decades.

A broad spectrum of studies has focused on the nature and structure of engagement (Christenson, Reschly, & Wylie, 2012; Corno & Mandinach, 2004; Fredricks, Blumenfeld, & Paris, 2004; Fredricks, McColskey, Meli, Mordica, Montrosse, & Mooney, 2011), as well as its definition (Azevedo, 2015; Christenson et al., 2012; Eccles & Wang, 2012; Klem & Connell, 2004; Li, 2011; Skinner et al., 2009).

As noted by Christenson et al. (2012), numerous essentially distinct definitions have been used to the term "engagement". As highlighted by some researchers, engagement can be defined as the extent to which students demonstrate dedication in educational activities (Skinner et al., 2009). In a similar vein, engagement can be characterized as the degree to which students get involve in interaction or participate in school-related tasks [e.g., activities, social relationships] (Suh & Suh, 2006).

Reeve (2012) identifies engagement as a "multidimensional construct" that can be defined as the degree to which a student actively participates in a learning activity. In some definitions put forth by scholars, engagement was illustrated through placing significance on three dimensions: affective, behavioral, and cognitive (Klem & Connell, 2004). As researchers have stressed the need of considering all three aspects of engagement (Sinatra et al., 2015), I refer to the three components of students' *cognitive*, *behavioral*, and *affective* participation as "engagement" in this study (Fredricks et al., 2004; Wang et al., 2011).

According to Fredericks et al. (2004), *behavioral engagement* is described as "participation, effort, and attention in classroom and school contexts; positive conduct; and the absence of disruptive behaviors." Also, "Positive and negative reactions to teachers, classmates,

academics, and school and is presumed to create ties to an institution and influence willingness to do the work" is how *affective engagement* has been defined (Fredricks et al., 2004). Ultimately, according to Fredricks et al. (2004), *cognitive engagement* can be defined as "thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills."

Students' behavioral engagement can also be recorded and measured as a separate component through classroom observation, as researchers have highlighted several advantages (e.g., collecting real-time information, being administrable, etc.) of using observational methods for measuring the dimensions of engagement. (Fredricks, 2022). In light of this, engagement subdomains will be categorized into four categories: behavioral engagement (observed) and (self-reported), cognitive, and affective, for the purpose of this study.

Furthermore, it is worth noting that scholars offer further elucidations of all three of these aspects of engagement beyond the scope of Fredricks et al. (2014). *Cognitive engagement* is the term used to describe students' psychological commitment to learning and their use of self-control techniques to meet learning objectives (Sinatra, et al., 2015). *Behavioral engagement* refers to students' active participation in academic tasks, as well as their attention to academic work (Sinatra et al., 2015). Finally, Students' emotional reactions to instructions from instructors, such as their interest in and response to tasks given to them, as well as their reactions to teachers and their classmates, are referred to as *affective engagement*. (Fredricks, 2011).

Culminating their 2012 Handbook of Research on Student Engagement, Christenson et al. (2012) provided thirteen "recommendations to advance the quality and utility of research on the construct of student engagement" (p. 815) in the epilogue. As one of our preferred factors [dependent variable here], three of the above issues were incorporated into the present study when

engagement was considered.: 1) defining and conceptualizing of student engagement; 2) using measures which are “align with” the used definition; 3) conceptualizing engagement.

Students' Engagement

The concept of student engagement has garnered significant interest from researchers, educators, and politicians as a potential solution to address several problems, including students' low performance, and elevated percentages of students leaving school prematurely. Previous research has established a correlation between student engagement and improved academic performance, increased educational attainment, and reduced rates of dropping out (Fredricks et al., 2004; Griffiths et al., 2009).

Above all, researchers have observed that students' level of engagement has a significant influence on their chosen career trajectory (Christenson et al., 2012). In the same manner, related studies have identified student engagement as a determinant of their chosen career path (Christenson et al., 2012). Researchers have also emphasized the significance of student engagement, describing it as fundamental to the feedback mechanisms that mold educational trajectories of students (Skinner and Pitzer, 2012).

Students' engagement is a significant issue for a variety of factors, as Christenson et al. (2012) pointed out. To begin with, as indicated by pertinent research, students' engagement is regarded as the primary theoretical framework for comprehending attrition and promoting school completion [high school graduation with the academic and social competencies required to pursue higher education] (Christenson et al., 2008; Finn, 2006; Reschly & Christenson, 2006; as cited in Christenson et al., 2012).

More importantly, engaged students demonstrate more than just attendance and academic achievement; they demonstrate diligence, perseverance, self-control in their conduct with regard to goals, strive for excellence, and have a genuine passion for learning (Klem & Connell, 2004; National Research Council and the Institute of Medicine [NRC and IoM], 2004; as cited in Christenson et al., 2012). Additionally, it has been established that there are positive correlations between student engagement and the desired outcomes of learning in the different areas and contexts (Klem & Connell, 2004; as cited in Christenson et al., 2012).

Single-Sex Education

A perennially debated subject in educational studies has been the comparison and contrast of coed and single-ed settings. More precisely, the persistent dispute regarding the capacity of single-sex education to either challenge or reinforce traditional gender biases and beliefs gained greater attention subsequent to the federal authorization granted to public schools to install single-sex classrooms adjacent to coed classrooms (Fabes et al., 2015). Also, scholars have emphasized that coeducational institutions may have detrimental impacts on the academic performance, career aspirations, academic achievement, and course selection of female students (Jenkins, 2006).

Currently, a considerable number of public schools offer specialized courses and classes for one gender in various academic disciplines, such as mathematics, alongside private schools that also provide such environments (Office of Civil Rights, 2014). More specifically, single-sex environments are considered as an opportunity to offer girls a supportive environment in which they can develop ambitions for improved academic performance, intensify curiosity and involvement, and ultimately flourish in STEM fields that have traditionally been male-dominated

(Pahlke, Hyde, & Allison, 2014). This is in addition to catering to the potentially different learning styles and needs of boys and girls.

As noted by researchers, single-sex settings are seen as a way to cater to the different learning styles and needs of boys and girls, and researchers have found that female students benefit more from single-sex educational settings (Eisenkopf et al. 2015; OECD 2009; Riggers-Piehl et al. 2018). Based on related studies single-sex schools are believed to offer girls a supportive environment where they can develop ambitions for improved academic performance, foster curiosity and involvement, and ultimately excel in STEM fields that have traditionally been dominated by males (OECD 2009; Pahlke, Hyde, & Allison, 2014).

In addition, co-ed contexts have been the primary location for the majority of research pertaining to gendered mathematical beliefs and mathematical mindsets (Good, Aronson, & Inzlicht 2003; Romero et al. 2014; Schmidt et al. 2017). Consequently, it is important to examine the determinants of mathematical mindsets and gendered mathematical beliefs within the unique context of an all-girls setting (Davies et al., 2002; Gunderson et al., 2011). As a result, this particular context was chosen by the researcher for the current investigation, which centered on the factors that contribute to influencing the mathematical mindsets and gendered mathematical beliefs of female students.

In addition, empirical studies suggest that single-sex classes may provide benefits for students of both the male and female sexes. For example, Kirschenbaum and Boyd (2007) conducted a study that demonstrated that gender-specific science and mathematics classrooms are most beneficial to females. As a result, it is logical to select this particular context for the present study in order to examine distinctive factors that influence the mathematical mindsets and

gendered mathematical beliefs of female students, which in turn impacts female students' level of engagement, and ultimately their future career choices.

Single-sex classroom can provide benefits for both boys and girls, according to related studies. Girls benefit the most from single-gender science and mathematics classrooms, according to related research (Kirschenbaum and Boyd, 2007). In addition, as related studies have shown, males gain advantages from single-sex classrooms as well because the activities are tailored to their unique requirements and learning styles (Kirschenbaum and Boyd, 2007).

According to Jenkins (2006), empirical evidence suggested that female students in coeducational courses were less inclined to participate in classroom discussions and received less attention compared to their male counterparts. More specifically, it was observed that boys, who possess greater self-assurance in mathematics and science domains, exerted dominance over discussions in these classes. Additionally, teachers tended to initiate more calls on the boys than the girls, according to related studies (Boyd & Kirschenbaum, 2007).

A single-sex mathematics classroom has the potential to positively influence the engagement of female students (Gavin et al., 2003). This is a significant determinant in female students' future career decisions and selection of math-intensive disciplines and careers (Reschly & Christenson, 2012). Previous research has found that middle school girls are more likely to participate in class conversations when asked questions in a single-sex math classrooms, since based on related studies they appeared more confident in their abilities and did not feel intimidated in the absence of male students (ex., Gavin et al. 2003).

Similar findings have been reported by researchers, who noted that students in exclusively female classrooms are more comfortable expressing their thoughts and views, as opposed to female students in coeducational environments, because the all-girl classroom is perceived as an inclusive

space where they are welcome to participate (Hughes, Nzekwe, & Molyneaux, 2013; Simpson & Che, 2016).

Additionally, prior research in this field has demonstrated that female students in all-girl mathematics classrooms not only report higher self-perceptions of themselves as mathematics learners, but they also achieve significant improvements in their mathematical performances (Baker, 2002). Similarly, within an all-girls classroom or school, girls reported feeling empowered and realizing that excellence is gender neutral (Flowers, 2005).

The unique nature of an all-girl environment for female students is not solely derived from the segregation of boys and girls. Instead, it is a combination of various factors, such as the support provided by teachers, sufficient access to resources, and a deliberate design of the proper curriculum and teaching methods that empower female students to achieve academic success. as emphasized by researchers (Baker, 2002; Herr & Arms, 2004; Hubbard & Datnow, 2005; Smithers & Robinson, 2006).

The present study will examine this distinctive environment in order to address its research questions, as previously stated, in light of the numerous positive effects that researchers have documented regarding all-girl classrooms (ex., Smithers & Robinson, 2006).

Chapter 3: Methodology

3.1 Purpose of the Study

This study aims to analyze the gendered mathematical beliefs and mathematical mindsets of female students in an all-girls school while examining the influence of these beliefs—held by both students and teachers—on students’ engagement. Additionally, this research seeks to evaluate how contextual factors, such as the unique characteristics of all-girls schools and the instructional actions employed by teachers, shape students’ engagement levels. Recognizing that engagement plays an important role in shaping female students’ academic trajectories and career aspirations, this study also considers the impact of teachers’ instructional actions and the school’s affordances on students’ engagement within this specific educational environment.

3.2 Research Question

The research questions which will guide this study (depicted in Figure 1) are:

- 1) In an all-girl school context, what are the mathematical mindsets, and the gendered mathematical beliefs that middle school girls hold? How do these compare to reports from the literature?
- 2) How do individual girl’s engagements (both self-reported engagement and observed behavioral engagement) relate to their mathematical mindsets and gendered mathematical beliefs?
- 3) In an all-girl mathematics classroom, how does the engagement of a typical student in the class (both self-reported engagement and observed behavioral engagement) relate to the teachers’ mathematical mindsets and gendered mathematical beliefs?

4) What are the perceived affordances [from teachers] of an all-girl school context which are influencing middle school girls' mathematical mindsets, and gendered mathematical beliefs? What instructional actions, in general, do the teachers feel like help improve girls' mathematical mindsets, and gendered mathematical beliefs?

3.3 Research Approach and Design

On account of the researcher's "integration of qualitative and quantitative research and data" (Creswell & Creswell, 2018, p. 51), the mixed-method study was chosen as the research design of the current study, to acquire results and tackle the research questions. As noted by Gay et al. (2012), the primary goal of a mixed-method design is to "extend the comprehension of a phenomenon beyond what can be achieved by exclusively employing quantitative or qualitative methods" (p. 481). In light of this rationale, the mixed method research approach was chosen due to its logical and applicable nature in enhancing our comprehension of the mathematical mindsets and gendered mathematical beliefs of female students in an all-girl setting.

As highlighted by Creswell & Creswell (2018, p. 299), there are three different types on mixed-method study including: *the convergent design, the explanatory sequential design, and the exploratory sequential design*. As the researcher "converges or merges quantitative and qualitative data to provide a comprehensive analysis of the research problem" (Creswell & Creswell, 2018), convergent mixed-method designs will be implemented rather than other mixed-method designs.

In order to address the first research question regarding the mathematical mindsets and gendered mathematical beliefs of female students in co-ed versus all-girl schools, the researcher will employ a qualitative descriptive methodology (Gay et al., 2012).

In order to address the second research question, the researcher will utilize a correlational design (Gay et al., 2012). More precisely, the researcher will employ the Chi-Squared test (Creswell & Creswell, 2018) to examine the correlation between students' mathematical mindsets, gendered mathematical beliefs, and their engagement levels, which serve as categorical variables.

To address the third research question, a qualitative descriptive approach (Gay et al., 2012) and a Mann-Whitney U test will be used to assess the correlation between teachers' mathematical mindset and gendered mathematical beliefs with students' engagement subdomains.

Finally, thematic analysis will be implemented to address the final research question, allowing middle school teachers to share their individual perspectives on their experiences in daily life (Gay et al., 2012).

3.4 The Context of the Study

Setting

Due to the fact that single-gender middle schools were the most suitable setting for the current study, the research was carried out and situated in a private middle school located in the Midwest that was exclusively for female students. The selection of this educational institution was influenced by the researcher's affiliation with this particular school and the convenience it offers in terms of conducting the study. The school is a distinguished independent day school for girls, located in a suburban area near a major metropolitan center northeastern part of the Midwest. This private school serves approximately 825 students from the Infant & Toddler age through 12th grade. The school employs around 225 faculty and staff members, resulting in a student-to-faculty ratio of approximately 8:1. Mathematics Department consists of 12 faculty members, with 7

teaching in the Upper School (Grades 9-12), 3 in the Middle School (Grades 5-8), and 2 in the Primary School (Grades K-4), ensuring comprehensive mathematics instruction across all grade levels. The majority of students who enroll at this institution, which is renowned for its extensive resources, are from high socioeconomic status families. This private institution is distinguished by its rigorous academic programs, which encompass advanced placement courses, STEM projects, and opportunities for global learning.

Considering that the current study investigated contextual factors affecting levels of engagement among female students, it appeared appropriate to select an all-girls environment. This decision was supported by empirical data indicating that female students enrolled in coeducational courses received less attention and were less inclined to participate in classroom discussions than their male counterparts (Jenkins, 2006), which was another reason behind selecting this specific school for the current study.

Moreover, as discussed in preceding chapters, researchers have noted that middle school students are most significantly influenced by gendered mathematical beliefs and mathematical mindset (Good, Aronson, & Inzlicht 2003; Romero et al. 2014). Therefore, middle school students and teachers were selected for the current study instead of students and teachers from higher educational levels such as high schools. An all-girl private school was selected for the current study, and all middle school teachers and their students were chosen for the present research, as the potential participants.

Invitation to Participate

Before inviting individuals to participate in the current study, the researcher requested a meeting via email with the head of the school. The principles, objective, and methodology of the research were succinctly outlined during the course of the meeting. Following the president of the school's approval for her school to participate in the research, she initiated communication with the middle school director via email in order to set up necessary arrangements for the study to be carried out at the middle school level.

During the second phase, the director of middle school communicated with the chair of her math department and established a connection between the researcher and the middle school math department via email. Subsequently, the researcher arranged a meeting with the mathematics department, during which the teachers were briefed on the research procedure. The researcher supplied the math department with printed copies of consent forms, which included assent forms from students, parents, and teachers, during the subsequent brief in-person meeting.

It was agreed that the teachers should request that students bring the consent records home for their and their parents' signatures and return it in upcoming days. Furthermore, the administration of the IAT's test and paper-based survey [students' mindset and engagement measure] was planned in accordance with the schedules of the teachers' classes. Moreover, the teachers provided a time slot for a face-to-face interview with the instructors in addition to their timetable availability to have their mathematics classes be recorded by the researcher.

Sampling and Selection of Participants

Due to the necessity of a single-sex educational environment and the specific focus on the middle school level, an all-girls private school was selected as the setting for the present study.

Within the mathematics department, all three middle school mathematics teachers were invited to participate, and all consented to inclusion in the study. Due to the teacher-to-student ratio in private schools, which restricted the number of students in each class, two mathematics classes from each teacher were chosen for the study, and all students were included as possible participants of the study. Only students who provided consent were included in this study, resulting in a total of 57 participating middle school students out of the potential 77 students. It should be noted that students who did not return the consent forms were omitted from the classroom database and excluded from classroom recording by placing them outside the camera's frame.

3.5 Data Collection Instruments

Survey

Students' mathematical mindset was assessed via a paper-based survey derived from Dweck's (2006; 2007) Mindset scale, as explained in chapter one. The Growth Mindset Scale design mitigates acquiescence bias, which occurs when respondents give affirmative answers due to perceived expectations (Dweck et al., 1995). To further reduce this bias, the survey includes both growth and fixed mindset items, minimizing the influence of social desirability and acquiescence biases. The math mindset scale, an adaptation of Dweck's general mindset scale, is a reliable measure with a reliability coefficient of 0.78 (Dweck, 2006).

The survey was consisting of six Likert-scale questions, modified to focus on math intelligence. Response options will range from strongly agree (1) to strongly disagree (6), with three questions addressing fixed mindsets and three addressing growth mindsets. Growth mindset items were reverse scored. Survey results were categorizing participants into Strong Fixed,

Moderate Fixed, Moderate Growth, or Strong Growth Mindsets based on their total scores (6–36 points).

Additionally, the survey assessed students' cognitive, behavioral, and affective engagement through 12 items. Four items measured each subdomain, with responses ranging from strongly disagree (1) to strongly agree (6). Engagement levels will be categorized as Strong (18-24 points), Moderate (11-17 points), or Low (4-10 points) based on the total scores within each subdomain.

To measure gendered mathematical beliefs, the researcher utilized a modified version of the Implicit Association Test (IAT; Greenwald et al., 1998). This version assesses both students' and teachers' gendered mathematical beliefs through categorizing words into academic domains. Modifying the IAT was essential to make it suitable for middle school students. The original IAT presented a high level of complexity, extended length with seven phases, and an age restriction of age 18, making it impractical for use with younger students. Adapting the test enabled a more age-appropriate and accessible assessment, while also still allowing for a way to assess the implicit gendered beliefs related to mathematical among middle school students, and without imposing the cognitive demands of the original test's structure. The modified version retained the essential elements while making it more suitable for younger participants.

In the original IAT, participants completed practice trials to familiarize themselves with the task, which involved classifying words related to science or liberal arts and gender categories like Male or Female. This step was essential to ensure participants understood the test format. The researcher used these preliminary sections in the modified version, allowing middle school students to grasp the process before the main assessment. This adaptation helped the participants focus on implicit gender associations during the categorization tasks.

The original IAT test calculates reaction times, premised on the idea that faster responses indicate stronger implicit associations. It also calculates a D-score to standardize and compare response times across participants, categorizing them based on their implicit associations with gender and academic fields. The modified version aimed to simplify the test for middle school students, although it aimed to retain the core feature of measuring implicit associations between gender and academic domains, though with fewer stages [three stages] and not including reaction times.

In the modified IAT, the researcher utilized a PowerPoint presentation and a paper answer key to make the assessment more accessible for middle school students. Visual aids and simplified instructions ensured the students' attention and accurate responses, while a fixed reaction time and binary scoring system were introduced. In this version, stereotypical associations (e.g., males with mathematics) were scored as zero, and non-stereotypical associations (e.g., females with mathematics) were scored as one, ensuring consistent and reliable data collection for both students and teachers.

Each participant's total score, ranging from 0 to 20 points, is determined by adding the points from the last 20 questions. The outcome is categorized by classifying participants into one of the five categories based on their total score as follows:

- **Strong Association of Males with Mathematics:** 0-4 points
- **Moderate Association of Males with Science/Mathematics:** 5-8 points
- **Little or No Automatic Preference:** 9-12 points
- **Moderate Association of Females with Science/Mathematics:** 13-16 points
- **Strong Association of Females with Science/Mathematics:** 17-20 points

To connect survey and IAT results, each student was assigned a unique code, provided through their teacher. These codes were used when submitting both the survey and IAT results, ensuring data consistency and linking the two sets of data for analysis.

Observation Protocol

As stated previously, the researcher assessed students' behavioral engagement during the teacher's instruction through observation using an observational protocol. This subdomain was designated as observed behavioral engagement, alongside three other self-reported subdomains: cognitive, affective, and behavioral. Indicators for observed behavioral engagement have been carefully selected from six prevalent observational protocols to ensure accuracy (Fredricks et al., 2011; Ocumpaugh et al., 2015; Pianta et al., 2012; Reynolds and Kamphaus, 2015; Shapiro 2011; Volpe and DiPerna, 2010).

Seven markers are identified in the observational protocol (Appendix A) for assessing individual student engagement. The first indicator, from Ocumpaugh et al. (2015), evaluates whether the student is prepared with essential supplies like paper, pencil, and a calculator. The second, from Pianta et al. (2012), assesses students' involvement in volunteering as a measure of their participation. Student-initiated questioning, a recognized measure of engagement, forms the third indicator, based on multiple studies(e.g., Fredricks et al., 2011).

The fourth indicator measures students answering questions posed by teachers or peers, aligning with protocols from Ocumpaugh et al. (2015) and Pianta et al. (2012). Positive social interactions, such as explaining concepts to peers, form the fifth marker, derived from Volpe and DiPerna (2010). The final two indicators include raising hands, grounded in Fredricks et al. (2011), and taking notes or actively participating, selected based on Fredricks and Shapiro (2011).

One observation session was conducted in each classroom, lasting each 40-45 minutes. Given the small class sizes, two classrooms was recorded per teacher as noted before, resulting in a total of six mathematics classrooms for the study. Each indicator was assigned a point value: one

point for one or two occurrences and two points for more than two occurrences during the observation. The findings then classified behavioral engagement into three tiers: low (0–4 points), moderate (5–8 points), and high (9–12 points), based on the total points accrued for each student across all indicators.

Interview

In order to address the fourth research question and gather information regarding the teachers' perceptions, the researcher conducted the semi-structured interviews. All three teachers were interviewed in order to collect data regarding their viewpoints on the affordances of and opportunities given by all-girls schools, which have the potential to influence the mathematical mindsets and gendered mathematical beliefs of the girl students. Teachers' viewpoints on their instructional actions that may influence the mathematical mindsets and gendered beliefs of female students were also explored through the interview sessions.

One interview session, lasting approximately sixty minutes, was conducted via face-to-face with each individual teacher. During this time, the researcher was recorded the voice of the teachers for subsequent transcription through iPhone recording application.

During the interview, a total of 8 questions were posed to each teacher. In instances where more information was necessary, follow-up interviews were scheduled to acquire further details, which ultimately did not occur. It is important to highlight that at the beginning of the interview, teachers were given essential definitions of certain notions, such as mathematical mindset and gendered mathematical views, which were incorporated into the interview questions.

The reliability of the data derived from the interviews with the teachers were evaluated according to a number of criteria, including but not limited to credibility, transferability, and dependability. Before conducting the study, the questions underwent peer reviewing [two experts] to evaluate the instrument's validity.

The interview questions were submitted to two experts for evaluation and subsequent revision as part of the peer debriefing procedure. In addition, interview questions were also disseminated to two educators; their responses were used to refine the questions.

3.6 Data Collection Procedures

Administering Surveys

As noted before, the researcher visited with the middle school teachers to clarify and outline the study's objective and methodology. During a subsequent brief meeting with the teachers, they received the printed version of the mindset and engagement survey along with consent forms. Furthermore, the researcher sent an additional email to the educators, which included the digital format of the mindset and engagement survey as well as a revised version of the IAT exam, prior to the scheduled day for administering the surveys and IAT test.

During the initial meeting, the researcher and the teachers agreed to give the surveys (Paper-based Mindset & Engagement and computer-based IAT's test) at specific sessions in the upcoming week. The consent forms for parents and students had already been sent to their homes beforehand, with the expectation of having enough number of participants in each class.

For the paper-based mindset and engagement survey, students were provided with a physical copy of the survey and the results were collected after a duration of 10 minutes. Additionally, computer-based IAT tests were administered at the end of mathematics classes. The questions were projected on the whiteboard, with each slide progressing automatically. Students recorded their responses using an answer key and the letters "E" and "I" [in accordance with the original IAT test]. It is important to emphasize that by presenting each image for a brief duration of time [5 seconds], the original IAT test was tried to be stimulated. Then, the researchers obtained both results of the IAT's test results and the mindset & engagement surveys. In addition, all mathematics classes finished these two measures and reported the results to the researcher through face-to-face communication.

Classroom Recording

The researcher was informed of the teachers' availability dates for the classroom observation and recording via email exchanges after the surveys' completion. In order to capture students' engagement level in their all-girl mathematics classes, a camera consisting of an iPhone was employed. Six mathematics classes, two from the first middle school teacher and two from the second middle school teacher, were included in the study due to the small class sizes.

In addition, the sample for the study consisted of two class taught by the third middle school teacher, during which the researcher documented one session of each mathematics lecture. Consequently, the researcher has documented a total of six mathematics classroom, whose students were formed the student participants of the study.

A unique identification number was assigned to each student enrolled in these six mathematics classrooms so as to protect the privacy of the students and for the linkage of the data.

The researcher diligently recorded the students while these numbers were located in front of each individual student. This enabled the researcher to verify the interoperability between the recording and the survey results. The researcher then utilized these classrooms' recordings to assess the students' observable behavioral engagement in accordance with the observational protocol. It is important to mention that a total of forty-five minutes were captured from each mathematics classroom.

Teachers' Interview

In order to investigate the fourth research question and examine how teachers perceive the affordances and characteristics of an all-girls school, as well as their unique teaching strategies and instructional actions which impact the mathematical mindsets and gendered mathematical beliefs of female students, face-to-face interviews were conducted as the appropriate methodological tool.

The researcher arranged the face-to-face interviews with the teachers through email exchange, which accounted for the teachers' availability. It should be noted that the interviews, were also recorded to ensure the accuracy of the transcription of the data in the future. With the comprehension and consent of the teachers, in-person interview was captured using the audio recording application on an iPhone.

The allotted duration for each interview was around 30 minutes; however, this could potentially differ depending on the specific interview conducted with each instructor. The preliminary interview conducted with the first instructor duration was approximately 27 minutes,

while the subsequent interview with the second instructor took about 19 minutes. Lastly, the interview with the third teacher also ended after approximately 26 minutes.

3.7 Data Analysis Procedure

Preparation of Raw Data for Analysis

The researcher systematically prepared the raw data for analysis by meticulously processing the survey responses, ensuring accurate and consistent manual grading across all assessments. Utilizing a structured scoring rubric specifically designed for each construct—mathematical mindset, engagement, and gendered mathematical beliefs—the researcher evaluated and categorized each participant's responses on an individual basis. This process entailed the consistent application of predefined evaluation criteria to each survey item, ensuring an objective and precise representation of the participants' responses. This rigorous grading procedure provided a reliable foundation for subsequent data analysis. A detailed explanation of the evaluation process for each construct is presented below.

Following the completion of the mindset survey, the researcher prepared the raw data for analysis by first initiating the process of data cleaning (Van den Broeck et al., 2005). This involved verifying and resolving incomplete answers, outliers, and inconsistencies to ensure correctness and reliability. The goal was excluding surveys with substantial missing data [which was not the case], while minor discrepancies were addressed using suitable imputation techniques. The researcher then evaluated each paper-based survey and categorized the responses according to four distinct mindset categories based on total points:

- **Strong Fixed Mindset (6–12 points)**
- **Moderate Fixed Mindset (13–18 points)**
- **Moderate Growth Mindset (19–24 points)**
- **Strong Growth Mindset (25–36 points)**

Utilizing this 6-item survey offered several advantages, particularly in time-sensitive educational environments like an all-girls private middle school. The simplicity and brevity of the survey enabled easy administration and completion without consuming much classroom time. Moreover, the Likert scale (ranging from strong agreement to strong disagreement) allowed for a range of detailed responses, aiding in the quick identification of students who might benefit from interventions promoting a growth mindset, which is linked to better academic performance and resilience (Dweck, 2006; Yeager & Dweck, 2012).

However, the length of the 6-item survey has limitations, as it may oversimplify the complex nature of students' mindset, which can vary across subjects. Its conciseness may reduce diagnostic capacity, making it harder for educators to gain detailed insights into the depth of a student's mindset or create tailored interventions. To overcome these challenges, supplementing the survey with more comprehensive tools can provide a fuller picture of students' beliefs (Duckworth & Yeager, 2015; Blackwell, Trzesniewski, & Dweck, 2007).

Additionally, students' engagement levels were assessed through a section in the paper-based survey. The survey focused on three key aspects: cognitive, behavioral, and affective engagement. Each subdomain was measured using four Likert-scale items, with participants rating their agreement from "strongly disagree" (1) to "strongly agree" (6):

- **Cognitive Engagement:** Questions 7-10 focus on students' mental investment in learning activities, their willingness to exert effort, and their commitment to understanding the material.
- **Behavioral Engagement:** Questions 11-14 assess students' participation in classroom activities, attendance, and adherence to classroom norms.

- **Affective Engagement:** Questions 15-18 evaluate students' feelings towards their learning experiences, including their interest, enjoyment, and sense of belonging in the classroom.

These items were selected based on validated instruments from previous studies (Wang et al., 2016), ensuring the survey's robustness and credibility. After administering the survey, the researcher applied a thorough cleaning process to ensure data accuracy and reliability (Van den Broeck et al., 2005). The raw scores for each subdomain were summed to create total engagement scores, which were then categorized into three levels.

- **Low Engagement:** Total scores between 4-10 points.
- **Moderate Engagement:** Total scores between 11-17 points.
- **Strong Engagement:** Total scores between 18-24 points.

This categorization helped identify the degree of engagement across different subdomains, offering a detailed analysis of how students engage with their learning environment. The self-reported engagement measure assesses three key areas: cognitive, behavioral, and affective engagement, ensuring a comprehensive understanding of student interaction. Cognitive engagement involves mental effort in learning, behavioral engagement assesses participation in classroom activities, and affective engagement measures emotions like interest and belonging. Behavioral engagement measure evaluates students' active involvement in learning activities, including their participation, attentiveness, and adherence to classroom norms, reflecting their commitment to the learning process and the classroom environment (Wang et al., 2016).

The survey is based on validated instruments, increasing its reliability. Using a Likert scale allows for diverse responses, offering insights into varying levels of student engagement. A thorough data cleaning process, including addressing missing data and encoding responses,

ensures precision. Numerical coding simplifies analysis and aids in drawing meaningful conclusions, ensuring the dependability of the results (Van den Broeck et al., 2005).

Despite these strengths, the self-reported measure is limited by subjectivity and social desirability bias, where students may respond in a way they believe is expected. This can distort the results, especially for behavioral and affective engagement, and affect the survey's accuracy (Schwarz, 1999; Paulhus & Vazire, 2007). Additionally, using only four items per subdomain may oversimplify the complex nature of engagement, potentially missing important nuances. Imputation methods, like mean-value substitution, may also introduce biases, affecting the final engagement scores, particularly if large amounts of data require imputation (Fredricks, Blumenfeld, & Paris, 2004; Van den Broeck et al., 2005).

Students' observable behavioral engagement in the mathematics classroom will be assessed using an observational protocol. Researchers have emphasized the advantages of observational methods for measuring engagement dimensions, including the ability to collect real-time data and their ease of administration (Fredricks, 2022). Accordingly, students' behavioral engagement will be captured as a distinct component through classroom observation. As a result, in the current study engagement subdomains would be classified as *(self-reported) cognitive, affective, and behavioral engagement*, as well as *(observed) behavioral engagement*.

To measure students' observable behavioral engagement, one observation session lasting approximately 40 to 45 minutes will be conducted in each of six mathematics classrooms, with two classes observed per each middle school teacher. This setup ensures a diverse sample from different classroom environments, capturing students with various mathematical mindsets and gendered mathematical beliefs. The observation sessions will be recorded to provide detailed data for subsequent analysis.

During the observation sessions, specific actions and indicators (Appendix 1) of behavioral engagement will be meticulously recorded. Each action will be assigned a point value based on its frequency:

- **1 Point:** For 1 to 2 occurrences of the action during the observation period.
- **2 Points:** For more than 2 occurrences of the action during the observation period.

The observed behaviors included participation in class discussions, asking questions, completing assignments, and interacting with peers. This coding system provides a quantifiable measure of student engagement. These seven indicators were carefully selected from commonly used observational protocols (Fredricks et al., 2011; Ocumpaugh et al., 2015; Pianta et al., 2012; Reynolds & Kamphaus, 2015; Shapiro, 2011; Volpe & DiPerna, 2010) to accurately capture observable engagement.

Using this method in mathematics classes offers advantages like capturing real-time behavior in its natural context and reducing bias from self-reports. Observations took place over 40 to 45 minutes in each six classrooms, ensuring diverse samples (Fredricks et al., 2011). The coding system, assigning points based on behavior frequency, allows for precise engagement measurement, with recorded sessions ensuring reliable data (Ocumpaugh et al., 2015; Pianta et al., 2012).

However, limitations include the Hawthorne effect, where students may change behavior due to the observer's presence (Reynolds & Kamphaus, 2015; Shapiro, 2011), and the time-consuming nature of the process, limiting its scalability for larger studies (Volpe & DiPerna, 2010).

Once collected, the data underwent a cleaning process (Van den Broeck et al., 2005). Observations were transcribed, focusing on individual students. Each behavior was coded, and consistency checks were performed to ensure accuracy. Missing data were handled through

Listwise Deletion (Allison, 2001). Finally, total points were summed for each student, categorizing their engagement into three levels.

- **Low Engagement:** 0-4 points
- **Moderate Engagement:** 5-9 points
- **High Engagement:** 10-14 points

This categorization provides a clear and quantifiable measure of each student's behavioral engagement during the observation periods. It should be also noted that, to have the same measurement for all the subdomain of the engagement, and consistency of the data for dependent variables, after scoring students' observable engagement, the scores where normalized. For Observable Behavioral Engagement, the values range from 0 to 14 in the original system, and we want to map them onto the 4 to 24 range (used in the other engagement subdomains). The Min-Max normalization technique, which scales data values to fit within a defined range (Han et al., 2011), can be applied to adjust the observable behavioral engagement scores to be consistent with other engagement measures. As highlighted before the result was standardized in relation to other engagement subdomains to ensure data consistency and result reliability. The normalization formula used:

$$\text{Normalized Value} = \frac{\text{Value} - \text{Old Value}}{\text{Old Max} - \text{Old Min}} * (\text{New Max} - \text{New Min}) + \text{New Min}$$

Normalization is a key data preprocessing technique that helps bring variables with different scales into a common range, ensuring that no single variable disproportionately influences the analysis (Han et al., 2011). In this research, normalizing the Observable Behavioral Engagement scores allows for direct comparison with other engagement subdomains, which are on different scales. This step improves the reliability and validity of the statistical analysis, particularly when using non-parametric tests like the Mann-Whitney U test, which are suitable for analyzing associations between categorical and ordinal data. Normalization ensures that the scales of

engagement subdomains do not skew the results, allowing for a more accurate interpretation of the relationships teachers' mathematical mindset and gendered mathematical beliefs with students' engagement levels.

In addition, the researcher used the modified the original Implicit Association Test (IAT) created by Greenwald et al. (1998) to measure implicit gendered beliefs about mathematics among middle school students and teachers. For calculating and categorizing the result below measuring system were applied:

Non-Stereotypical Association: 1 point (e.g., females with mathematics, males with liberal arts)

Stereotypical Association: 0 points (e.g., males with mathematics, females with liberal arts)

Each participant's total score, ranging from 0 to 20 points, is determined by adding the points from the last 20 questions. The outcome is categorized by classifying participants into one of the five categories based on their total score as follows:

- **Strong Association of Males with Mathematics [/Females with Liberal Arts]:** 0-4 points
(Indicates most responses aligned with stereotypical associations, such as males with mathematics and females with liberal arts).
- **Moderate Association of Males with Science/Mathematics [/Females with Liberal Arts]:** 5-8 points
(Indicates a moderate amount of stereotypical associations).
- **Little or No Automatic Preference:** 9-12 points
(Indicates balanced associations, with no strong preference toward stereotypical or non-stereotypical associations).
- **Moderate Association of Females with Science/Mathematics [/Males with Liberal Arts]:** 13-16 points
(Indicates a moderate amount of non-stereotypical associations, such as females with mathematics and males with liberal arts).
- **Strong Association of Females with Science/Mathematics [/Males with Liberal Arts]:** 17-20 points
(Indicates most responses aligned with non-stereotypical associations).

For instance, if a participant consistently selected stereotypical associations (e.g., males with mathematics) for 18 out of 20 questions, their total score would be 2, classifying them as having a *Strong Association with Science for Males*. Conversely, if another participant selected

non-stereotypical associations (e.g., females with mathematics) for 18 out of 20 questions, their total score would be 18, classifying them as having a *Strong Association with Science for Females*.

The modified IAT retains the fundamental elements of the original test, such as measuring implicit biases through automatic associations, but introduces key changes that make it more suitable for educational environments, particularly middle school students. By maintaining the focus on implicit associations with a binary scoring system (1 point for non-stereotypical and 0 for stereotypical associations) and a fixed reaction time of 5 seconds, the test preserves its ability to uncover biases while reducing cognitive load and anxiety for middle school students. This simplified structure, with fewer sections and questions, ensures the test remains practical and accessible without compromising its purpose. These modifications align with the goals of the original IAT, making this version an adaptation that enhances usability in school settings while keeping the core principles intact. Thus, it can be considered a valid modification of the actual IAT, aimed at improving objectivity, efficiency, and user-friendliness, particularly for younger audiences (Greenwald, Nosek, & Banaji, 2003; OECD, 2017).

The modified version of the Implicit Association Test (IAT) offers certain advantages but comes with trade-offs in sensitivity, validity, and diagnostic power. Researchers opted for this version, which uses constant reaction times and binary scoring for middle school girls, after considering alternatives like creating a child-specific IAT. Similar to the original IAT, the modified version is affected by contextual factors such as the testing environment, peer presence, and time of day, along with cultural differences that may require interpretation adjustments based on students' backgrounds. The fixed time for responses can be limiting, especially for younger students or those with slower cognitive processing, potentially causing stress and affecting performance. This may lead to misinterpretations of implicit biases as hesitation could be seen as

bias. Additionally, cultural factors influence reaction times, and a standardized timeframe may prioritize speed over accuracy, missing subtle biases. The binary scoring simplifies complex cognitive processes and may overlook important nuances, underscoring the need to combine both implicit and explicit measures for a fuller understanding of gender biases in STEM.

Finally, Semi-structured interviews with teachers served as the primary data source for addressing research question four. These face-to-face interviews were designed to gather in-depth information about teachers' perceptions regarding different factors impacting female students' engagement. The interviews consist of eight questions each, focusing on teachers' views and perceptions regarding the all-girl school's features and teachers' instructional actions that might impact girl students' mathematical mindsets and gendered mathematical beliefs. This semi-structured format allows for flexibility in responses, providing rich, qualitative data while maintaining a consistent framework for analysis.

To ensure the trustworthiness of the data, various factors were considered by the researcher including Credibility, Transferability, and Confirmability (Creswell & Poth, 2017):

- **Credibility:** Techniques such as peer debriefing were employed before conducting the interview. Peer debriefing stage was involved discussing the data and findings with teachers to ensure that interpretations are unbiased. Member checking allowed participant teachers to review and verify the accuracy of the transcripts and the interpretations of their responses.
- **Transferability:** Detailed descriptions of the context [all-girl middle school as setting] and participants [middle school teachers and students] were provided to enable others to determine the applicability of the findings to other settings.

The exact transcription of the recorded interviews was executed to ensure that conversational nuances and details were properly recorded. Transcription involved converting audio recordings into text while maintaining the participants' exact language and structure. The thorough

transcription method was essential to preserving the data's authenticity and enabling exact analysis. The raw data were subsequently prepared for the thematic analysis procedure.

Analyzing the Data

Following the researcher's preparation of the raw data, the dataset was finalized and prepared for analysis. In order to address the first research question regarding the mathematical mindsets and gendered mathematical beliefs of female students in co-ed versus all-girl schools, the researcher employed a qualitative descriptive methodology (Gay et al., 2012). This approach involved comparing the results of the female students' mathematical mindsets and gendered mathematical beliefs with the results reported by existing literature that has been conducted in co-ed settings, with the aim of elucidating any potential differences (Gay et al., 2012). Utilization of qualitative descriptive approach was appropriate for the first research question as the researcher was implementing different sources of data (Gay et al., 2012; Magilvy & Thomas, 2009).

To do that, the researcher first evaluated and categorized the survey and modified IAT test results, specifically examining female students' mathematical mindsets and gendered mathematical beliefs within an all-girl middle school setting. Following this analysis, a comprehensive literature review was conducted to further understand and compare the mathematical mindsets and gendered beliefs of middle school girls in all-girl versus co-educational environments.

The initial goal was to locate studies specifically focusing on the mathematical mindsets of middle school female students in co-educational settings and the prevalence of gendered

mathematical beliefs among them. This analysis was meant to compare findings from an all-girls' private middle school to those from co-ed schools to reveal any key differences or similarities.

A thorough investigation approach was utilized to identify pertinent studies. Academic databases such as JSTOR, Google Scholar, ERIC, and PubMed were used, with search terms including but not limited to “middle school female students' mathematical mindsets in co-ed schools”, “gendered mathematical beliefs in co-ed middle schools”, and “mathematical mindset in middle school level”. These terms were designed to capture studies explicitly mentioning middle school female students and their mathematical mindsets and beliefs.

The initial search yielded numerous articles, but a careful selection process was applied. Abstracts were reviewed to ensure relevance to the research question, specifically targeting studies that discussed the mathematical mindsets and gendered mathematical beliefs of middle school students in co-ed settings, and more specifically including both genders. This step reduced the number of studies to a manageable pool directly addressing the research focus.

Several evaluation criteria were used to ensure the quality of the selected studies. The studies had to focus on middle school students, explicitly mentioning/ including female students, and address either mathematical mindsets or gendered beliefs. Peer-reviewed studies were prioritized for their academic rigor and reliability, narrowing the final selection to several studies that were directly relevant to the research.

In order to address the second research question, the researcher utilized a correlational design (Gay et al., 2012). Since, the objective of the researcher was to determine the correlation between the mathematical mindset and gendered mathematical beliefs of female students, with their level of engagement in an all-girl mathematics classroom. Furthermore, the second research question was seeking to determine whether and to what extent the level of engagement in an all-

girls context was impacted by the mathematical mindsets and gendered mathematical beliefs of female students. As stated by Gay et al. (2012), in correlational design the objective is to determine "whether and how a set of variables are related". Therefore, in order to investigate the second research question, a correlational design is appropriate.

More precisely, the researcher employed the Chi-Squared test (Creswell & Creswell, 2018) to examine the correlation between students' mathematical mindsets, gendered mathematical beliefs, and their engagement levels, which served as categorical variables. The Chi-Squared test is particularly useful for non-parametric data, such as ordinal and nominal variables, where no assumptions are made about the distribution of the data. In this study, students' engagement levels—categorized as low, moderate, and high—represent ordinal data, making the Chi-Squared test an effective method for assessing the relationship between these variables without requiring normally distributed data or linear relationships.

The test was ideal for examining the independent variables, students' mathematical mindsets, and gendered mathematical beliefs, both measured on categorical scale, against the dependent variable, student engagement, which is ordinal. Since the Chi-Squared test does not require a specific distribution, it is robust for analyzing naturally occurring categories in educational settings, such as growth or fixed mindsets and varying engagement levels. This statistical method can provide insights into whether and how students' mindsets and beliefs are associated with engagement, potentially guiding future educational strategies and interventions (Creswell & Creswell, 2018; Agresti, 2013).

The results of the surveys and the modified IAT test were used to categorize each student's mathematical mindset, gendered mathematical belief, and engagement subdomain according to the scoring system previously described. These were then compiled for 57 individual students and

entered into an Excel file. The Excel file contained categories of the independent and dependent variables that represented students' levels of mathematical mindset, levels of gendered mathematical beliefs, and the levels of each four dimensions of engagement: cognitive, behavioral, affective, and observational. Then, the SPSS software was used for conducting the Chi-Squared test using this data. To do that, the Excel file was initially transferred into SPSS, where the independent variables—mathematical mindset level and gendered mathematical beliefs—were coded as categorical variables. The four dimensions of engagement were then designated as dependent variables. After running the Chi-Squared test, and interpreting the results, the second research question was addressed.

To address the third research question, a qualitative descriptive approach (Gay et al., 2012) and a Mann-Whitney U test was used to assess the correlation between teachers' mathematical mindset and gendered mathematical beliefs with students' engagement subdomains. The qualitative descriptive method was suitable for understanding and explaining the relationship between teachers' mindset and gendered mathematical beliefs with students' engagement levels, as it allowed for comprehensive data collection from multiple sources to provide a thorough description of the phenomena (Magilvy & Thomas, 2009).

The Mann-Whitney U test, chosen for its ability to analyze ordinal or continuous data that are not normally distributed. This non-parametric test compares the medians of two independent samples, making it ideal for the study's focus on engagement subdomains and the categorical nature of teacher gendered mathematical beliefs (Creswell & Creswell, 2018). The Mann-Whitney U test is appropriate for investigating the association between teachers' gendered mathematical beliefs and students' engagement scores across four subdomains, as it allows for comparison between two independent groups (teachers with "Strong" versus "Moderate" gendered beliefs).

Here, students' engagement scores are considered on their numerical scale ranging from 4 to 24 points (not just the categories of low, moderate, high), the Mann-Whitney U test was suitable for non-parametric data, especially in cases where the data may not follow a normal distribution or when sample sizes are relatively small (Field, 2018).

To analyze the data, teachers' mathematical mindsets and gendered mathematical beliefs were initially evaluated and categorized. Following this, students' raw scores across the four engagement subdomains were prepared for analysis. It is important to note that all three teachers demonstrated the same level of mathematical mindset (Strong Growth Mindset), which was subsequently excluded from further analysis. Using the categorization of teachers' gendered mathematical beliefs alongside students' raw scores for each engagement subdomain (Cognitive, Affective, and Behavioral), as well as the normalized scores for Observable Behavioral Engagement, the researcher conducted a Mann-Whitney U test through SPSS. This approach allowed for a non-parametric analysis of potential differences in student engagement associated with the teachers' gendered mathematical beliefs, thereby addressing the third research question in a statistically rigorous manner.

It should be highlighted that the classification of engagement subdomains as either categorical or numerical was carefully determined based on the research questions, analytical requirements, and data characteristics. In addressing the second research question, which examined the relationship between students' mathematical mindset and gendered mathematical beliefs with their level of engagement, the engagement subdomains were treated as categorical variables. This decision aligned with the categorical nature of the predictors, allowing for the application of the Chi-squared test, a statistical method specifically designed to evaluate associations between categorical variables (Agresti, 2018). Notably, no modifications were made

to the original results for Observational Behavioral Engagement, ensuring both the accuracy and validity of the analysis.

In contrast, to address the third research question, the second statistical analysis required normalization across all four engagement subdomains to align their scoring scales, thereby enhancing comparability and reliability. This analysis examined the association between teachers' gendered mathematical beliefs (categorical) and students' engagement levels, where the engagement subdomains were treated as numerical variables. Treating engagement as numerical preserved the full range and variability of the scores, facilitating a more nuanced exploration of differences between groups. The Mann-Whitney U test, a robust non-parametric method suitable for comparing distributions of numerical data between two independent groups, was employed for this analysis (Gibbons & Chakraborti, 2020). By employing these complementary methodological approaches, the study ensured that each research question was addressed using the most appropriate statistical techniques, thereby enhancing the rigor and relevance of the findings.

To address the fourth research question, a thematic analysis was implemented, allowing middle school teachers to share their individual perspectives on their experiences in daily life (Gay et al., 2012). This method enabled teachers to express their understanding of the benefits of an all-girls school and how their teaching techniques influence female students' mathematical mindsets and gendered mathematical beliefs in such a setting. The focus of this approach was to describe rather than analyze the events, aligning with the objective of the last research question, which seeks to provide a detailed description of teachers' instructional actions in an all-girls classroom (Kim et al., 2017).

Data collected through interviews was analyzed using thematic analysis, following a series of systematic and structured steps. This included Familiarization with the Data, Generating Initial

Codes, Searching for Themes, Reviewing Themes, Defining and Naming Themes, and Producing the Report (Braun & Clarke, 2006; Creswell & Poth, 2017). The analysis focused on teachers' perceptions of the affordances of an all-girl school and the impact of special teaching techniques on middle school students' mathematical mindsets and gendered beliefs.

The first step involved transcribing the teachers' voices, recorded via an iPhone app, using the Otter website. Then, during Familiarization, the researcher read the transcripts multiple times to gain a deep understanding of the responses and documented initial impressions and recurring ideas. In the Generating Initial Codes stage, significant data features were identified that related to the research questions. Each interview question was coded separately, and key phrases, sentences, or paragraphs that captured important concepts about mathematical mindsets and gendered beliefs were highlighted and labeled. The codes served as descriptive markers of the content.

Next, the researcher organized the codes into broader themes by clustering related codes, which represented significant patterns in the data. This phase involved identifying commonalities and relationships among the codes to consolidate them into overarching concepts that provided deeper insights. In the Reviewing Themes stage, the researcher assessed and refined the themes to ensure they were clear, unambiguous, and representative of the data. A structured framework was created by systematically organizing the codes into themes, ensuring a thorough analysis of participants' perspectives (Braun & Clarke, 2006; Nowell et al., 2017).

Finally, in the Defining and Naming Themes stage, the researcher investigated each theme to write clear and accurate definitions that captured the essence of the data. Concise, descriptive names were assigned to each theme, ensuring they reflected the core idea or pattern within the theme, enhancing the clarity and interpretability of the findings (Nowell et al., 2017; Guest et al., 2012).

In the final stage of thematic analysis, a *report was generated* that organized and logically presented the themes that had been identified, utilizing direct quotations from the interview transcripts to elucidate each theme and substantiate the interpretations (Braun & Clarke, 2006). Additionally, it was extremely important for the researcher to guarantee that the report explicitly connects to the research questions, offering a glimpse into the teachers' perspectives on the advantages of all-girl schools and their instructional strategies that influence students' gendered beliefs and mathematical mindsets. This alignment with the research questions helped the relevance and significance of the findings, ensuring that the report not only presented the data but also addressed the research question posed by the study (Nowell et al., 2017; Guest et al., 2012).

Limitations

In educational research, limitations are the inherent constraints and potential shortcomings that may affect the generalizability, reliability, and validity of the research findings. These limitations may result from a variety of factors, such as the study context, sampling procedure, and methodology. It is essential to acknowledge these constraints, as it contextualizes the findings, impact the interpretation of results, and informs future research directions to address these constraints and develop a more profound understanding of the educational phenomena under investigation (Creswell & Creswell, 2018). In the subsequent paragraphs, the researcher outlines the constraints associated with this study.

Despite the precise design of this study, there are several inherent limitations that need to be acknowledged. One significant limitation pertains to the subjectivity and potential bias in self-reported measures of engagement. Students may respond to survey questions in ways they believe are expected or favorable rather than providing honest answers, a phenomenon known as social

desirability bias. This can skew the results and limit the survey's effectiveness in capturing true levels of engagement. Social desirability bias is particularly impactful in responses related to behavioral and affective engagement, where students might feel pressured to conform to perceived norms (Schwarz, 1999; Paulhus & Vazire, 2007).

Another limitation is the potential oversimplification of complex constructs by using only four items per subdomain in the engagement survey. Engagement is a multifaceted construct, and a limited number of questions may not fully capture the depth and breadth of students' cognitive, behavioral, and affective experiences. This simplification can lead to incomplete or inaccurate assessments, potentially overlooking important nuances and variations in engagement levels. Consequently, the findings may not provide an accurate picture of student engagement (Fredricks, Blumenfeld, & Paris, 2004).

The observational protocol, although offering real-time data on student behavior, also has possible limitations. The presence of an observer in the classroom may influence students' behavior, a phenomenon referred to as the Hawthorne effect, wherein students may behave differently only due to being observed (Reynolds & Kamphaus, 2015; Shapiro, 2011).

Another challenge associated with utilizing observation is that the observational protocol is both time-intensive and resource-demanding. Conducting 40 to 45-minute observation sessions in multiple classrooms requires significant time and effort from researchers. This can limit the number of observations that can be feasibly conducted, potentially reducing the generalizability of the findings. The analysis of recorded sessions requires meticulous attention and can be labor-intensive, adding to the overall resource demands of the study. These practical constraints might hinder the scalability of the observational method for larger studies or routine use in educational settings (Volpe & DiPerna, 2010).

In addition, the modified IAT, which uses the fixed reaction time for answering questions can disadvantage students with slower cognitive processing speeds or motor skills, leading to outcomes that do not accurately reflect their true biases. The stress and anxiety induced by strict time constraints can also affect performance, resulting in responses driven by the need to respond quickly rather than genuine implicit associations (Cvencek et al., 2011; DeLay et al., 2018).

Chapter 4: Results and Discussion

4.1 Introduction

The survey results reveal significant trends in female students' mathematical mindsets, gendered mathematical beliefs, and engagement within an all-girls mathematics classroom. The strong presence of growth mathematical mindsets and the high percentage of students associating mathematics with females present a distinct contrast to findings from studies conducted in co-educational settings. Broadly, students' cognitive, behavioral, and observable behavioral engagement were influenced by their mathematical mindsets and gendered mathematical beliefs; while teachers' gendered mathematical beliefs also influenced students' cognitive and behavioral engagement. Unique features of all-girls learning environments, such as the absence of boys, collaborative learning, and effort-based grading, appeared to promote growth-oriented mathematical mindsets and reduce gendered mathematical beliefs, fostering a supportive and empowering space for female students in mathematics.

4.2 Results and Discussion

Research Question 1

“ 1) In an all-girl school context, what are the mathematical mindsets, and the gendered mathematical beliefs that middle school girls hold? How do these compare to reports from the literature?”

Understanding the mathematical mindset of female students is important for fostering their academic success and choice of the STEM fields as future career choice. Addressing research question one, the researcher compares the mathematical mindsets of female students in co-educational (co-ed) settings [using the existing literature] with those in an all-girls middle school [using data of the present study]. In the first section, the researcher will provide the descriptive analysis of female students' mathematical mindset results in an all-girl school, then compare these findings with the existing literature on female students' mathematical mindsets in co-educational settings to highlight similarities and differences. In the second section, the result of female students' gendered beliefs about mathematics in an all-girl school will be provided by the researcher, then using the results of related literature conducted in co-ed settings, the researcher compares female students gendered mathematical beliefs in all-girl versus co-ed setting.

Mathematical Mindsets of female students in an all-girl school

The current study was conducted in an all-girl middle school, as a specific setting for exploring factors impacting female students' mathematical mindset and gendered mathematical beliefs. The survey results on the mathematical mindsets of 57 students, categorized based on their responses to six Likert-scale items, reveal insightful trends. Based on the results of the survey, students' mindsets were classified into four categories: Strong Fixed Mindset, Moderate Fixed Mindset, Moderate Growth Mindset, and Strong Growth Mindset. This classification allows the researcher to analyze the distribution and implications of different mathematical mindsets within the student cohort. The result of female students' mathematical mindset is presented in Figure 2.

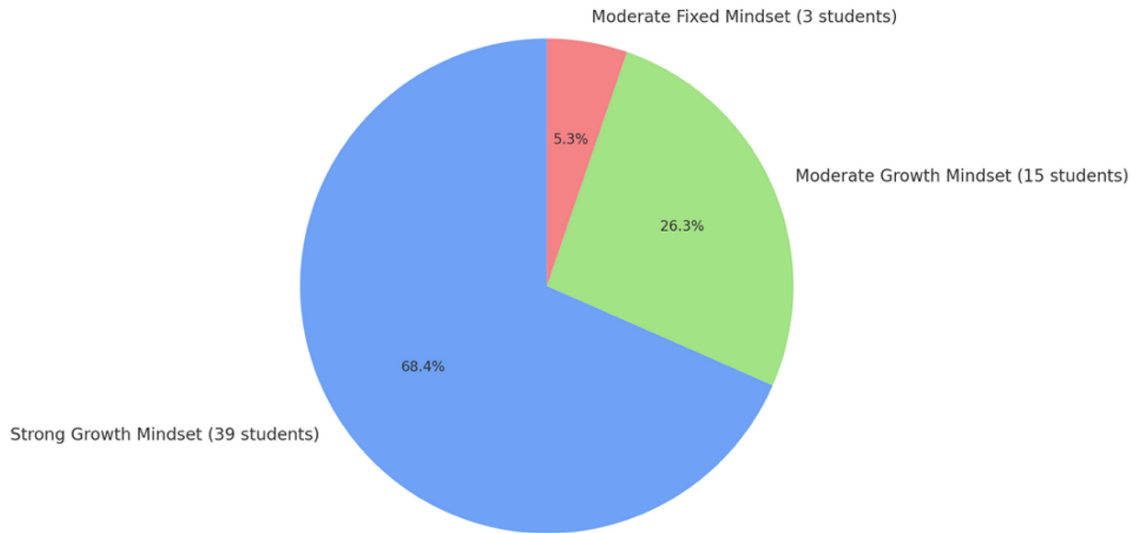


Figure 2 : Distribution of Students by Mathematical Mindset Categories

- **Strong Growth Mindset: 68.4% (39 students)**
- **Moderate Growth Mindset: 26.3% (15 students)**
- **Moderate Fixed Mindset: 5.3% (3 students)**
- **Strong Fixed Mindset: 0% (0 students)**

Mathematical Mindsets of female students in an all-girl vs. co-ed setting

In co-educational contexts, the mathematical mindsets of female students often diverge from the findings of the present study. Research indicates that a significant proportion of female students in co-ed settings are likely to adopt fixed mindsets regarding their mathematical abilities, particularly at the middle school level, though exact percentages are not specified in some studies (Boaler et al., 2018; Heyder et al., 2020; Todor, 2014; Romero et al., 2014). Boys, in contrast, more frequently adopt growth mindsets, perceiving their mathematical abilities as improvable through effort and persistence. This mindset fosters greater resilience in overcoming challenging

problems and increases the likelihood of their enrollment in advanced mathematics courses (ex., Boaler, 2013; Heyder et al., 2020).

In co-educational environments, female students are more likely to develop a fixed mindset towards mathematics, seeing their intelligence as unchangeable. This perception can elevate math anxiety and lead to a reluctance to engage in challenging math tasks, contributing to a gender performance gap (Gunderson et al., 2012). Evidence from multiple studies, including Verniers and Martinot (2015) [68%], Dweck (2007) [about 50%], and Good et al. (2012) [about 55%], reflects a majority of female students in co-ed environments exhibiting fixed mindsets. In contrast, the current study found that 68% of female students held a strong growth mindset in mathematics, 26% had moderate growth mindsets, and only about 5% exhibited moderate fixed mindsets, highlighting a striking difference. (See Figure 3.)

Several studies suggest that teachers may unintentionally reinforce fixed mindsets among female students through less encouraging feedback, subtly conveying that their efforts would not yield improvement. This lack of positive reinforcement can deter female students from pursuing advanced math and STEM pathways, ultimately widening the gender gap in these fields (Verniers & Martinot, 2015). The findings of the current study, however, indicate a higher prevalence of growth mindsets among female students, suggesting potential progress in fostering resilience in mathematics and a greater likelihood of future STEM career choices.

Additional studies have shown that external influences, such as the attitudes of adults (teachers and parents) and classroom environments, can reinforce a belief that boys are innately more skilled in mathematics, discouraging girls from active participation and risk-taking in math-related tasks (Todor, 2014). Consistently, researchers found the same results across various

educational levels. At the high school level (Mendick, 2005) and college level (Good, Rattan, & Dweck, 2012), noting that female students often reported a reduced sense of belonging in mathematics. This sense of exclusion, associated with a fixed mindset, led to lower confidence and reduced interest in math-related careers, despite equivalent performance to male students. Conversely, male students commonly internalized societal beliefs portraying them as naturally adept at mathematics, resulting in greater confidence and a growth mindset that emphasized improvement through effort. Meanwhile, female students frequently encountered gendered messages that discouraged them from viewing mathematics as their domain, fostering a fixed mindset and undermining their self-confidence. However, in contrast to these trends, the current study in an all-girls middle school found 68% of female students demonstrating strong growth mindsets, 26% with moderate growth mindsets, and only 5% with moderate fixed mindsets.

It is also worth noting that, contrary to the findings of studies highlighting gender differences in mathematical mindsets within co-educational settings, some research has observed no significant differences in mindset levels between male and female students. For example, Romero et al. (2014) found no substantial gender differences among middle school students (48 males, 67 females) in the United States, indicating that gender may not universally dictate mindset disparities in mathematics.

In light of these findings, the current study suggests that single-gender educational environments may provide unique benefits by supporting and fostering a growth-oriented mindset in mathematics. This setting may promote a more supportive atmosphere where female students can embrace the malleability of intelligence, ultimately enhancing their engagement and confidence in math-related tasks.

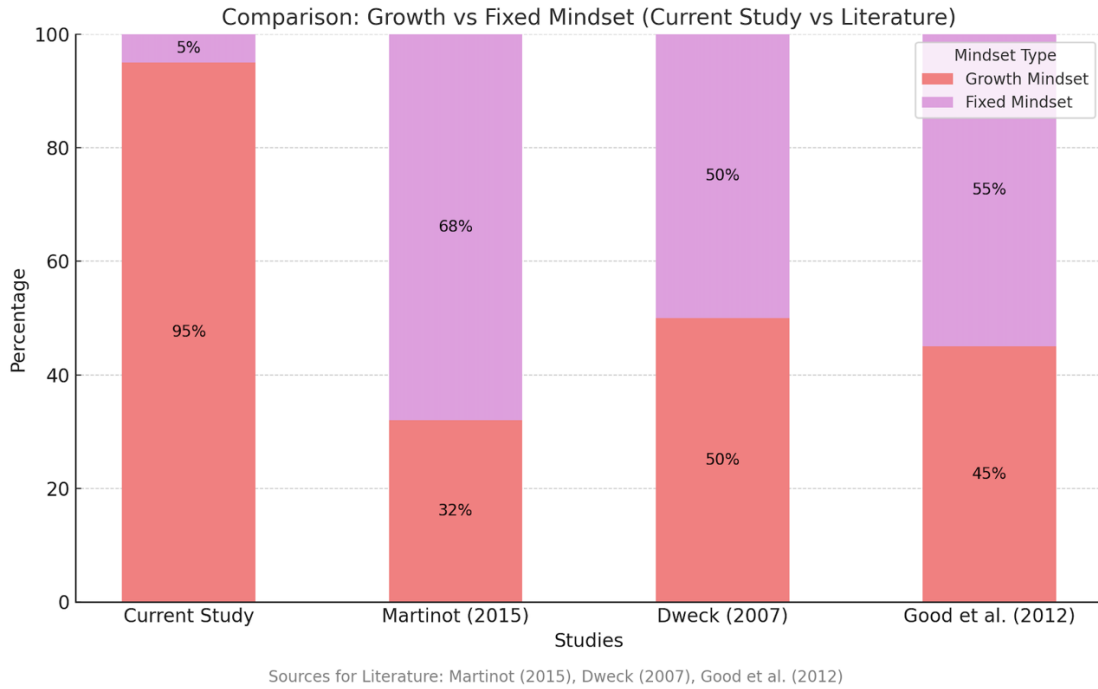


Figure 3: Female Students’ Mathematical Mindset in All-Girl VS. Co-Ed

Gendered Mathematical Beliefs of female students in an all-girl school

Understanding the gendered mathematical beliefs of female students in an all-girl school is essential for understanding how these girl students perceive their role in STEM fields, particularly in mathematics and science. This section uses descriptive analytics of the collected data from the modified IAT test, to explore the gendered mathematical beliefs among female students, in an all-girl private middle school. Figure 4 presents the primary results.

Associations with Science/Math for Females

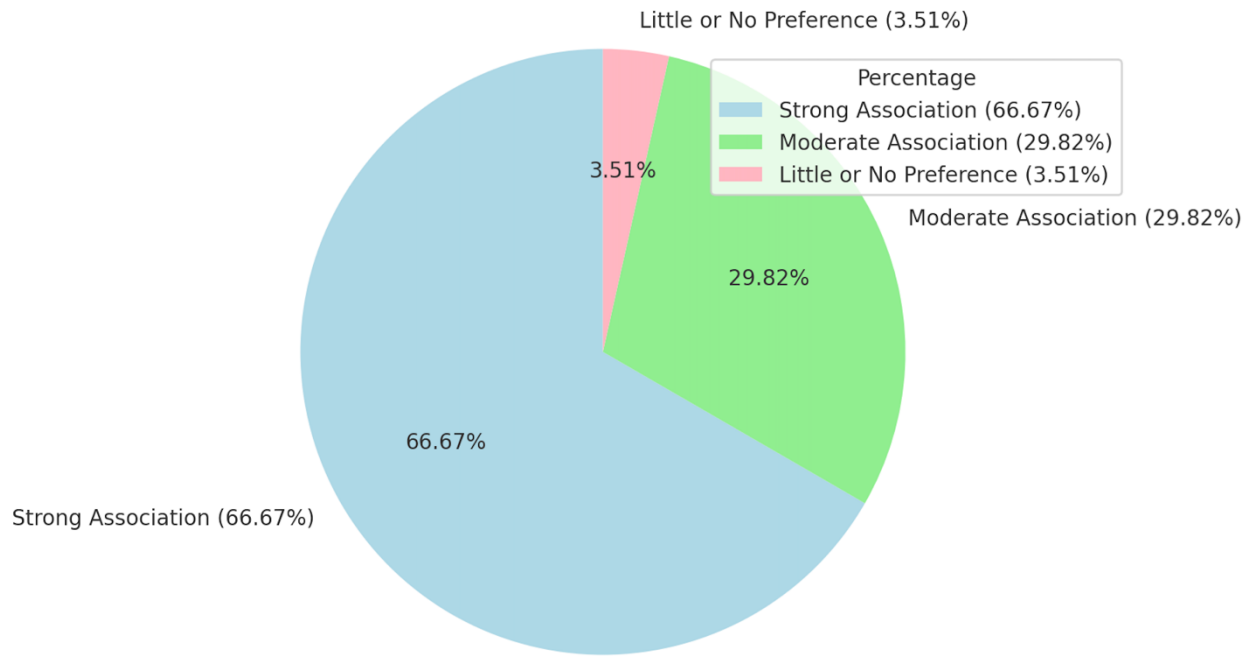


Figure 4: Result of students' Gendered Mathematical Beliefs in All-Girl

- Strong Association with Science/Math for Females: 66.67% (38 students)
- Moderate Association with Science/Math for Females: 29.82% (17 students)
- Little or no preference: 3.51% (2 students)
- Moderate Association with Science/Math for Male: 0% (0 Students)
- Strong Association with Science/Math for Male: 0% (0 Students)

The data suggest that the all-girls school environment is effective in fostering non-stereotypical gender beliefs in the majority of students, promoting greater gender equity in STEM. However, the presence of students with moderate beliefs or little preference highlights the importance of recognizing individual differences. While single-gender settings can be empowering for many, it is crucial for educational systems to continue supporting all students in developing their own, positive identity in relation to STEM, encouraging inclusivity and diversity in thought.

Analyzing these beliefs through a qualitative lens reveals the complex interplay between educational environment, mathematical mindset, and gendered mathematical beliefs. The strong associations observed in the majority of students suggest that all-girl schools provide a supportive environment for developing non-stereotypical beliefs. The single-sex schools likely foster a sense of belonging and empowerment in STEM fields that might not be as prevalent in co-educational settings.

Moreover, the presence of moderate associations and the lack of strong preference among some students highlight the diversity of thought within this setting. It suggests that while the environment supports the decrease in common social beliefs and norms resulting in minimizing students' gendered beliefs about mathematics, it also allows for a range of perspectives, providing students with the freedom to form their own mindset and gendered beliefs in relation to mathematics.

In conclusion, the data from this all-girl school suggests that the educational environment plays an essential role in shaping gendered mathematical beliefs. The strong association between women and science observed in the majority of students indicates that single-gender schools can effectively challenge traditional gender norms and promote greater gender equity in STEM fields. However, the presence of varied beliefs also emphasizes the importance of individual differences and the need for educational approaches that support all students in developing a positive and empowering identity in relation to STEM.

Gendered Mathematical Beliefs of female students in an all-girl vs. co-ed setting

The level of gendered beliefs about mathematics among female students varies significantly depending on the educational environment. In co-ed middle schools, gendered beliefs about math are often more salient and common, with many female students internalizing the belief that math is a male-dominated field. In contrast, the data of the current study conducted in a private, all-girls middle school reveals a notably different trend, with students demonstrating a strong association between mathematics and females. This section compares the level of gendered beliefs about mathematics between female students in co-ed schools using the relevant literature and those in this specific all-girls private school, exploring the differences between these two settings.

Single-sex schools provide an environment that significantly reduces gendered beliefs about mathematics among female students. For instance, Hyde et al. (2008) found that only 25% of girls in single-gender schools believed that mathematics was a male-dominated field, compared to nearly 40% of girls in coeducational schools. Similarly, the data from the present study shows that 66.67% of female students across three classes in a single-sex school exhibit a strong association with science for females, indicating that the single-gender environment fosters non-stereotypical beliefs about mathematics and science. This finding reinforces the idea that single-sex environments can play a crucial role in minimizing gendered mathematical beliefs, helping female students to view STEM fields as equally accessible to both genders.

On the other hand, Cimpian, Lubienski, and Ganley (2016) demonstrated that girls in coeducational settings are more likely to internalize the belief that mathematics is for boys, with over 35% of female students subscribing to this gendered belief by the middle school years. This is a huge contrast to the present study, where only 3.51% of students in a single-sex environment demonstrated little or no preference in their gendered mathematical beliefs, showing minimal

endorsement of traditional gender beliefs about STEM including mathematics. The findings suggest that single-gender schools may offer a more supportive environment for dismantling these gendered beliefs, compared to coeducational schools, where such beliefs are more commonly internalized.

Despite the fact that coeducational institutions have the potential to reduce gendered beliefs about mathematics through targeted interventions, as demonstrated in certain studies (Robinson-Cimpian et al., 2014), the level of gendered beliefs among female students—even after intervention—is still not comparable to the results of a single-sex setting. Robinson-Cimpian et al. (2014) found that with the right support, the percentage of girls in coeducational settings who hold these gendered beliefs can be reduced by 15-20%. While these interventions are essential, the data from the present study suggests that single-gender schools naturally provide an environment that minimizes gendered beliefs more effectively, with only 3.51% of students showing little or no preference regarding gender roles in science. This indicates that single-gender schools may offer a more inherently supportive environment for dismantling stereotypes, highlighting the need for more targeted strategies in coeducational settings to match the impact seen in single-gender environments.

Research in this area consistently shows that female students in all-girls schools are less likely to internalize gendered beliefs about mathematics compared to their peers in co-ed schools. For instance, Herr and Turner (2013) found that female students in single-gender settings exhibited higher confidence in their math abilities and were less likely to associate mathematics with males, aligning with the current study's findings in an all-girls private middle school. Conversely, female students in co-educational settings often face implicit biases and classroom dynamics that reinforce

the perception that math is a male-dominated field. Studies such as Hyde et al. (2008) and Nosek & Smyth (2011) highlighted that female students in co-ed environments are more prone to self-doubt due to gendered biases and lower confidence in their math abilities.

Classroom interactions can further contribute to the issue, as boys are often more likely to lead discussions or show less receptiveness to girls' contributions, as highlighted by Robinson-Cimpian et al. (2014). This social dynamic can perpetuate a culture where math is implicitly seen as more suitable for boys. In addition, Riegle-Crumb and Morton (2017) observed that peer interactions in co-ed schools reinforce gendered beliefs, leading many girls to feel out of place in math-related activities. While specific percentages of female students holding these gendered beliefs are not provided in these studies (Herr and Turner, 2013 ; Nosek & Smyth, 2011; Riegle-Crumb and Morton, 2017), the evidence suggests that co-educational environments can present additional challenges in overcoming these gendered beliefs about mathematics, though proactive interventions can help mitigate these effects (Schiebinger et al., 2018).

In conclusion, female students in single-gender schools exhibit significantly lower levels of gendered beliefs about mathematics compared to those in co-educational settings. The present study shows that 96.5% of girls in an all-girls school associate science with women [Strongly and Moderately], and while co-ed environments often reinforce traditional gendered beliefs. Although co-educational schools can reduce these beliefs with targeted interventions, the impact is generally more pronounced in single-gender settings, which naturally provide a more supportive environment for challenging gendered mathematical beliefs.

Figure 5 provides a comparative representation of gendered beliefs about mathematics among female students across various studies in co-ed [literature]and single-sex [current study]

setting. It emphasizes the extent to which mathematics is associated with females, presenting percentages. Notably, the present study, conducted in an all-girls private middle school, reports that 96.5% of female students demonstrate a strong association of mathematics/science with females, significantly surpassing the 3.5% of students who exhibited little or no preference in this setting. This finding contrasts with earlier research in coeducational settings, such as Hyde et al. (2008), which documented 25% of students in single-gender schools holding similar associations, and Cimpian et al. (2016), which identified 35% of female students in co-educational schools associating mathematics with females. Even with targeted interventions, as reported by Robinson-Cimpian et al. (2014), the proportion of students associating mathematics with females in co-educational environments reached only 85%. These results suggest the potential role of single-gender schools in mitigating traditional gender beliefs about mathematics among female students, highlighting a stark contrast with the outcomes observed in co-educational settings.

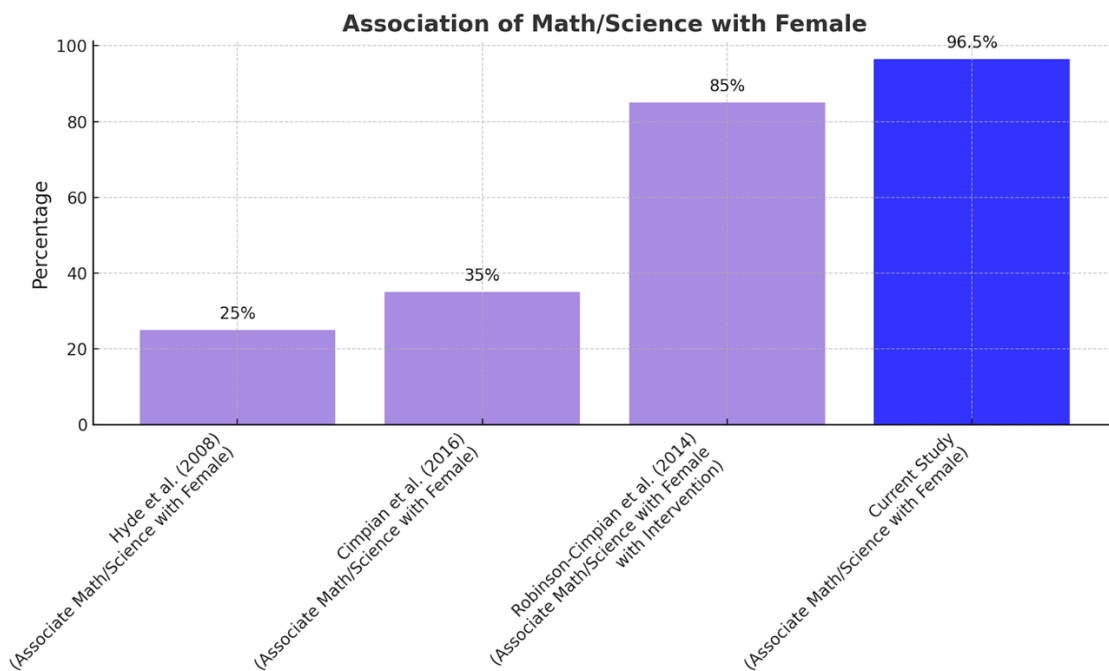


Figure 5: Female Students' Gendered Mathematical Beliefs in All-Girl VS. Co-Ed

Research Question 2

“2) How do individual girl’s engagements (both self-reported engagement and observed behavioral engagement) relate to their mathematical mindsets and gendered mathematical beliefs?”

To answer the second research question, using the SPSS software, the *Chi-Squared test* was conducted to examine the main effects of students’ mathematical mindset and gendered mathematical beliefs on each of the four dimensions of engagement (see Table 1 for detailed results). The *Chi-Squared test* is an appropriate statistical method for this research question, as it investigates the relationship between categorical independent and dependent variable (Creswell & Creswell, 2018). Tables 2-5 and Tables 6-9 provide more detailed counts for each of the variable pairs being tested. Although some cell counts were less than the recommended number of 5, this seemed connected to the relatively small number of participants; limitations are discussed in the last chapter.

Variable Pair	Chi-Squared (χ^2)	P-Value
Cognitive * Mindset level	8.169	0.017
Behavioral * Mindset	9.098	0.011
Affective * Mindset Level	1.091	0.579
Observable Behavioral * Mindset	3.568	0.468
Cognitive* Gendered Beliefs	10.197	0.006
Behavioral * Gendered Beliefs	11.751	0.003
Affective * Gendered Beliefs	2.233	0.327
Observable Behavioral *Gendered Beliefs	17.390	0.002

Table 1: Result of Chi-Squared Test

Mindset Level * Cognitive Crosstabulation

Count

		Cognitive		Total
		Moderate	High	
Mindset Level	Moderate Fixed	0	3	3
	Moderate Growth	4	11	15
	Strong Growth	1	38	39
Total		5	52	57

Mindset Level * Behavioral Crosstabulation

Count

		Behavioral		Total
		Moderate	High	
Mindset Level	Moderate Fixed	0	3	3
	Moderate Growth	6	9	15
	Strong Growth	3	36	39
Total		9	48	57

Mindset Level * Affective Crosstabulation

Count

		Affective		Total
		Moderate	High	
Mindset Level	Moderate Fixed	0	3	3
	Moderate Growth	4	11	15
	Strong Growth	8	31	39
Total		12	45	57

Mindset Level * Observable Crosstabulation

Count

		Observable			Total
		Low	Moderate	High	
Mindset Level	Moderate Fixed	1	1	1	3
	Moderate Growth	1	9	5	15
	Strong Growth	2	22	15	39
Total		4	32	21	57

*Tables 2-5: Crosstabulation Tables[Mathematical Mindset * Engagement Level*

Gendered Beliefs * Behavioral Crosstabulation

Count

		Behavioral		Total
		Moderate	High	
Gendered Beliefs	Little or No Preference	0	2	2
	Moderate Association with Science for Females	6	7	13
	Strong Association with Science for Females	3	39	42
Total		9	48	57

Gendered Beliefs * Cognitive Crosstabulation

Count

		Cognitive		Total
		Moderate	High	
Gendered Beliefs	Little or No Preference	0	2	2
	Moderate Association with Science for Females	4	9	13
	Strong Association with Science for Females	1	41	42
Total		5	52	57

Gendered Beliefs * Affective Crosstabulation

Count

		Affective		Total
		Moderate	High	
Gendered Beliefs	Little or No Preference	1	1	2
	Moderate Association with Science for Females	4	9	13
	Strong Association with Science for Females	7	35	42
Total		12	45	57

Gendered Beliefs * Observable Crosstabulation

Count

		Observable			Total
		Low	Moderate	High	
Gendered Beliefs	Little or No Preference	0	1	1	2
	Moderate Association with Science for Females	0	2	11	13
	Strong Association with Science for Females	4	29	9	42
Total		4	32	21	57

*Table 6-9: Crosstabulation Tables [Gendered Mathematical Belief * Engagement Levels]*

The Chi-Square analysis highlights significant associations between Mindset Level and Cognitive Engagement ($\chi^2 = 8.169$, $p = 0.017$) and Behavioral Engagement ($\chi^2 = 9.098$, $p = 0.011$), suggesting that a stronger growth mindset is linked to higher engagement in these areas. However, no significant associations were found between Mindset Level and Affective or Observational Behavioral Engagement ($p = 0.579$ and $p = 0.468$, respectively).

Regarding gendered mathematical beliefs, significant positive associations were observed with Cognitive Engagement ($\chi^2 = 10.197$, $p = 0.006$) and Behavioral Engagement ($\chi^2 = 11.751$, $p = 0.003$), indicating that stronger gendered beliefs, reflecting a higher association of science with females, are linked to increased engagement in these dimensions. Conversely, Observational Behavioral Engagement exhibited a significant negative association with gendered beliefs ($\chi^2 = 17.390$, $p = 0.002$), suggesting that a higher association of science with females correlates with decreased observable engagement. Affective Engagement, however, showed no significant relationship with gendered beliefs ($p = 0.327$). It should be noted that the small sample size of 57 participants could also contribute to the non-significant Linear-by-Linear Association value, as smaller samples often reduce the statistical power needed to detect linear trends or subtle associations between variables (Field, 2013).

Impact of Female Students' Mathematical Mindset and Gendered Beliefs on Cognitive Engagement

The Chi-Squared test results revealed significant effects for both Mathematical Mindset and Gendered Mathematical Beliefs on Cognitive Engagement. The Pearson Chi-Squared value for Mathematical Mindset was 8.169, with a p-value of 0.017, indicating a strong positive

relationship between mathematical mindset and cognitive engagement. This suggests that students with a growth mindset—those who believe that their mathematical intelligence can improve with effort and persistence—are more cognitively engaged in learning mathematics. These students are more likely to approach challenges as opportunities to learn rather than obstacles, leading to deeper and more sustained engagement with mathematics. Cognitive engagement involves processes such as attention, concentration, and a deep understanding of mathematical concepts, and students with a growth mindset tend to invest significant mental effort in understanding complex problems.

Similarly, Gendered Mathematical Beliefs also had a significant positive effect on cognitive engagement, with a Pearson Chi-Squared value of 10.197 and a p-value of 0.006. This finding suggests that female students who strongly associate mathematics with females (higher levels of gendered mathematical beliefs) are more cognitively engaged in mathematics. In contrast, female students who internalize gendered beliefs and associate math with males, may experience reduced cognitive engagement due to the belief in their inherent mathematical inferiority.

Impact of Female Students' Mathematics Mindset and Gendered Mathematical Beliefs on Behavioral Engagement

Mathematical Mindset had a significant effect on Behavioral Engagement, as indicated by a Pearson Chi-Squared value of 9.098 and a p-value of 0.011. This suggests that students with a stronger growth mindset—those who believe that mathematical intelligence can grow with effort—are more likely to be behaviorally engaged in the classroom. These students actively participate in classroom activities, discussions, and assignments, likely driven by the belief that their efforts will lead to improvement and success in mathematics. Such a mindset fosters persistence and enthusiasm, motivating students to engage more fully in learning activities.

Similarly, Gendered Mathematical Beliefs also showed a significant effect on Behavioral Engagement, with a Pearson Chi-Squared value of 11.751 and a p-value of 0.003. Students with higher levels of gendered beliefs—reflecting a stronger association of mathematics with females—exhibit increased behavioral engagement. This positive association suggests that viewing mathematics as a female domain may encourage female students to take an active role in classroom learning, participating more consistently in tasks and collaborative activities. Such beliefs can provide a sense of belonging and empowerment, enhancing their overall engagement in the classroom.

Impact of Female Students' Mathematical Mindset and Gendered Mathematical Beliefs on Affective Engagement

The Chi-Squared results showed that Mathematical Mindset did not have a statistically significant effect on Affective Engagement. The test results, with a Pearson Chi-Squared value of 1.091 and a p-value of 0.579, suggest that a student's belief in the malleability of their mathematical intelligence does not significantly influence their emotional engagement, such as interest, enjoyment, or sense of belonging in the mathematics classroom.

Similarly, Gendered Mathematical Beliefs did not significantly impact affective engagement, with a Pearson Chi-Squared value of 2.233 and a p-value of 0.327. This finding highlights the complexity of affective engagement, suggesting that other factors beyond mathematical mindset and gendered mathematical beliefs, such as the classroom environment or personal experiences, may play a larger role in shaping students' emotional engagement.

Impact of Female Students' Mathematical Mindset and Gendered Mathematical Beliefs on Observable Behavioral Engagement

As demonstrated by the result of the Chi-Squared test, Mathematical Mindset did not have a statistically significant effect on Observable Behavioral Engagement, with a Pearson Chi-Squared value of 3.568 and a p-value of 0.468, suggesting that students' mindset about mathematical intelligence being malleable may not directly translate into observable behaviors like hand-raising or asking questions.

In contrast, Gendered Mathematical Beliefs had a significant negative impact on Observable Behavioral Engagement, with a Pearson Chi-Squared value of 17.390 and a p-value of 0.002. This indicates that students' stronger association of mathematics with females appeared to negatively influence their observable behaviors in the classroom, such as actively participating by asking questions or raising hands. This result contrasts with the positive relationship found between gendered mathematical beliefs and (self-reported) behavioral engagement.

Conclusion

In summary, the Chi-Squared test results revealed that both Mathematical Mindset and Gendered Mathematical Beliefs significantly influence key aspects of student engagement, particularly Cognitive and Behavioral Engagement. Students with a growth mindset and those with stronger associations of mathematics with females exhibited higher levels of cognitive and behavioral engagement. Specifically, the results show that students' Mathematical Mindset has a significant influence on Cognitive Engagement ($p = 0.017$) and Behavioral Engagement ($p =$

0.011). This highlights the role of a growth mindset in enhancing students' mental and active involvement in learning mathematics. Students who view challenges as opportunities for growth are more likely to engage deeply with mathematical content, ask questions, and persist in problem-solving tasks.

In addition, students' Gendered Mathematical Beliefs significantly impact Cognitive Engagement ($p = 0.006$), Behavioral Engagement ($p = 0.003$), and Observable Behavioral Engagement ($p = 0.002$). However, while stronger associations of mathematics with females positively influenced cognitive and behavioral engagement, they negatively affected observable behavioral engagement. This suggests that students who view mathematics as more closely aligned with females may struggle with visible classroom participation, such as raising hands or asking questions, potentially due to conflicting social norms or expectations.

However, Affective Engagement did not show a statistically significant relationship with either Mathematical Mindset ($p = 0.579$) or Gendered Mathematical Beliefs ($p = 0.327$). This suggests that students' emotional connection to mathematics, such as their interest, enjoyment, or sense of belonging, may be driven by factors outside of mindset and gender beliefs. Classroom environment, teacher support, peer dynamics, and personal experiences may have a more substantial impact on students' affective engagement. Although fostering a growth mindset and reducing gendered beliefs are important, addressing emotional engagement requires a more extensive approach involving emotional support and a positive classroom culture.

Finally, Observable Behavioral Engagement (e.g., raising hands, asking questions) was significantly influenced by Gendered Mathematical Beliefs ($p = 0.002$), but not by Mathematical Mindset ($p = 0.468$). Notably, stronger gendered beliefs associating females with mathematics were negatively associated with active classroom participation, as students with such beliefs were more likely to exhibit moderate rather than high engagement levels. This highlights that gendered beliefs play a critical role in shaping visible classroom behaviors, while students' perceptions of the malleability of mathematical intelligence may not directly translate into observable active participation. These findings underscore the impact of societal norms and expectations on classroom behaviors, emphasizing the importance of addressing these factors to foster an environment where all students feel confident and encouraged to actively engage.

Research Question 3

“ 3) In an all-girl mathematics classroom, how does the engagement of a typical student in the class (both self-reported engagement and observed behavioral engagement) relate to the teachers' mathematical mindsets and gendered mathematical beliefs?”

To investigate how the engagement of students in an all-girl mathematics classroom relates to teachers' mathematical mindsets and gendered mathematical beliefs, a *Mann-Whitney U Test* was utilized (see Table 10 for detailed results). This non-parametric test is ideal for comparing differences between two independent groups when the dependent variable is either ordinal or continuous [while not necessarily assuming normal distribution]. In this study, the dependent variables were various subdomains of student engagement (cognitive, behavioral, affective, and

observational), while the independent variable was the teacher's Gendered Mathematical Belief, with the results categorized as either Moderate Association with Science for Females or Strong Association with Science for Females.

Why Teachers' Mindsets Were Not Considered

In this study, Teachers' Mathematical Mindset was not included as a variable due to the lack of variability in this factor across the three teachers. All teachers in the dataset shared the same level of mathematical mindset, specifically a Strong Growth Mindset. In this case, since all three teachers held the same mindset, it would have been redundant to include this variable in the analysis, as there was no variation in mathematical mindset levels of the teachers that could explain differences in student levels of engagement in four subdomains.

When all teachers share the same mathematical mindset, it becomes impossible to measure its effects using traditional statistical methods, as there is no contrast or comparison group. Including a variable with no variation would not provide meaningful insights or contribute to the model's explanatory power. Thus, the focus was placed on Teacher's Gendered Beliefs, where variability existed, to better understand how different gendered associations with science might affect student engagement. Given that mindset is held constant, this also allows for a cleaner interpretation of the impact of Gendered Mathematical Beliefs, without the confounding influence of varying mindsets.

In conclusion, the analysis using the Mann-Whitney U Test revealed that while Cognitive and Behavioral Engagement of students in an all-girl mathematics classroom were significantly influenced by teachers' Gendered Mathematical Beliefs, both Affective and Observable Behavioral

Engagement were not notably impacted. Students taught by teachers with a Strong Association with Science for Females demonstrated slightly lower levels of cognitive and behavioral engagement in the classroom compared to those with teachers holding a Moderate Association. These findings suggest that while emotional involvement and observable classroom engagement may be more stable and less dependent on external influences, students' cognitive and behavioral engagement behaviors appear to be significantly shaped by the gendered beliefs of their teachers.

Engagement Subdomain	Null-Hypothesis	P-value	Z-value	Effect Size = r	Significant Difference	Decision
Cognitive Engagement	The distribution of Cognitive Engagement is the same across categories of Teachers' Gendered Mathematical beliefs	0.039	-2.069	-0.274	Yes	Reject the null Hypothesis
Behavioral Engagement	The distribution of Behavioral Engagement is the same across categories of Teachers' Gendered Mathematical beliefs	0.010	-2.575	-0.341	Yes	Reject the null Hypothesis
Affective Engagement	The distribution of Affective Engagement is the same across categories of Teachers' Gendered Mathematical beliefs	0.050	-1.958	-0.259	No	Retain the null Hypothesis
Observational Engagement	The distribution of Observable Behavioral Engagement is the same across categories of Teachers' Gendered Mathematical beliefs	0.076	1.776	0.235	No	Retain the null Hypothesis

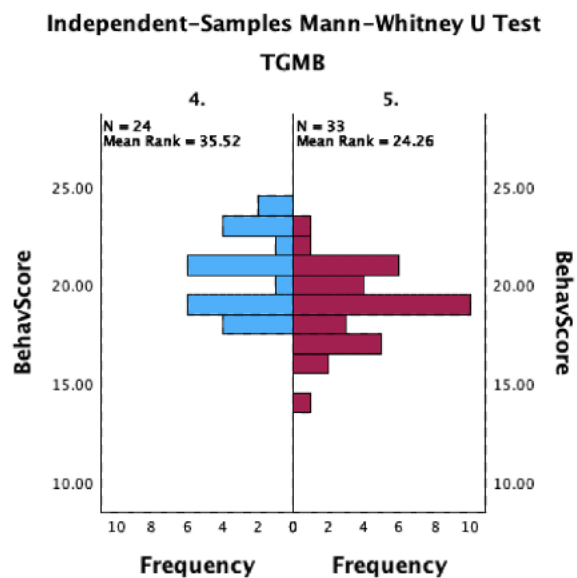
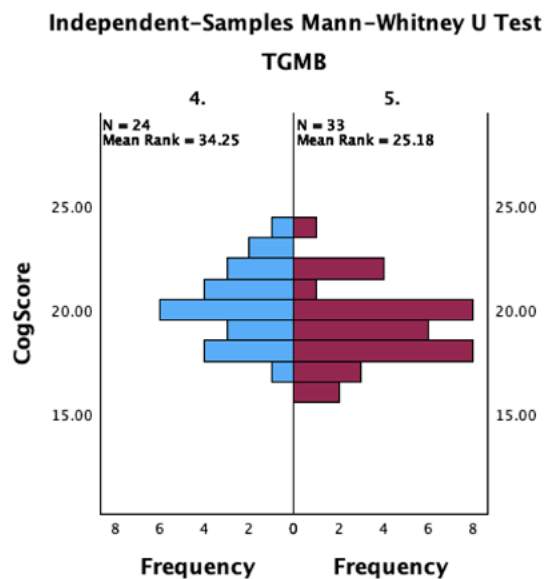
Table 10: Result of Mann-Whitney U Test

Cognitive and Behavioral Engagement

The Mann-Whitney U test results indicate statistically significant differences in *Behavioral Engagement* ($p=0.010$, $r=-0.341$) and *Cognitive Engagement* ($p=0.039$, $r=-0.274$) across categories of teachers' Gendered Mathematical Beliefs. These findings suggest that students' cognitive and behavioral engagement levels are influenced by the teacher's association of science

with females/male. The negative direction of the association [negative effect sizes (r)] indicates that stronger associations of science with females by teachers are linked to slightly lower levels of both behavioral and cognitive engagement among students. Tables 11-12 provide the associated distributions.

It is important to note that while these differences are statistically significant, the effect sizes are modest. Using cutoffs for r of less than 0.3 for small, between 0.3 and 0.5 for medium, and greater than 0.5 for large, the effect sizes are small-medium for Behavioral Engagement and small for Cognitive Engagement, indicating modest practical differences between the groups. This suggests that while teachers' gendered beliefs do exert an influence, the overall magnitude of their impact on cognitive and behavioral engagement is limited. One possible explanation is that teachers who more strongly associate science/math with females may foster an environment that actively encourages student involvement and promotes strategic learning behaviors slightly more. Such teachers may, either consciously or unconsciously, cultivate a more inclusive and supportive classroom atmosphere, positively influencing students' willingness to participate in class and invest effort in learning tasks.



Figures 6-7: Mann-Whitney U Test's mirrored histograms for Cognitive & Behavioral Engagement

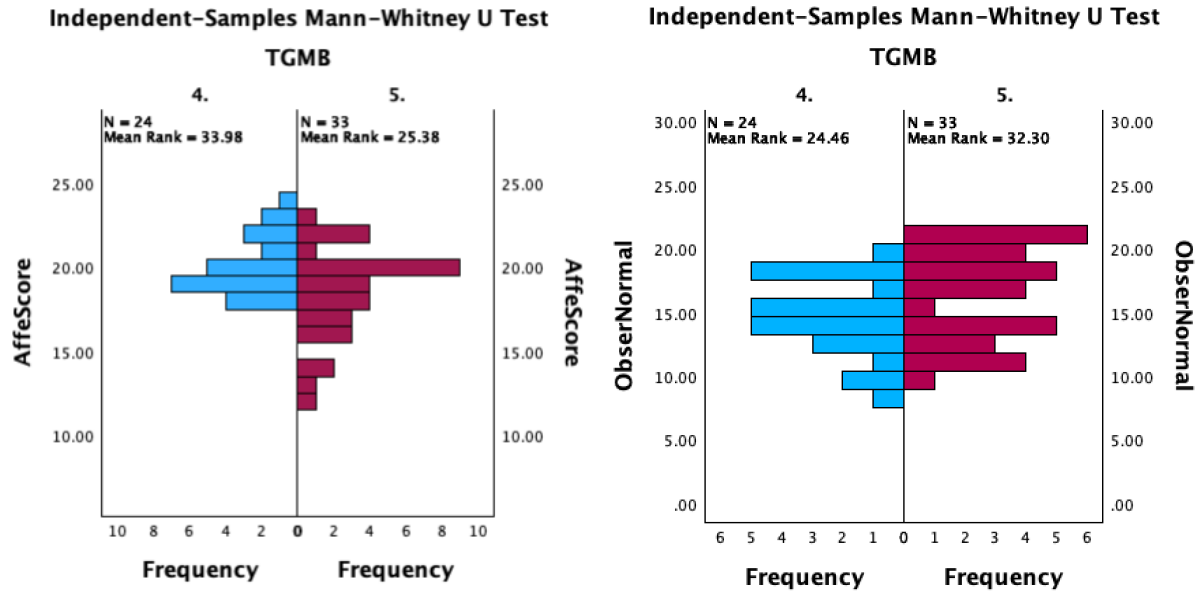
(5=Strong Association of Female with Science/Math; 4=Moderate Association of Female with Science/Math)

- TGMB= Teachers' Gendered Mathematical Beliefs
- CogScore = Numerical Value of Cognitive Engagement
- BehavScore= Numerical Value of Behavioral Engagement

Affective and Observational Engagement

Conversely, the Mann-Whitney U test results for Affective Engagement ($p = 0.050$) and Observational Engagement ($p = 0.076$) reveal no statistically significant differences across teachers gendered mathematical beliefs' categories. Affective engagement, which reflects students' emotional responses to learning, including interest, enthusiasm, and emotional involvement in the subject matter, appears unaffected by the teacher's gendered beliefs. Similarly, observational engagement, or the degree to which students' engagement is externally observable by the teacher, also shows no significant variation across teachers' gendered mathematical categories.

It should be also noted that although for *Affective Engagement* ($p=0.050$, $r=-0.259$) and *Observational Behavioral Engagement* ($p=0.076$, $r=0.235$), no statistically significant differences were observed. However, the p-values for both subdomains were close to the threshold of significance, and the effect sizes were small. These findings suggest that the impact of teachers' gendered beliefs on these subdomains is relatively minor and may require further exploration. Overall, while the results highlight the role of teacher beliefs in shaping engagement, the small effect sizes reinforce the importance of considering other potential influences, such as instructional practices, classroom dynamics, and individual student factors, in understanding the complexity of student engagement in all-girls' classrooms. Tables 13-14 provide the associated distributions.



Figures 8-9: Mann-Whitney U Test's mirrored histograms for Affective & Observable Behavioral Engagement (5=Strong Association of Female with Science/Math; 4= Moderate Association of Female with Science/Math)

- TGMB= Teachers' Gendered Mathematical Beliefs
- AffeScore = Numerical Value of Affective Engagement
- ObserNormal= Normalized Numerical Value of Observable Behavioral Engagement

Conclusion

In conclusion, the Mann-Whitney U Test analysis revealed that Cognitive and Behavioral Engagement among students in an all-girls mathematics classroom were significantly influenced by teachers' Gendered Mathematical Beliefs, while Affective and Observational Engagement showed no significant differences across these beliefs. Students taught by teachers with a Strong Association with Science for Females exhibited slightly lower levels of cognitive effort and observable participation compared to those with teachers holding a Moderate Association. These findings suggest that cognitive and behavioral engagement are more susceptible to teacher beliefs,

indicating that students' intellectual and active involvement in learning may be influenced by gendered beliefs and messages in the mathematics classroom.

Additionally, Teacher's Mindset was not included as a variable in this analysis because all teachers shared the same Strong Growth Mindset. Since there was no variability in mindset across the sample, it could not be used as an indicator in the statistical model. This allowed the focus to be placed solely on Gendered Beliefs, providing more meaningful insights into how these beliefs influence different aspects of student engagement. This highlights the importance of fostering gender-equitable beliefs in science and mathematics education, as these attitudes directly impact students' emotional and behavioral engagement in the classroom.

Research Question 4

“4) What are the perceived affordances [from teachers] of an all-girl school context which are influencing middle school girls' mathematical mindsets, and gendered mathematical beliefs? What instructional actions, in general, do the teachers feel like help improve girls' mathematical mindsets, and gendered mathematical beliefs?”

This section explores the perceived affordances of an all-girls school context, as identified by teachers, which influence middle school girls' mathematical mindsets and gendered beliefs about mathematics. Additionally, it explores the instructional techniques that teachers perceive as effective in enhancing these factors, providing valuable insights into how these learning settings foster the cultivation of a growth mathematical mindset and mitigate gender-based beliefs among young female students in the field of mathematics.

The researchers conducted face-to-face interviews with each teacher to collect data for addressing the last research question. The interview questions were responded by the teachers and collected by the researcher using the recorded voices. Using thematic analysis, the responses were

coded and analyzed, and the fourth research question was addressed. Table 15 presents a categorization of teachers' responses in accordance with the objective themes associated with research question four.

Category	Aspect	Details	Teachers who mentioned
School Affordances	Absence of Boys	Creates a safe space for girls to participate actively, without intimidation or competitive pressure from boys.	Mrs. K Mrs. R Mrs. L
School Affordances	Supportive and Collaborative Atmosphere	Creates a safe space for girls to participate actively, without intimidation or competitive pressure from boys.	Mrs. L Mrs. K
School Affordances	Small Class Sizes	Allows for more personalized attention, making students feel comfortable participating and asking for help.	Mrs. K
School Affordances	Role Models and Emphasis on Girl Power	Promotes the visibility of female mathematicians and scientists, helping girls see themselves in these roles and challenging gender beliefs.	Mrs. R Mrs. K
School Affordances	Inclusive and Safe Environment	Encourages risk-taking and resilience by framing mistakes as learning opportunities, which is important for developing a growth mindset.	Mrs. L Mrs. K
Instructional Actions	Individualized Support	Provides one-on-one assistance and extra help sessions, such as Math Lab, to address individual learning needs and reinforce mathematical understanding.	Mrs. L Mrs. K
Instructional Actions	Positive Reinforcement	Uses positive feedback to encourage students, especially when they make mistakes, fostering a positive attitude towards learning and resilience.	Mrs. K Mrs. L
Instructional Actions	Effort-Based Grading	Grades homework and assessments based on effort rather than correctness, emphasizing the importance of the learning process over the outcome.	Mrs. R Mrs. L
Instructional Actions	Clear Expectations and Rubrics	Provides detailed rubrics and clear expectations in assessments and projects, helping students understand what is required and reducing anxiety.	Mrs. K Mrs. L
Instructional Actions	Self-Assessment and Reflection	Encourages students to reflect on their mistakes and learn from them, promoting self-regulation and a continuous learning process.	Mrs. R
Instructional Actions	Use of Real-Life Applications and Examples	Connects mathematical concepts to real-world scenarios, making the subject matter more relevant and engaging for students.	Mrs. R Mrs. K
Instructional Actions	Encouraging problem-solving and critical thinking	Focuses on problem-solving and critical thinking to help students develop deeper understanding, creativity, and confidence in mathematics.	Mrs. R, Mrs. K

Table 11: Teachers' Interview Key Points & Main Ideas

School Affordances

One of the primary affordances of an all-girls school context, as perceived by all teachers, is the absence of boys, which significantly reduces intimidation and competition that might otherwise deter female students' participation. In co-educational settings, girls often retreat into the background, allowing boys to dominate classroom discussions. This dynamic can undermine their confidence and willingness to engage. The absence of boys in all-girls schools encourages girls to speak up, share their ideas, and participate actively in mathematics. This environment enables girls to develop their voices without the pressure of competing with boys, fostering a sense of self-efficacy and confidence for their academic and personal growth. As Mrs. R explained, "The girls speak up. They don't sit back and wait for the boys to answer... They feel more comfortable in class and more confident to participate and be part of the class discussion". This absence encourages girls to express their ideas freely and actively engage in mathematics without the pressure of gendered comparisons. Mrs. K emphasized, "They don't even have to worry... They don't have to navigate that or deal with that," referring to how this environment alleviates the concerns of looking less capable compared to male peers.

Another important benefit is the collaborative environment that all-girls schools foster. Teachers highlight the importance of group work and collaborative projects, which they suggest aligning with girls' natural interest to communicate and learn from each other. This collaborative spirit enhances learning and builds a supportive community where girls feel comfortable exploring mathematical concepts without fear of judgment. Collaboration encourages peer learning, allowing students to explain concepts to one another, thereby solidifying their understanding and building

a sense of camaraderie and mutual support that is essential for personal and academic growth. According to Mrs. L, “I encourage them to talk to each other about math and learn from each other,” underscoring that group activities align with girls' natural communication tendencies. This collaborative atmosphere not only enhances understanding through peer learning but also builds a supportive community where students feel comfortable exploring mathematical concepts. This dynamic strengthens camaraderie, mutual support, and reinforces personal and academic growth among students.

Small class sizes are another significant advantage of this all-girls school. One of the teachers emphasizes that smaller class sizes allow for more personalized attention, making students feel more comfortable participating in discussions. This intimate setting helps build strong teacher-student relationships, which are essential for encouraging students to ask questions and seek help when needed. In a smaller class, teachers can tailor their instruction to meet each student's individual needs, providing targeted support and intervention to address specific challenges and promote deeper understanding. This personalized approach is particularly important in mathematics, where students often have varying levels of proficiency and confidence. Mrs. R pointed out that: “smaller class sizes make students feel comfortable participating and asking for help, allowing her to provide more targeted support and intervention to address specific challenges”. She highlighted the benefits of this arrangement by saying, “I offer after-school help on Mondays... We put out snacks, and that tends to be kind of fun,” creating a welcoming environment that encourages active participation.

This all-girls school also provided additional resources such as Math Labs and online math portals. These resources offer extra support and practice opportunities outside regular class hours. For instance, two teachers mention the availability of Math Labs, which serve as drop-in centers

where students can receive help with their math problems, thus reinforcing their learning and boosting their confidence. Online math portals provide students with access to a wealth of practice problems and instructional materials, allowing them to work at their own pace and receive immediate feedback. These resources ensure that students have multiple avenues for support and can seek help whenever needed, fostering a culture of continuous learning and improvement. Mrs. K noted, “We offer Math Lab, which is a once-a-week drop-in class, which allows students to receive help outside regular class hours”. According to the teachers Math Labs serve as drop-in centers for personalized assistance, reinforcing student learning and boosting their confidence in mathematics. Additionally, online math portals allow students to access practice problems and instructional materials independently, providing immediate feedback to enhance their understanding.

Role models play an important role in shaping students' aspirations. All-girls schools often highlight female mathematicians and scientists, providing students with relatable role models. One of the teachers, for example, uses bulletin boards featuring women in math to inspire her students. These representations help girls see themselves in these roles, making the pursuit of a career in mathematics seem more attainable. By showcasing the achievements of women from various backgrounds, schools can broaden students' perspectives and help them envision a future where they too can succeed in STEM fields. Role models not only provide inspiration but also offer practical examples of perseverance, resilience, and success, which are essential qualities for overcoming challenges and achieving long-term goals. Mrs. R shared that she uses bulletin boards featuring women in math to inspire her students, reinforcing the belief that girls can excel in STEM field. Mrs. K echoed this approach, stating, “I always try to mention female mathematicians across

all races... so that they can see themselves”. This emphasis on role models helps broaden students’ perspectives and envisions a future where they too can succeed in STEM.

Finally, the supportive and inclusive environment of all-girls schools cannot be overstated. All three teachers emphasize the importance of creating a safe space where mistakes are seen as part of the learning process. This supportive environment encourages risk-taking and resilience, essential components of a growth mindset in mathematics. When students feel safe to make mistakes, they are more likely to take on challenging problems and persist in the face of difficulties. This approach fosters a culture of experimentation and inquiry, where students are encouraged to explore new ideas and learn from their experiences. The emphasis on support and inclusivity helps students develop a positive attitude towards learning and builds the confidence they need to tackle complex mathematical concepts. Mrs. R mentioned, “I’m constantly saying, ‘It’s okay to make mistakes’ ...and reinforcing that it is okay, it’s actually better to make mistakes,” which fosters a growth mindset by encouraging risk-taking and resilience. This environment allows students to tackle challenging problems with confidence and explore new ideas, fostering a culture of experimentation and inquiry that promotes continuous learning and self-efficacy.

Instructional Actions

Teachers in all-girls schools employ specific instructional actions to support and improve their students' mathematical mindsets and gendered beliefs. One such action is providing one-on-one assistance. Two teachers mentioned offering extra help sessions, ensuring that students receive personalized attention to address their individual challenges. This approach helps students

overcome specific difficulties and fosters a deeper understanding of mathematical concepts. By working closely with students, teachers can identify areas where they need additional support and provide targeted instruction that addresses their unique needs. This personalized attention not only helps students improve their mathematical skills but also boosts their confidence and motivation to succeed.

In an all-girls mathematics classroom, the absence of male students allows for a learning environment where girls can focus solely on their own progress, free from gender comparisons. Positive reinforcement plays an important role in this setting, as teachers can provide tailored feedback that encourages female students to embrace challenges and learn from mistakes. Two of the teachers emphasized the importance of using positive feedback to motivate students, especially when they make errors. By praising effort and reminding students that mistakes are a natural part of learning, teachers help foster a resilient, growth-oriented mindset. In this supportive atmosphere, girls are more likely to see challenges as opportunities for growth and feel a stronger sense of accomplishment as they make progress. This approach not only builds confidence but also reinforces the belief that their intelligence and abilities in mathematics can be developed through perseverance and hard work, further dismantling gendered mathematical belief that may exist in co-educational settings. Mrs. L shared, “I’m available every flex period, and they can come in if they need help or have questions,” underscoring the importance of personalized attention to address individual challenges. Mrs. K described how she uses phrases like, “Check yourself, so you don’t wreck yourself,” to encourage students to self-reflect and keep pushing through challenges.

Encouraging problem-solving and critical thinking are also important instructional actions. One of the teachers emphasizes problem-solving and collaborative work, while the other teacher

uses motivational feedback and quotes to keep her students engaged and persistent. These strategies help students develop important skills that are essential for success in mathematics and beyond. By challenging students to think critically and solve complex problems, teachers help them develop a deeper understanding of mathematical concepts and build the confidence to tackle difficult tasks. Problem-solving activities also encourage creativity and innovation, as students explore different approaches and strategies to find solutions. Two teachers' Mrs. K and Mrs. R highlighted the usage of problem-solving in their classes, Mrs. K highlighted: "I provide ample practice problems so that they can they have opportunities to practice on what skills they need to". These strategies help students develop essential skills for success in mathematics and beyond.

Effort-based grading is a common practice among teachers in this all-girls school. Two teachers mentioned that they grade homework based on effort rather than correctness, while emphasizing the importance of the learning process over the outcome. This approach helps students understand that effort and persistence are valued, encouraging them to keep trying even when they encounter difficulties. By focusing on effort, teachers create a supportive environment where students feel comfortable taking risks and making mistakes. This approach fosters a growth mindset, where students believe that their abilities can improve with practice and hard work.

Providing detailed rubrics and clear expectations is another effective instructional action. Mrs. L explained, "Homework is effort grade only. If it is completed thoroughly, they get full credit," emphasizing the importance of valuing effort and persistence over final outcomes. This approach fosters a supportive environment where students feel comfortable taking risks and making mistakes, promoting a growth mindset that acknowledges the learning process.

All teachers use rubrics to outline what is expected in assessments and projects, giving students a clear understanding of how they will be evaluated. This transparency helps students

focus on their learning objectives and feel more confident in their abilities. Detailed rubrics provide students with specific criteria for success, helping them understand what they need to do to achieve their goals. By setting clear expectations, teachers help students take ownership of their learning and develop a sense of accountability for their progress. Mrs. K highlighted providing the detailed rubric:” I provided like a very detailed, ..., because I wanted them to have some direction”.

Encouraging self-assessment and reflection is also important. One of the teachers emphasized using formative assessments and allowing students to reflect on their mistakes and learn from them. This practice not only helps students identify their areas of improvement but also fosters a growth mindset by reinforcing the idea that learning is a continuous process. Self-assessment encourages students to take an active role in their learning, as they analyze their performance and set goals for improvement. Reflective practices help students develop metacognitive skills, where they become aware of their thinking processes and learn how to regulate their learning strategies for better outcomes. Mrs. K noted that:” I always ask them to check yourself”. Also, Mrs. R highlighted the opportunity provided for students to assess themselves and learn from their errors:” Checkups are an opportunity for them to see what the types of questions I'm going to askThis is an opportunity to learn from their errors.”

Finally, the use of real-life applications and examples helps make mathematics more relevant and engaging for students. Two teachers mentioned that they use word problems and scenarios that students can relate to, making the subject matter more interesting and accessible. This approach helps students see the value of mathematics in everyday life and motivates them to engage more deeply with the subject. By connecting mathematical concepts to real-world situations, teachers help students understand the practical applications of their learning and develop a greater appreciation for the subject. Real-life examples also make abstract concepts more

concrete, helping students grasp complex ideas more easily. Mrs. K noted:” We use so many real-life and word problems in our class.” This strategy helps students to make mathematics more relevant to them and boost their mindset regarding mathematics.

Conclusion

The unique environment of all-girls schools, combined with the targeted instructional actions employed by educators, creates a powerful setting for fostering growth mindsets and challenging gendered mathematical beliefs of girl students. The absence of boys, collaborative learning environments, small class sizes, and additional resources all contribute to creating a supportive and encouraging atmosphere for female students. These affordances of the single-sex settings provide girls with the confidence and support they need to excel in mathematics, free from the societal beliefs that often hinder their progress. The emphasis on girl power and the presence of positive role models further reinforces the message that girls are capable and talented mathematicians.

Instructional actions such as one-on-one assistance, positive reinforcement, effort-based grading, detailed rubrics, self-assessment and reflection, and real-life applications further support the development of growth mathematical mindset and competent young women in mathematics. By employing these strategies, teachers create a classroom environment that promotes a growth mindset, where students believe that their abilities can be developed through hard work and perseverance. This mindset is important for overcoming challenges and achieving success in mathematics and other STEM fields.

In conclusion, all-girls schools offer a unique and effective approach to mathematics education, empowering female students to overcome common gendered beliefs about mathematics and excel in a traditionally male-dominated field. By comprehending and utilizing these inherent advantages and pedagogical measures, educators may continue in establishing environment that foster and motivate the next generation of female mathematicians and scientists.

Chapter 5: Discussion and Conclusion

5.1 Brief Summary of the Results of Four Research Questions

This study investigated female students' mathematical mindsets and gendered mathematical beliefs in single-sex settings and explored how their level of engagement can be impacted by both their own and their teachers' mathematical mindsets and gendered mathematical beliefs. Additionally, it examined how contextual factors—such as teachers' instructional actions and the unique characteristics of all-girls schools—impacted female students' mindset toward mathematics and their gendered mathematical beliefs. In addition, by comparing the mathematical mindsets and gendered mathematical beliefs of female students in an all-girls middle school to findings from analogous studies conducted in coeducational settings, the study highlighted key differences in mathematical mindsets and gendered mathematical beliefs of girl students in these two different academic settings.

The research evaluated the interplay between individual beliefs [students' and teachers' here], engagement dimensions (cognitive, behavioral, affective, and observational), and the broader school environment, provided a comprehensive understanding of the factors that support female students in mathematics. To do that, the study assessed the influence of gendered mathematical beliefs and mathematical mindsets—of both students and teachers—on students' engagement levels.

In addition, it explored the impact of contextual factors, such as the instructional strategies employed by teachers and the distinctive characteristics of all-girls schools, on the mathematical mindset and gendered mathematical beliefs of students in this specific setting.

Using a mixed-methods approach, the investigation integrated quantitative analyses, including chi-squared tests and Mann-Whitney U tests, with qualitative methods like thematic analysis to address its research questions. Descriptive analysis was employed to compare female students' mathematical mindsets and gendered mathematical beliefs in the two settings of co-educational and single-sex schools. These methodologies allowed the study to comprehensively explore the relationships among mathematical mindsets, gendered beliefs, engagement, and other contextual factors.

This investigation offers valuable insights into strategies that promote growth mindsets, challenge traditional gender stereotypes, and foster deeper engagement in mathematics. The findings aim to inform educational practices and policies in both single-gender and coeducational contexts, empowering young women to confidently pursue mathematics and STEM fields. The study's findings across the four research questions provided key insights into the female students' mathematical mindsets, gendered mathematical beliefs, and level of engagement in an all-girl setting. The following section presents the four research questions alongside a concise summary of the findings for each.

1) In an all-girl school context, what are the mathematical mindsets and the gendered mathematical beliefs that middle school girls hold? How do these compare to reports from the literature?

This study's findings suggest that female students in single-gender settings, especially all-girls schools, may exhibit a significantly stronger inclination toward a growth mindset in mathematics than those in co-educational settings. Specifically, 95% of female students in these environments demonstrated growth mathematical mindset, indicating a belief in the potential to enhance their mathematical intelligence and abilities through effort and persistence. This

supportive environment seems to not only cultivates growth mathematical mindsets but also reduces gendered mathematical beliefs, as 96.5% of the female students strongly associated science and mathematics with female. This association appears to be less common in co-educational settings, where traditional gender beliefs persist among female students.

2) How do individual girl's engagements (both self-reported engagement and observed behavioral engagement) relate to their mathematical mindsets and gendered mathematical beliefs?

Results from the second research question highlighted the potential influence of mathematical mindsets and gendered mathematical beliefs on various dimensions of student engagement. A Chi-Squared analysis indicated that students' mathematical mindset positively impacts cognitive and behavioral engagement, whereas gendered beliefs positively influence cognitive and behavioral engagement but negatively affect observable behavioral engagement. Female students who dismiss the belief that mathematics is male-dominated exhibit greater cognitive and active engagement in the classroom, viewing challenges as opportunities for growth and persisting through difficulties. Students with a growth mindset in mathematics reported higher levels of cognitive and behavioral engagement, as evidenced by self-reported measures. The negative association observed in the context of observable behavioral engagement may also be influenced by other underlying factors, such as societal norms or classroom dynamics, which warrant further in-depth investigation.

3) In an all-girl mathematics classroom, how does the engagement of a typical student in the class (both self-reported engagement and observed behavioral engagement) relate to the teachers' mathematical mindsets and gendered mathematical beliefs?

The result of the Mann Whitney U Test, addressing the third research question suggest that while cognitive and behavioral engagement of students in an all-girl classroom were impacted by teachers' gendered mathematical beliefs, both affective and observable engagement did not appear to be influenced by this construct. Female students taught by teachers who strongly associate science with female potential exhibited slightly lower levels of cognitive and behavioral engagement compared to those taught by teachers with moderate associations. This finding suggests the potential unintended consequence, where teachers' strong alignment of science and mathematics with female potential may inadvertently create pressure or disengagement in certain dimensions of student engagement, particularly cognitive and behavioral.

However, the lack of significant impact on affective and observational engagement indicates that these dimensions might be less sensitive to teachers' gendered beliefs and more influenced by other factors such as the classroom environment, teaching methodologies, or intrinsic student motivations. The nuanced differences across the subdomains of engagement underscore the importance of considering multiple aspects of student engagement when examining the effects of teacher beliefs.

4) What are the perceived affordances [from teachers] of an all-girl school context which are influencing middle school girls' mathematical mindsets, and gendered mathematical beliefs? What

instructional actions, in general, do the teachers feel like help improve girls' mathematical mindsets, and gendered mathematical beliefs?

Finally, the results for the fourth research question point to some potential advantages of single-gender settings in fostering growth mindsets and reducing gendered beliefs. Factors such as the absence of boys, smaller class sizes, collaborative learning, and targeted resources may contribute to creating a supportive environment for girls in mathematics. Teachers in these settings often employ instructional strategies like one-on-one assistance, effort-based grading, and self-assessment, which may help reinforce a growth mindset. Such strategies could encourage female students to pursue mathematics and STEM fields with confidence and resilience, providing opportunities to challenge traditional gendered beliefs and supporting a new generation of competent young women in mathematics.

5.2 Implications in Mathematics Education

The findings from this study suggest that single-gender educational settings, particularly all-girls schools, may have positive influence on female students' growth mathematical mindsets and gendered beliefs about mathematics. In this single-gender settings, female students demonstrated a much stronger inclination towards a growth mindset, with 68.4% of students scoring high in growth mindset assessments. Additionally, 66.67% of students in these settings associated science and mathematics with females, a trend that appears to be less common in co-educational settings, where traditional gender stereotypes may be more prevalent. This difference suggests that single-gender environments provide a foundation where female students feel more

capable of excelling in mathematics, seeing their mathematical intelligences and abilities as improvable through effort and resilience.

The study also highlights potential connections between growth mindsets, gendered beliefs, and engagement. Findings related to the second research question suggest that growth mindsets are associated with cognitive and behavioral engagement, with students who adopt a growth mindset appearing more likely to persevere and actively participate in mathematical tasks. Similarly, rejecting traditional gendered beliefs in mathematics was associated with higher levels of engagement across cognitive, behavioral, and observable domains. While this suggests that single-gender environments may support these attitudes and behaviors, the observed effects were relatively modest, indicating that other factors may also contribute to fostering these outcomes. Additionally, affective engagement was not significantly associated with students' growth mindset, highlighting the importance of considering other influences such as classroom relationships, teaching strategies, and individual student differences in fostering emotional connections to mathematics.

The role of teachers also emerged as an important factor in shaping student engagement. The results from the third research question suggest that teachers' gendered mathematical beliefs may influence cognitive and behavioral engagement, but affective and observable engagement did not show significant associations. Teachers who strongly associate science with female potential may help create environments that encourage greater student engagement, particularly in cognitive and behavioral domains. This finding highlights the potential value of professional development programs that equip teachers with strategies to promote inclusive and supportive environments, though further research is needed to better understand these relationships.

Lastly, findings related to the fourth research question suggest that single-gender schools may offer unique opportunities for fostering growth mindsets and challenging gendered beliefs in mathematics. These settings, characterized by smaller class sizes, collaborative learning opportunities, and additional resources, may create a supportive environment for female students. Teachers in these settings often utilize strategies such as effort-based grading, personalized feedback, and opportunities for self-assessment, which may help reinforce the idea that mathematical abilities can improve with effort and persistence. While these findings highlight potential benefits of single-gender environments, the small effect sizes observed suggest that the influence of these factors may vary depending on individual and contextual differences.

In conclusion, these findings suggest that single-gender educational settings and growth mindset-oriented practices in mathematics education may support female students in overcoming gendered beliefs and developing confidence in their abilities. However, the observed effects are modest, indicating that additional factors, such as teaching strategies, classroom dynamics, and individual characteristics, play a significant role in shaping these outcomes. Expanding these practices in a way that accounts for these complexities may help create more inclusive educational environments that support female students in mathematics and STEM fields.

5.3 Assumption, and Limitations, of the Study

Assumption

Several assumptions were made by the researcher in this study in order to facilitate its conduction and continuation. According to Simon (2011), an assumption is an unquestioned notion

that someone has without being aware of it. Assumptions are external variables that are outside the control of a researcher. However, if these assumptions are eliminated, the study may lose its relevance (Simon, 2011).

The following is a list of the assumptions made in the current study:

- 1) It is assumed that the middle school teachers participating in the current study exhibit professional honesty and fidelity while their math classes are being recorded.
- 2) It is assumed that participants, including students and teachers, answered survey questions honestly and to the best of their abilities, without obtaining any benefit from manipulating responses.
- 3) It is assumed that participants who have prior knowledge of growth and fixed mindsets will respond to the mindset survey according to their beliefs. This logic implies that volunteers who took part in the study would not change their responses based on their perceptions of which is more socially acceptable.
- 4) It is assumed that teachers participating in the interview process will respond candidly to the interview questions without attempting to exaggerate or highlight just the positive aspects of all-female setting.

Limitation

Certain categories and varying degrees of limitations are an unavoidable component of every study. Limitations are the constraints and boundaries imposed on the work of a researcher and the methodology and procedure of the study on account of factors and variables over which the researcher has no control (Simon, 2011). The limitations of a study can be assigned to various

factors, including the methodology, design, sample size, sources of data, data collection methods, and data analysis techniques (Simon, 2011).

During the process of developing and performing the present investigation, the researcher was cognizant of potential limitations that could be associated with the study. In order to overcome these limitations and mitigate their impact, the researcher implemented a series of procedures and employed proper tactics. It is essential to emphasize that these restrictions are imposed by external circumstances beyond the researcher's control. Consequently, the present study still has certain limitations that are impracticable to complete elimination.

- 5) A limitation of this study was the small number of middle school teachers as teacher participants. This limitation could potentially undermine the transferability of the results obtained from this study. The rationale behind the using these limited number of teachers was that the number of participant teachers was adequate enough to collect the necessary data for the qualitative analysis that was a prerequisite for investigating research question four.
- 6) Another limitation of this study was the fact that, for research question 2, several of the cell counts in the Chi-Squared analysis were below the recommended minimum of 5. This fact may impact the reliability of the associations found in this study.
- 7) Another limitation of this study was the small number of middle school students. Private educational institutions generally maintain a maximum class size of fifteen students. The rationale for selecting this small sample of students as participants was that the number of participants in the study would exceed the minimum threshold of 30 (Gay et al., 2012) required to conduct and sustain the research.
- 8) The final limitation of the current study is the potential for participant bias in relation to the concept of mindset, which could subsequently influence the results of the mindset survey. The rationale for conducting the mindset survey was based on its widespread usage in educational research, as it has demonstrated a high level of validity and reliability.

5.4 Recommendations

Based on the implications and limitations of this study, several targeted recommendations are proposed to enhance the mathematical mindsets and reduce gendered mathematical beliefs of female students in various educational settings, particularly co-educational environments. These recommendations are directed toward specific audiences, including mathematics teachers, education researchers, policymakers, and teacher education programs.

1. For Mathematics Teachers:

Teachers play an important role in fostering growth mindsets and minimizing gendered mathematical beliefs. The study highlighted specific teaching strategies that appeared particularly effective in supporting female students' mathematical mindsets and reducing gendered beliefs, especially within the context of single-gender environments. Providing feedback that emphasizes the learning process rather than outcomes can encourage students to see mistakes as valuable opportunities for growth. Activities such as goal setting, reflective journaling, and peer support groups further promote resilience and persistence in mathematics, provided these interventions are designed to be free from gendered messaging—a practice noted by the teachers involved in this study. Prioritizing collaborative learning opportunities can help create environments where students feel comfortable asking questions, making mistakes, and supporting one another without fear of judgment. Additionally, integrating instructional strategies like effort-based grading, one-on-one assistance, and self-assessment into regular teaching practices can reinforce growth mindsets and challenge gendered beliefs, ensuring a more inclusive and supportive classroom culture.

2. For Mathematics Education Researchers:

Further research is needed to deepen the understanding of how single-gender settings influence mathematical mindsets, gendered beliefs, and students' engagements. The current study demonstrated that students' mathematical mindsets significantly impacted their cognitive and behavioral engagement, while their gendered beliefs influenced cognitive, behavioral, and observable behavioral engagement. Additionally, teachers' gendered mathematical beliefs were found to impact students' cognitive and behavioral engagement. These findings highlight the complex interplay between mindsets, beliefs, and engagement, emphasizing the importance of contextual factors such as classroom dynamics, teacher beliefs, and instructional strategies.

Researchers should conduct longitudinal studies in both single-gender and co-educational settings to explore how these factors contribute to sustained changes in mathematical beliefs and engagement over time. Such studies could provide deeper insights into the mechanisms through which teacher beliefs and classroom practices influence different dimensions of engagement. Moreover, targeted research should investigate the specific factors that drive affective and observable behavioral engagement, as these were less influenced by teachers' gendered beliefs in the current study. Developing and evaluating data-driven interventions tailored to these findings can help identify effective strategies for fostering growth mindsets and reducing gendered beliefs across various educational contexts, including mixed-gender environments.

3.For Policy-Makers:

Policymakers should support initiatives that integrate growth mindset principles and strategies for reducing gendered beliefs in mathematics classrooms. The study highlights the importance of smaller class sizes, collaborative learning structures, and targeted resources in

fostering growth mindsets and improving engagement among female students. Funding professional development programs for teachers to learn inclusive practices and strategies for challenging gender beliefs and biases is essential. Additionally, resources should be allocated to programs that celebrate women's achievements in STEM, incorporate female role models, and involve the broader community in discussions on gender equity. Supporting these initiatives can create systemic changes that promote gender equity and close the STEM gender gap.

4.For Mathematics Teacher Education Programs:

Teacher preparation programs should equip future educators with the tools needed to address gendered beliefs and foster growth mindsets in mathematics. The results of this study demonstrated that teachers who strongly associate science/math with females, positively influence cognitive and behavioral engagement among female students. This finding suggests the important role teachers play in shaping student behaviors and engagement level in mathematics. Preparation programs should emphasize training that enables teachers to provide constructive, process-focused feedback that encourages resilience and persistence by framing mistakes as opportunities for growth. Teachers should also learn to design assessments that highlight effort and improvement, rather than solely focusing on outcomes, to foster a growth mathematical mindset in their students.

Also, as demonstrated in this study, contextual factors such as classroom dynamics and instructional strategies have significant effects on students' mindsets and engagement. For instance, based on the results of the current study, strategies like collaborative learning, individualized support, and effort-based grading have been shown to reinforce growth mindsets and reduce gendered beliefs. By preparing teachers to create equitable and supportive classroom

cultures, these programs can play a vital role in addressing the gender disparities in mathematics participation and achievement. Training that integrates reflective practices, inclusive strategies, and mindset-focused interventions can help ensure that teachers are equipped to empower all students—particularly girls—to excel in mathematics and develop the confidence needed to pursue STEM-related fields. This holistic approach is essential for creating classroom environments where all students feel valued, supported, and capable of achieving their potential in mathematics.

5. For Schools and Educational Institutions:

Schools should adopt inclusive instructional practices that promote growth mindsets and support female students in overcoming gendered beliefs about mathematics. Real-life applications and collaborative learning can make mathematics more engaging and relevant, while individualized support like mentoring and tutoring can address specific student needs. The current study also suggests that creating emotionally safe classroom environments—where mistakes are framed as learning opportunities—can help students build resilience and a positive attitude toward mathematics. In addition, according to the results of this study, ensuring that teachers consistently employ strategies like self-assessment and effort-based grading can reinforce students' confidence in their mathematical abilities and promote a culture of persistence and improvement, which impact students' level of engagement.

6. For Long-Term Development and Data-Driven Interventions:

The findings of this study highlight the potential benefits of single-gender settings in fostering growth mindsets and reducing gendered beliefs about mathematics. Female students in these settings demonstrated stronger mathematical mindsets and were more likely to associate mathematics and science with female potential, which positively influenced their cognitive, behavioral, and observable behavioral engagement. However, to sustain and expand these benefits, ongoing evaluation and adaptation are essential.

Schools and researchers should collaborate on longitudinal studies to assess how single-gender environments compare to co-educational settings in shaping students' mathematical mindsets, gendered beliefs, and various dimensions of engagement over time. Additionally, the study found that teachers' gendered beliefs influenced students' cognitive and behavioral engagement, emphasizing the need to investigate how teacher beliefs and instructional strategies impact engagement in different educational contexts.

Regular surveys and feedback mechanisms should be implemented to gather student perspectives and track their experiences. This data can inform continuous refinement of instructional practices, ensuring that they remain effective and relevant. By adopting a data-driven approach, schools can identify successful strategies, address areas of need, and better support all students—particularly girls—in developing confidence, resilience, and engagement in mathematics. This iterative process will help ensure that educational practices evolve to meet the diverse and changing needs of learners effectively.

By expanding the recommendations to incorporate these findings, educators, researchers, policymakers, and institutions can work collaboratively to create equitable learning environments that empower female students to excel in mathematics and consider future careers in STEM.

By implementing these recommendations, educators, researchers, policymakers, and teacher preparation programs can work collaboratively to create more equitable and supportive learning environments that empower all students, particularly girls, to thrive in mathematics and pursue careers in STEM fields. These efforts are essential for fostering gender equity in education and ensuring that every student has the opportunity to reach their full potential in mathematics and beyond.

5.5 Conclusion or Epilogue

This study sheds light on the female students' mathematical mindsets and gendered mathematical beliefs, in a specific setting of all-girl school. Across all four research questions, the findings illustrate how the setting of single gender foster a growth mathematical mindset while dismantling gendered mathematical beliefs that often hinder girls' confidence in STEM subjects.

In all-girl setting, an impressive 95% of female students demonstrated a robust growth mindset, either Strong or Moderate, fostered by an environment that emphasizes perseverance, effort, and a positive attitude toward learning mathematics. This supportive atmosphere not only nurtures academic resilience but also cultivates a strong sense of confidence and competence in mathematics, free from the gendered beliefs that often prevail in co-educational settings. Additionally, 96.5% of these students strongly or moderately associated mathematics and science with female potential, reflecting a significant departure from traditional gendered beliefs regarding mathematics. This alignment suggests that single-gender classrooms, by reducing gendered beliefs and messages, provide an empowering space for girls to fully embrace their mathematical abilities.

These findings highlight the essential importance of inclusive and supportive learning environments in fostering growth mathematics mindsets. When liberated from unconscious gendered biases and external pressures, female students are more adept at perceiving problems as chances for progress and actively participating in their learning. This not only provides them with the skills and confidence necessary to flourish in mathematics but also confronts broader cultural narratives, facilitating more gender equity in STEM disciplines.

Moreover, the influence of mathematical mindset and gendered beliefs extends into key aspects of students' engagement. The study reveals that students' mathematical mindsets significantly affect both cognitive and behavioral engagement, enhancing their mental involvement and active participation in mathematical learning. In addition, students' gendered mathematical beliefs play an important role in impacting cognitive, behavioral engagement, suggesting that when students view mathematics as an inclusive field, their commitment and enthusiasm for the subject flourish. However, students' gendered mathematical beliefs negatively impact observable behavioral engagement, suggesting that when students internalize gendered beliefs in mathematics, their outwardly visible behaviors, such as asking questions, participating in class discussions, or seeking help, may diminish. This highlights the critical need to foster a perception of mathematics as an inclusive field to counteract such negative effects and encourage greater engagement.

Additionally, the study demonstrates that the cognitive and behavioral engagement of female students is negatively influenced by the gendered mathematical beliefs of teachers. This finding suggests the crucial role of teachers' beliefs in shaping students' engagement levels, revealing that when teachers hold strong gendered associations in mathematics, it can inadvertently

hinder students' mental involvement and active participation in mathematical learning. Addressing these beliefs is essential to fostering a more equitable and engaging classroom environment.

Moreover, the instructional actions of instructors can be a significant factor in the establishment of inclusive spaces. Teachers can employ targeted instructional strategies to reinforce growth mindsets and dismantle gendered mathematical beliefs of their students. These practices, which include real-life applications, effort-based grading, and one-on-one assistance, foster an environment in which female students feel both competent and motivated to succeed in mathematics.

In conclusion, the study's findings highlight the importance of both students' and teachers' mindset and gendered beliefs, as well as the importance of single-gender educational settings and thoughtful teaching strategies in empowering female students in mathematics. The findings, which consider the mathematical mindset and gendered mathematical beliefs of students and teachers, establish a foundation for future educational reforms aimed at motivating and empowering female students to pursue careers in mathematics and science, while advocating for single-gender environments as suitable contexts for achieving these objectives.

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Appendix A: Research Instruments and Data Collection Tools

Students' Survey

Part A

Mathematical Mindset

Direction: Please read the questions below and circle the statement which best describes you.

Part A: Mathematical Mindset Survey

1. You have a certain amount of mathematical intelligence, and you really can't do much to change it.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

2. No matter who you are, you can change your mathematical intelligence a lot.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

3. Your mathematical intelligence is something about you that you can't change very much.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

4. No matter how much mathematical intelligence you have, you can always change it quite a bit.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

5. You can learn new mathematics, but you can't really change your basic mathematical intelligence.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

6. You can always greatly change how intelligent you are in mathematics.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

Part B: Engagement Subdomains Survey

7. I go through the work for math class and make sure that it's right.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

8. I think about different ways to solve a problem.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

9. I try to connect what I am learning to things I have learned before.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

10. I try to understand my mistakes when I get something wrong.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

11. I stay focused.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

12. I put effort into learning math.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

13. I keep trying even if something is hard.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

14. I complete my homework on time.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

15. I look forward to math class.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

16. I enjoy learning new things about math.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

17. I want to understand what is learned in math class.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

18. I feel good when I am in math class.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

Teachers' Survey

Mathematical Mindset

Direction: Please read the questions below and circle the statement which best describes you.

1. You have a certain amount of mathematical intelligence, and you really can't do much to change it.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

2. No matter who you are, you can change your mathematical intelligence a lot.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

3. Your mathematical intelligence is something about you that you can't change very much.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

4. No matter how much mathematical intelligence you have, you can always change it quite a bit.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

5. You can learn new mathematics, but you can't really change your basic mathematical intelligence.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

6. You can always greatly change how intelligent you are in mathematics.

Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, Strongly Disagree

Teachers' Interview Questions

Key words & Definitions:

Mathematical Mindset: belief about malleability or changeability of mathematical intelligence.

Gendered Mathematical Beliefs: beliefs that men are inherently better than women at learning mathematics, or the idea that men are more likely than women to excel in mathematics, and have a greater aptitude toward science and mathematics.

Teachers' Interview Questions – Interviewer Version

1. Do you use any specific strategy (i.e., specific phrase, student-friendly rubric, one-to-one assistances) in your all-girl mathematics classroom that are aimed to support students' growth mindsets in mathematics (the belief that their mathematical abilities are changeable through hard work, persistence, and time)?
2. Recognizing students' effort may support students' mindsets in mathematics. In what way do you recognize your students for their efforts, as opposed to just their grades (i.e., any awards, extra credit, grading for mastery versus the average or sum of point they earned)?
3. What are the unique aspects of an all-girls school that support students' growth mindset in mathematics? Can you identify any factors/resources/characteristics of an all-girl environment (classroom/school) that make it a unique context for fostering students' mathematical mindsets?
4. How do you perceive the presence of gendered beliefs about mathematics being a male domain in your mathematics classroom? Are you using any strategies in your classroom to minimize students' gendered beliefs about mathematics?
5. How does your classroom environment help to minimize students' gendered beliefs about math? any distinguishing feature or factor? (i.e., Recognizing female mathematicians in class, using gender neutral words, etc.)
6. What factors influence whether the all-girl school is an advantageous or detrimental environment for female students' gendered mathematical beliefs? Can you identify any

factors/resources/characteristics of an all-girl environment (classroom/school) that make it a unique context for minimizing students' gendered mathematical beliefs? Please explain.

7. How do you perceive the impact of male students' absence on female students' gendered mathematical beliefs and mathematical mindsets in an all-girl setting?

8. Do you believe that being in an all-girl classroom has any benefits or obstacles for fostering and supporting female students' growth mathematical mindsets and gendered mathematical beliefs?

Teachers' Interview Questions – Interviewee Version

1. Do you use any specific strategy in your all-girl mathematics classroom that are aimed to support students' growth mindsets in mathematics?

2. Recognizing students' effort may support students' mindsets in mathematics. In what way do you recognize your students for their efforts, as opposed to just their grades?

3. What are the unique aspects of an all-girls school that support students' growth mindset in mathematics? Can you identify any factors/resources/characteristics of an all-girl environment (classroom/school) that make it a unique context for fostering students' mathematical mindsets?

4. How do you perceive the presence of gendered beliefs about mathematics being a male domain in your mathematics classroom? Are you using any strategies in your classroom to minimize students' gendered beliefs about mathematics?

5. How does your classroom environment help to minimize students' gendered beliefs about math? any distinguishing feature or factor?

6. What factors influence whether the all-girl school is an advantageous or detrimental environment for female students' gendered mathematical beliefs? Can you identify any factors/resources/characteristics of an all-girl environment (classroom/school) that make it a unique context for minimizing students' gendered mathematical beliefs? Please explain.

7. How do you perceive the impact of male students' absence on female students' gendered mathematical beliefs and mathematical mindsets in an all-girl setting?

8. Do you believe that being in an all-girl classroom has any benefits or obstacles for fostering and supporting female students' growth mathematical mindsets and gendered mathematical beliefs?

Observation Protocol (Individual Student's behavioral engagements)

Students' Behavioral Engagement Checklist				
Classroom#: Teacher:	Citation	Date & Time of Observation:		
Engagement indicator		Student #1	...	S #12
Student is prepared with necessary materials (ex. Paper, pencil, calculator)	Ocuppaugh et al. (2015)			
Student is volunteering	Pianta et al. (2012)			
Student is asking questions.	Ocuppaugh et al. (2015), Pianta et al. (2012), Reynolds and Kampaus (2015)			
Student is answering a variety of questions from teachers or peers.	Ocuppaugh et al. (2015), Pianta et al. (2012), Reynolds and Kampaus (2015)			
Student is involving in a positive social interaction (ex. explaining things to others. Expressing ideas)	Volpe and DiPerna (2010)			
Student is raising hand and participating actively in class activities.	Fredricks et al. (2011)			
Student is taking note and engaging in learning process.	Fredricks et al. (2011), Shapiro (2011)			

Student Engagement Level (0-2 each indicator) total 0-12 (low to high)			
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0- showing no sign/presence of the favorite indicator

1-showing 1-2 times of the indicator

2-showing more than 2 times of the indicator

Modified IAT's Answer Sheet

IAT Test

Name:

Number:

Teacher:

- | | | |
|-------------|-------------|-------------|
| Q 1.: ____ | Q 21.: ____ | Q 41.: ____ |
| Q 2.: ____ | Q 22.: ____ | Q 42.: ____ |
| Q 3.: ____ | Q 23.: ____ | Q 43.: ____ |
| Q 4.: ____ | Q 24.: ____ | Q 44.: ____ |
| Q 5.: ____ | Q 25.: ____ | Q 45.: ____ |
| Q 6.: ____ | Q 26.: ____ | Q 46.: ____ |
| Q 7.: ____ | Q 27.: ____ | Q 47.: ____ |
| Q 8.: ____ | Q 28.: ____ | Q 48.: ____ |
| Q 9.: ____ | Q 29.: ____ | Q 49.: ____ |
| Q 10.: ____ | Q 30.: ____ | Q 50.: ____ |
| Q 11.: ____ | Q 31.: ____ | Q 51.: ____ |
| Q 12.: ____ | Q 32.: ____ | Q 52.: ____ |
| Q 13.: ____ | Q 33.: ____ | Q 53.: ____ |
| Q 14.: ____ | Q 34.: ____ | Q 54.: ____ |
| Q 15.: ____ | Q 35.: ____ | Q 55.: ____ |
| Q 16.: ____ | Q 36.: ____ | Q 56.: ____ |
| Q 17.: ____ | Q 37.: ____ | Q 57.: ____ |
| Q 18.: ____ | Q 38.: ____ | Q 58.: ____ |
| Q 19.: ____ | Q 39.: ____ | Q 59.: ____ |
| Q 20.: ____ | Q 40.: ____ | Q 60.: ____ |