# GIRLS' PERCEPTIONS OF THE CONNECTIONS BETWEEN CLASSROOM ACTIVITIES AND CONFIDENCE IN MATHEMATICS

by

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A Dissertation Submitted to the Faculty of the College of Graduate Studies at Middle Tennessee State University in Partial Fulfillment of the Requirements for the Degree of Doctorate of Philosophy in Mathematics and Science Education

Middle Tennessee State University

December 2022

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This work is dedicated to my daughter, Oakley Webster, and all the girls in my mathematics and computer science classes past, present, and future.

You inspire me.

## ACKNOWLEDGEMENTS

First and foremost, I would like to thank my family for their love and support as I followed my heart and pursued my dream. Thank you to my parents, David Rowe and Linda Cart, who as young parents instilled in me a love of learning and an inquisitive mind. You always said I would be a life-long student and you were right. To my husband, Dub, thank you for picking up my slack with the kids and around the house. Thank you for learning to sleep with the light on so I could stay up and finish my work. To my children, Boston, Oakley, Easton, and Madden, thank you for being so proud of me and for understanding why I have been so busy. I cannot wait to be there for you as you follow your hearts and pursue your dreams. Thank you to my siblings, in-laws, and friends for your words of encouragement, willingness to lend a hand, and all the special ways you have supported my family and me.

I would like to express my gratitude to my committee chair, professor, and mentor, Dr. Alyson Lischka. You possess a special magic: knowing when to push me, when to hold me accountable, and when to give me grace. Your wisdom, advice, suggestions, support, and flexibility have been vital to my completion of this dissertation. Thank you for everything. To my committee members, Dr. Sarah Bleiler-Baxter, Dr. Seth Jones, Dr. Jennifer Kaplan, and Dr. Chris Stephens, I appreciate the time you devoted to my work, your helpful ideas, your thought-provoking questions, and your words of encouragement. My dissertation is better because of your support.

I would not have been able to teach full time and complete this program without the encouragement of my colleagues and the administration at my school. Thank you for

believing this research was worth your support. Without my students, I would not have had the inspiration or motivation to go back to school and grow as a student myself.

Finally, I would like to thank my peers and professors at MTSU for challenging my thinking, lending a helping hand, and being my friends.

## ABSTRACT

Girls are less likely than boys to pursue a degree or career in a mathematics-based field. Girls tend to have higher grades and similar test scores when compared with boys. However, girls' affective beliefs, including confidence, fall behind those of their male counterparts. The purpose of this study was to understand how girls perceive the connection between classroom activities and their feelings of self-efficacy in the mathematics classroom. I used a multiple case study to explore five Algebra 2 students' confidence throughout a unit of study on polynomial functions.

The study addressed the following research questions:

1. What are high school girls' perceptions of the connection between various forms of classroom activities and their confidence on mathematics assessments, if any?
2. How do specific forms of classroom assessment contribute to the growth of high school girls' mathematical confidence, if at all?

This case study analyzed survey responses, assessment reflections, and interview data collected from five students over the course of approximately three weeks as their Algebra 2 classes covered a unit on polynomial and rational functions. The survey, reflections, and interview questions were centered around understanding the girls' confidence in mathematics. Bandura's (1995) four sources of self-efficacy provided a framework for analyzing the reflection and interview data.

The findings of this study included a collection of student perceived benefits and limitations to their confidence in mathematics based on the type of classroom activity discussed. Mastery experiences had the greatest impact on student confidence. Vicarious experiences and social experiences influenced the students' confidence; however, the

social influence came from the teacher rather than peers most of the time. Finally, there were other factors outside of the classroom impacting the students' confidence in mathematics.

This study produced results that are significant in four ways. First, the results connect to prior research by supporting the four sources of self-efficacy (Bandura, 1997) as influential to girls' confidence in mathematics. Second, this study offers theoretical implications as to how Women's Ways of Knowing (Belenky et al., 1986) informs the four sources of self-efficacy (Bandura, 1997). Third, the results provide suggestions for practice for secondary mathematics teachers to support girls' confidence in mathematics. Finally, questions and considerations for future research emerged from the results of this study.

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# CHAPTER I: INTRODUCTION

## Introduction

As a mathematics teacher, I want to foster mathematical confidence in the girls I teach so they believe themselves capable of success in a STEM career. I wish to encourage my students to overcome adversity, persist when they encounter problems, and grow in confidence as they experience success. Such desires led me to research reasons why some girls veer away from a STEM career path and fueled the present study.

This dissertation contains a detailed description of a multiple case study investigation detailing girls' perceptions of connections between classroom assessments and their self-efficacy in mathematics class. Specifically, this study took place in Algebra 2 courses in an all-girls setting and focused on the girls' self-reported confidence level during assessments, classroom activities, and other factors to which they attribute their level of confidence. This chapter includes an introduction to the research including the background of the study, description of the theoretical framework, brief explanation of the problem, and the significance of the study. Definitions of key terms are provided to ensure clarity of use throughout the report.

## Background of the Study

This section provides background for three ideas underpinning the study. First, women are underrepresented in STEM fields and much research has concentrated on factors contributing to the removal of women along STEM pathways (Buck et al., 2020). Second, there are many studies on sex and gender related difference in mathematics; however, most were conducted using large scale assessments rather than focusing on students in mathematics classes. Third, gender studies in mathematics have shifted over

the years from an emphasis on performance discrepancies (Fennema, 1979), to affective differences, namely differences in confidence in mathematics (Zander et al., 2020).

Throughout mathematics education research, gendered terms have been used inconsistently (Leyva, 2017). When citing relevant literature, terminology used by each author referenced will be maintained.

**The Leaky STEM Pipeline**

Women are grossly underrepresented in most science, technology, engineering, and mathematics (STEM) career fields (Hill et. al 2010). Diversification of the STEM fields enhances creativity, innovation, and quality in critical decisions (Jean et al., 2015), and therefore the underrepresentation of women must be explored. Though women held nearly half of all jobs in the workforce in 2015, they accounted for under 25% of STEM jobs (Noonan, 2017). Despite an overall decrease in the gender gap in recent years when all STEM careers are grouped together, there are still many disproportionately represented STEM fields. For example, women are now the majority in health-related STEM fields and hold nearly half of all jobs in life-science focused professions (Buck et al., 2020). However, women are far less likely than men to pursue a career in the mathematics-based STEM fields (Hill et al., 2010; Noonan, 2017). The mathematically intensive fields of physical sciences, technology, engineering, and mathematics are considered the more masculine of the STEM concentrations (Buck et al., 2020) and undergraduate women are underrepresented in these majors (Cheryan et al., 2017; Leslie et al., 1998). Such disparities do not suddenly appear when individuals begin their career or select an undergraduate major. The gender divide in mathematics emerges much earlier along the pipeline.

Factors leading to women's underrepresentation in STEM majors and careers emerge in adolescence, especially in the years preceding college (Geary et al., 2019; Leslie et al., 1998). Fox, Fennema, and Sherman (1977) reported that sex-related differences in mathematics achievement were first evident in the eighth or ninth grade. Such early studies investigating gender differences in mathematical achievement focused heavily on large-scale assessment data and indicated that many other variables should be considered including prior achievement, mathematics experience, and affective influences (Fennema & Sherman, 1977; Leder, 2019; Sherman & Fennema, 1977). Though such large-scale assessments offer no explanation for why there is gender disparity in mathematics performance, they indicate the point along the STEM pipeline at which girls begin to turn away from these fields.

Much research has focused on understanding factors that contribute to the removal of women along STEM pathways (Buck et al., 2020). These factors range from stereotypes and bias (Hill et al., 2010) to family-related challenges (Jean et al., 2015). The goal of this research is to focus on one of these mitigating factors at the point along the pipeline where gender related differences emerge.

**Large-Scale Assessment Data**

Large-scale assessment data continues to indicate that the mathematics achievement gender gap persists (Reardon et al., 2019) in favor of boys. However, researchers have questioned the validity of gendered comparisons made from such large-scale examinations (Fennema & Sherman, 1977; Leder, 2019; Leder & Forgasz, 2018; Sherman & Fennema, 1977). According to Leder and Forgasz (2018), factors such as teacher preference, class emphasis, and access to expertise can influence students'

experience with mathematics. Such variations in mathematics learning and unequal access to the necessary mathematical knowledge can influence large-scale test results; however, these are not often highlighted in test result data.

One such factor that impacts gendered achievement results is female students often experience stereotype threat during mathematics testing, which can negatively affect their performance (Tomasetto et al., 2011). This occurs when, during a test, a female student encounters a trigger that reminds her of a previously encountered stereotype of male dominance or female inferiority in mathematics. The threat of not combatting this negative stereotype can raise anxiety and negatively impact her performance on the test (Steele, 1997). In stereotypically masculine contexts, boys scored significantly higher than girls (Zohar & Gershikov, 2008). However, when stereotypically masculine spatial orientation tests were reframed into a less masculine context (the human body), gender difference in performance disappeared (Tarampi et al., 2016). It is clear from large-scale assessment research that, for girls, context is linked with performance (Leder, 2019), which calls into question inherent gender bias in large-scale assessment.

Although boys perform better than girls on large-scale assessments, across all subjects, girls make higher grades in school than boys and earn grades equivalent to or higher than boys in mathematics (O'Dea et al., 2018; Reardon et al., 2019; Voyer & Voyer, 2014). Such contrasting evidence of gender parity suggests an exploration of classroom assessments may lead to a better understanding of assessment practices that benefit boys and girls equally. Voyer and Voyer (2014) found the way achievement is measured can influence apparent gender differences in performance. Though much

gender specific research has been conducted on large-scale assessment, there is little in literature on classroom assessment related to gender differences.

**Confidence**

Over the years, discussions of gender differences in mathematics have shifted their focus from performance difference to differences in affective variables such as confidence. Male superiority in mathematics was a prevalent observation in the late 1970s. This is highlighted in the research published before the mid-1970s, which claimed boys performed better in mathematics than girls (e.g., Aiken, 1971; Parsley et al., 1964). Fennema (1979), however, questioned the research methods that led to such conclusions. She broadened the scope of this biased research when she considered cognitive variables, affective variables, and educational variables that informed sex-related differences in mathematics performance. Fennema and Sherman (1977) discovered when prior experience was considered, there was no significant gender difference in mathematical ability. Rather, the differences were instead related to affective factors. Their findings revealed that mathematics confidence was higher in boys than in girls, and boys were more likely to continue further in a mathematics sequence of study than girls. Since the 1980s, mathematics education has shifted from an emphasis on experimental design studies to qualitative research (Inglis & Foster, 2018). Likewise, the body of gender research in mathematics education has shifted to explore the affective difference in mathematics learning for boys and girls (Becker, 1981; Burton, 1986; Reyes, 1984; Vale & Leder, 2004; Zander et al., 2020).

From early research on gender differences in mathematical achievement to current research on the leaky STEM pipeline, affective variables including levels of self-efficacy

and confidence play a role in females' achievement and participation in mathematics (Buck et al., 2020; Fennema & Sherman, 1977; Leder, 2019; Leder & Forgasz, 2018; Leyva, 2017; Sherman & Fennema, 1977; Tellhed et al., 2017). Girls have a lower self-efficacy than boys across STEM subjects, but the gap is larger in mathematics than in science (Buck et. al, 2020). Large-scale assessments do not contribute to a clear understanding of mathematical self-efficacy in girls because they differ by assessment design, can be influenced by stereotype threat, and include problems with unintentionally male-biased contexts.

In her later research, Fennema went further to question whether researchers were even asking the right questions or using appropriate methods to understand the state of gender equity in mathematics education (Fennema & Hart, 1994). Fennema and Hart (1994) suggested that rather than generalizing all female, or male, mathematics students from large data sets, focusing on individual participants may "bring into consciousness hidden social forces and structures" (Scotland, 2012, p. 12). This more individual approach to gender research was used by Boaler (1997) who attempted "to show the importance of giving voice to girls' concerns, because what they are saying appears to make a lot of sense" (p. 304).

Therefore, this study will capitalize on insights gleaned from large-scale assessments while shifting the focus to activities and assessments in the mathematics classroom, a setting where girls are reported to perform as well as or better than boys. The goal of this study is to investigate girls' perceptions of the relationship between assessment and confidence (O'Dea et al., 2018).

## Theoretical Framework

To situate the current study in the literature and to articulate the lens through which I plan to develop, conduct, and analyze the research, I followed Stinson and Walshaw's (2017) distinction of high-, mid-, and ground-level theory. High-level theories situate the study philosophically while mid-level theories focus the position more narrowly—adding specificity to the broader philosophical position. Ground-level theories are used to make sense of the data and therefore serve as the analytical framework for the study. Each level of theory to be employed for this research is described below.

### High-Level Theory

This research is undertaken from an interpretivist paradigm. The interpretivist paradigm comes from a position of wanting to understand (Stinson & Walshaw, 2017). In this study, I seek to understand girls' perceptions of connections between classroom activities and assessments and their confidence. From an ontological perspective, reality is subjective and differs between individuals (Lincoln & Guba, 2017). Knowledge is constructed individually, in social contexts, and in the context of the world around the knower (Scotland, 2012). More specifically, there are five perspectives on knowing specific to women: silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge, which will be used to structure the mid-level theory below (Belenky et al., 1986).

### Mid-Level Theory

Three mid-level theories serve to frame the design of this study. First, to explore girls' confidence in the mathematics classroom, I needed a frame to guide the development of an assessment structure. In his social cognitive theory, Bandura (1997,

2001) identified four sources of self-efficacy: mastery experiences, social persuasion, vicarious experiences, and physiological states. These sources of self-efficacy served as a framework for study design. Additionally, women's ways of knowing (Belenky et al., 1986) served as a lens for understanding how girls see themselves as learners of mathematics. Finally, I wanted to design activities and develop interview questions that would elevate the feminine perspective. To that end, I used Burton's (1995) framework for women's ways of knowing in mathematics to guide my work. These three theories are described in more detail below.

Self-efficacy is defined by Zander et al. (2020) as "learners' confidence in their skills and capabilities to succeed in certain tasks – irrespective of their actual performance" (p. 2). Based on years of research and a synthesis of nearly two thousand studies, Bandura (1997) developed a coherent frame for self-efficacy. In reference to the first source of self-efficacy, Bandura (1997) explained that "effective mastery experiences are the most influential source of efficacy information because they provide the most authentic evidence of whether one can muster whatever it takes to succeed" (p. 80). The second source of self-efficacy beliefs is verbal or social persuasion (Bandura, 1997). If significant individuals express the belief that a student can succeed at their desired objective, then social persuasion can positively influence the growth of their self-efficacy. Bandura (1997) referred to this third source of self-efficacy as vicarious experiences. When measuring success, there is often no clear indicator of adequacy. In such a situation, individuals can compare themselves with others to determine their relative level of ability. Finally, Bandura (1997) refers to the fourth way of altering self-efficacy beliefs as physiological and affective states because the state of the body and

emotions can influence how individuals assess their capabilities. The current study will be designed to ensure students have multiple opportunities to access each of the four sources of self-efficacy in the assessments for the units.

Belenky et al. (1986) interviewed over one hundred women and asked them about their experiences as related to school and family. This study resulted in a framework of epistemological perspectives through which women know and view the world. The five major epistemological categories are silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge. The first four categories involve some lack of voice, authority, ownership, or application of knowledge whereas constructed knowledge is "a position in which women view all knowledge as contextual, experience themselves as creators of knowledge, and value both subjective and objective strategies for knowing" (Belenky et al., 1986, p. 15). It is through this lens that I studied girls who positioned themselves in different epistemological categories, and they were asked how various assessment practices affected their self-perception as students of mathematics. Though the interpretivist paradigm serves to situate the theoretical paradigm of the researcher, as Fennema and Hart (1994) wrote, "we think feminist perspectives can contribute to mathematics education research in the kinds of research questions that are explored, whose questions are asked, whose voices are heard, and the research methods employed" (p. 653). In this study, I seek to understand girls' perceptions and therefore plan to use such a feminist framework to guide the use of language in the development of interview, reflection, and assessment questions. Burton (1995) analyzed feminist literature to describe women's ways of knowing in

mathematics. By following Burton's framework, I hoped to capture feminist perspectives of connections between classroom activities and confidence in mathematics.

**Ground-Level Theory**

Although Bandura's (1997) social cognitive theory guided the development of the assessment profile for the unit of study, it also served as the analytical framework used to code assessment reflection and interview data. The four sources of self-efficacy: mastery experiences, social persuasion, vicarious experiences, and physiological states were codes used to organize the data into types of classroom activities and assessment experiences the students described. Table 1 lists the theoretical perspectives that framed this study and the purpose each framework served.

**Table 1**

*Ways the Theoretical Frameworks Informed the Study*

| Level | Theoretical Framework | Purpose of the Framework |
|---|---|---|
| High | Interpretivist Paradigm Stinson & Walshaw, 2017 | I used the interpretivist lens to understand connections between classroom activities and assessments and girls' confidence in mathematics. |
| Medium | Four Sources of Self-Efficacy Bandura, 1997 | The instructional design for this unit was bounded by the four sources of self-efficacy and this framework guided what questions were asked in the interview process. |
| | Women's Ways of Knowing Belenky et al., 1986 | The five categories for women's ways of knowing provided an interpretive lens through which to understand the student participants. |
| | Feminist Perspective of Knowing in Mathematics Burton, 1995 | The instructional design for this unit included activities selected for their attention to a feminist perspective for knowing mathematics. |
| Ground | Four Sources of Self Efficacy Bandura, 1997 | The four sources of self-efficacy served as categories for analysis of the reflection and interview data. |

## The Problem Statement

Gender, the socially constructed characteristics of females and males, is a differentiating factor in the STEM pipeline from the middle grades to the workplace that privileges one group and leaks others from the stream (Bergeron & Gordon, 2017; Cheryan et al., 2017). Though large-scale assessment studies once indicated boys performed better in mathematics than girls (e.g., Aiken, 1971; Parsley et al., 1964), this achievement gap disappeared when controlled for prior experience (Fennema & Sherman, 1977). In fact, girls earn grades equivalent to or higher than boys in the

mathematics classroom (Voyer & Voyer, 2014). As described above, where girls continue to fall behind is not in mathematical performance but in affective factors such as self-efficacy and confidence (Zander et al., 2020). This gap is especially pronounced among high achieving female students (Zhou et al., 2017). Gender differences in both ability and affective factors were explored in many studies using large-scale assessment data, yet the literature lacks exploration of gendered influence of assessments on self-efficacy and confidence within the classroom, a place where girls are known to perform well.

## Statement of Purpose

Understanding how girls perceive the connection between in-class assessments and their feelings of self-efficacy in the mathematics classroom is a first step towards narrowing the confidence gap between boys and girls in mathematics. More specifically, identifying the characteristics of in-class assessments that have a positive or negative influence on girls' self-efficacy can help teachers remove unnecessary barriers to girls' confidence in mathematics. Therefore, the purpose of this study is to investigate girls' perceptions concerning in-class assessments and the accompanying connection to their mathematical confidence.

The study addressed the following research questions:

3. What are high school girls' perceptions of the connection between various forms of classroom activities and their confidence on mathematics assessments, if any?
4. How do specific forms of classroom assessment contribute to the growth of high school girls' mathematical confidence, if at all?

## Significance of the Study

This study will be significant in three ways. First, the study will contribute to the larger body of literature related tothe gender gap in mathematics along the STEM pipeline (Bergeron et al., 2017; Jean et al., 2015; Leslie et al., 1998; O'Dea et al.; 2018). Some such studies focus on a performance gap in favor of males (Zhou et al., 2017). Others claim girls perform as well as boys when controlled for variables such as prior experience (Fennema & Sherman, 1977), but on affective variables such as confidence girls fall behind their male counterparts (Buck et al., 2020; Cheryan et al., 2017; Fennema & Sherman, 1977: Zander et al., 2020). Many of these studies are conducted using large-scale assessments and surveys (Zander et al., 2020; Zhou et al., 2017). This study aims to investigate the perceived deficit by asking girls about their confidence in a classroom setting.

This leads to the second area of significance for the study: it will introduce classroom assessments as a means for understanding girls' perceptions of their mathematical ability. It is well documented that the mathematics classroom is a domain where girls perform as well as or better than boys in mathematics (Frenzel & Pekrun, 2007) often earning higher grades (Hill et al., 2010; O'Dea et al., 2018), and "yet only a few studies have examined the relationship between student confidence in learning mathematics and classroom processes" (Reyes, 1984, p. 562). Since Reyes (1984), studies have been conducted on the impact confidence has on achievement in mathematics (Aysel et al., 2020; Chionh & Fraser, 2009) and how classroom environments influence self-efficacy in mathematics (Chionh & Fraser, 2009; Dorman et al., 2003). Studies on connections between confidence and classroom processes are

missing from the literature. This study will focus on classroom activities and assessments as classroom processes that may influence girls' self-efficacy in mathematics.

This leads to a final area of significance for the present study. For teachers, this study will contribute to understanding how classroom assessments influence girls' feelings of self-efficacy. Huang et al. (2019) studied gender as a moderating effect for self-efficacy, mathematics anxiety, and growth mindset on STEM career interest. The study found that for girls, mathematics anxiety had a direct impact. Leslie et al. (1998) offered suggestions for teachers to challenge, engage, and have high expectations for the girls in their classroom. Riegle-Crumb et al. (2019) connected inquiry-based instruction with higher self-efficacy in girls and boys. Others recommended helping girls to combat stereotype threat in the mathematics classroom (Seo & Lee, 2021; Steele, 1997; Tomasetto et al., 2011). My study will ask girls directly about the effect of a varied classroom assessments influence their self-efficacy in hopes that it will inform classroom assessment practices.

In preparation for the present study, I conducted a pilot study in the Algebra 2 classes at Hillside School (Webster, 2021). Based on my understanding of the literature and 15 years of experience as a mathematics classroom teacher, I formed hypotheses about what students might say about classroom assessments. I expected them to reference the ideas prevalent in the theory of stereotype threat (Seo & Lee, 2021; Tomasetto et al., 2011), such as feeling they could not be successful because girls are not usually good at math. I also expected the students to focus on summative assessments and cite perfectionism as a barrier to their self-confidence. However, the responses were more illuminating than I had anticipated. It was these responses that shaped the present study

and helped me to understand the need to listen to these young women and give voice to their concerns and their experiences (Boaler, 1997).

## Definitions

In the following sections, many key terms will be used repeatedly. This section is intended to bring clarity to the meanings of these terms.

### Assessment

The term assessment will refer to individual tasks in the broad category of intentional activities executed to measure the mathematical competency of students. This term includes both summative and formative assessments that may or may not be graded.

### Classroom Assessment

The phrase classroom assessment will be used in this paper to describe a collection of activities assigned by classroom teachers, completed by students in both classroom and home environments, to measure the mathematical competency of students. Such assessments are different from large-scale assessments that are standardized assessments administered across classes, schools, school systems, or countries. Classroom assessments may take on many forms (e.g., summative quizzes or tests; presentation of student work; take-home practice). Classroom assessments include both summative and formative assessments that may or may not be graded.

### Confidence

Throughout this report, the term confidence will be used to indicate certainty. However, as noted by Bandura (1997) “confidence is a nondescript term referring to strength of belief but does not necessarily specify what the certainty is about” (p. 382). Though the definition does not require confidence to refer to a positive belief, in this

paper I will use the term to discuss the strength of a student's belief in both their own mathematical ability and the likelihood of their success in mathematics. That is, the use of the word confidence will imply self-efficacy in this study. Though self-efficacy is more accurate term, confidence is a common part of the vernacular at Hillside School. At Hillside, there are faculty and student confidence committees aimed at decreasing inhibitors that negatively affect girls' perception of their ability.

**Gender**

The term gender will be used in this study to refer "to the nonphysiological aspects of being female or male – the cultural expectations and roles for femininity and masculinity" (Lips, 2020, p. 7). In mathematics education literature, the terms gender and sex have been conflated, used interchangeably, and not clearly defined (Leyva, 2017). In the review of literature, if the term gender was used in a report, then I will use the term as was presented in the literature when referring to the results of the study. In the present study, however, I will not use the term gender to differentiate between male and female, instead I will use the term sex.

**Girl**

This study will be conducted at an all-girls school where at the time of their admission to the school, all students were biological females who identified as female. The term girl is used to identify the sex or the biological femaleness of the student (Lips, 2020).

**Self-efficacy**

Self-efficacy is a broad term of which confidence is a component. "Perceived self-efficacy refers to belief in one's power to produce given levels of attainment. A self-

efficacy assessment, therefore, includes both the affirmation of capability and the strength of belief" (Bandura, 1997, p. 382). In this paper, the term self-efficacy will be used interchangeably with confidence but will imply a student's positive belief in her mathematical ability.

**Sex**

The term sex will be "used to refer to a person's biological maleness or femaleness" (Lips, 2020, p. 7).

## Chapter Summary

This chapter included a brief introduction to a case study investigating high school girls' perceptions of the connection between classroom assessments and self-efficacy presented in this dissertation. Chapter Two will provide a summary of the literature that will guide this study. A detailed description of the research and data analysis plan follows in Chapter Three. Chapter Four will present the findings of the study. Finally, Chapter Five will consist of an analysis and interpretation of study results as well as a discussion of their connection to literature and implications for future work.

# CHAPTER II: LITERATURE REVIEW

## Introduction

Gender diversification of the STEM professional community strengthens the quality of critical innovations (Jean et al., 2015). Therefore, it is imperative to examine points along the STEM pipeline where girls and women veer away from STEM and to understand the nature of their departure (Hill et al., 2010). This study will examine the STEM pipeline specifically focused on mathematics education. Confidence is an important factor in mathematics achievement, gender-related differences, pursuit of higher-level mathematics study, and mathematics classroom processes (Leder, 2019; Reyes, 1984), all of which play a part in a female's experience in school mathematics. Thus, the purpose of this study is to investigate girls' perceptions concerning in-class assessments and accompanying connection to their mathematical confidence.

This chapter will begin with a review of the literature on gender in large-scale assessment studies. This will be followed by a synthesis of literature on classroom assessments. Finally, a review of the literature on girls' confidence in mathematics will be examined. When discussing literature on sex or gender, terminology used in the cited articles is also used in this review. This literature review does not encompass all the literature available on these topics. Instead, the review will focus on the most pertinent available research, which includes research to support the development of the research questions, the theoretical framework used to inform the study design, and the analytical framework used to interpret findings.

## Large-Scale Studies of Gender Differences

This section contains a synthesis of studies on gender differences in mathematics conducted on a large-scale. Such studies include but are not limited to: reports across many school systems, analysis of international or national standardized mathematics achievement tests, and surveys sent to thousands of students. In the discussion below the studies are grouped by large-scale achievement tests and large-scale evaluation of affective factors. Gendered terms are included in the discussion in alignment with the terminology used in the citing articles.

### Girls' Achievement on Large-Scale Assessments

The body of research attending to gender differences in mathematics education has changed over time. Much of the research published before the mid-1970s claimed that boys performed better in mathematics than girls (e.g., Aiken, 1971; Parsley et al., 1964). Fennema and Sherman (1977) discovered that when controlled for prior experience, there was no significant gender difference in mathematical ability; rather, the differences were caused by affective variables. The work of Fennema and Sherman led to additional research on gender differences in the affective sphere (Fennema & Hart, 1994; Zander et al., 2020), but research on mathematics achievement differences between boys and girls has continued.

Conclusions on whether an achievement gap exists between boys and girls vary depending on the parameters of the study. In a meta-analysis of over one-hundred different studies of mathematics performance, Frost et al. (1994) concluded that males had a slight performance advantage over females with an effect size of 0.15. One study claimed that a gender gap in mathematical achievement exists in kindergarten to third

grade (Lee et al., 2010). However, another study argued that, as a whole, school districts in the United States do not have an achievement gap but rather an achievement gap favoring boys in more socioeconomically advantaged districts (Reardon et al., 2019). When researchers focused on the top performing mathematics students, a consistent male advantage in mathematics performance appeared (Zhou et al., 2017). Therefore, the existence of a performance gap between the sexes in mathematical achievement differs depending on the year, scope, and variables considered in the study.

One of the reasons to study gender differences in achievement is to understand the source of potential inequalities (Leder, 2019). Girls can be influenced by notions of female inferiority (Leyva, 2017) or stereotype threat (Leder & Forgasz, 2018; Steele, 1997; Tomasetto et al., 2011) while taking an achievement test and therefore underestimate their own ability to perform well on the assessment. Girls can also be affected by the context of standardized assessment questions leading to questions about the gender neutrality of the content of such exams (Leder & Forgasz, 2018). Therefore, the accuracy of any achievement gaps found using such large-scale assessments may be questioned on the grounds of implicit biases of the tests themselves and the testing environment.

In a meta-analysis of gender related research in mathematics education, Leyva (2017) indicated that other researchers began to question male superiority in mathematics when the gap was not evident in the early grades. As mentioned earlier, Fennema and Sherman (1977) discovered that when controlling for appropriate variables, there was no significant gender difference in mathematical ability but the differences were instead in affective variables. They found that mathematics confidence was higher in boys than in

girls, and boys were more likely to continue further into a mathematics sequence of study than girls. Since the late 1970s, the body of research has shifted to explore the affective difference in mathematics learning for boys and girls. This research is the focus of the following section.

**Affective Factors in Girls on Large-Scale Assessments**

Though the research on sex related differences has shifted from achievement to the affective domain, many such studies have been conducted on a large-scale via survey or assessment follow-up questionnaire given to hundreds or thousands of participants (e.g., Fennema & Sherman, 1977; Frenzel & Pekrun, 2007; Zander et al., 2020). In a meta-analysis of seventy studies of gender differences in attitude, Frost et al. (1994) found that boys have higher attitudes and affect about mathematics than girls, but the average effect sizes were small. It is necessary to look at the individual studies to understand the details of the affective gender gap.

Some dissimilarities in affective factors stem from feelings and beliefs held by the students themselves. Though girls and boys receive similar grades in mathematics with girls holding a slight advantage (O'Dea et al., 2018; Reardon et al., 2019), girls reported a more negative emotional pattern than boys (Frenzel & Pekrun, 2007). Frenzel and Pekrun's (2007) findings suggested the difference is a result of girls' low competence beliefs and domain value of mathematics, combined with their high subjective values of achievement in mathematics. In other words, girls have a more negative perception of both their own ability and the importance of the mathematics they are using than do boys. Yet girls place great value on their need to be successful and experience negative

emotions because they feel they are falling short of their expectations (Frenzel & Pekrun, 2007).

There are factors contributing to girls' lower affective feelings about mathematics, which arise from external sources. Gender stereotyping in mathematics begins to form in preschool and early elementary grades (Gunderson et al., 2012). Perceptions of mathematics as a masculine domain (Leyva, 2017), are messaged to students through outside influences such as teachers and parents (Becker, 1981). In an analysis of literature, Becker (1981) found that the expectations of teachers differed based on the sex of students and these expectations reflected societal views of the roles of men and women in mathematics.

Positive aspects of mathematics such as joyfulness of solving challenging problems, usefulness for future work, importance, and success are associated with boys but the negative aspects of the subject such as finding mathematics boring or difficult and the hard work required are characterized as female perceptions (Brandell & Staberg, 2008). Surrounded by societal stereotypes of girls' inferiority in mathematics, girls are subject to the influence of stereotype threat when they participate in large-scale assessments and surveys (Buck et al., 2020; Steele, 1997; Tomasetto et al., 2011). This body of literature indicated there are negative external influences contributing to the affective gender gap in mathematics.

Whether stemming from internal or external factors, one of the most prevalent affective sex-related discrepancies in literature is in self-efficacy or confidence (Buck et al., 2020; Cheryan et al., 2017; Fennema & Sherman, 1977; Zander et al., 2020). The gap in self-efficacy favors boys and is observed across the STEM pipeline from elementary

school through college (Buck et al., 2020; Cheryan et al., 2017). Girls tend to have lower confidence in their ability even when they perform at the same level as their male counterparts (Buck et al., 2020). Zander et al. (2020) conducted a study in which participants completed a standardized mathematics test followed by three self-reported measures of mastery. Despite reporting similar grades, girls reported lower self-efficacy and self-esteem in mathematics. These findings suggested that different cognitive and affective experiences of boys and girls after testing situations may impact their self-efficacy beliefs.

Finally, Preckel, Goetz, Pekrun, and Kleine (2008) found that gender differences in self-concept, interest, and motivation in mathematics are more prevalent in gifted compared to average-ability students. This means the most promising of students for future mathematics related careers are those most impacted by these differences, thus illuminating the need to combat the stereotypes and negative perceptions of girls in mathematics. In the pursuit of eliminating gender differences in mathematics education, it remains important to understand the underlying reasons behind the disparity. One of the most prevalent disparities is self-efficacy, and as such a review of literature on confidence and self-efficacy follows in the next section.

## Self-Efficacy and Confidence

One of the most prevalent affective domains in which girls fall behind boys remains self-efficacy (Buck et al., 2020), often referred to in literature by the catch word "confidence" (Bandura, 1997). Because confidence and success are closely intertwined (Burton, 2004), influences and inhibitors to self-efficacy must be explored. In Bandura's (1997) book on self-efficacy, he described four principal sources of information by which

self-efficacy beliefs are constructed: mastery experiences, vicarious experiences, social influences, and one's physiological and emotional states. Bandura claimed the most influential source of self-efficacy was mastery experiences, a claim that has been supported by more contemporary research on self-efficacy (e.g., Britner & Pajares, 2006; Usher & Pajares, 2008).

However, Usher and Pejares (2008) suggested that contextual factors such as gender may affect the strength and influence of each of the four sources on a student's self-efficacy. The four sources of self-efficacy are an integral part of the theoretical framework of the present study and are discussed in greater detail later in the chapter. Although high self-efficacy beliefs enhance school success, an inhibitor to self-efficacy beliefs is school failure (Flammer, 2001). Students who lack confidence in their skills are more likely to give up when they encounter activities that require those skills (Pajares, 2002).

One of the most important affective variables, confidence helps students to learn more and feel better about themselves (Reyes, 1984). Teachers are well positioned to influence the development or hindrance of students' self-confidence. Evidence suggests one way to mitigate gender differences in self-efficacy is through clear feedback (Pajares, 2002). It is important, therefore, to provide students with performance evaluations to help them understand their progress. Teachers can also impede self-efficacy by reinforcing masculine stereotypes (Becker, 1981; Leyva, 2017) or making negative remarks, reinforcing blossoming thoughts of self-doubt in their students (Webster, 2021). Research shows girls have less self-confidence than boys in general, but this gap is widest in mathematics. In the following section I explore more research on self-

confidence, but I will narrow the focus of my exploration to girls' confidence in mathematics.

## Girls' Confidence in Mathematics

In a previous section I reviewed literature that used large-scale assessments to establish a gender gap in affective factors in mathematics education that favored boys and used deficit language to describe girls' self-efficacy in mathematics. In this section, I explore similar literature conducted at the classroom level and literature offering suggestions that can be instituted by a teacher in the classroom.

Large-scale assessment studies were clear in establishing self-efficacy as an important sex-related difference in the affective measures of mathematics learning (Buck et al., 2020; Cheryan et al., 2017; Fennema & Sherman, 1977; Zander et al., 2020). Similar to the large-scale findings of Brandell and Staberg (2008), Vale and Leder (2004) studied the classroom setting and found girls were more likely to give responses about computers enhancing mathematics performance while boys saw computers in mathematics class as pleasurable or used to make mathematics relevant.

Once again, the fun, positive perceptions of mathematics with computers were viewed as male while the functional perceptions were female. Such masculine stereotypes were reported in large-scale assessments (Buck et al., 2020; Steele, 1997; Tomasetto et al., 2011) and research suggested stereotype threat impacts performance (Steele, 1997). Tomasetto et al. (2011) extended this research further to show girls perform worse when hampered by the threat of such stereotypes, a situation which was exacerbated by the parents' role in reinforcing gendered stereotypes. Although schools cannot control

parents' influence on girls' confidence in mathematics, the literature remains unclear about ways teachers can impact the self-efficacy of their students.

At the classroom level, female students lacked confidence in mathematics (Leyva, 2017). Leyva (2017) offered that a possible hinderance to girls' lack of confidence was the teacher's unintentional bias towards male students in mathematics class, an eventuality that can be avoided by a teacher's mindful use of language and attention to personal biases. Instead, teachers should provide support and encouragement for girls who have an interest in learning mathematics (Noddings, 1998) or rather they should nurture that interest while providing support for all girls in their mathematics classes. Students explained that environments conducive to fostering self-efficacy in mathematics involved opportunities for agency, ownership, working with peers, and reflection as opposed to dependency (Burton, 2004). Rather than over-asserting authority, teachers can minimize or eliminate gender differences in self-efficacy by providing their students with clear feedback to help them navigate their learning process (Pajares, 2002). As a result, students with more confidence spend more time in class engaged with the mathematics (Hart, 1989).

Another recommendation to improve girls' performance is to separate the boys from the girls in mathematics class. Admittedly, this is likely out of the control of most teachers. In a study by Streitmatter (1997), girls were more likely to ask and answer questions about the mathematics in an all-girls setting. The setting promoted freedom to take risks when speaking in class, even if they might be wrong, because it provided a space where no one questioned their ability to offer ideas based on gender. The environment also enhanced the girls' ability to learn mathematics, perception of

themselves as mathematicians, and confidence in their mathematical abilities. Whether this is a feasible possibility or not, it is important to examine what factors help explain girls' confidence in mathematics (Reyes, 1984; Zander et al., 2020) and to be fervent and creative in studying why so many girls who are interested and talented in mathematics are lost to other fields of study (Almukhambetova et al., 2021; Noddings, 1998). Developing a greater understanding of these things is important because confidence in mathematics ability increases the likelihood a student will choose tasks involving mathematics and persevere longer than those who are less certain of their ability (Miele et al., 2022; Reyes, 1984). Additionally, mathematics confidence is an important factor in predicting future choices to take mathematics courses (Blotnicky et al., 2018; Reyes, 1984). A recommended focus for combatting negative self-concepts for girls in mathematics include early interventions geared towards improving girls' self-perceptions in mathematics and counteracting relevant effects of peers (Leslie et al., 1998). Understanding of girls' perception of their self-efficacy in mathematics as related to classroom assessments remains the purpose of this study. Therefore, the following section will explore the literature of classroom assessments and will make connections between assessments and self-efficacy or confidence when possible.

## Classroom Assessments

Assessments come in many forms. Wiliam (2007) identified three types of assessment, each with a different purpose: formative assessment to support learning, summative assessment to gauge achievement or potential of individuals, and evaluative assessment to evaluate the quality of programs. Large-scale assessments discussed in a previous section in this chapter are categorized as summative or evaluative assessments.

Classroom assessments, however, can be categorized as formative or summative. Despite reports that males have a performance advantage over girls on large-scale assessment tests, females hold an advantage over their male counterparts in school grades (Voyer & Voyer, 2014). Large-scale assessments have been used to identify a confidence gap between boys and girls (Buck et al., 2020; Fennema & Sherman, 1977; Zander et al., 2020). Thus, an investigation of assessments at the classroom level can lead to a better understanding of the relationship between girls' confidence and assessment because the classroom is a domain where girls excel and hold a performance advantage over boys (O'Dea et al., 2018).

Studies focused on girls' confidence and assessment in the classroom have offered some suggestions applicable to the present study. Boaler (1997) found girls related underachievement to a competitive environment, but they related open work, discussion, and cooperation with understanding. Such classroom practices afford teachers formative assessment opportunities which contribute to coherent and equitable assessment systems (Shepard et al, 2016).

Hill et al. (2010) recommended teaching students about stereotype threat to help mitigate its effects for girls on assessments. They also recommended promoting a growth mindset as a lens through which students can approach their participation in assessments and the interpretation of their results. Finally, they recommended that teachers make performance standards and expectations clear because girls may interpret a similar performance differently than it may be interpreted by a boy. A girl may interpret a grade on an assessment as an indicator that she is not performing well, and as a result, it may impact her confidence in her mathematical ability. Whereas, if the teacher makes it clear

that the new concept takes time to master and that a particular grade is merely a marker for student progress in their understanding, the girl is more likely to believe she is making appropriate progress on the new material. Each recommendation given remains an indicator that there are opportunities to explore the relationship between girls' confidence and classroom assessments.

The way achievement is measured can influence apparent gender differences in performance (Voyer & Voyer, 2014). If teachers or researchers elicit students' interests, experiences, and knowledge they can make use of the information to guide instruction (Penuel & Shepard, 2016). Such insight can be difficult to acquire and there are few studies using such an intervention, thus indicating an area where future research is needed. In literature, there is little attention paid to teachers' assessments and how they might improve mathematics learning (Wiliam, 2007). There is a need for research that asks girls about their experiences with classroom assessments. Such an investigation will provide a better understanding of girls' confidence in mathematics.

## Theoretical Framework

This section explores the theoretical framework used to guide the present study. Zander et al. (2020) used Bandura's (1997) four sources of self-efficacy to frame their large-scale assessment and survey investigating explanations of the gender confidence gap in mathematics. Their results indicated that boys have an advantage over girls in their mathematics self-efficacy beliefs as a result of more positive feelings and more cognitive self-enhancement after testing (Zander et al., 2020). Because this study seeks to understand the connections girls perceive between assessments and their confidence,

Bandura's (1997) four sources of self-efficacy served as a guide for developing the methodology. This section explores the literary basis for this theoretical frame.

In reference to the first source of self-efficacy Bandura (1997) explained that mastery experiences provide support for one's ability to succeed and are therefore the most instrumental sources of self-efficacy. He also noted that failure can damage self-efficacy as can easy success. It remains important for students to meet challenges and persevere to realize obstacles will arise, yet they have the ability to overcome them and succeed. Whereas personal mastery experiences can build (or diminish) efficacy, feedback received from external sources also plays a role.

The second source of self-efficacy beliefs is verbal or social persuasion (Bandura, 1997). If significant individuals express the belief that a student can succeed at their desired objective, then social persuasion can positively influence the growth of their self-efficacy. Bandura (1997) asserted "people who are persuaded verbally that they possess the capabilities to master given tasks are likely to mobilize greater effort and sustain it than if they harbor self-doubts and dwell on personal deficiencies when difficulties arise" (p. 101). Significant individuals may take the form of teachers, parents, classmates, or anyone whose perspective is valued by the student.

When measuring success, there is often no clear indicator of adequacy. In such a situation, individuals can compare themselves with others to determine their relative level of ability. Bandura (1997) referred to this third source of self-efficacy as vicarious experiences. "When adequacy must be gauged largely in relation to the performance of others, social comparison operates as a primary factor in the self-appraisal of capabilities" (p. 87). At times modeling by others in a similar situation helps individuals

recognize they too are capable of success in comparable activities. However, for girls in particular, comparisons with others can diminish confidence (Archard, 2012) and can cause self-doubt. Therefore, vicarious experience should be introduced intentionally so they serve to promote rather than diminish self-confidence.

Finally, the state of the body and emotions can influence how individuals assess their capabilities. “Affective states can have widely generalized effects on beliefs of personal efficacy in diverse spheres of functioning” (Bandura, 1997, p. 106). Bandura referred to the fourth way of altering self-efficacy beliefs as physiological and affective states. Together these four sources of self-efficacy provide a theoretical basis for the development of the assessment profile for the present study.

Since the early 1970s, Perry’s (1970) framework for describing how students’ conceptions about their knowledge and their understanding of themselves as knowers develop over time has been used by researchers and educators to understand intellectual development of adolescents in schools (Belenky et al., 1986). Perry (1970) described a set of positions through which students’ progress starting with dualism, followed by multiplicity, then relative subordinate, and finally relativism as they move through their educational experiences.

Though Perry’s research included female participants, only interviews with the males were used in validating his scheme (Belenky et al., 1986). Women were later found to conform to the epistemological progression, yet this showed only the ways in which women were similar to men as opposed to discovering ways of knowing are unique to women. As a result, Belenky et al. (1986) interviewed 135 women from “diverse ages, circumstances, and outlooks” (p. 13) to develop a framework of epistemological

perspectives from which women know and view the world. The five major epistemological categories are silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge. The first four categories involve some lack of voice, authority, ownership, or application of knowledge suggesting that women who fall into these ways of knowing are unable to reconcile reason with their own intuition and the expertise of others to move to the goal category of constructed knowledge.

Belenky et al. (1986) did not ascribe any stage-like qualities to the ways of knowing and therefore movement between the different perspectives may be different for individual women. Becker (1995), however, described the categories as stages, not as a developmental sequence learners pass through but as a progression from dependence to autonomy (see Figure 1) with Constructed Knowledge describing the desired way of knowing. Because women do not necessarily move through the ways of knowing in a linear progression (Belenky et al., 1986), I approach this research with the notion that girls' ways of knowing can move between categories, with the goal of movement towards improved autonomy and eventually—Constructed Knowledge (see Figure 2).

**Figure 1**

*Progression of Women's Ways of Knowing from Dependence to Autonomy*

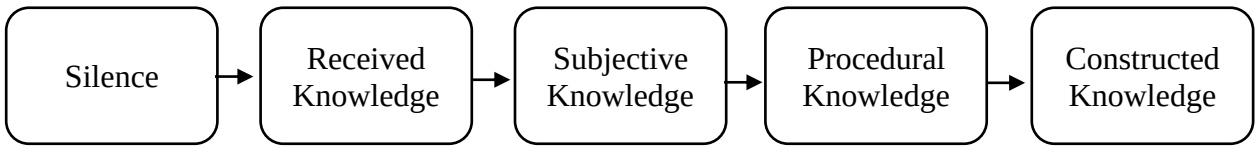


**Figure 2**

*Possible Movement between Women's Ways of Knowing*

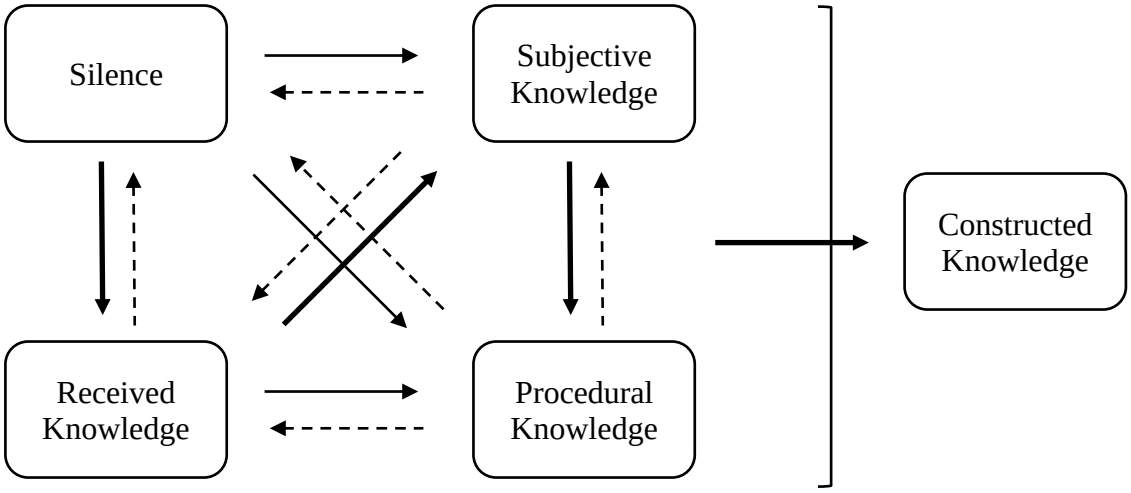



Figure 2 illustrates the way movement occurs between the categories for Women's Ways of Knowing (Belenky et al., 1986). The trajectory following the bold solid arrows moves through all ways of knowing from the most silent and dependent to the discovery of inner voice and independence. However, all women do not necessarily transition between ways of knowing in such a sequential way. The bold and non-bold solid arrows all represent the desired direction of movement from a more dependent category to one with more autonomy. Girls also described painful, negative experiences which influenced their movement to a more silent and dependent state (Webster, 2021) prompting me to include dashed lines to indicate undesirably movement through the ways of knowing.

How a girl perceives herself as a knower is closely tied with her self-efficacy as a student. Though Belenky et al. (1986) did not connect Women's Ways of Knowing with

self-efficacy directly, comments on the confidence level of women within many of the categories was discussed. Women located in the category of silence were described as having no confidence in their ability to learn from herself or others or to find meaning in what she encountered at school. Women in a position of received knowledge were described as having very little confidence in themselves and some confidence in their ability to understand what others tell them. The confidence level of women categorized as subjective knower was described as unstable. Evidence of confidence increased with the progression of autonomy. Belenky et al. (1986) also described scenarios where women credited teachers for helping them to improve their confidence as they transitioned to a way of knowing characterized by more independence of thought than before. These ideas support the selection of women's ways of knowing as a framework for connecting student descriptions of their way of knowing with their perceived connections between classroom activities and confidence in mathematics classes.

Burton (1995) synthesized philosophical, pedagogical, and feminist literature to define knowing in mathematics in relation to five categories: "its person- and cultural/social-relatedness; the aesthetics of mathematical thinking it invokes; its nurturing of intuition and insight, its recognition and celebration of different approaches particularly in styles of thinking; and the globality of its application" (p. 526). Burton (1995) asserted "inviting students to define and describe their knowing in mathematics in these ways does have gender implications" (p. 526). I therefore designed the activities for this unit of study to complement these categories of women's ways of knowing in mathematics.

This study makes use of three theories, and two schemes were combined to inform the study's development. Bandura's (1997) four sources of self-efficacy advised the development of the unit activities and assessment profile. Burton's (1995) feminist ways of knowing mathematics was employed in the development of the unit profile as well as the semi-structured interview protocol. The third theory, Belenky et al. (1986), was used to connect the female perspective to the understanding of girls' confidence in mathematics class.

## Chapter Summary

Large-scale assessment studies suggested cognitive and affective experiences of girls following testing situations may contribute to their self-efficacy beliefs (Zander et al., 2020). Few studies, however, have investigated the relationship between student confidence in learning mathematics and classroom processes such as assessment (Reyes, 1984). Like on large-scale assessment, there are factors that can influence what students experience and value in classroom assessments (Leder & Forgasz, 2018). These factors are often ignored or not included in literature when reporting test results from large-scale studies. A focused, intentional study of the student experience at the classroom level will add to the literature in this area.

The tone of some literature on sex-related differences in mathematics is suggestive of ways girls should change to become more like the boys (Leyva, 2017). This study, however, follows the recommendation of Fennema and Hart (1994) to study the voices and perspectives of females in mathematics with a focus on how they see mathematics and its connectedness with their lives. Girls' perspectives contribute greatly to the understanding of how classroom assessments influence their self-efficacy. This

study focuses on the voices of girls in the mathematics classroom because there is much to be learned from listening to their perspective (Boaler, 1997).

Finally, many decisions made in the development of the methodology for the present study are supported by the literature discussed in this section. Streitmatter (1997) suggested the girls-only classroom as a desirable context for research on girls' sense of confidence. Because research has shown that sex differences between boys and girls emerge around grade eight or nine (Fox et al., 1977) this study focuses mostly on girls in the tenth grade, the level at which most girls will likely measure their own self-efficacy as lower than their male counterparts. Many confidence studies in literature are conducted with high achieving students (Burton, 2004; Hart, 1989). Though there remains a sex-related confidence gap in mathematics across all ability levels, it is especially pronounced among high achievers (Zhou et al., 2017). Therefore, this study will focus on investigating confidence in high achieving girls to measure the impact of confidence of girls in mathematics class. The following chapter will provide details of the methodology for this study as informed by this review of the literature.

# Chapter III: METHODOLOGY

## Introduction

Research indicates that the gender gap in STEM fields has narrowed (Fennema & Sherman, 1977; Reardon et al., 2019), yet a gap in affective factors remains in mathematics related fields (Buck et al., 2020, Fennema & Sherman, 1977; Zander et al., 2020). Although large assessment studies have revealed some limiting factors that may disadvantage girls (Buck et al., 2020; Leder & Forgasz, 2018), little is known about how in-class assessments connect with girls' self-efficacy in mathematics. Therefore, this study is designed to investigate how high school girls perceive the relationship between classroom assessments and self-efficacy in mathematics.

This chapter details the research methodology utilized in this study. It begins with an overview of the design and context of the study, followed by a description of the participant selection process. Then, the sources of data to be collected are described as well as the process and instruments used for the data collection process. The analytical framework and data analysis process are presented. Finally, boundaries of the study including limitations and delimitations are addressed.

## Research Overview

This study utilized a multiple case design (Yin, 2009) to investigate girls' perceptions of connections between classroom assessments and their self-efficacy in mathematics class. Specifically, the research questions were:

1. What are high school girls' perceptions of the connection between various forms of classroom activities and their confidence on mathematics assessments, if any?

2. How do specific forms of classroom assessment contribute to the growth of high school girls' mathematical confidence, if at all?

There were four features of this study that supported the choice of multiple case study methodology (Yin, 2009). First, this research sought to understand how girls perceive the impact of classroom assessments on their confidence and was therefore exploratory by nature. Because the nature of student perceptions remain unknown, there were many variables of interest and multiple results. Second, this study used a combination of theoretical frames to guide the data collection and analysis process, an important characteristic of case study design (Yin, 2009). Next, a multiple case design was selected because the goal of understanding girls' perceptions yielded stronger findings when the voices of multiple girls were heard through the inclusion of multiple cases. Finally, the multiple case design was holistic because there was only one unit of analysis, the students, in each case. These four aspects of the current research provide support for the use of holistic multiple case design for this study.

## Research Context

The elements of the research context are described in this section: the school, the courses, the instructors, and the students. The study focused on high school girls enrolled in an Algebra 2 course at an independent girls' school in the southeast United States during the 2021-2022 school year. This section describes relevant details for each of the elements of the study.

### The School

This study took place at Hillside School (all names are pseudonyms), an independent college preparatory school for young women in the southeastern United

States. The school had 720 students in grades five through twelve. It was accredited by the Southern Association of Colleges and Schools and the Southern Association of Independent Schools. In the 2020 graduating class, 14% of the class was recognized as National Merit Finalists or National Merit Commended Students. The middle 50% SAT score in Evidence-Based Reading & Writing ranged from 650 to 740 and in Mathematics ranged from 610 to 760. The middle 50% ACT Composite scores ranged from 29 to 33. Over 50% of students took a calculus course and approximately 30% took AP Statistics before graduation from high school. The matriculation rate was 100% with 99% of students attending a 4-year college and 1% attending a 2-year college.

Many alumnae matriculated to prestigious colleges and universities around the world. Examples from the four years preceding the study included: Brown University, California Institute of Technology, Columbia University, Cornell University, Dartmouth College, Duke University, Stanford University, University of Oxford (England), Vanderbilt University, and Yale University. The school as a community was interested in girls' confidence and created a faculty confidence committee in the Fall of 2014 and a student confidence committee in the Fall of 2019.

**The Courses**

The course in which the students were enrolled during the study was Algebra 2. There were two sections of Honors Algebra 2 and five sections of standard level Algebra 2 from which participants were selected. The courses met for 80 minutes on four out of every seven school days. The schedule was fully rotating so a given class met at a different period of the day for each of the four meetings in a cycle. Algebra 2 was compulsory for graduation and consisted mostly of tenth grade students. There were three

ninth-grade students enrolled in Honors Algebra 2 and a small number of eleventh-grade students in the standard level course. All students enrolled in the course had successfully completed a high school level Algebra 1 and Geometry course.

The unit covered during this study was polynomial functions. This unit was included in both the honors and standard levels of the course, with slight variations in coverage and at different points during the school year.

**The Instructors**

There were three instructors who teach the seven Algebra 2 sections in this study. Names provided in the descriptions below are pseudonyms. These instructors were not the participants in the study but agreed to implement assessment practices and include requested study prompts as a part of their course delivery.

The first teacher, Ms. Albert, taught two sections of standard level Algebra 2. She held a Bachelor of Science in Education and a Master of Education in Curriculum and Teaching. She had been teaching secondary school mathematics for thirteen years at the time of the study.

Ms. Johnson taught three sections of standard level Algebra 2. She held a Bachelor of Science in Mathematics and a Master of Arts in Teaching. She had been teaching secondary mathematics for six years at the time of the study.

I taught two sections of honors level Algebra 2. I held a Bachelor of Science in Mathematics, Physics, and Computer Science; a Master of Arts in Mathematics; and was pursuing a Doctor of Philosophy in Mathematics and Science Education at the time of the study. I had been teaching secondary mathematics for sixteen years. I was also the principal investigator for this study.

### The Students

The students in this study attended Hillside School, an all-girls school. At the time of the study, there was no written policy designating what sex and gender criteria must be met for acceptance into the school. At the time of admission, all students were assumed to have female anatomy and identify as female. It is possible that a student may have been in the early stages of gender transition, however the researcher had no access to this confidential information. Participants were enrolled in Algebra 2 or Honors Algebra 2. They were all in the ninth, tenth, or eleventh grade at the time of the study. All students had received high school credit for a course in Algebra 1 and in Geometry.

## Data Sources and Instruments

The data collected for the study focused on giving voice to students' perceptions (Boaler, 1997; Burton, 1995). Student cases were selected to represent girls with a variety of responses to the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976). Data sources for the study included a case selection survey, semi-structured interviews conducted with each case study participant after selection and at the completion of each unit, and reflection feedback collected from all Algebra 2 students after each written assessment. A description of each of these data sources is included in this section. Furthermore, in qualitative inquiry the researcher is an instrument (Patton, 2015), thus a description of my background is included.

### Case Selection Survey

In order to understand the perceptions of girls, I sought students with a variety of attitudes about mathematics upon entering Algebra 2. Algebra 2 students took a survey (see Appendix A) comprised of a subset of scales on the Fennema-Sherman Mathematics

Attitude Scales (Fennema & Sherman, 1976). Fennema and Sherman (1976) indicated "the scales can be used as a total package to assess a variety of attitudes toward the learning of mathematics, or the scales can be used individually" (p. 1). I selected the following four scales to include in the survey which was given to all Algebra 2 students: The Attitude Towards Success in Mathematics Scale, The Confidence in Learning Mathematics Scale, The Mathematics Anxiety Scale, and The Mathematics Usefulness Scale.

The Attitude Towards Success in Mathematics Scale was selected because it "is designed to measure the degree to which students anticipate positive or negative consequences as a result of success in mathematics" (Fennema & Sherman, 1976, p. 2). As the ability to see oneself as successful in mathematics is an important aspect of self-efficacy, this scale was important to include in the survey. Next, The Confidence in Learning Mathematics Scale was selected because it "is intended to measure confidence in one's ability to learn and perform well on mathematical tasks" (Fennema & Sherman, 1976, p. 4). Because confidence is the focus of the present study, this scale was included in the survey. The Mathematics Anxiety Scale was chosen because it is "intended to measure feelings of anxiety, dread, nervousness and associated bodily symptoms related to doing mathematics" (Fennema & Sherman, 1976, p. 4). Such physiological and emotional states are of interest because according to Bandura (1997) such feelings influence one's self-efficacy.

Finally, The Mathematics Usefulness Scale was selected because it "is designed to measure students' beliefs about the usefulness of mathematics currently and in relationship to their future education, vocation, or other activities." (Fennema &

Sherman, 1976, p. 5). Mathematical usefulness is of interest to this study because according to Bandura (1997) a strong sense of self-efficacy fosters motivation and interest in the subject and "can play a key role in setting the course their [adolescents] life paths take" (p. 177). Understanding students' perceptions of the usefulness of mathematics may provide additional insight into their self-efficacy.

Each subscale on the survey consisted of twelve Likert Scale questions consisting of the following choices: strongly agree, agree, neutral, disagree, and strongly disagree. The most favorable responses in The Attitude Towards Success in Mathematics Scale indicated a positive attitude towards mathematics whereas the least favorable responses indicated a negative attitude towards mathematics. The most favorable responses on The Confidence in Learning Mathematics Scale indicated a high level of confidence in learning mathematics while less favorable responses indicated low confidence in learning mathematics. The most favorable responses for The Mathematics Anxiety Scale, however, indicated a low level of mathematics anxiety and indications of high levels of mathematics anxiety were the least favorable responses.

Finally, the most favorable responses on The Mathematics Usefulness Scale indicated a high level of perceived usefulness of mathematics whereas the least favorable responses indicated little to no perceived usefulness of mathematics. For each subscale, questions 1 to 6 positioned a response of strongly agree as the most favorable response while strongly disagree was least favorable. For questions 7 through 10, the scoring was reversed and a response of strongly disagree was most favorable while strongly agree was least favorable. Each answer was given a numerical weight with five points assigned for the most favorable response to a survey item and 1 point assigned to the least favorable

response. For each student, a numerical score between twelve and sixty was calculated for each subscale and a numerical score between forty-eight and two-hundred forty was calculated for the survey as a whole. Responses to these surveys were used to illuminate the self-efficacy related mathematical attitudes and beliefs of each student at the beginning of the study. Case study participants were selected based on answers to this survey.

**Semi-structured Interviews**

Once cases study participants were selected using the Fennema-Sherman Attitude Scales (Fennema & Sherman, 1976), a semi-structured interview (see Appendix B) was conducted with each of the students to gain a more nuanced understanding of their survey responses. The questions selected were intentionally broad to capture the true voices of the girls interviewed (Burton, 1995). Additionally, one of the follow-up questions asked "Why do you think you feel this way?" This question was designed to align with Burton's (1995) framework for women's ways of knowing mathematics. I conducted each of the interviews. The interviews were audio recorded and transcribed for analysis.

An additional round of interviews was conducted (see Appendix C) at the end of each of unit to solicit student perceptions of connections between the assessments from the unit and their confidence level in mathematics. The students participating in the interviews were those selected as cases. I conducted each of these interviews, which were audio recorded and transcribed for analysis.

**Classroom Assessment Feedback**

Upon completion of each warm-up, exit ticket, quiz, and test, all Algebra 2 students were asked to reflect on their experience with the assessment. During the unit,

students completed five or six such reflections. The reflection prompts were short to prevent consuming too much class time and therefore were only two questions in length (see Appendix D). Students were asked to mark their confidence on the assessment with a marker on a scale. Then, they were asked to explain their reason for marking their confidence in this way. This question was intentionally broad to elevate the voice of the student and to capture her perspective (Burton, 1995). For the selected cases, these reflections were reviewed by me before the end-of-unit interviews to see how their answers differed among the assessments. They were shown reflections and asked clarifying questions as needed. For other Algebra 2 students, I used the reflections to determine if there were common themes among all participants. I also looked for comments not otherwise represented in the student cases that should be examined more closely.

**The Researcher as an Instrument**

A description of the relevant experience, training, and perspective I bring to the study is included because the researcher is an instrument in qualitative research (Patton, 2015). I am a woman who chose to study mathematics, physics, and computer science and to pursue a STEM career, experiencing highlights and setbacks along the way. Three years of doctoral coursework in mathematics and science education provided relevant knowledge on teaching and learning of mathematics as well as educational research methodologies. I participated in multiple research projects supervised by university faculty, which provided experience with qualitative research methodologies. Finally, I had two years of experience teaching mathematics at the university level and sixteen

years teaching secondary school mathematics and computer science in an all girls' school. These experiences contributed to the lens through which I view the study.

## Data Collection Procedures

After receiving institutional review board approval, the data sources described above were collected in four distinct stages. The procedures for each stage are provided in the following sections.

### Participant Selection

The sixty-three participants in this study were all consenting students enrolled in standard level or Honors Algebra 2 at Hillside School at the time of the study. The students completed the four subscales of the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) in October of the 2021-2022 school year (see Appendix A). The four sections included twelve questions each about confidence, attitude, usefulness, and anxiety. Survey responses for each student were converted to numerical scores. Cumulative scores were sorted in numerical order to determine the maximum and minimum scores. Next, scores for each category were sorted in numerical order to determine the highest and lowest reported scores for each category.

Individual student scores were then evaluated with respect to the overall scores for nuance. Because the honors students began the unit of study before the regular level students, selection of honors student cases were made with respect to other honors students. However, regular level students were selected by comparing scores to the combined participant pool. As Stake (2005) recommended, "the benefits of multicase study will be limited if fewer than, say, 4 cases are chosen, or more than 10." Therefore, the goal was to select between five and ten cases from the students surveyed. The process

of selecting the five cases for this study is described in the following paragraphs. All student names are pseudonyms. Each student either named their own pseudonym or opted to use a randomly generated name. The discussion of highest and lowest scores in the selection process below refers to the highest and lowest scores of the students willing to be interviewed.

The honors classes completed the survey first because they returned study permission forms quickly and the unit on polynomials was to begin a few weeks earlier than in standard classes. Twenty-nine honors students consented to participate in the study and sixteen of these students indicated on their survey that they were willing to participate in follow-up interviews. I used continuum sampling (Patton, 2015) when selecting students to interview so they represented various levels on the survey subscales. From the sixteen possible interviewees, I reached out to four students to schedule interviews. These honors level students were identified as follows: a student with the highest overall score, a student with a high overall score but with a low score for anxiety, a student with the lowest overall score, a student with the lowest confidence and anxiety scores.

Two of the students never replied to repeated attempts to schedule an interview. Therefore, only two students were selected as cases from the honors level classes. Susie had the lowest confidence and anxiety scores of all honors students willing to be interviewed. She had a low overall score but a high score for attitude. Hilda had the lowest overall score of all honors students willing to be interviewed. The scores for Hilda and Susie in relative position with their peers are illustrated in Figure 3.

**Figure 3**

*Attitudes Subscale Scores for Case Study Participants Relative to their Classmates*


After the honors level participants were selected and the interview process began, the regular level students completed the survey. Thirty-four regular level students consented to participate in the study and nineteen of these students indicated on their survey they were willing to participate in follow-up interviews. From these nineteen possible interviewees, I reached out to five students to schedule interviews. These students were identified as follows: a student with the lowest overall score, a student with the lowest confidence score but an average score for attitude, a student with the highest overall score, a student with the highest confidence score, a student with a below average total score with above average scores in usefulness and attitude and a low score in confidence along with the lowest score in anxiety. The first two students described above did not reply to my interview requests. Therefore, three students were selected as case study participants from the regular level classes. Yuliana had the highest confidence,

attitude, and anxiety scores of any regular level student willing to be interviewed. Her usefulness score was a bit lower but still above the average for all students. Magnolia had the highest overall score of all students willing to be interviewed, including both honors and regular level students. She had the highest scores of all students in both confidence and usefulness, with a perfect score for usefulness. Her scores for attitude and anxiety were not as extreme but were still above the average in each category. Teagan had an overall score that was more than twenty points below the average. Her score for confidence was below average. Her scores for attitude and usefulness, however, were within a point of the average for all students. Teagan had the lowest score of all students in the study on the anxiety subscale. Scores for selected cases are summarized in **Figure *3***.

**Survey Follow-Up Interview**

After the cases were selected, I conducted semi-structured interviews with each of the case study participants (see Appendix B). The interviews ranged from approximately five to fifteen minutes in length. The interviews were audio-recorded and transcribed using Otter.ai. I then double checked the transcripts and corrected any errors in translation from Otter.ai. The purpose of these interviews was to gain perspective on each girls' prior experience in mathematics and their academic interests. These interviews gave the participants an opportunity to provide further detail about their survey responses including specific experiences that led them to answer in a particular way. At the same time, these interviews provided context for where the student is situated as a mathematics student at the beginning of the study.

**Unit Activities and Assessment Profile**

The unit of Algebra 2 material included in this study was polynomial functions. Instruction in this topic was provided in the honors sections in November of 2021 and in the standard level sections in December of 2021. All students learned about quadratic functions, their graphs, maximum or minimum values, zeros, and applications. Next, they explored polynomials of degree greater than two and their graphs, including end behavior and multiplicity of zeros. Then students learned polynomial and synthetic division. They were also introduced to complex zeros. Finally, students were asked to find all zeros and write the complete factorization of polynomials over the complex number system. Additionally, the honors classes learned how to find asymptotes and intercepts, and then to graph rational functions. The unit spanned approximately four weeks of class time.

Assessment opportunities for the unit were selected according to the theoretical framework described in a previous section. Based upon Bandura's (1997) four sources of self-efficacy, mastery experiences were offered in the form of quick checks, discovery explorations, daily challenge problems, homework assignments, a mid-unit quiz, and an end of unit summative test. Feedback on quick checks, challenge problem discussions, and quiz feedback afforded students the opportunity to experience social persuasion. Discovery exercises, challenge problem discussions, and test review offered vicarious experience opportunities. Finally, the physiological state of the students was highlighted at the beginning of the unit with a request for the students to be attentive to their physiological and emotional states throughout the unit. Assessment Reflections (see Appendix D) were administered with the quick checks, unit quiz, and unit test and afforded students the opportunity to reflect on their physiological and emotional states.

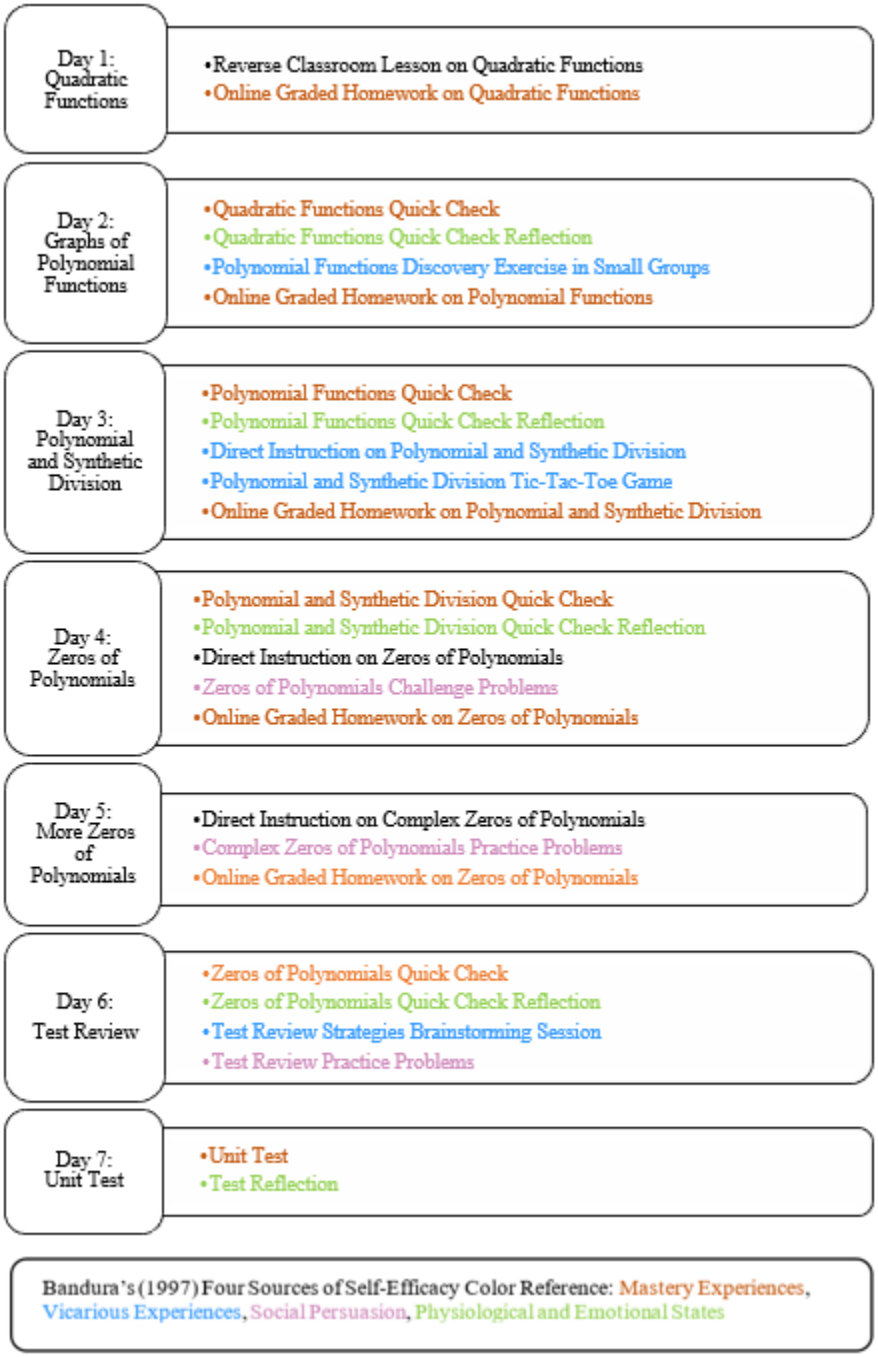
Figure 4 gives the assessment profile and accompanying timeline for the Honors Algebra 2 course and Figure 5 gives the assessment profile and accompanying timeline for the regular level Algebra 2 course.

**Figure 4**

*Polynomials Unit Timeline for Honors Algebra 2*

**Figure 5**

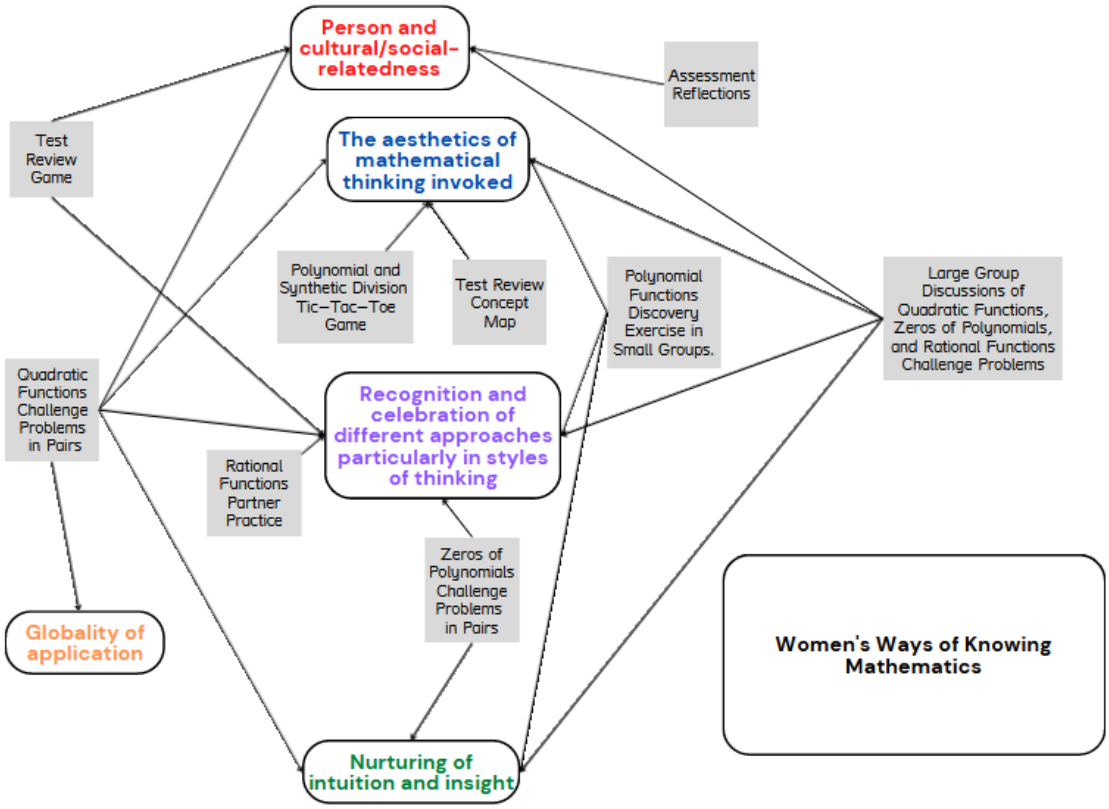
*Polynomials Unit Timeline for Regular Algebra 2*



The instructional techniques selected for each activity were designed to align with Burton's (1995) Women's Ways of Knowing Mathematics. Group work illuminated the social relatedness of mathematics and reflections humanized the student experience. A variety of activities helped to illustrate the diversity and beauty of mathematical thinking. Large and small group activities exposed the students to multiple problem approaches and styles of thinking. Exploration problems and discovery exercises nurtured intuition and insight. Application of quadratic functions highlighted the globality of mathematics application. Connections between select activities and intended feminist ways of knowing mathematics are illustrated in Figure 6.

**Figure 6**

*Connections Between Selected Activities and Feminist Ways of Knowing Mathematics*




The same assessment profile was used in all sections of Algebra 2, though individual assessments differed in length, difficulty level, and questions asked. Homework was given in both the honors and regular level courses after each lesson via an online homework platform associated with the textbook. In the regular level classes, students had three submission attempts per problem. There was no penalty for wrong answers but if the student submitted a third incorrect solution, the problem was marked wrong. They could earn full credit for all problems completed before the next class and half credit for any problems completed after the following class period. In the honors

course, students were allowed two attempts with no penalty. If they correctly answered the question on the third try or beyond, five percentage points were deducted from the score for that problem for each attempt past two. Scores for homework were not recorded until the day of the summative unit test.

Assessment Reflections collected from all consenting Algebra 2 students after each selected assessment served as artifacts from this phase of this study and were used for the end of unit follow-up interviews with each case-study participant. All students' reflections were also read for unique responses to identify possible additional case-study participants, however no additional student participants were identified. Follow-up interviews gave students an opportunity to explain their reflection and gave me an opportunity to understand their perspective. The follow-up interview process will be described in the following section.

### End of Unit Interview

Following the completion of the unit on polynomials, I conducted interviews lasting between twelve and twenty minutes with each case-study participant (see Appendix C). The interviews were audio-recorded and transcribed using Otter.ai. I asked students to reflect on the unit as a whole as well as their confidence levels as they navigated the unit. I showed many of them their Assessment Reflections and asked for further explanation or clarification as needed.

## Data Analysis

Upon completion of each phase of the data collection, the data were compiled and transcribed in preparation for the data analysis process. The following section describes

the analytical framework implemented in the process of coding the interview and reflection data described in the previous section.

**Analytical Framework**

Bandura's (1997) four sources of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states, served as the analytical framework for this study. Once the data were transcribed and imported into ATLAS.ti, I read through the assessment reflections for all Algebra 2 students and the interview transcripts for the five student cases. The first lines of the coding memo say, "I have spent several days reading over the data and writing down code ideas. I feel like much of what the students talk about in the interviews connects with Bandura's sources of self-efficacy" (Webster, Coding Memo, 01/10/2022). Therefore, I began the coding process using a provisional coding technique (Saldana, 2013). I used nine codes: four codes for the four sources of self-efficacy and five codes for Belenky et al.'s (1986) ways of knowing. I established these provisional codes for use in coding the interviews hoping I would be able to assign each participant to a category of knowing. I quickly realized there were several codes emerging in the reflection and interview data I was unable to categorize in one of the sources of self-efficacy. Therefore, the nine provisional codes were disregarded, and I began to follow an initial coding scheme (Saldana, 2013) creating codes for reasons students gave for their indicated confidence scale marks as they emerged, hoping I would be able to sort them into networks later. Table 2 is a list of the initial codes created in the first round of coding.

**Table 2**

*Initial Codes from the First Round of Coding*

| Code | Frequency |
|---|---|
| uncertainty – didn't seem right | 66 |
| specific problem (I know what I missed) | 77 |
| need more practice | 16 |
| need more time to complete assessment | 14 |
| learned it well | 92 |
| I am bad at math | 3 |
| I haven't seen it before/this isn't like what we practiced | 4 |
| need resources – notes | 5 |
| positive reaction to setback/mistake | 17 |
| blame teacher | 3 |
| used prior knowledge | 2 |
| similar to ones we did in class | 3 |
| I was more confident than I expected | 5 |
| trouble with the details | 11 |
| second guessing myself | 34 |
| student lack of preparation | 29 |
| need resources – teacher help | 12 |
| I forgot how to do it | 29 |
| I just learned this – the material is still too new | 17 |
| student identified confidence boost | 84 |
| disinterest/I don't like | 3 |
| hard/lots of work/I don't get it | 13 |

After completing the first round of coding, I noticed that students often expressed that they felt confident except for one problem or some small detail. I also noticed many

of the items coded “student identified confidence boost” were marked as such because the student felt confident as a result of something they did. I decided I should set aside this code for further sorting. I planned to pull all quotes associated with the code into the network editor in Atlas.ti, allowing me to move and sort the quotations visually to find patterns and connections. The goal of this network analysis was to help me understand what the students were doing to help their confidence.

As I reread the participant interviews. I created an attribute code (Saldano, 2013) for each participant to label quotations about their personal characteristics. I then isolated all quotations assigned to each participant’s attribute code to develop a description of the student participant. I also created a code called “transitions” as each student had a unique story of their transition to Hillside School and the resulting impact on their confidence. These stories were also included in the characterization of each student case.

Next, I created a network for the popular code “student identified confidence boost.” This network is displayed in

**Figure 7**7. As I sorted these comments, I found they all fell under codes created in round one and the additional codes listed in Table 3. Each of these codes gave reasons for high confidence marks. I noticed types of assessments and classroom activities were emerging as reasons for student confidence in mathematics. Although there were codes emerging in the assessment reflection data for all Algebra 2 students in this first round of coding, there was not enough information to contextualize the short responses. I decided, therefore, to group the data for each participant and look closely at the codes that existed across the reflection and interview responses.

**Figure 7**

*Network of Comments for Student Identified Confidence Boost*

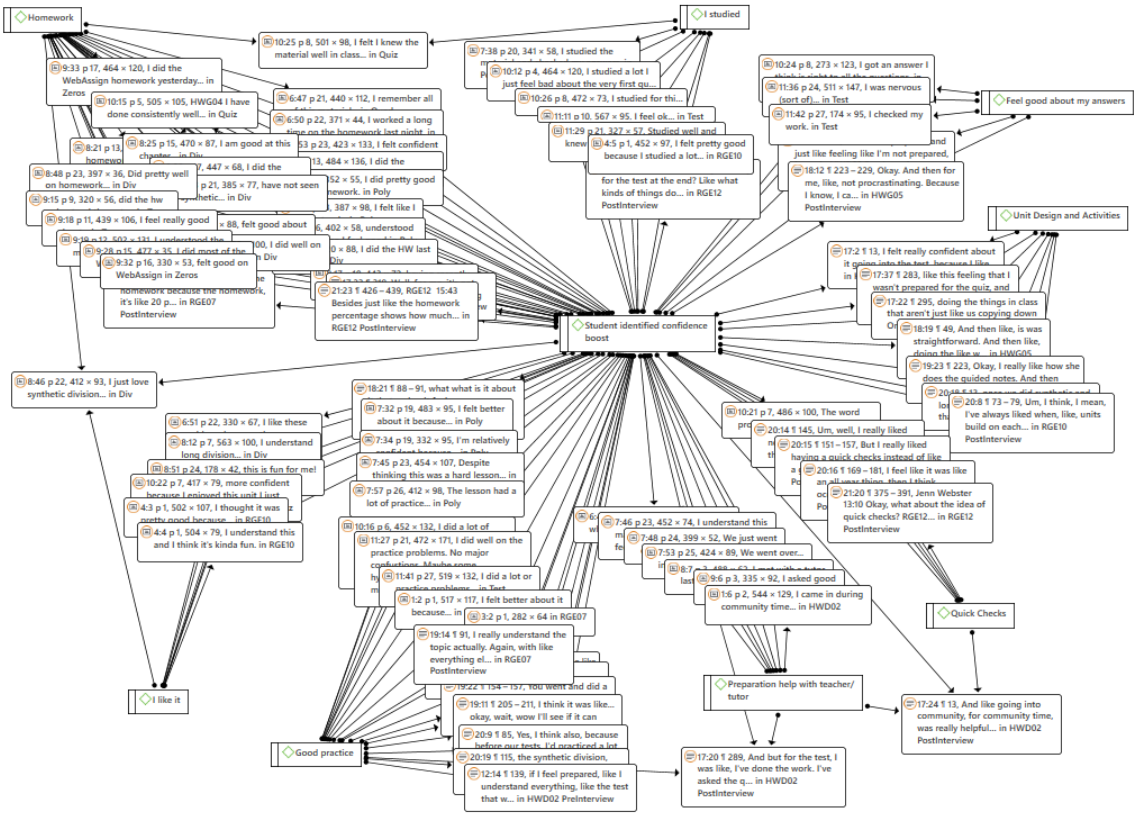


**Table 3**

*Codes Created from the Student Identified Confidence Boost Network*

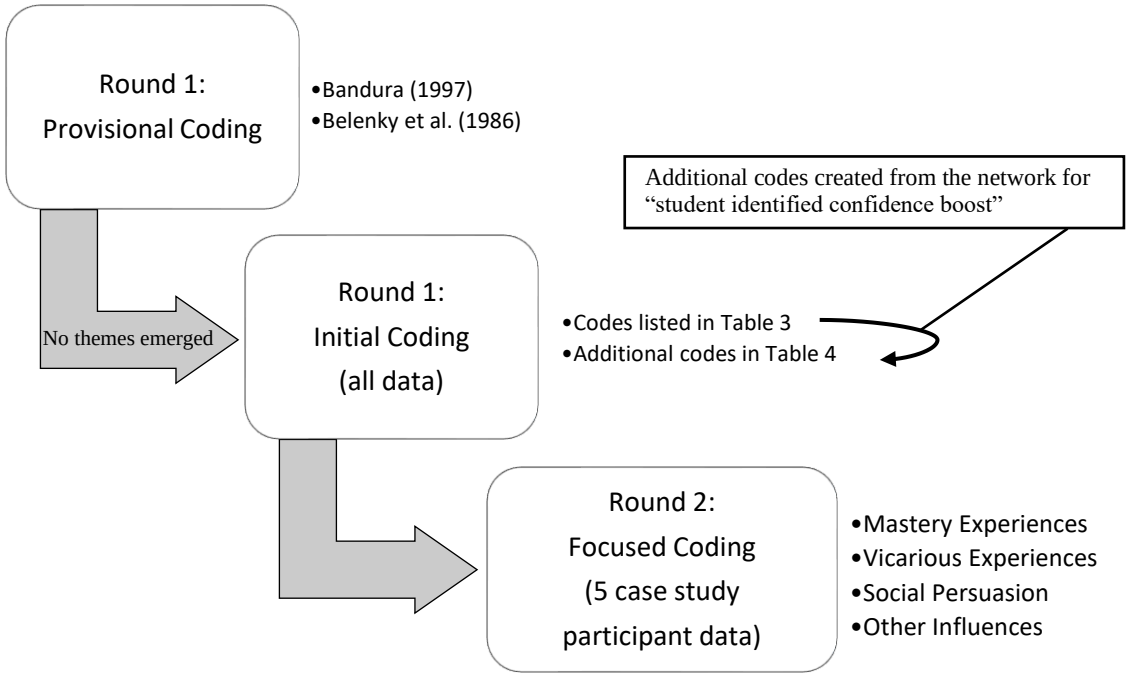
| Code | Frequency |
|---|---|
| feel good about my answers/preparation | 5 |
| homework (did well on it, did it all, got practice from it) | 28 |
| I studied | 8 |
| I like it (the material) | 7 |
| good practice (besides HW or studying) | 19 |
| preparation help with teacher/tutor | 9 |
| Quick Checks (helped) | 6 |
| unit design and activities (teacher decisions) | 7 |

When I reviewed the codes assigned within each participant's data. I began to see references to Bandura's (1997) sources of self-efficacy emerge. All the codes I created in round one were connected with one of the four sources of self-efficacy when reviewed in the context of the story of the participant's perceptions. Students emphasized good practices that helped their confidence and each of them connected with a classroom activity or assessment and a corresponding source of self-efficacy. There were some additional factors that did not fit nicely into the Bandura sources yet could be loosely related to physiological and emotional states (Bandura, 1997). Therefore, I grouped these factors with the fourth source of self-efficacy, physiological and emotional states, and titled the code "other influential factors." Thus, the four sources of self-efficacy (Bandura, 1997) were used as the focused categories (Saldana, 2013) in the second round of coding and served as the analytical framework for this study. Figure 8 illustrates the

steps taken in the coding process for this study. The next section will continue the discussion of the data analysis process, specifically addressing the within case analysis.

**Figure 8**

*Illustration of the Coding Process*




## Within Case Analysis

Next, I turned to analysis of the individual cases. I read all the data for a case and made sure codes for characterization of the student, the student transition story, Women's Ways of Knowing (Belenky et al., 1986), mastery experiences, vicarious experiences, social persuasion, and other influential factors (Bandura, 1997) were coded appropriately. Then I synthesized the data within the case creating a written description of the student participant for comparison across the cases. The within case analysis was organized to tell the story of each participant. Because the pre-interview with each participant was designed to better understand the student and their responses to the mathematics attitudes

survey (see Appendix A), I followed the same outline for each case to build a rich description of the student participant. Therefore, the analysis of each case is organized as follows. An account of each student's survey results explains why she was selected as a participant. Also included are detailed descriptions of her attitude towards success and beliefs about the usefulness of mathematics, her mathematics anxiety and confidence in mathematics, and other influential factors on her confidence in mathematics as cited by the participant. Next, a summary of what the student believes she needs to feel confident in mathematics is provided. Finally, each section concludes with a summary of the case. A discussion of the cross-case analysis process is included in the following section.

### Cross-Case Analysis

After a narrative was created for each of the five student cases, I printed out the analysis and read the description of each case. Then, I used colored pencils to highlight important parts of the narrative that discussed the four sources of self-efficacy (Bandura, 1997), and the associated classroom activities and assessments, highlighting each activity in a different color. I compiled a list of all allusions to each activity, assessment, classroom experience, and source of self-efficacy. Using this list, I synthesized the data across cases and wrote a description of similarities and differences among the cases within each category. The results of the cross-case analysis are included in Chapter 4 of this dissertation and a discussion of the results can be found in Chapter 5.

## Boundaries of the Study

In designing qualitative research, it remains important to consider constraints of the study from the beginning and to be transparent about the limitations of the study (Patton, 2015). Boundaries arise as a result of the context of the study, data sources and

instruments selected, and other restrictions of which the researcher may or may not possess control. The boundaries of the current research are described in the section below and include trustworthiness, limitations, and delimitations.

**Issues of Trustworthiness**

Trustworthiness remains an inevitable issue when conducting qualitative research, and this issue was taken into consideration for this present study. Lincoln and Guba (1985) gave four criteria for trustworthy research: credibility, transferability, dependability, and confirmability. Credibility is established in this study through the triangulation of data sources (Patton, 2015) including: survey responses, multiple interviews with each of the case study participants, and many reflection artifacts collected for the unit. Engagement with the participants over the entire period of the unit of instruction improved the credibility of the research. Transferability also remains evident in the thorough thick descriptions of the research context and participants provided in this chapter. In addition, dependability must be established throughout the unit using multiple data sources. Finally, confirmability can be addressed when the researcher is aware of his/her own biases and the use of multiple data sources.

**Limitations**

Limitations of the study involve circumstances out of the researcher's control. In this study, I was limited by student participation, teacher decisions, school context, and time constraints. Student participation was a limiting factor at three different points during the study. First, I could only use data collected from the girls who returned their consent form. Most of the Honors Algebra 2 students returned their consent forms while a smaller percentage of regular Algebra 2 students gave consent. Next, when students

completed the case selection survey, they had the option to opt-in or opt-out for the interview portion of the study (see Appendix A). Many students whose survey responses would have made them a candidate for a case study participant indicated that they did not wish to be interviewed. Finally, there were a few students with signed consent, who opted-in for the interview portion of the study, and whose survey responses made them likely case study participants. These students, however, either did not reply to my email requesting to schedule an interview or they scheduled an interview and failed to come to the scheduled meeting one or more times. Therefore, my case study participants were limited to the five girls who satisfied all the interview participant requirements and attended the interview session as scheduled.

Teacher decisions played a role in the execution of the unit profile. Feeling the pressure to complete this unit before fall exams and winter break, one teacher changed the format of the first lesson in the unit to a flipped classroom model. She asked the students to watch a video on quadratic functions for homework following the completion of the summative assessment at the end of the previous unit. Because I was not the instructor in the regular level classes, the lessons were not executed exactly as I had intended.

The third limitation of this study was the school context. All participants attended the same all-girls school and were exposed to pedagogy focused on the way girls learn best. The students experienced similar school closures and hybrid learning periods during the two school years prior to the study.

The final limitation of this study was time constraints. Because this was the last unit of the fall semester, teachers felt pressure to modify my classroom activities and

assessment plan to ensure they covered the required material before fall exams. There were also timing problems because the honors level course was a few weeks ahead of the regular classes. Therefore, I had to select participants from Honors Algebra 2 before the other students had returned enough consent forms for me to administer the case selection survey. As a result, I had to select cases from the honors sections by comparing them only to other honors students, although I could select students from the regular level course by comparing them with the entire population of Algebra 2 students at Hillside.

**Delimitations**

Delimitations of the study include characteristics of which the researcher had control that contributed to the establishment of the study's boundaries. The context for the study was selected because of my access to the school community. More specifically, I am a teacher in two of the seven classes from which cases were selected. I chose to study confidence in a girls' school setting and therefore my findings are limited to girls. Additionally, comparison between boys and girls is removed in an all-girls setting, focusing specifically on girls' voices. This choice aligns with my theoretical position because I am trying to understand girls. Controlling for the comparison between boys allowed me to more authentically hear the girls' voices. However, this limits the findings of this study.

Research indicated that sex differences in mathematics emerged around grade eight or nine (Fox et al., 1977). I chose Algebra 2 as the course from which to select cases because most of the Algebra 2 students are in tenth grade and may have interesting perceptions about their confidence in mathematics.

I also selected the unit included in the study because they were both included in the regular level and honors level Algebra 2 classes. This unit was also selected for the opportunities it could afford students to encounter Bandura's (1997) four sources of self-efficacy. My years of experience teaching girls may encourage the development of unintentionally leading questions that could influence the results of the study. The choice of theoretical framing will further delimit the study as it provides focus on opportunities to encounter sources of self-efficacy in assessment practices (Bandura, 1997).

## Chapter Summary

This chapter provided a detailed description of the methodology to be followed in this multiple case study research on girls' perceptions about connections between classroom assessments and their confidence in mathematics class. An overview of the research questions and the context of the study was included. Data sources and instruments were described in detail and data collection procedures were outlined for each phase of the research design. A description was provided of the analytical framework to be used for the first round of coding in the analysis of the data. Finally, the boundaries of the study were made clear. The following section will include an analysis of the data at the conclusion of the data collection process.

# Chapter IV: RESULTS

## Introduction

Women are less likely than men to pursue a career in mathematics-based STEM disciplines, which are considered more masculine than other STEM fields (Buck et al., 2020; Cheryan et al., 2017; Hill et al., 2010; Leslie et al., 1998; Noonan, 2017). Such disparities in females' participation in mathematics are often connected to affective variables such as levels of self-efficacy and confidence (Buck et al., 2020; Fennema & Sherman, 1977; Leder, 2019; Leder & Forgasz, 2018; Leyva, 2017; Sherman & Fennema, 1977; Tellhed et al., 2017). Literature based on large-scale assessment studies indicated that assessment may influence girls' self-efficacy beliefs in mathematics (Zander et al., 2020). Although a similar relationship may exist between girls' confidence and classroom assessments (Leder & Forgasz, 2018; Reyes, 1984), there is an opportunity to add to the literature on such a connection.

This study was designed to investigate how girls in Algebra 2 perceive various forms of classroom activities influence their confidence on mathematics assessments as well as how assessments contribute to the growth of their mathematical confidence. Based on their results on the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) survey (see Appendix A), five students were selected as case study participants. Table 4 provides pseudonyms, Algebra 2 level, and a summary of the reasons they were selected as a participant.

**Table 4**

*The Five Case Study Participants and Reasons for Selection*

| Case Participant | Algebra 2 Level | Survey Score of Note | Relativity of Score |
|---|---|---|---|
| Teagan | Regular | Overall | Twenty points below average of all students |
| | | Anxiety [a] | Lowest of all students |
| Susie | Honors | Confidence | Lowest of all honors students willing to be interviewed |
| | | Anxiety [a] | Lowest of all honors students willing to be interviewed |
| Hilda | Honors | Overall | Lowest of all honors students willing to be interviewed |
| Yuliana | Regular | Confidence | Highest of all regular level students willing to be interviewed |
| | | Attitude | Highest of all regular level students willing to be interviewed |
| | | Anxiety[b] | Highest of all regular level students willing to be interviewed |
| Magnolia | Regular | Overall | Highest of all students willing to be interviewed |
| | | Confidence | Highest of all students |
| | | Usefulness | Highest of all students |

[a] A low anxiety score indicates high mathematics anxiety.

[b] A high anxiety score indicates low mathematics anxiety.

The sections in this chapter include an analysis of each of the five participants followed by a cross case analysis. The cases are organized to build a rich description of each student and her perception of her experiences in mathematics. A description of her survey results is provided to situate the mathematical beliefs and attitudes of each student. A discussion of interview data is presented to better understand each student's

interview responses. Additional sections are included to describe other important information provided by the students to aid in understanding influences on her confidence. First, I will begin with Teagan whose overall score was twenty points below average for all students in the study and whose anxiety score was the lowest of all students in the study, indicating high anxiety.

## The Case of Teagan

Teagan was a student in the regular Algebra 2 course. She was good at mathematics at her public elementary school but the transition to Hillside School in the fifth grade was tough for her. Her schedule was altered her freshman year to ensure her mathematics placement was correct, which made her feel like she was bad at mathematics. She had a strong dislike for geometry and believed she did not understand shapes. This belief conflicted with her perception of her strength with respect to spatial reasoning. Teagan was interested in computer science as a little girl. She loved spatial reasoning and block coding when she was younger but believed at the time of the study that mathematics and science were not her strongest subject. Thus, she feared she would not be able to pursue a degree or career in a computer science field. Teagan was selected as a case because she had an overall score twenty points below average and her anxiety subscale score was the lowest of all students in the study indicating a high level of anxiety.

The case of Teagan is presented in five parts. This section provides a description of Teagan as a mathematics student with evidence from survey results, pre-interview, assessment reflections, and post-interview. Provided first is a description of Teagan's numerical responses to the case selection survey. Next, Teagan's interviews and

assessment reflections are used to provide further description of her attitude about mathematics and her perception of its usefulness. Then there is a discussion of her confidence in mathematics and her mathematics anxiety level. The fourth section introduces additional factors that impact her mathematical self-efficacy. Finally, a description of what Teagan believed to be beneficial to increase her confidence in mathematics is included. These five parts are followed by a summary.

**Teagan's Survey Results**

Teagan had the lowest score of all students in the study on the anxiety subscale, indicating high mathematical anxiety, and her overall score was more than twenty points below the average. As a result, she was chosen as a participant to investigate why she had such low scores. Teagan had an overall score of 138 out of 240, which was 27 points below average for all students surveyed. On the anxiety subscale, she scored a 14 out of 60, indicating high mathematics anxiety. This score was the lowest of all students surveyed. Her survey scores, in relative position to her peers, are displayed in Figure 3.

**Attitude Toward Success and Mathematics Usefulness**

Teagan's survey scores indicate her attitude toward success in mathematics and her belief in the usefulness of mathematics remain near average for all students surveyed. She disagreed with statements about winning mathematics awards, yet she agreed with the statement, "Being regarded as smart in mathematics would be a great thing" (Fennema & Sherman, 1976, p. 24). Teagan strongly agreed with statements about being an outstanding mathematics student such as "It would make me happy to be recognized as an excellent student in mathematics" and "I'd be happy to get top grades in mathematics" (Fennema & Sherman, 1976, p. 24). This response was reinforced by her

discussion in the post-interview of the import she placed on earning a perfect score on each homework assignment. She said, “I like the homeworks. Because you can see like, 100% kind of thing” (Teagan, Interview, 12/15/21). Most of her homework was assigned in an online environment associated with her textbook. She was allowed several attempts on each problem without penalty. Though students were allowed multiple attempts, there were a fixed number of attempts allowed before the question was marked incorrect. She would try the problem multiple times to see if she could figure it out on her own but never used her last submission without going to see her teacher. This was because she wanted to earn a 100% as her homework score.

Teagan disagreed with statements with negative connotation about success in mathematics. For example, she disagreed with the statement, “I don’t like people to think I’m smart in math” (Fennema & Sherman, 1976, p. 24). Other than having no desire to win or be recognized for winning mathematics prizes, Teagan had a favorable attitude towards success in mathematics.

Though her attitude towards success in mathematics was favorable, her attitude about the class depended on her ability to understand the material. For example, when asked about how she felt about the polynomials unit as a whole, Teagan said, “I liked some parts of it, and then others [I] just didn't really understand ‘til the, towards the end of it, or when doing test corrections” (Teagan, Interview, 12/15/21). She liked the parts that made sense to her but did not like the other concepts. One lesson she did not like was the discovery exercise on polynomial functions (see Appendix E). She explained:

> I did not like that. Because it didn't really… I like the format of notes. And so that was kind of just confusing because it was just like, cross, touch, but I didn't know

> what was crossing and touching. So I didn't realize that till the end, after seeing, like [the] first graded something. And I was like, “oh, that's how we were supposed to do it.” (Teagan, Interview, 12/15/21)

From the description and images in the lesson, Teagan realized crossing and touching were characteristics of a polynomial, but could not discern what they were crossing or touching. Therefore, she did not like this lesson. When she said she prefers notes, she meant that she prefers when her teacher delivers the content in a lecture and the students take notes.

Teagan’s attitude about mathematics was tied to how important she percieved the material to be. The unit of study was the last one for the first semester. Teagan had done well on the first few units of the semester. She did not do well, however, on the unit covered before polynomials. Therefore, she believed doing well on the polynomials unit would not improve her semester grade so she was indifferent about the unit. She explained:

> I think, compared to earlier tests, like chapter one and two, that I felt more confident on that one, I was like, “eh,” and then the test before it I didn't do too well on so it was kind of like “eh,” and then it was kind of like “this won't really move up my grade that much.” So it was like, “eh.” (Teagan, Interview, 12/15/21)

When Teagan said, “eh” she gave a dismissive shrug of her shoulders. Her survery responses indicated she wanted to do well in mathematics but as she explained here, when her desired performance level was out of reach, she became indifferent about her performance.

In terms of the usefulness of mathematics for her future, Teagan gave many high scoring responses. She strongly agreed with the statements “I’ll need mathematics for my future work” and “I will use mathematics in many ways as an adult” (Fennema & Sherman, 1976, p. 27). She disagreed with statements such as “Mathematics is of no relevance to my life” and “Taking mathematics is a waste of time” (Fennema & Sherman, 1976, p. 27). She did, however, disagree with the statements, “I study mathematics because I know how useful it is” and “I’ll need a firm mastery of mathematics for my future work” (Fennema & Sherman, 1976, p. 27). Although most of Teagan’s responses indicated a belief in the usefulness of mathematics for her future, some of her answers conflicted with this belief.

Teagan’s belief in the usefulness of mathematics for her future can be explained by her college and career interests. When asked what she planned to do with her life, Teagan said:

> This is like… where my hmmm… I'm like, ugh! Because I've always liked computer science and I've done Intro to Computer Science, but then math and science haven't always been my best subjects. So I'm like, “I don't know if I want to do that in college and mess myself up for the rest.” So that's why I'm doing an internship [this year]. (Teagan, Interview, 12/01/21)

Teagan was frustrated by trying to express her sentiments. She liked computer science but was concerned that she would not be able to do the mathematic required to earn a degree in computer science. She wondered if her difficulties with mathematics and science would prevent her from earning a degree in computer science and therefore, if she should even bother with this goal. She planned to participate in a three week coding

internship with a local business about a month after our first interview. Teagan's mother suggested she pursue the internship opportunity so Teagan could see if she remained interested in a computer science related career path. Teagan said, "my mom was like, just to see if you really... because if I've liked it before, I don't know" (Teagan, Interview, 12/01/21).

Teagan's mother suggested she participate in the internship to see if she still possessed the love of coding she held as a young girl. Teagan explained, "in middle school, whenever we did the spatial reasoning blocks and stuff, I always understood that" (Teagan, Interview, 12/01/21). When I asked if her interest in a career in computing would involve coding, she said, "I don't know because math, I don't want to do it and not be good at it" (Teagan, Interview, 12/01/21). Teagan's concerns about her mathematics ability made her question whether she could do computer science in college. Then she presented a counter point by saying, "I just kind of think 'oh, maybe the math here… and [Hillside] is a harder school, so when I go to college, it won't be maybe as hard, or the teachers are there to help me" (Teagan, Interview, 12/01/21). She questioned whether it was the challenging environment at Hillside that made mathematics hard or if the subject would be more accessible for her in college with the support of the faculty at her institution. She continued:

> And it's a growing career. So like it would be something good to look into. And I've always liked computer stuff. Or when I was younger, I could figure out how to like mod games and stuff in elementary school, so I don't know. (Teagan, Interview, 12/01/21)

Teagan circled back around to her interest in computing because of its predominance as a career opportunity and her affinity and love for it as a child.

Although Teagan's survey responses about her attitude towards success in mathematics and the usefulness of mathematics for her future were positive, her interviews revealed some underlying indifference and self-doubt about her ability to experience the success that she desires and to pursue her interest in a mathematics based career field. The next section explores Teagan's confidence in mathematics and mathematical anxiety to further understand her as a student.

**Confidence and Mathematics Anxiety**

This section analyzes Teagan's responses to survey questions about her confidence in mathematics and her mathematics anxiety. Responses from assessment reflections and interview comments help to further xplain her levels of mathematics confidence and anxiety.

Teagan's confidence score was a 32 and although it was 17 points above the minimum confidence score it was still 10 points below the average for all students in this study. On the survey, Teagan's only positive responses were from agreement with statements such as "Generally I have felt secure about attempting mathematics" and "I am sure that I can learn mathematics" (Fennema & Sherman, 1976, p. 21). She demonstrated a tendency towards low confidence in mathematics by disagreeing with statements such as "I think I could handle more difficult mathematics" and "I have a lot of self-confidence when it comes to math" and agreeing with statements like "I don't think I could do advanced mathematics" and "Math has been my worst subject" (Fennema & Sherman, 1976, p. 21). Although she did not indicate strong agreement or

disagreement with any statements and hovered around the neutral, her negative responses outnumbered the positive ones.

It was Teagan's responses to the mathematical anxiety portion of the survey that made her stand out as a case. On all but two of the survey responses she gave the least favorable response, indicating high mathematics anxiety. For example, she strongly disagreed with the statement "Math doesn't scare me at all" and strongly agreed with statements such as "I get a sinking feeling when I think of trying hard math problems" and "Mathematics makes me feel uneasy and confused" (Fennema & Sherman, 1976, p. 28). The only responses that did not earn a score of 1 were her disagreement with the statement "I usually have been at ease during math classes" and her agreement with the statement "Mathematics usually makes me feel uncomfortable and nervous" (Fennema & Sherman, 1976, p. 28). Each response to the survey indicated high mathematical anxiety, these two were the only two less strongly held beliefs. I was very interested when interviewing Teagan to understand more about what made her mathematical anxiety so high.

Teagan began her pre-interview by describing her mathematics journey leading up to Algebra 2. She began with a description of mathematics in her public elementary school:

> I guess, I kind of, in elementary school, I was pretty on top of it. But because I went to a public school and then coming to a private school, it was very different. So I was really behind compared to everyone else. And especially because no one else went to the public school I went to, so I didn't have anyone else struggling along with me. (Teagan, Interview, 12/02/21)

Teagan felt she was good at mathematics in elementary school but when she began attending Hillside she felt as though she was behind compared to her peers. She also felt isolated because she was the only student who came to Hillside from her elementary school so there was no one with the same background as her with whom to commiserate.

Teagan was asked what grade she made the transition and she said, “Fifth grade. . . and then I started doing a little bit better in eighth grade” (Teagan, Interview, 12/02/21). She entered Hillside School in the fifth grade, the lowest grade at Hillside School. All fifth grade students were new. However, from Teagan’s vantage point the other girls had an advantage because they had previously attended school with at least one other student, and she also believed her classmates maintained a more robust mathematics background. She indicated it was eighth grade before she felt like she began to do better in mathematics.

I asked if there were any specific experiences to which she could point. Teagan said, “mainly just I didn't know how to do long division, and then the, like, switching of math classes in ninth grade, that thing” (Teagan, Interview, 12/02/21). Long division was one topic she identified not having learned in elementary school that made her feel as though she was behind all of her peers. Then she alluded to a traumatizing experience she had in the ninth grade. She explained, “and so then I kind of, like got moved out of the math thing. So that kind of made me feel bad at math” (Teagan, Interview, 12/02/21). After four years at Hillside, Teagan started to feel better about mathematics in the eighth grade in Algebra 1. Then, she began ninth grade in Geometry with the majority of her peers. A few weeks into the first semester, her Geometry teacher was concerned she was

going to have a difficult time because she was not proficient in her algebra skills. I asked her if that was a tough experinece and she said:

> Yes because I heard someone else had the same grade as me. And then just a lot of stuff. So I was like, “oh man.” Yeah, because that day, I came in to ask [my teacher] a question about something on homework, but before I could talk, [my teacher] was just like, “oh, I saw that you can move.” And it was just like, a lot happened that day. And then I had an advisor meeting. And instead of just talking with my advisor, I just started crying. (Teagan, Interview, 12/02/21)

Teagan felt blindsided by her move from Geometry to Algebra 1 a few weeks into the semester. She heard another student had the same grade as her and was not being moved down. She was forging ahead and working on geometry homework, but when she went to ask her teacher a question, before she could speak, she was told the move was going to happen. Teagan did not feel as though she had a voice in the process. Even when she went to her advisor to talk about her concerns, all she could do was cry. I asked Teagan if going back to Algebra 1 benefited her in the long run. She said:

> I think so. I think I'm doing better in Algebra 2, but I just didn't understand geometry, because I didn't do well with geometry last year, too. So, I don't think it helped me with geometry, but maybe algebra. (Teagan, Interview, 12/02/21)

Teagan believed her additional year of algebra did not help with her struggles with geometry as intended. She believed she simply had more difficulty with the material covered in the Geometry course. She did admit, however, that repeating Algebra 1 as a freshman probably has helped her with Algebra 2 this year.

I wanted to understand why Teagan felt Geometry was so difficult. She explained, “I still didn't like [it the second time]. I did well, at the beginning, maybe but like, I just didn't, I don't understand the shape stuff” (Teagan, Interview, 12/02/21). She was frustrated, trying to convey her sentiments to me. She was trying to say she liked Geometry better the second time around but only in the beginning. She said she simply could not make sense of shapes. She continued: “[Geometry was] not as good because like, I mean, the homework, we could correct it. But then sometimes it's so many problems. It's like I just based it off the quiz. Like what grade I got on the quiz” (Teagan, Interview, 12/02/21).

One aspect of the Geometry course that was troublesome for Teagan was the homework. Homework problems from her textbook were assigned and students were expected to correct their own homework using the odd answers in the back of the book. She lamented that this extra step took a lot of additional time and she often skipped this step. Instead, she was using the quiz as her first opportunity to discover how well she understood the material. As described in the previous section, Teagan prefered the online homework in Algebra 2 where she received immediate feedback and benefited from the opportunity to learn from her mistakes on lower-stakes assessments before a summative quiz or test. I asked Teagan if she was ever surprised by material on summative assessments in Geometry and she replied, “Yeah.” (Teagan, Interview, 12/02/21). To clarify, I asked if she felt as though she was unprepared for the assessments to which she replied, “Yeah. I think it's just, I just don't get the shapes stuff” (Teagan, Interview, 12/02/21). Once again, she fell back on her belief that she just does not understand shapes.

I asked Teagan to compare her experience with assessment in Geometry to that in Algebra 2. About her experience in Algebra 2, she said, “I guess everything's kind of building off each other. So like, even if I kind of don't really understand it, I might know something from the last unit that can help” (Teagan, Interview, 12/02/21). To better understand her confidence level throughout the unit, we looked at her assessment reflections and discussed the reasons behind her answers.

Teagan and I began by reviewing her Quadratics Quick Check Reflection. On this assessment she marked her confidence level close to the bottom and wrote, “HW wasn’t due till next week therefore I didn’t start it” (Teagan, Quadratic Functions Quick Check Reflection, 11/22/21). Her reason for the low confidence mark was she had not done the homework because it was not due until the following week. When I asked her to explain during the post-interview, she said, “I remember she assigned it our homework” (Teagan, Interview, 12/15/21). I asked if the homework assignment was to watch a video on quadratic functions as it had been for other students in Ms. Albert’s class. She replied, “Yeah, but then it wasn't our homework yet, due that day” (Teagan, Interview, 12/15/21). The homework was to watch a video but she had not watched it yet because the assignment was not due yet. I asked if her confidence was negatively impacted and she said, “yeah, I didn't do it. I was gonna save it for later. And then she was like, ‘quick check.’ And I was like, ‘oh, crap’” (Teagan, Interview, 12/15/21). She thought she had more time to complete the homework and watch the video.

When the teacher passed out the quick check, Teagan’s anxiety level increased and the panic set in. I asked how she ended up performing on that quick check and she said:

> It was just kind of, I don't know, it felt like I was making up stuff kind of thing. But then I guess when doing the homework, I had an idea of what I was going into. (Teagan, Interview, 12/15/21)

Teagan acknowledged she did not know what she was doing on the quick check, she was just making up her answers. When it was time to practice problems on this material, however, she had an idea of what to do because she had at least been exposed to the material on the quick check. I asked if they had gone over the solutions to the quick check as a class and she said, "I think we went over it after that" (Teagan, Interview, 12/15/21). Although Teagan was not prepared before the quick check, because she attempted this assessment and the assessment was reviewed as a class, she felt more confident working problems on her own.

When discussing the polynomials discovery exercise in the post-interview, Teagan and I compared learning: by watching a video, through discovery exercise, and by direct instruction from the teacher. As mentioned in the previous section, Teagan did not like the discovery exercise and preferred her teacher to lecture on the material. In this discussion, I asked Teagan if she thought the material would stay with her longer if she learned it by working through it on her own or if her teacher told her what to do via lecture or video. Teagan said:

> I think Ms. [Albert] going through it. And like, say she drew a picture of like, "that's touch and then that's cross" but it was more of, we look at it. And then we guess what it is kind of thing. . . I got the number part, but I didn't really get the graphing. I kind of got stuck with it. [My friend] explained it, so… (Teagan, Interview, 12/15/21)

Teagan believed the idea behind discovering characteristics of polynomials was helpful but she preferred the teacher guide the lesson. She would have liked her teacher to prompt students to answer questions about the degree, number and multiplicity of zeros, graph, and end behavior in order to help them make connections. As it happened, Teagan got stuck and had to ask a friend. Therefore, I asked if they had worked in pairs or groups on the discovery exercise or if it was independent work. She said, "Uh, kind of, yeah. It like depends on what table. Yeah, sometimes" (Teagan, Interview, 12/15/21). In other words, some students worked together but it depended on who was sitting around them. As for Teagan, she did not believe she had the necessary support from her peers or the teacher to learn the material.

When Teagan completed the quick check on the characteristics of polynomials, she marked her confidence slighly below the middle of the scale. In her reflection she wrote, "I didn't feel as good in 4.2 compared to 4.1" (Teagan, Polynomial Functions Quick Check Reflection, 11/29/21). Although Teagan marked her confidence much lower on the previous quick check, at the time of the second one, she felt more comfortable with the material from the first section.

On the subsequent quick check on polynomial and synthetic division, Teagan's confidence rating was even higher. She marked the scale in the middle. Her reflection included an illustration of an emoji with fangs and hearts for eyes and it read, "I was sick yesterday missed a whole class" (Teagan, Polynomial and Synthetic Division Quick Check Reflection, 12/01/21). I asked Teagan in the post-interview why she indicated she did not like learning via a discovery exercise on polynomial functions and then missed

the lesson on polynomial and synthetic division, yet her confidence scores had increased with each of these lessons. She addressed the division quick check score by saying:

> I think I went in in the morning and then she went over the whole thing with me. But like, really quickly. And then there were also videos. I didn't watch those. Like, the day before, I was like, "I'd rather just hear her explaining." And so the stuff that I knew or . . . had a general idea kind of when doing it, rather than just like, "Oh my God, this, I don't know any of it." And then she went over it. (Teagan, Interview, 12/15/21)

Despite her absence, Teagan explained that her confidence increased because she sought help from her teacher and that brief explanation gave her confidence to try the problems. She mentioned her teacher had posted videos for her to watch so she would not fall behind when she was abscent. Teagan preferred not to watch the offered videos, as she had not watched the video for the first lesson, because she prefers to learn it from her teacher in person.

I asked Teagan if she had worked any problems on the tic-tac-toe activity. She said, "oh, I did that the last, yeah, the last day but I think I only got through one of them because it was towards the end of class" (Teagan, Interview, 12/15/21). She had learned the material quickly from the teacher, taken a quick check, and at the end of class had very little time to work on the division practice activity. I asked how this formative assessment activity made her feel about the material. She replied, "not good, I was gonna ask for help on the homework" (Teagan, Interview, 12/15/21).

Teagan did not percieve any benefit from the tic-tac-toe practice because it did not help her complete the homework that night. To clarify, I asked if in addition to seeing

her teacher the day after she missed, did she go back to see her with questions about division. She replied, “I did the homework, yeah, I had to because I wanted the 100%” (Teagan, Interview, 12/15/21). As discussed previously, Teagan wanted to do well and to feel confident in her understanding of the material. As such, she took whatever steps necessary to ensure she earned a 100% on the homework assignment for that particular lesson.

Next, Teagan and I discussed the culminating section of the unit on finding all of the zeros of polynomial functions and factoring them completely. On the quick check for this lesson, she marked her confidence level very low on the scale. Her reflection read, “sick went into understand it at lunch so only like 2 hours ago” (Teagan, Zeros of Polynomials Quick Check Reflection, 12/02/21). In the post interview I asked Teagan if she had seen her teacher at lunch the day she returned from being sick to ask her about the material she missed. She said, “Yeah, and someone was kind of explaining it. Well, because [the quick check] was like right after” (Teagan, Interview, 12/15/21). When Teagan went to the classroom, other students were there discussing the material and asking questions because they wanted to be prepared for the quick check they would be taking in the class right after lunch.

I acknowledged that Teagan was not prepared enough to feel well about the material on the quick check at the time she took it. I asked, however, how she felt about the material once she had time to learn it. She said, “yeah, [Ms. Albert] explained, went through it because not a lot of people felt too good about it. They wanted to know the answers like right after” (Teagan, Interview, 12/15/21). Teagan was reassured that others in the class, who had been there for the lesson, were also having trouble with the

material. As a result, the teacher took time to go over the solutions to the quick check with the class. I asked Teagan how she felt after that and she replied, “it made sense” (Teagan, Interview, 12/15/21). Despite having missed the lesson, Teagan had a positive experience with the quick check because she discovered she was not the only one who did not understand the material yet.

As described in the previous section, Teagan’s approach to the end-of-unit summative assessment was one of indifference because her desired performance level was unattainable as a result of a low score on the previous test. I asked her if knowing her grade would not be raised or lowered much by her performance on the test influenced how much pressure she felt during the test. She explained, “yeah, because then it's like, if you do bad, I don't know. It, like kind of, sometimes I'll calculate while doing it and try to guess how many points are worth each thing” (Teagan, Interview, 12/15/21). When her class average was such that her test performance would influence the letter grade, she would mentally assign points and keep up with her perceived estimation of her score while taking the test. For this test, however, her performance would have little impact on her average.

Nonetheless, her confidence mark on the unit test was very low and she wrote in her reflection, “I did bad bad on the test before this especially compared to my other tests. I need to come in for help for almost every HW assignment” (Teagan, Test Reflection, 12/08/21). Although she implied it was less stressful when her semester average could be influenced by test performance, Teagan still lacked confidence on this test because of her previous poor performance. She also explained her lower confidence was due to the fact that she had to see her teacher for help on nearly every homework assignment. This was

despite having explained earlier that getting a 100% on her homework helped her confidence. Apparently, too much reliance on her teacher to reach the 100% lowered her confidence. I asked Teagan to explain her test reflection further and she said:

> That's what I was noticing that, with that one [unit four] and [unit] three I was coming in for help so much. But then earlier, I wasn't needing to come in for help with the homework. It was more just like one part I didn't understand how to answer on there. But it was just like, I don't understand each thing every time I do it. But then it's like, I'm asking for help. (Teagan, Interview, 12/15/21)

Teagan explained that the amount of help she required on the homework for this unit was similar to the previous unit on which she struggled. On the first units of the semester, she was seeking help when needed but it was an occasional quick question or two that she needed to ask the teacher.

On units three and (the current unit) four, however, Teagan felt she had to ask about nearly everything, and that made it hard to be confident about the mathematics.

I asked Teagan what she did to prepare for tests. She said:

> I just look over the notes and then like, the problems with the notes. I tried to do it again, kind of thing. And then, like the cross and [touch] stuff I like wrote down, like cross equals even and then like, because I just didn't understand that and I needed to get it down. (Teagan, Interview, 12/15/21)

To prepare for the test, she reviewed her notes and practiced the problems she knew were challenging for her. She recalled being confused by the multiplicity of zeros and their resulting representation on the graph so she made sure to practice this skill. I also asked Teagan what impact the quick checks had on her confidence throughout the unit. She

said, “well, they let me know, what I didn't know, and what I needed to know, kind of thing and then it gave examples of problems we'll see on the test, what to expect” (Teagan, Interview, 12/15/21). Teagan felt the quick checks provided her some basis for knowing what type of problems she would be expected to solve and helped her to distill a vast amount of material and focus on the most important information needed to understand.

**Other Influential Factors**

Teagan experienced factors outside of the mathematics she was learning and the classroom experience that influenced her confidence in mathematics. For example, Teagan lived farther from Hillside than most of her peers. Especially on days when she had extracurricular activities after school, she believed she was disadvantaged by the amount of time she had to spend on her studies. She explained, “because I had rowing after school in ninth grade, and I live far away, I didn't get home ‘til like 8:30, something like every night” (Teagan, Interview, 12/02/21). This explained why she believed her mathematics journey was challenging, and she believed her commute was a factor worth mentioning.

When discussing her confidence during the unit of study, Teagan talked a lot about her absences and their impact on her confidence. She said, “I've been sick for like, two of the days. So that might kind of mess it up a little bit” (Teagan, Interview, 12/02/21). Missing two days of a unit that spanned only seven class periods, one of which was the unit test, made it hard for Teagan. She added:

> I missed the day we learned how to divide them, which is a big part of it. . . and so then, like, I had to do a lot of makeup work homeworkwise. Because I had to push

> it back and then, what's it called? I was confused about the cross and touch thing, but then I got it towards the end, once I was like doing the test, or like finished with the test. (Teagan, Interview, 12/15/21)

When she missed the lesson on polynomial and synthetic division she was already confused from the previous lesson on polynomial functions. She had to push back her assignments and had to juggle learning new material, catching up on missed work, and figuring out material she was confused about from before the absence. It was difficult to manage, and as a result, it was hard for Teagan to feel confident about her understanding.

I asked Teagan if being absent from mathematics class always had a negative impact on her confidence. She said:

> It depends. At the beginning of the year, I missed a day, but we were looking over Algebra 1 stuff so it was just like, “eh, it's fine, I got it.” But then when it was like, dividing polynomials, and then they were doing the line stuff, I didn't know what synthesis was, and it was just kind of like, “ooh.” And then we had talked about dividing polynomials the day before, kind of, but then when we came back, it was different, a whole different thing. And so then, because we had talked about it a little bit, when was it? I don't know if it was before break kind of thing, before Thanksgiving break. So then we already had that pause. And it was like another pause. (Teagan, Interview, 12/15/21)

Teagan mentioned that missing a day earlier in the year did not have a negative impact on her confidence because the material was a review of Algebra 1 and she was able to catch up with no problem. When she missed the lesson on polynomial and synthetic division, however, this was not the case. She saw a preview of polynomial long division before her

absence. Then when she returned, her classmates were doing synthetic division. The structure of the division looked different, yet it was still called division. Teagan wondered if it was the same division she had seen before or if it was something completely different. The Thanksgiving break was also around this same time. The time between her presence in mathematics class was spread wide by the holiday and her illness which made this absence particularly challenging.

I asked Teagan to articulate how her absence during this unit impacted her confidence. She said:

> That is kind of stressful. Coming back in, that seemed like a bunch of notes. And then especially because it was stuff when… because sometimes we'll try to do the homework. But then I just could not, I didn't understand a single problem on it. So that was kind of stressful knowing that I was gonna have to come ask her. (Teagan, Interview, 12/15/21)

She said it was stressful to miss because it felt as though she missed a vast amount of material. She recalled that sometimes when she was absent, she would try the homework to see if she could understand the mathematics. In this instance, however, she could not figure out any of it. This added to her stress level because she had to make time to see her teacher to catch up. This led me to ask what would help such a situation not have such a negative impact on her confidence. She suggested:

> I mean, having the homework pushed back and stuff and then going in was good for it. And then I did get back, like I felt good about that stuff. That was, out of unit four, that was the stuff that made the most sense. (Teagan, Interview, 12/15/21)

Teagan explained that her teacher allowing her extra time to make up her missing work as well as spending time explaining the material outside of class was helpful. She said she ended up feeling best about this material in the current unit of study.

**What Teagan Needs**

In both interviews, Teagan and I discussed things that impact her confidence on assessments. She offered examples of positive and negative influences. She described a negative experience from Geometry her sophomore year. She said:

> I guess this year, math has made more sense to me. I don't know. But I don't know what's different. I think, when I go ask for help, it's not like the question. Usually, last year [they] would have been like, “what do you think?” But it was more of explaining how to do it, and then I understand from the explaining. But when it's just “what do you think?” I don't know. (Teagan, Interview, 12/02/21)

When Teagan went to a teacher for help. She prepared good questions in hopes of getting answers from her teacher. In Geometry, her teacher would often answer her question with another question, probing Teagan to figure it out for herself. This did not help her confidence and she felt as though she left with more questions than answers. This year, however, her teacher offers more explanation and Teagan feels like this helps her better understand.

To clarify, I asked if she felt she benefited from someone showing her what to do and then giving her the opportunity to go practice on her own. She replied:

> Yeah, I feel like I know it more. And then also, maybe this year, because our homework is through, [the online platform] and stuff. So I see like, “Oh, I got it right.” But then if it's like, just textbook and stuff, I'm doing it and I'm like, “oh,

> okay, this might not be right" or "this doesn't seem right." Like, I don't know. (Teagan, Interview, 12/02/21)

Teagan confirmed she prefers for her teacher to demonstrate how to do a problem with which she needs help as opposed to asking probing questions to help her learn. Teagan also explained that the type of homework assigned impacted her confidence in the mathematics as well. When she worked problems through an online platform where she received instantaneous feedback about her solutions, she gained confidence when she was performing well on the homework. When problems were assigned from the textbook as they were in Geometry, however, she never knew whether what she was practicing was correct or not and therefor she had no way to gague her understanding until she took a graded assessment. It was much harder to be confident in what she was doing without knowing if she had been successful in practice.

Teagan emphasized her support of the online homework platform in the post-interview. As discussed above, Teagan appreciated the online homework because she could ensure she earned a 100% on each assignment. She said:

> Besides just like the homework percentage shows how much I missed, kind of, like that I have to get a 100 with it. . . I don't like using up all my tries. If I know, I can ask I guess. . . I don't know. I don't know how people just press enter knowing they'll get it wrong. It's just because I don't, I feel like the points matter with those a lot gradewise. (Teagan, Interview, 12/15/21)

She liked to try the problems on her own to see if she understood. However, she would never use all of her attempts without seeing help from her teacher. She believed strongly in the value of getting all of the problems on her homework correct both in terms of her

understanding and her grade in the class. Teagan added, “so if I don't know, I'll go ask.” (Teagan, Interview, 12/15/21).

With online homework, she knew when she did and did not understand the material and she was committed to seeking help with any problem she could not complete on her own. She continued, “because that can like really [impact] your grade. Like a lot of them” (Teagan, Interview, 12/15/21). Teagan said she believed many grades of 100% would have a big positive impact on her grade in the course. It did not appear as though Teagan realized homework was a weighted category and only counted toward 10% of her overall course grade.

I shifted the conversation from grades by asking if she felt that ensuring perfect scores helped her to understand the material. She said:

> Yes. I like [a different online practice platform] more, though, because it gives examples. But we don't really do that with [the online textbook problems]. Because then with the examples, then I can really, then I don't have to always go in for help. Then I can just like, look at it. And then I'm like, “oh, that makes sense.” (Teagan, Interview, 12/15/21)

Although Teagan prefers homework from the online platform associated with her book to paper textbook problems, she likes a different online practice platform even better because it offers example problems. When she is stuck while using this platform, she can see a similar example worked and then figure out how to do her problem without having to go in for help outside of class.

When it came to learning new material, Teagan clearly expressed that she preferred when her teacher presented new information in person. She said, “and then they

were also videos. I didn't watch those. . . I'd rather just hear her explaining" (Teagan, Interview, 12/15/21). She did not like to learn from a video. She also said:

> I guess I just like her lecture style kind of thing, and then to see example problems. And then the sheet was kinda like eh, because it was, I mean, it was example problems, but it was just different less information. I don't know, I didn't like it. (Teagan, Interview, 12/15/21)

Teagan was referring to the discovery exercise [appendix] on polynomial functions. She wanted her teacher to explain the material to her and give practice problems. She felt the worksheets did not give enough information for her to learn the material.

Finally, Teagan mentioned it was important for her confidence to have enough time to learn new material and practice sufficiently. She explained:

> I think the homework, it depends. And then oh yeah, when we had the test, we had two homework assignments due. I mean, we had a while to do [them] but we had two homework assignments, and then test corrections due that we got Friday, and then it was Tuesday. So it was like trying to study for everything and then not going over the beginning stuff for the unit. So I think maybe spreading it out more could help study wise. (Teagan, Interview, 12/15/21)

Teagan felt many things were due at once and some things were rushed in this unit. She was asked to start this unit via video lesson the night after the previous unit's test. The test was returned and the corrections due sometime during the current unit. Her teacher also allowed students some extra time to complete the last two homework assignments of the unit, leaving them online until the day of the test. For some, this was too much work due on the same day as the unit test. Teagan continued:

> Yeah, or like how much time I have, like, one kind of thing, and then just having the study time, because I feel like I didn't get to spend as much time with the earlier stuff as I wanted, to like, to go back to it. Because I was trying to do the homework kind of thing. Because I had other stuff due, or tests in [other] subjects. So I couldn't have done the homework earlier. Even though she did give us a while to do it. It was just like I couldn't kind of thing. (Teagan, Interview, 12/15/21)

Teagan pointed out that she had so much make up work in all of her classes, when her teacher allowed them to turn in the last couple of homework assignments later, it was not an option for her. She had no other choice, she had to put them off and complete them the night before the test because she had other work to finish.

**Case Summary**

Teagan was selected as a participant because she had the lowest score of all students on the anxiety subscale, indicating her high mathematical anxiety. Teagan entered Algebra 2 with past experiences negatively impacting her confidence. Having to repeat Algebra 1 because she was struggling with Geometry in the 9$^{th}$ grade, Teagan believed her teachers did not believe in her. This had a negative impact on her confidence as related to her mathematical ability.

Teagan stressed the importance of practice with immediate feedback and examples to help her learn. Through this practice she discovered where she needed more practice and what topics she had mastered. She also learned what material was most important and what types of problems she would be expected to solve.

Teagan had to overcome illness and resulting absences from class throughout this unit. She was asked to watch videos made by her teacher to catch up on missed lessons, and she had to seek additional help outside of the classroom as well. She did not feel comfortable learning from the videos and therefore sought her teacher out for explanations. While seeking teacher help, she encountered many of her classmates, in the room seeking help as well, and they worked together to understand the material and build their confidence. Working through problems with her peers and learning new material via face-to-face instruction from her teacher were to factors Teagan believed were important to her confidence on assessments.

The next participant to be analyzed was Susie who was selected for her low confidence and anxiety scores, indicating low confidence and high anxiety. Unlike Teagan, however, Susie is a student in the Honors Algebra 2 course.

**The Case of Susie**

Susie was a student in the Honors Algebra 2 course. Susie and her family moved across the country between her sixth and seventh grade years for better educational opportunities for Susie and her sibling. Susie earned nearly perfect scores on her entrance exams and was placed on the honors mathematics track. Mathematics was not her favorite subject, but she believed it was valuable to study mathematics and had high expectations for her performance in the course. At the time of the study, Susie planned to pursue a career in psychology. She was specifically interested in "child psychology and helping children with learning disabilities" (Susie, Interview, 11/19/21). She was selected as a case study participant because she had the lowest confidence and anxiety scores of all honors students willing to be interviewed. The following sections provide a

description of Susie as a mathematics student with evidence from survey results, pre-interview, assessment reflections, and post-interview.

The case of Susie will be described in five parts. First, a description of Susie's numerical responses to the case selection survey is given. Then, Susie's attitude about mathematics and its usefulness is explained in greater detail using data from her interviews and assessment reflections. Third, Susie's confidence in mathematics and her mathematics anxiety level are explored. The subsequent section includes a discussion of Susie's comments on additional influences on her self-efficacy in mathematics. Finally, Susie's perceptions about what she needs to be confident in mathematics are described. These will be followed by a summary.

**Susie's Survey Results**

Of all honors students willing to be interviewed, Susie had the lowest confidence and anxiety scores and was therefore chosen as a participant to learn more about why she scored so low in these categories. Her confidence score was a 34 out of 60. A response of neutral on all 12 confidence survey items would yield a score of 36. Therefore, Susie's score of 34 indicated her confidence in mathematics was low. Similarly, Susie had an anxiety score of 22 out of 60. This score was below the average score of 37 for honors students and 33 for regular students. Such a low score indicated that Susie has a high level of math anxiety. Her overall score was 142 out of 240 which was below the average of 170 for all honors students. However, Susie had a score of 52 out of 60 for her attitude about mathematics, which was above average for all honors students surveyed. Susie's survey results in relative position with her peers are illustrated in Figure 3.

**Attitude Toward Success and Mathematics Usefulness**

Based on her survey responses, Susie had an excellent attitude towards success in mathematics but a relatively low perception of the usefulness of mathematics. Susie's responses to interview questions helped bring clarity to her survey responses. On the attitude subsection of the survey, Susie marked strongly agree for the first six questions which included: "It would make me happy to be recognized as an excellent student in mathematics," "I'd be happy to get top grades in mathematics," and "Being regarded as smart in mathematics would be a great thing" (Fennema & Sherman, 1976, p. 24). The idea of being a strong mathematics student appealed to her. Susie said, "I have very high expectations for myself in all my classes" (Susie, Interview 11/19/21).

Despite viewing success in mathematics in a positive light, Susie's survey responses on the usefulness of mathematics were low. She disagreed with statements indicating mathematics would be helpful for her future career such as: "I'll need mathematics for my future work" and "Knowing mathematics will help me earn a living" (Fennema & Sherman, 1976, p. 27). Susie also agreed with statements describing the uselessness of mathematics for her career such as: "Mathematics will not be important to me in my life's work" and "I see mathematics as a subject I will rarely use in my daily life as an adult" (Fennema & Sherman, 1976, p. 27). Though her responses to comments about the general usefulness of mathematics were more neutral or positive, it was clear Susie did not see mathematics as important to a future career. When I asked Susie about the usefulness of mathematics in her pre-interview, she explained:

> I feel like math is a good skill. There is some stuff, I feel like it's going to have a use. I just don't know what it is yet. But I also don't really try to do well in school

> for the future. I just try to do well in school because I want to do well in school. I'm not one of the people that's like, "oh, I'll never have to use this in the future." I'm like, "I very well might never have to know how to use sine, cosine, and tangent but I still want to do well for school." (Susie, Interview 11/19/21)

Susie explained that though she does not think she will need mathematics for her future career, this is not a focus for her while in school. She sees success in school mathematics and the usefulness of mathematics for her future as disparate ideas. She wants to do well in school and in school mathematics for the sake of overall academic success. Therefore, the study of mathematics and success in that pursuit is important to Susie.

**Confidence and Mathematics Anxiety**

Susie's high expectations for herself and desire to succeed in school mathematics help to set the scene for understanding her unfavorable survey responses for confidence in learning mathematics and mathematics anxiety. On the confidence subscale, Susie disagreed with the statement, "I have a lot of self-confidence when it comes to math" (Fennema & Sherman, 1976, p. 21). She agreed with the statement, "Math has been my worst subject" (Fennema & Sherman, 1976, p. 21). Moreover, Susie strongly agreed with the statement, "For some reason even though I study, math seems unusually hard for me" (Fennema & Sherman, 1976, p. 21). These responses make it clear Susie did not see herself as a strong math student because she did not experience the level of success she expected in mathematics. On the anxiety subscale, Susie strongly disagreed with the statement, "I haven't usually worried about being able to solve math problems" (Fennema & Sherman, 1976, p. 28). Susie then strongly agreed with the statement "Mathematics makes me feel uneasy and confused" (Fennema & Sherman, 1976, p. 28).

Through interview and assessment reflection responses, Susie further described her experiences with low confidence and high anxiety in mathematics.

Susie's family moved across the country and enrolled Susie in Hillside School for better educational opportunities. Susie lamented, "[at] my old school, I didn't know what a noun was . . . I'm not a huge fan of my old school, but that's why we moved." (Susie, Interview 11/19/21). When she transitioned to Hillside School in middle school, Susie felt as though she was behind her peers despite having earned extremely high scores on standardized entrance exams. Susie said, "Hillside School is a harder school than where I was. I didn't have the foundation that I needed" (Susie, Interview 11/19/21). Susie indicated that this feeling of inferiority had a negative impact on her confidence in mathematics:

> I just feel like I was missing a lot. I mean, everyone who was there kind of had learned it before in other schools and at Hillside. And I just didn't and so I was behind . . . since then, I've been a lot less confident in my ability to do well. (Susie, Interview 11/19/21)

Susie identified this transition as the point in her education when her confidence in mathematics changed. Before the move, she was a very confident mathematics student who "used to be able to get 98's on all my tests" (Susie, Interview 11/19/21). At the time of the study, however, Susie's confidence in mathematics learning had decreased significantly.

Susie's confidence was impacted by the performance expectations she set for herself. When she did not meet these self-imposed standards or at least feared she had not performed as she would have liked, her confidence was impacted. Susie said:

> I know grades don't matter but when I do "not what I was hoping for," it might be something that someone else is really happy about, but I still don't think it is good enough. And so, I am always pushing myself to do better. (Susie, Interview, 11/19/21)

Susie acknowledged her standards were high and others may be thrilled to earn the grades she earned in mathematics. But the fear of not doing as well as she would like was pervasive throughout the instructional unit included in this study.

The first lesson of the unit was on quadratic functions. At the beginning of the following class period, Susie completed a three-question quick check on quadratic functions. On the confidence scale she marked just to the left of the midline and gave the following reflection. "I didn't really understand the lesson well, but I felt better as I went along" (Susie, Quadratic Functions Quick Check Reflection, 11/12/21). I asked Susie to elaborate on this reflection and she said, "before the quick check I was like 'oh, shoot, I don't know any of this.' But then I was like, 'oh wait, I actually do'" (Susie, Interview 12/13/21). She was worried about her understanding and lacked confidence in her ability to answer the questions before she knew what would be asked. By the end of the assessment, she felt more confident because she successfully completed more than anticipated.

At the midpoint of the polynomials unit, Susie took a graded formative quiz. When I asked about her confidence level going into this quiz Susie said it was "horrible. I was crying during the test. Like during the quiz when I was taking it, I was literally sobbing" (Susie, Interview, 12/13/21). She was upset during the assessment because she felt as though she did not understand any of the material and lacked confidence in her

performance. After taking the quiz, she marked the confidence scale at the bottom and reflected, “I don’t feel prepared at all. I put down answers I know are wrong and I left answers blank. I didn’t understand how to do 3.1 [quadratic functions] or 3.2 [polynomial functions] going into this” (Susie, Quiz Reflection, 11/19/21). Susie was in a state of panic with tears flowing and high anxiety when she wrote the reflection. She had no confidence in her ability to answer the assessment items.

In the post-interview, when I showed this reflection to Susie and asked her why she responded in such a way she said, “I just felt like the thing was with that quiz specifically, I was saying in my head, I was like ‘oh, I got this wrong. I got this wrong.’ And I was getting it right” (Susie, Interview, 12/13/21). Despite her ability to answer questions correctly, she lacked confidence in her answers and doubted her understanding. I asked Susie why she felt this way and she replied:

> That was probably the worst week I’ve had this entire semester . . . but I ended up doing the same [as] I do on every test on this quiz. It was so unreasonable for me to be that stressed because it was fine. (Susie, Interview, 12/13/21)

Susie was able to look back on the assessment and discuss it rationally. She acknowledged outside influences affected her performance and impacted her physiological and emotional state. Her heightened anxiety made her question her ability to work the problems when in reality, she performed at a level similar to that of her other graded assessments in this course.

Later in the unit, Susie learned how to find the real and complex zeros of polynomials and to factor polynomials completely over the complex numbers. On the quick check at the beginning of the next class, Susie marked her confidence very close to

the bottom of the scale and wrote in her reflection, “I didn’t remember anything from this section, and I guessed on this whole thing” (Susie, Zeros of Polynomials Quick Check Reflection, 11/23/21). She was certainly not confident in her understanding of the material. When asked why, Susie responded:

> I think I just didn’t remember anything . . . oh yeah, because I didn’t know what the Rational Zeros Theorem was. I don’t even think I do still. Oh, that’s the five over six thing, right? . . . Yeah, I didn’t know how to do any of that. (Susie, Interview, 12/13/21)

Susie was quick to say she did not remember anything, but when she stopped to think about it, she understood the Rational Zeros Theorem. Once again, she was not confident in her knowledge of the mathematics though her understanding may have been better than she perceived.

In her follow-up interview, I asked Susie to further discuss the pattern of misalignment between her low confidence and high anxiety during assessments and her performance. She said, “A lot of it is definitely just me freaking out about school, all the time. I psych myself out. I don’t have a very strong mental game” (Susie, Interview, 12/13/21). Susie acknowledged her negative perceptions about her ability were psychological and not necessarily based on her actual performance. However, she made this statement about school in general, not just mathematics. When asked to clarify this point Susie said:

> I feel like specifically for math, I tend to doubt myself. Even if I know that I’m prepared, I don’t think that I am unless I’m one-hundred percent sure that I know

everything about what we're being tested on. Then I just start freaking out. (Susie, Interview, 12/13/21)

Susie acknowledged that unless she feels she has prepared thoroughly, she succumbs to self-doubt, influencing her mental state during the assessment. Even the smallest uncertainty can lead to a big problem. Susie explained, "I feel like as soon as I kind of start doubting myself or what I'm able to do then it spirals into everything, not being able to understand anything" (Susie, Interview, 11/19/21). Her confidence during assessments was fragile and only the smallest amount of self-doubt exacerbated the situation, causing her to question her understanding of the material.

Though a pattern of unfounded doubt was evident in Susie's discussion of her assessments, in the follow-up interview Susie insisted, "I know when I understand something and when I don't" (Susie, Interview, 12/13/21). This confidence in her own self-awareness explained why she felt insecure about her performance on many assessments. If she felt as though she did not prepare well enough to ensure complete understanding, it opened the door for her to question her work. However, when she prepared to the best of her ability, she believed herself capable of success.

On the end of unit test, Susie completed many review problems, sought help from her teacher, and as a result felt very good about the assessment, marking her confidence high on the scale. She said, "for the test, I was like, I've done the work, I've asked the questions, I've done the practice problems . . . I understand this. And so, I felt like I was more confident on all of that" (Susie, Interview, 12/13/21). Susie attributed her strong self-efficacy on this assessment to the time and attention she was able to devote to preparation and practice. When her self-efficacy waned, Susie pointed to a lack of

preparation on her part which was often influenced by physiological and emotional issues outside of the mathematics classroom. These factors will be discussed in the following section.

**Other Influential Factors**

Susie's described factors beyond those already discussed that impacted her confidence in mathematics. She examined internal factors connected with her attention and focus during class. She also discussed the effect of activities outside of the mathematics classroom on her confidence in mathematics.

Susie admitted having a hard time focusing on lessons during mathematics class, which in turn left her concerned about important material she might have missed. She said, "I've always kind of struggled with paying attention in math. I kind of have a hard time focusing" (Susie, Interview, 11/19/21). The lack of focus in mathematics classes was not a new problem, she claimed to have always experienced this difficulty. When she told me, "I space out a little bit during class" (Susie, Interview, 11/19/21), I asked if this only happens in math or in other classes as well. Susie said:

> Well, in other classes too but a lot in math because I feel like as soon as I start not being able to understand something, or it's kind of like the [opposite] poles. If I'm like "oh, I totally get this" [then] I don't have to pay attention. But it's also like, "oh, I don't understand this stuff." (Susie, Interview, 11/19/21)

What Susie described is her understanding of why she had trouble paying attention in class. If she understood the material well, she felt she had license to think about or do other things. If, on the other hand, she felt lost in class, she stopped paying attention because she did not feel as though there was a reason to continue listening or working.

Because she was aware of this tendency and noticed when she lost focus, she felt less secure about her mathematical learning.

In addition to attention factors, Susie had a part time job she felt hurt her ability to succeed in mathematics class. When Susie reflected on the quiz she felt poorly about during this unit of study, she said, “I didn’t have sufficient time to study because of my job and I also didn’t know there was a quiz until two days ago” (Susie, Quiz Reflection, 11/19/21). Though the assignments for the entire unit were posted before the unit began in an online learning management system, Susie’s time spent working prevented her from keeping up with what assessments were coming and therefore reduced her study time. Susie lamented:

> That was probably the worst week I’ve had this entire semester. My job assigned me shifts on days that I couldn’t work. And I also had like four other tests that week that I was trying to cram for. I just didn’t remember anything for math because I didn’t have time to study for it. I tried coming in and there wasn’t enough time. (Susie, Interview, 12/13/21)

Susie acknowledged she was overwhelmed by demands on her time outside of the mathematics classroom. Both her job and assessments in other classes competed for time she believed she could have used to better prepare for her mathematics quiz.

Susie’s understanding of her focus and attention in class as well as the demands on her time and attention outside of class helped her to explain why her perceived confidence was low on some of her assessments.

**What Susie Needs**

In her assessment reflections and interviews, Susie indicated what she felt she needed to be successful on assessments in mathematics class. Some of her remarks referred to specific tasks or practices that were helpful during the current unit of study. Other comments were more general suggestions or reflections about what she finds most helpful.

I asked Susie to describe the purpose of quick checks throughout the unit and their impact on her self-efficacy. She said:

> I felt like the quick checks helped because I obviously don't really do my homework until before the quiz or before the test as a way to review but the quick checks kind of helped me assess where I was throughout the unit and then I do more problems according to that. (Susie, Interview, 12/13/21)

Though homework was intended to offer practice on new material and an opportunity for students and teachers alike to gauge the students' understanding of new concepts, Susie chose to use quick checks to serve this purpose. Homework was used, instead, as practice problems for test review. Homework was assigned on material learned in class that day. The learning management system indicated homework was to be completed by the subsequent class; however, the assignment was open for editing and completion until the end of the unit. Therefore, students were at liberty to delay completing, or even starting, their homework assignments. When asked if the flexibility of the due date was preventing her from getting the daily practice she needed to learn the material, she said:

> I feel like maybe if it was like half of your homework is due in the next class and then half is due at the test, I feel like that'd be helpful just to make me do some of

> it but then have the option of me being able to revisit the harder problems later. (Susie, Interview, 12/13/21)

She felt the due date flexibility allowed her to sit with the material for a time before having to work the more difficult problems. She also recognized the need for an earlier deadline for some of the work to make her start on it sooner.

I also asked Susie if she thought she would feel differently about the quick checks if they had been graded. She said:

> Yes, because I feel like if I got, if they were graded, I would have been more stressed about them. But knowing that they were just a way to self assess was definitely a destressor and kind of make it less high stakes for the quick checks. (Susie, Interview, 12/13/21)

Because there was no grade associated with her performance on the quick checks, Susie used them as a self assessment tool without creating anxiety about the assessment. Then, I asked if the self-assessment benefits would decrease if she continued to have ungraded quick checks each time she learned new material. She replied:

> I don't know. I feel like I'd be more like "oh, I know we're gonna have a quick check" so then I'll be able to know where I am for the unit . . . like studying for the quiz or studying for the test, it's hard to know what we need to know. And then when we did the quick checks I was like "oh, okay, I need to study this and this and this." (Susie, Interview, 12/13/21)

One of the greatest benefits of the quick checks for Susie was the opportunity to see what types of problems the teacher selected for these short assessments. She indicated that she

often has trouble discerning what material she should study, and the quick checks helped her know where to focus her preparation and practice.

In preparation for the unit test, Susie participated in a review game where students were asked to solve problems on a mini whiteboard and hold up their solutions for the teacher to see. The full set of problems was posted after class for extra practice in preparation for the test. When asked about the review problems' influence on Susie she said:

> Especially that night studying, I feel like, you know, I can go through the book and go to the exercises section, and do a bunch of the problems, but I don't really know which ones I should be doing. So the review problems that you put on [the online class notebook] were super helpful to go through all of them just to know if I understood the concepts in general. (Susie, Interview, 12/13/21)

Susie needed some guidance to determine what types of problems to practice. Having this set of review problems strengthened her confidence for the test because she knew she understood problems similar to the review.

Immediately following the test, Susie gave a high confidence score and reflected on what helped her to feel confident about this assessment. She said, "I came in during community time (CT) and I was still iffy on a few things but I got them figured out during CT and I was careful to check my work so I feel much more comfortable" (Susie, Test Reflection, 12/1/21). She found time the morning before her test to visit her teacher's classroom and clarify some concepts. This helped her feel more confident about her understanding of the material.

During the post-interview, Susie was asked to explain her test reflection comment in more detail. Susie remembered:

> I felt really confident about it going into the test becaues I felt like there was a lot of new ways that we learned about the units other than just what was in the textbook . . . overall, I felt like I understood the concepts more. And going in for community time was really helpful as well. But the quick checks were definitely super helpful. And the different things that we did in class rather than just writing down notes and things like that, like the sheet that we did. (Susie, Interview, 12/13/21)

By the end of the unit, Susie felt the variety of ways she had interacted with the material, including discovery exercises, quick checks, meeting with the teacher, etc. provided her with the support she needed to feel confident in her understanding of the material. She said, “I feel like doing the things in class that aren’t just like us copying down notes where we’re applying what we’re learning as we’re learning it, that definitely helps me remember it” (Susie, Interview, 12/13/21). Susie saw sufficient opportunities to practice using the new material as paramount to her confidence in mathematics.

**Case Summary**

Susie was selected as a participant because she had the lowest confidence and anxiety scores of all honors students willing to be interviewed, indicating low confidence and high anxiety. She also scored low on the mathematics usefulness subscale but scored high on the attitude scale. These marks indicated she valued the study of mathematics and wanted to perform well in the class yet saw little use for the subject in her future in child psychology.

Susie experienced low self-confidence when she did not perform to her self-imposed standards of success and when she fell short of her intended outcome, regardless of the eventual result. When Susie prepared sufficiently according to her own standards, she was confident in her performance.

Susie admitted there were external influences, outside of the mathematics and the classroom that influenced her confidence on mathematics assessments. She described trouble focusing during mathematics class causing her to worry that she had not paid attention in class as well as she should have to be successful. Susie's part time job monopolized much of her time outside of school during this unit and she knew it prevented her from having the time she needed to practice and prepare for her assessments.

Susie talked about strategies for improving her confidence on mathematics assessments. Susie said it would be helpful for her if the teacher would require half of the homework to be completed each night to hold her accountable for daily practice while allowing her to save problems to practice for review. She wished to continue having ungraded quick checks because regular opportunities to practice with no pressure to perform helped her build her confidence while also gaining insight about what types of problems she would be expected to complete on high stakes assessments. Similarly, she appreciated the robust test review offered for this unit. In all, Susie needed a variety of activities to see the material in different ways, ample opportunities to practice a variety of problems, and time to visit her teacher outside of class to ask questions. With these three things, Susie felt she had done all she could to prepare and was confident during the assessment.

The next participant to be described is Hilda. Like Susie, Hilda is in the honors Algebra 2. She was selected for having the lowest overall score of all honors students willing to be interviewed.

## The Case of Hilda

Hilda was a student in the Honors Algebra 2 course. She liked math as an elementary student because she was advanced in the subject, and it was easy for her. She came to Hillside School in seventh grade and suddenly math was hard for her. Since then, Hilda has not had favorable feelings about mathematics. At the time of this study, Hilda was interested in pursuing a degree and a career in business. She believed mathematics would likely be important for the business field. Hilda was selected as a case because her overall survey score of 136 out of 240 was the lowest of all honors students willing to be interviewed.

The case of Hilda will be presented in five parts. A description of Hilda's numerical responses to the case selection survey is given first followed by a further discussion of her attitude about mathematics and her perception of its usefulness. Next, evidence from Hilda's interviews and assessment reflections are used to describe her confidence in mathematics and her mathematics anxiety level. The fourth section includes a discussion of additional factors that influence her self-efficacy in mathematics. Finally, Hilda's comments about what she believed to be helpful for her confidence in mathematics are included. These five parts will be followed by a summary.

### Hilda's Survey Results

Of all honors students willing to be included in the interview portion of the study, Hilda had the lowest overall survey score of 136 out of 240. All her individual category

scores were below average for honors students in this study. Therefore, Hilda was selected as a participant to better understand her survey results. She had a confidence score of 37 out of 60. A neutral response on all survey items would yield a score of 36 so Hilda's score was just above the middle of the range of possible scores. Hilda's attitude score was 42 out of 60. Though this score indicated a favorable attitude about mathematics, it was five points below the average attitude score for her honors peer group. Hilda's mathematical usefulness score was 32 out of 60. This score was only two points above the minimum score for her peer group. Her low score for usefulness indicated that her beliefs about the usefulness of mathematics for her future were low.

Finally, Hilda had an anxiety score of 25 out of 60. This score was twelve points below the average for her peer group. Such a low score on the anxiety scale suggested a high level of mathematical anxiety. Hilda's survey results, in relative position with her peers, are displayed in Figure 3. In the review of Hilda's case to follow, a description of Hilda as a mathematics student with evidence from survey results, pre-interview, assessment reflections, and post-interview are provided.

**Attitude Toward Success and Mathematics Usefulness**

Based on her survey responses, Hilda does not believe mathematics is useful, nor does she have a positive attitude about success in mathematics. Her answers to questions about her mathematical background in the pre-interview helped to explain her survey responses. On the usefulness subsection of the survey Hilda disagreed with the following statements: "Mathematics is a worthwhile and necessary subject" and "I will use mathematics in many ways as an adult" (Fennema & Sherman, 1976, p. 27). She also agreed with the following statements: "Mathematics is of no relevance to my life" and "I

see mathematics as a subject I will rarely use in my daily life as an adult" (Fennema & Sherman, 1976, p. 27). However, when asked about how important she thought mathematics was to what she might do in the future she replied, "I think I want to go into business and math will probably be important" (Hilda, Interview, 11/22/21). In her interview response, Hilda conceded that mathematics would be useful for her future career, but the use of mathematics in everyday life seemed unlikely, despite her contradictory survey responses.

Although Hilda's attitude score was below average for Honors Algebra 2 students in this study, her scores were all three or four out of five on all but two survey items. Hilda strongly agreed with the statement, "I'd be happy to get top grades in mathematics" (Fennema & Sherman, 1976, p. 24). Yet she also agreed with the statement "winning a prize in mathematics would make me feel unpleasantly conspicuous" (Fennema & Sherman, 1976, p. 24). While she maintained a slightly positive attitude about success in mathematics, she did not appear to want attention for such success.

According to Hilda's description of herself as a mathematics student, her attitude about mathematics changed when she transitioned to Hillside School and mathematics became challenging. She explained:

> Well, in elementary school math was really easy and all we did was simple stuff. I always liked it back then because I was pretty advanced. Then [at] Hillside [in] seventh grade, once we started Prealgebra, it was really hard for me. I completely failed some tests. Ever since then, I haven't really enjoyed math or been excited about it. (Hilda, Interview, 11/22/21)

Hilda's attitude about mathematics was positive while the work was comfortable for her but as soon as she was challenged by the material her attitude towards mathematics became negative. When asked whether there have been times since the seventh grade when she felt more positive about mathematics she said, "eighth grade Algebra was kind of easier. I figured out how to study in seventh grade. Then ninth grade was Geometry and now I have to think in an Algebra way again" (Hilda, Interview, 11/22/21). Hilda was unhappy with the path of her mathematics courses because she felt as though she was having to switch back and forth between different ways of thinking. By eighth grade, she had finally figured out how to successfully prepare for an Algebra class. The she had to start the process over again in ninth grade Geometry. One year later, she was back in an Algebra course.

Because Hilda's negative attitude about mathematics seemed to be connected to the difficulty of the material, I asked why she continued to enroll in honors level mathematics courses if the higher level removed the joy she had experienced as a young child. Hilda replied, "I would rather do honors than regular because I feel like I'm challenging myself even though it's hard" (Hilda, Interview, 11/22/21). Hilda wanted to challenge herself by taking the harder courses, but her attitude about mathematics was dependent on her level of success in these courses and the ease with which success could be attained.

Hilda held a number of positive beliefs about mathematics. When asked directly about her future, she said mathematics would be important. She expressed joyful feelings towards mathematics as a young child. She desired to be challenged in school mathematics and would be happy to earn top grades in her mathematics classes.

However, all other responses about the usefulness of the subject were not favorable. These adverse remarks coupled with her downturn in attitude towards mathematics when it became more difficult necessitated further exploration into the dichotomy Hilda felt when it came to mathematics.

**Confidence and Mathematics Anxiety**

To further understand Hilda as a mathematics student, this section explores both Hilda's perceptions of her confidence in mathematics and her mathematics anxiety. On the confidence subscale, Hilda agreed with the following statements: "I'm not the type to do well in math" and "Most subjects I can handle O.K., but I have a knack for flubbing up math" (Fennema & Sherman, 1976, p. 21). She also strongly agreed with the statement, "Math has been my worst subject" (Fennema & Sherman, 1976, p. 21). Hilda lacks confidence in her mathematical ability and does not see herself as a strong student of mathematics.

On the anxiety subscale, Hilda scored a 2 out of 5 on each item except for two items, meaning most responses indicated high mathematical anxiety. She strongly disagreed with the statement, "I almost never have gotten shook up during a math test" (Fennema & Sherman, 1976, p. 28). In other words, Hilda had been rattled during mathematics tests before and perhaps this was a regular occurrence for her. Hilda then agreed with the statement "I usually have been at ease during math classes" (Fennema & Sherman, 1976, p. 28). This was the only positive response on the anxiety section of the survey. She disagreed with a similar statement about being at ease during a mathematics test. Therefore, Hilda was comfortable during mathematics class, but assessments raised her anxiety level.

The negative influence of assessments on Hilda's confidence and anxiety levels continued to be a theme in her interview and assessment reflection responses. When describing what would help her confidence, she remarked, "I know, I can tell when I'm ready for a test and when I'm not" (Hilda, Interview, 12/17/21). Hilda intimated that she had a grasp on how well prepared she was for a test. When asked what helps her feel confident in mathematics class, however, she said:

> This is probably not very good but [high] test scores… I think that affirmation really boosts my confidence. And there's this weird thing that happens. When I feel bad about a test, I usually end up doing good and when I feel good about a test, I don't do as well. (Hilda, Interview, 11/22/21)

Hilda explained that success on a test was helpful for boosting her confidence on subsequent assessments. She believed she had a firm grasp on her understanding of concepts in mathematics, yet she claimed her intuition about her performance on an assessment was usually wrong. These two comments offered conflicting perspectives. On one hand, Hilda felt confident she could gauge her preparedness for a test. After the test, however, she felt as though the results of the assessment were usually the opposite of how her performance felt.

This pattern of self-doubt was pervasive throughout her reflections and interviews. On her Polynomial Functions Quick Check Reflection, Hilda marked her confidence level high on the scale and wrote, "[W]e just went over this in class, but I am scared I went too fast and made a careless mistake" (Hilda, Polynomial Functions Quick Check Reflection, 11/16/21). Before completing the quick check, the class had discussed

the material and Hilda felt prepared. Yet, after completing the quick check problems, she was anxious about her performance assuming something must have gone wrong.

In her post-interview, Hilda offered more explanation about this reflection by saying, “that’s probably because I was so confident that I started doubting myself like ‘what if I did something wrong?’” (Hilda, Interview, 12/17/21). This remark helped to explain the seemingly opposing feelings of her preparedness before an assessment and misjudgment of her performance after the assessment. Hilda indicated that high confidence caused her to worry about the possibility that she was being overconfident and therefore raised her level of self-doubt. I then pushed further and asked for clarification. “When you feel good about something, that gives you negative thoughts?” (Webster, Interview, 12/17/21). Hilda answered in the affirmative.

Hilda’s description of her experience with synthetic division offered more insight into the interplay of her anxiety and confidence. On her Polynomial and Synthetic Division Quick Check Reflection Hilda wrote, “It is hard to check your answer for synthetic division if there is a remainder. I got a lot of 0.95/1 on the hw which lowered my confidence” (Hilda, Polynomial and Synthetic Division Quick Check Reflection, 11/18/21). She preferred problems she could easily check for the correct answer. When she learned synthetic division for the first time, she did not know how to check her solution and that caused her to miss most of the problems on the first attempt. The computer-based homework system allows for two incorrect attempts with no penalty and then a penalty of 0.05 points for each subsequent attempt. Therefore, a score of 0.95 on most of the problems meant she determined the correct answer on the third attempt on

average. Knowing it took her three tries to get most of the homework problems lowered her confidence in her ability to solve correctly on the first attempt on the quick check.

When I asked her in the post interview to tell me about this reflection she said, "I don't know because I think that the division was probably the easiest part of the unit. So, it's probably because it was the first time testing it" (Hilda, Interview, 12/17/21). Hilda explained that it was hard in the beginning because it was new and unfamiliar. By the end of the unit, she was much more confident in her ability to divide polynomials. It appeared that having more time to process new information was possibly a key to improving Hilda's confidence on an assessment of the material. When I asked her, however, if time to allow new material to take root helped her feel more confident, she did not indicate that this was the case. Instead, she said, "if I've gotten a lot of those problems right" (Hilda, Interview, 12/17/21). So according to Hilda, it was not more time to process new material that she perceived to improve her confidence but more experience or practice with the material and above all, successful practice.

Hilda's confidence was most dramatically impacted by graded assessments. During her pre-interview Hilda admitted, "my confidence depends on the test score or a major grade" (Hilda, Interview, 11/22/21). When asked if her confidence is impacted differently for graded assessments and those that are not graded, she said:

> If it's a quick check, I just feel like it's fine and it's not going to matter as much. And it's okay to get it wrong which improves my confidence because I know that even if I get it wrong, that's just going to help me. But then if it's a grade, I automatically prepare for the worst. (Hilda, Interview, 12/17/21)

Her marks on the assessment reflections were consistent with Hilda's comment that her confidence is much lower for graded assessments than for non-graded, formative assessments. Her confidence marks were all on the bottom half of the scale for graded assessments. However, confidence marks for the quick checks were all on the top half of the scale, even though she indicated some uncertainty about her understanding. On the Quadratic Functions Quick Check Reflection Hilda wrote, "I know how to do the problems from class and hw, but the transformation in #2 confused me" (Hilda, Quadratic Functions Quick Check Reflection, 11/12/21). She was uncertain about one of the transformations on the quick check, yet she marked her confidence level about three quarters of the way up the scale. When asked about this is the post-interview Hilda said, "I think I understood most of it and then that one problem that I was talking about…" (Hilda, Interview, 12/17/21). She indicated she felt good about it, other than the one transformation, and knowing she was uncertain about a problem did not seem to weigh heavily on her confidence level.

Hilda had a similar reaction to the Zeros of Polynomials Quick Check. She wrote, "I feel like I understood this quick check, even though I didn't understand some problems on the hw yesterday" (Hilda, Zeros of Polynomials Quick Check Reflection, 11/23/21). Hilda appeared surprised by how well she felt about this assessment. She felt a bit uneasy after some difficulty with the homework but when she took the assessment, she felt good about it. She marked her confidence level very high on the scale for this quick check. When asked later about her comment on the reflection she said, "I think I thought the quick check was a lot easier than the homework" (Hilda, Interview, 12/17/21). It appears the low stakes design of the quick checks enabled Hilda to be more confident and less

anxious about uncertainties with these assessments. The same was not true for the summative quiz and test for the unit.

Hilda's confidence marks on the summative quiz and summative test were both on the bottom half of the scale. Yet when asked in the follow up interview about her level of success on the quiz, Hilda said, "it was okay, not too bad but not the grade that I would have wanted" (Hilda, Interview, 12/17/21). Despite her reasons for feeling less confident on the quiz, after the fact she recognized she did not perform too badly after all.

A similar scenario transpired for Hilda with the unit test. Her class had a review activity the day before the test. When asked about test review Hilda indicated that this activity bolstered her confidence in the material. She said, "well, I knew what we were talking about. And I knew how to do all problems from the beginning of the unit when most people forgot. So, I'm doing better than I think" (Hilda, Interview, 12/17/21). When observing the understanding demonstrated by her classmates, Hilda was able to gauge her own level of comprehension. She recognized that she remembered some of the earlier concepts from the unit that many others forgot. She left this class feeling very confident about the upcoming unit test.

The unit test was the assessment with the most impact on her grade in the class. Despite her confidence level during the review, Hilda marked her confidence level the lowest of the entire unit for this assessment because she doubted the accuracy of some of her answers. She said, "there were a few that I know I got wrong" (Hilda, Test Reflection, 12/6/21). Hilda's self-doubt is evident once again. She felt good about the material when reviewing but then after the assessment she had very low confidence, certain that she missed some of the problems. When asked how the test went, she said,

"pretty good" (Hilda, Interview, 12/17/21). Despite how she felt right after taking the test, she was happy with her performance overall. When she reflected on the unit as a whole, she said, "I felt pretty good about it, that's my overall thing" (Hilda, Interview, 12/17/21). By the end of the unit, Hilda felt good about her understanding of the material, but her confidence and anxiety levels fluctuated throughout the unit.

Hilda had high expectations for her performance on assessments and therefore the pressure to meet her self-imposed standards of success raised her anxiety level on graded assessments and caused her to be less confident about her performance. Despite her lower confidence on graded assessments, she reported that she did well on them. When the assessments were not graded, she was more confident, even when she was certain she missed problems or concepts.

**Other Influential Factors**

In her assessment reflections and interviews, Hilda described physiological and situational factors that impacted her confidence during assessments. She cited work for other classes and extra-curricular activities as reasons for having insufficient time to study and not allowing her to get enough sleep for assessments. She also attributed a positive change in her confidence to excitement for upcoming events.

The first time Hilda cited a lack of time to complete work and a lack of sleep as reasons for lower confidence was on the Polynomial and Synthetic Division Quick Check. She wrote, "I was too tired to finish hw last night, so now I feel like I am missing something" (Hilda, Polynomial and Synthetic Division Quick Check, 11/18/21). Hilda marked her confidence on the top half of the scale for all quick checks, but this was the lowest mark she had on all her quick checks at just above the halfway point. Hilda

recognized that she could not complete the homework because she was too tired. The need for sleep prevented her from completing practice she believed was important for her understanding.

Hilda took the graded unit quiz the next class period, and on the Quiz Reflection wrote, “I did not study at all because of my English paper and I got not a lot of sleep. I know I got the last question wrong” (Hilda, Quiz Reflection, 11/22/21). She cited the lack of sleep and the lack of time to prepare for the assessment as the reasons her low confidence mark and for her incorrect answer to the last quiz question. When asked about this she said, “I remember this. It’s because I procrastinated on my English paper and that was the only thing I did that weekend. Then I was only relying on my past practice and not studying” (Hilda, Interview, 12/17/21). Because she had procrastinated the writing of her English paper, she was left to complete it when she should have been studying for her mathematics quiz.

Hilda also acknowledged that she had interacted with the material in class, practiced problems, and completed her homework, all of which supported her ability to do the problems on the quiz. Even so, she would have felt as though she was better prepared if she had time to study for the quiz. When I asked how the quiz went, she said, “it was okay, not too bad, but not the grade that I would have wanted… and then I was also really tired and falling asleep” (Hilda, Interview, 12/17/21). Writing the English paper took time away from her desire to study for the mathematics quiz. Instead, she stayed up late writing, and did not get enough sleep to be able to focus during the mathematics quiz. She was exhausted and falling asleep while taking the quiz. When asked if sleep influenced her confidence Hilda said:

> Yes, only recently because before I used to get the right amount of sleep and then I didn't even consider it. But then, at the beginning of the school year, I was getting not enough sleep and then that dropped my grades in all my classes. So then I was like, 'I have to get more sleep.' So now every time I don't get enough sleep, I feel like I'm going to get a bad grade. (Hilda, Interview, 12/17/21)

Based on her experience at the beginning of the school year, Hilda made a connection between lack of sleep and bad grades. This erected a barrier to her confidence because after that, anytime she did not get sufficient sleep before an assessment, she assumed she would perform poorly on the assessment.

In the class period following the quiz, Hilda was surprised by how well she thought she did on a quick check and wrote, "I feel like I understood this quick check even though I didn't understand some problems on the hw yesterday." She continued this reflection with, "Maybe I am just excited because it's almost Thanksgiving Break" (Zeros of Polynomials Quick Check Reflection, 11/23/21). Because Hilda did not understand some of the problems from her homework, she had assumed she was not well prepared for the Quick Check. After working the problems, however, she was pleasantly surprised she understood all the problems on the assessment. In an effort to explain this situation, she pointed out that Thanksgiving Break was beginning soon and as a result, her spirits were high. When asked for further explanation she said, "I just feel like it doesn't matter as much because then I'm just not going to think about that for the next five days" (Hilda, Interview, 12/17/21). Hilda connected a break from school with a lightening of her spirit and a reason to not have to worry about how well she understood the material.

Hilda's low confidence on the unit test, despite her high confidence during the test review, was described in the previous section. Once again, Hilda cited a lack of time for preparation and a lack of sleep as reasons for her diminished confidence on the test. She wrote, "I didn't get enough time to study this weekend. I also did not get enough sleep. There were a few that I know I got wrong" (Hilda, Test Reflection, 12/6/21). When I asked her about this reflection in her follow-up interview, she said:

> And then the sleep again, I don't really know why I didn't get enough sleep over the weekend or enough time to study. What was I doing? What day was this? December 6th? Oh, I had MidState. I don't know. Maybe I just didn't feel like studying. (Hilda, Interview, 12/17/21)

Hilda was an accomplished violinist, and the unit test followed an eventful weekend for her as a musician. She reasoned that either the event itself prevented sleep and studying or the emotions from the weekend caused some avoidance. Either way, Hilda perceived that factors outside of the mathematics influenced her confidence on the test.

**What Hilda Needs**

In her interviews and assessment reflections, Hilda described the importance of making good grades in mathematics class. When she described what she needs to be confident in mathematics, she described activities completed in class, external factors, and the impact of grades on her confidence.

When talking about the discovery exercise completed in class to introduce polynomials, Hilda said, "I felt pretty good about the worksheet because we got to work with our partners. And then, it was straightforward. And then doing the worksheet with [the shared class notebook] helped a lot" (Hilda, Interview, 12/17/21). Although the

material was not taught using direct instruction, Hilda was given simple instructions in a guided worksheet and a peer with whom to work. This lesson format helped her feel good about learning the new concept. Recall also from a previous section that Hilda felt good about the test review because the class worked review problems in a game format, and it became clear to Hilda that she remembered more than most of her peers about the unit before she had studied for the test. These peer interactions offered Hilda vicarious experiences (Bandura, 1997) to gauge her own understanding of the material. When she was able to successfully complete the problems either with her peers or better than them, her confidence was bolstered.

The previous section explored lack of sleep and time for preparation as Hilda's reason for low confidence on the Polynomial and Synthetic Division Quick Check. Upon further discussion during the follow-up interview, Hilda commented when she wrote this reflection, it was the first time she was tested on the new skill. When I pressed for more information she said, "even if I know it, I'll know it the same before the quick check or before the test. But then before the quick check, it hasn't settled in for me. Even though it probably has, I don't feel like it has" (Hilda, Interview, 12/17/21). Hilda explained that she may have known how to do polynomial and synthetic division equally well on the quick check as she did on the unit test. Her confidence, however, was not likely to be as high simply because of the newness of the material.

In the post interview, I asked what a teacher needs to know about how her confidence and how she was assessed. She explained, "I liked having the quick checks because even though they're three questions, getting a 100 was like 'you're on the right track.' And then just reviewing because I have to make sure that I know what this stuff is.

And then for me, not procrastinating" (Hilda, Interview, 12/17/21). Hilda acknowledged the frequent, low-stakes formative assessment design of the quick checks was helpful for knowing whether she was on the right track or she needed more practice. She also explained that she has to review the material to feel as though she is prepared for an assessment. Whether or not she really needed to review and study on top of the practice completed when learning the material in order to perform well on assessments, she does need the review and studying for her to feel confident on the assessment.

Hilda also admitted that procrastination, whether on mathematics or in other classes, was a hindrance to her having the time needed for sufficient preparation to feel confident on assessments. Hilda continued, "and then sleep, because if I don't get enough sleep, I'd make a lot of weird mistakes and it's really bad" (Hilda, Interview, 12/17/21). In previously discussed comments, she cited sleep as a reason for lower confidence. In this case, she cited the importance of sleep to her successful performance on assessments and implied that knowing she did not get enough sleep before an assessment caused her to feel less confident in her ability to perform well.

Because Hilda acknowledged the importance of quick checks for gauging her understanding, I asked for more clarification about the details of these assessments. When asked if quick checks would be as helpful if she did them after every lesson and they became habit she said, "well then I'd get used to them and then I don't think they'd be as effective" (Hilda, Interview, 12/17/21). Quick checks were used frequently during this unit of study but were not used with the same regularity earlier in the course. Hilda admitted they may lose their effectiveness if they became too commonplace. When asked about the impact of quick checks if they were graded, she said, "well, if they're for a

grade, they automatically bring my confidence down. I liked not having them for a grade." (Hilda, interview, 12/17/21). Hilda was evidently aware of her lower confidence on graded assessments. When I pointed out that she marked her confidence level as below the midline when the assessment was to be graded and above the midline for ungraded assessments, she said, "If it's a quick check, I just feel like it's fine and it's not going to matter as much. And it's okay to get it wrong which improves my confidence because I know that even if I get it wrong, that's just going to help me. But then if it's a grade, I automatically prepare for the worst" (Hilda, Interview, 12/17/21).

Hilda placed great importance on her grade in the class. Though there were many factors influencing her confidence on assessments, whether or not the assessment was graded seemed to have a great impact on her confidence. She needed to have the small assessments without a grade to help guide her learning along the way. Grading the quick checks would have diminished their effect.

**Case Summary**

Hilda was selected as a case because she had the lowest survey score of all honors students willing to be surveyed. Hilda lacked confidence in mathematics and had high mathematics anxiety especially on major assessments. When Hilda felt confident during an assessment, she worried she was overconfident, and this led to self-doubt. She believed high scores on major assessments were necessary to raise her confidence in mathematics.

Hilda's confidence scores on assessments were lower when the assessment was summative, high stakes, and graded. Hilda made more mistakes on smaller, low-stakes or ungraded assignments such as homework or quick checks, yet she marked her confidence

scores higher in these. There appeared to be a connection between her confidence and the type of assessment she was taking.

Hilda made connections between her physiological and emotional state and her confidence on assessments. She discussed assignments for other classes and extracurricular activities and their resulting impact on the time and energy she had do her algebra homework or study mathematics. She valued adequate sleep and made connections between the time she slept the night before a major assessment and her performance on the assessment.

When Hilda described what helps her feel most confident on mathematics assessments, she mentioned the importance of learning in a variety of ways. She benefited from sufficient time to practice new material and allow it to settle in before being assessment on the topic. She also listed things she strived to do to help herself feel confident such as not procrastinating, allotting herself ample review time, and getting enough sleep. Achieving these goals helped Hilda to feel confident and not satisfying these requirements had a negative impact on her confidence.

The next student, Yuliana, was selected because unlike Teagan, Susie, and Hilda, she scored high on many of the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976). Yuliana was selected because she had the highest confidence, attitude, and anxiety scores of all regular level students willing to be surveyed, indicating confidence, a positive attitude, and low anxiety towards mathematics.

## The Case of Yuliana

Yuliana was a student in the regular Algebra 2 course. She entered Hillside School in the fifth grade and described herself as very confused in mathematics class. She believed Hillside mathematics classes were much more in depth than those at her elementary school. She believed fifth and sixth grades were her worst years in mathematics class, but she remembered a lightbulb moment from in seventh or eighth grade. Since then, she realized she had to work through new concepts to understand them, but once she did, mathematics was a good subject for her in school. At the time of the study, Yuliana planned to pursue a career in the music business. She believed the basics of mathematics would be useful to her in the future and perhaps more if she ended up working on the financial side of the music industry. Yuliana was selected as a participant for this study because she had the highest confidence score, highest attitude score, and highest anxiety score indicating low anxiety of any regular level student willing to be interviewed.

The case of Yuliana will be given in five sections. A presentation of the numerical responses Yuliana provided to the case selection survey is followed by a description of her attitude about mathematics and her perception of its usefulness. Then, Yuliana's interviews and assessment reflections provide insight about her confidence in mathematics and her mathematics anxiety level. The next section describes additional factors that impact her mathematical self-efficacy. Finally, a depiction of what Yuliana believes is beneficial for her confidence in mathematics is included. These five sections will be followed by a summary.

**Yuliana's Survey Results**

Of all regular level students willing to be interviewed, Yuliana was selected because she had the highest confidence, attitude, and anxiety scores. She had a confidence score of 58 out of 60, an attitude score of 57 out of 60, and an anxiety score of 47 out of 60, indicating low anxiety. Her usefulness score was not as high relative to her peers with a score of 46 out of 60, but it was still above the average for all students. Yuliana had an overall score of 208 out of 240, the third highest of all students willing to be interviewed. Her survey scores in relative position with her peers are presented in Figure 3.

**Attitude Toward Success and Mathematics Usefulness**

Yuliana indicated through her survey responses that she had a positive attitude about success in mathematics and she believed it will be useful for her future. Her attitude scores were all either 4 or 5 indicating a positive response to all survey items. Her usefulness scores were all 4 or 5 except for her responses to three items. She gave a neutral response to the following items: "I study mathematics because I know how useful it is" and "I will use mathematics in many ways as an adult" (Fennema & Sherman, 1976, p. 27). She also disagreed with the statement, "I'll need a firm mastery of mathematics for my future work" (Fennema & Sherman, 1976, p. 27). To clarify these responses, I asked Yuliana about her career interests, and she said, "I'm actually interested in the music business" (Yuliana, Interview, 12/01/21). When I then asked how important she thought the school mathematics she was doing was for her future, she said:

> I'd say it's important to the basics, but I don't think it's going to be too useful. Like maybe if it was economics or something like finance it'd be a lot more

> useful or important for my career. I feel like finance is [an] important thing. But Algebra, not so sure. (Yuliana, Interview, 12/01/21)

Yuliana understood that basic mathematical skills would be useful for her as an adult, but in terms of her career, she did not see herself needing much mathematics. Despite her seeing little use for mathematics in her career, she had positive things to say about mathematics as a subject and saw value in the subject overall.

Throughout her post-interview, Yuliana had a positive attitude about the unit. When asked about the zeros of polynomials quick check, she saw she had marked her confidence high on the scale, yet she left no comment. She said, "I think it went good" (Yuliana, Interview, 12/01/21). When I pressed and reminded her that this material was particularly challenging because there are a lot of steps, she said with utter nonchalance, "you just find the rest of the zeros" (Yuliana, Interview, 12/01/21). I continued to talk about how challenging this material could be, and I mentioned that her reflection marks were consistently high. She said, "Oh yeah, I think I felt pretty good . . . should I do synthetic division, or should I do long division, or should I do possible zeros? It was just about finding what to do first on all that . . . you just have to know what to use" (Yuliana, Interview, 12/17/21). Here she was describing how she did not get worried about the complexity of the material. She felt she had the tools she needed to work the problems. She was unflappably positive about the entire unit.

When I asked Yuliana about what teacher or student actions influenced how assessments impacted her confidence, she mentioned the importance of "having motivation as a student to want to understand. It's something that's really important, especially – well actually for anything really . . . having the dedication" (Yuliana,

Interview, 12/17/21). She attributed her confidence in mathematics to her motivation and dedication as a student. Yuliana approached her work in school mathematics with determination and high expectations of herself. Her positive attitude pervaded all interactions I had with Yuliana.

**Confidence and Mathematics Anxiety**

Based on her survey responses, Yuliana's level of confidence in learning mathematics was high. Her confidence scores were all either 4 or 5 indicating a positive response to all survey items. Her anxiety scores were also very high, indicating her low mathematics anxiety. She scored all items with a 4 or 5 except for three items. She indicated a neutral response to "My mind goes blank, and I am unable to think clearly when working mathematics" (Fennema & Sherman, 1976, p. 28). She also disagreed with the following statements: "I haven't usually worried about being able to solve math problems" and "I almost never have gotten shook up during a math test" (Fennema & Sherman, 1976, p. 28). These responses gave me the impression that though Yuliana may have struggled occasionally on a math test or had her mind go blank when working mathematics, she had low anxiety and high confidence in learning mathematics. Her responses to interview questions and assessment reflections helped to further explain Yuliana as a mathematics student.

In Yuliana's pre-interview I asked about her confidence in her past mathematics classes. She said:

> Whenever I came into Hillside School, I was very confused because at my elementary school, we didn't go as in depth as they would have at Hillside. I wasn't exactly prepared. I remember fifth and sixth grade, it was probably my

> worst years of math. But then in seventh and eighth grade, I remember it was like a lightbulb moment or something in Algebra that just happened. And, I don't know, ever since then, it's just been like once I understand the concept, it's pretty good for me. (Yuliana, Interview, 12/01/21)

She immediately identified her transition to Hillside School as a time when her confidence waned. When I asked her to explain her confidence through those years, she said:

> Well, I mean, the stuff you're doing in elementary school is pretty much basics, but it was just enough for when I came to Hillside. So, I guess in elementary school, I'd say I was like at a 7 or 8 out of 10. And then when I came to Hillside, I dropped to a 5 or so. (Yuliana, Interview 12/01/21)

She gave her confidence level on a scale of 1 to 10, indicating high confidence in elementary school and a drop to the middle of the scale when she started attending Hillside in the fifth grade. I asked Yuliana if the struggle accompanying the added level of difficulty of mathematics at Hillside School impacted her confidence level. She said, "sort of, but once I started to understand the material, that changed" (Yuliana, Interview, 12/01/21). She perceived a period of transition, perhaps her entire fifth and sixth grade years of mathematics.

Once she grew accustomed to the material, however, her confidence improved as well. Because she indicated fluctuation in her confidence level, I asked if she saw her confidence level as being relatively stable or if she felt like it went up and down from one section or one day to another. She said, "I guess it just depended on the topic. Like for me, specifically, this one moment when I learned how to use negative numbers. I

remember that was so difficult for me. But, for instance, doing polynomials or whatever, that's really easy for me" (Yuliana, Interview, 12/01/21). Understanding negative numbers was viewed as a hurdle to Yuliana's confidence in mathematics. When she was unable to do mathematics correctly with negative numbers, she was not confident in her ability. In her discussion, she intimated that the lightbulb moment that changed her confidence level in mathematics was her finally being able to use negative numbers correctly. Once she overcame this obstacle, she felt comfortable with new material. Since mastering the use of negative numbers, she continued to encounter more challenging material, but her attitude was one of patience and understanding made evident by the discussion to follow.

Most of Yuliana's assessment reflection confidence marks were high on the scale, however, she marked her confidence level on the Quadratic Functions Quick Check Reflection near the bottom of the scale. Her comment said, "I didn't do the homework yet" (Yuliana, Quadratic Functions Quick Check Reflection, 11/22/21). When I asked her about this she said, "actually, Ms. Albert was like, 'okay you can do this either this weekend or Tuesday or whatever. I think I did it Tuesday, so I was so confused on that quick check" (Yuliana, Interview, 12/17/21). Ms. Albert chose to present this lesson in the flipped classroom format where students were to watch a short video at home and practice problems before coming to class to discuss the lesson. Yuliana had not yet watched the video or practiced problems and therefore was unprepared for the quick check. She said, "No. I hadn't even done it, no." Despite her low confidence mark on the quick check, not completing her homework had been the problem and she no longer had any trouble with that material. She said:

> Overall, in this topic, I feel like it's – I understand it. But it was just a lot more steps in Algebra than I've experienced before. Because usually I just do equations, you know, find x or whatever. You have to find [the] vertex and everything or you have to find zeros and all that but there was so many different ways to do it, or so many steps. It was a bit more challenging, but I still felt pretty confident. (Yuliana, Interview, 12/17/21)

Yuliana acknowledged that the material was challenging and required more steps than other simpler algebraic topics. She also recognized that there were different ways to approach the problems. She did not indicate whether the multiple approaches made the topic more or less challenging. But she was confident with the material at the end of the unit despite her slow start with the material.

After learning about polynomial and synthetic division, Yuliana made a mark high on the confidence scale and said, "I've done a lot of practice" (Yuliana, Polynomial and Synthetic Division Quick Check Reflection, 11/18/21). Yuliana connected her confidence level on an assessment with the amount of practice she did in preparation for the assessment. In the follow-up interview I asked Yuliana what she meant by "practice." I wanted to know if it was the Tic-Tac-Toe activity from class, homework, or additional practice that helped her feel prepared and confidence for the quick check. She said, "it was probably just the homework because the homework, it's like 20 problems. You really get the hang of it, I think" (Yuliana, Interview, 12/17/21). Yuliana put great value on the practice she got from simply completing the daily homework assignments. She felt practice was sufficient to ensure her understanding of new concepts. Yuliana continued, "I really understand the topic, actually. Again, with everything else, it just takes practice.

I feel like it wasn't something I got immediately but over time, with more practice problems, I could get it" (Yuliana, Interview, 12/17/21). She did not falter when she did not understand new material right away. She had a positive outlook on the process of learning and mastering new mathematical concepts. And she remained confident that with enough practice she would succeed.

When I asked Yuliana about the impact of having quick checks this unit she said, "I personally didn't like it that much" (Yuliana, Interview, 12/17/21). I asked her to explain why she did not like them, and she said, "Oh my gosh, they were just kind of random up there. I wasn't confident yet, so I was not really confident of my ability to actually do well" (Yuliana, Interview, 12/17/21). She did not feel confident being assessed on the material before she had time to understand it. To clarify, I asked if the quick checks were given too soon after she saw the material and she said, "sort of, in a way. Yeah. Not really a fan of quick checks in general because I like to feel really confident that I can do it before I can show my teacher" (Yuliana, Interview, 12/17/21). Yuliana did not perceive that she was given the quick checks too soon after learning new material, but instead, she had not practiced sufficiently to feel confident showing her work to another, her teacher. I asked whether it mattered that the quick checks were not graded, and she said, "Oh yeah. Well, I mean, I guess it doesn't matter at that point. But I still like to feel like I'm doing good and stuff" (Yuliana, Interview, 12/17/21). When pushed to acknowledge that the quick checks were not graded and therefore did not hold a lot of weight, she conceded the point. She insisted, however, that whether it was graded or not, it was important to feel good about what she was doing on an assessment.

In the post-interview, Yuliana reflected on the unit as a whole. When I asked about her confidence level on the test she said, “Oh yeah! Yeah, I think I felt pretty good because I had seen different ways of doing it: different examples, different problems, what could show up and everything. So, I felt really confident” (Yuliana, Interview, 12/17/21). The combination of learning and practice opportunities with which she was presented and of which she took advantage during this unit were ample for her to feel confidence in her ability to succeed on the unit test.

**Other Influential Factors**

Yuliana did not name any additional factors influencing her confidence not addressed in other sections. She did, however, have very strong feelings about virtual online learning and the flipped classroom model. She said, “I hate doing videos. Honestly, like last year, I remember a lot of our learning was over video, especially I know my history class. . . she [my teacher] was online and everything” (Yuliana, Interview, 12/17/21). Yuliana was referring to the 2020-2021 school year when many students and teachers spent some time in virtual and hybrid classroom settings. Her history teacher spent most of the year teaching virtual synchronous lessons. Yuliana continued, “it was not helpful for me at all. I can’t retain things online. I think I need someone to speak to me, actually talk to me in person for me to actually grasp it or understand it” (Yuliana, Interview, 12/17/21). Yuliana did not believe she could learn as well, or at all, when the learning did not take place face-to-face in the classroom. When making these remarks, Yuliana spoke forcefully and with certainty. She had very strong opinions about virtual learning.

In the follow-up interview, I asked if there was anything else I should consider that negatively impacted her confidence during the unit. Yuliana said, “videos, I really don’t like videos. Like, so much!” (Yuliana, Interview, 12/17/21). Yuliana was no longer referring to learning virtually but instead learning from videos via the flipped classroom model. She vehemently opposed the effectiveness of learning in this way. Yuliana never specifically mentioned the impact of this instructional model on her confidence, but she did mention it several times and each time with strong feelings.

**What Yuliana Needs**

Yuliana was clear about what she needed to feel confident on mathematics assessments. Some of the needs were personal actions she could take to help her feel confident with the material. Other needs were external, related to the teacher or the course itself. Yuliana perceived the interplay of these factors as important to her confidence.

Yuliana believed her confidence grew with time spent practicing the material. During her pre-interview she said:

> For me, I think my confidence comes from spending a lot of time with one topic or something. Because when I have practice, I go into a test feeling very, very confident. When I do lots of practice problems and I know I can get it right without doubting myself or what the concept is, I have confidence. (Yuliana, Interview, 12/01/21)

She believed her confidence came from working practice problems successfully and building the assurance that she would be able to work similar problems on an assessment equally well.

I pushed further in the post-interview and asked Yuliana about the more challenging material in the unit. I asked about her confidence performing the multi-step process of finding all the complex zeros of a polynomial using the Rational Zeros Theorem, finding zeros and using synthetic division to divide out factors and ultimately to factor a polynomial over the complex numbers. She said:

> Yeah, that's one of the things I was talking about where it's a lot of steps, where you just have to go through it a lot of times to grasp it. . . There's like, the zeros and everything. Yeah, I think I understood it a bit after, overtime really. And then before the test I specifically remember doing some of the practice problems, like on the [online homework system] notebook or the textbook. (Yuliana, Interview, 12/17/21)

Even when the problems were complex with multiple steps and multiple solution paths, Yuliana believed that with enough practice, she would be successful on assessments. As a follow-up question, I asked about the quantity of problems she did to prepare for the summative unit test. She said, "yeah, like the zeros and everything… it was just a lot of practice" (Yuliana, Interview, 12/17/21). Yuliana's perception of what gives her confidence on assessments was sufficient practice to ensure she could do any problem on the assessment.

When I asked Yuliana directly what I should consider in my study to boost girls' confidence on assessments, she said, "okay, I really like how she [Ms. Albert] does the guided notes. And then again, the different types of problems. I think that's really helpful" (Yuliana, Interview, 12/17/21). She had previously made clear that she did not feel comfortable learning from a teacher virtually or learning from videos in a flipped

classroom. Her follow up response indicated that guided notes and practice led by her teacher were very important to her. I then asked about the discovery lesson, which required the students to work with their peers to understand the properties of polynomial functions and the corresponding behavior of their graphs. Yuliana reflected:

> I thought that one class was really helpful because we did a problem, and we did examples with it. Ms. Albert taught us how to do it, and then we like, then did it on our own, which I thought was typically a good way to learn because honestly, you just see different ways how you do it. (Yuliana, Interview, 12/17/21)

Yuliana referred to the layout of the discovery exercise (See Appendix E). There were notes about characteristics of polynomials, followed by exercises to practice identifying the characteristics. She liked learning a skill and then practicing the skill with her partner because it gave her experience looking at different aspects of polynomial functions.

When asked what a teacher could do to help her feel more confidence, Yuliana did not bring up quick checks on her own. In fact, in a previous section, I described why she did not like them. When asked about the process of completing a quick check and going over the answers in class, however, she admitted:

> I think it helped me to know what I should work on. I guess there were some things that I could do. I could find the zeros of something. But would I know, what the end directions were like? That was something that I knew I had to work on. Because I did the quick check, so I guess that was something that helped. (Yuliana, Interview, 12/17/21)

Yuliana recognized the quick checks made her aware of different ways questions could be asked and helped her to know the aspects of the material on which she needed more work.

Yuliana described things both she and her teachers could do to improve her confidence on mathematics assessments. Most importantly, she believed the combination of personal and teacher aided factors were key. Recall, she previously said, “okay, I really like how she [Ms. Albert] does the guided notes. And then again, the different types of problems. I think that’s really helpful” (Yuliana, Interview, 12/17/21). In the same comment she continued, “and then just like having motivation as a student to want to understand it. It’s something that’s really important” (Yuliana, Interview, 12/17/21). Yuliana acknowledged that the teacher could do all the right things, but the student must also want to understand the material or be motivated to put in the work to learn.

Even before the polynomial unit began in her class, Yuliana articulated the importance of both the student and teacher to the students’ confidence level on assessments. I asked how much of the confidence she feels on assessments comes from what the teacher does in class and how much comes from her own preparation. She said, “I think the teacher makes a big impact. Whether I like the teaching style is very important to me” (Yuliana, Interview, 12/01/21). She continued, “but also, you have to put determination into actually understanding the thing and taking time to practice and stuff” (Yuliana, Interview, 12/01/21). Again, having a good teacher helped to build her confidence but she recognized her personal responsibility to put in the time and practice to be well prepared.

I asked if she needed more practice to be assigned by the teacher to be worked in class or if she was referring to selecting problems and working them on her own, outside of class. Yuliana said, “I guess sort of like in class is a lot better because you have a teacher to ask questions” (Interview, 12/01/21). If she had to choose, she preferred doing practice in class because the teacher was available to answer questions if she got stuck. Yuliana contrasted this in-class practice with work completed outside of class by saying, “like with homework, you’re kind of just like trying to grasp it yourself, without help” (Yuliana, Interview, 12/01/21). Though she appreciated having her teacher nearby to answer questions, Yuliana also valued the importance of having to work through new concepts on her own.

I asked Yuliana for more detail about the online homework she completed for each lesson in this unit and how it impacted her confidence on assessments. She said, “well it helps me to see different types of problems that could show [up] on a test or something which helps me feel more confident that I know everything completely that will show up when I’m getting assessed” (Yuliana, Interview, 12/17/21). Seeing a variety of problems on daily homework assignments contributed to practice Yuliana believed she needed to feel confident on assessments. Next, I asked her if she completed the homework the night it was assigned. She said, “usually unless I like forget or something” (Yuliana, Interview, 12/17/21). This assured me that she kept up with her homework daily and did not save it for review practice before an assessment. Then I asked if she would go in to ask Ms. Albert questions when she got stuck on her homework. She said:

> Yes, definitely! There’s sometimes where it’s a problem that I haven’t really seen, or it’s a number that I don’t know, just something I haven’t seen in my notes

> because I really refer to my notes in my homework a lot, to similar problems. (Yuliana, Interview, 12/17/21)

Yuliana did see Ms. Albert outside of class time to ask questions from her homework as necessary. She also pointed out that she used class notes, homework problems, and other resources to try to figure the material out on her own before seeking help from her teacher.

**Case Summary**

Yuliana was selected as a case because she had the highest confidence, attitude, and anxiety scores, indicating a low level of anxiety, of all regular level students willing to be interviewed. Her positive attitude and confidence were evident in her interviews and assessment reflections. However, she did not mention anxiety or nervousness about mathematics. Instead, her responses reflected on herself and what she had to do to succeed. She believed her confidence in mathematics stemmed from her motivation and dedication as a student.

Yuliana believed practice was important to build confidence. She liked doing many homework problems and never worried when she did not solve them right away. She knew that with enough practice, she would understand the material. Yuliana said she benefited from practicing a variety of problems because it made her feel confident on tests. Yuliana believed that motivation to succeed and sufficient practice on her part were crucial to her high confidence in mathematics, but she also believed her teacher played a role in her confidence.

Yuliana insisted she needed synchronous, face-to-face instruction from her teacher to feel confident about learning new mathematics. She emphasized the

importance of teaching style as well as good practice and instruction provided by her teacher to her confidence. She also cared about her teacher's belief in her ability to succeed in mathematics. She did not like to take an assessment before she had ample time to master the material because even if the assessment was formative and ungraded, if the teacher would see it, she did not want to let her teacher down. Yuliana appreciated the opportunity to ask her teacher questions and counted on her as a resource when she was stuck on homework problems. If she had done her part to learn the material and the teacher had done her part to teach and prepare her, Yuliana would be confident in her understanding on any assessment.

Yuliana's case is followed by the final student participant, Magnolia. Magnolia was a regular level Algebra 2 student who was selected as a case because she had the highest overall score of all students willing to be interviewed. She also had the highest confidence and usefulness scores of all students.

## The Case of Magnolia

Magnolia was a student in the regular Algebra 2 course. She did not like mathematics in elementary school because subtraction was challenging for her. She moved several times before going to Hillside School. She lived in Switzerland for a few years, taking mathematics class in German. When she returned to the United States, she lived in New York City and attended a school where she continued her mathematics education in German. She moved from New York City after the eighth grade and enrolled at Hillside School for high school where, for the first time in many years, she took mathematics classes in English. Magnolia's unique mathematical journey and the impact her experiences had on her confidence in mathematics will be discussed in this section.

At the time of this study, Magnolia was interested in studying industrial design because she was interested in problem solving with skills she acquired from her studies in mathematics, science, and art. Magnolia was selected as a case because she had the highest overall score of all students willing to be interviewed. She had the highest scores of all students in both confidence and usefulness, with a perfect score for usefulness.

The case of Magnolia will be presented in five sections. First, a report of Magnolia's numerical responses to the case selection survey is given. This is followed by a description of Magnolia's attitude about mathematics and her perception of its usefulness using evidence from her interviews and assessment reflections. Third, a discussion of her confidence in mathematics and her mathematics anxiety level are included. The subsequent section presents additional factors impacting her mathematical self-efficacy. The final section is a description of what Magnolia believes is beneficial for her confidence in mathematics. These five sections will be followed by a summary.

**Magnolia's Survey Results**

Of all students, both honors and regular, willing to be included in the interview portion of the study, Magnolia had the highest overall score of 212 out of 240. She had a score of 58 out of 60 in confidence, the highest of all regular level algebra 2 students. She had a perfect score of 60 out of 60 for mathematical usefulness. For these high scores, Magnolia was selected as a participant to better understand her survey results. Magnolia's score for attitude was 49 out of 60, just slightly above average for all students surveyed. Her score for mathematics anxiety was 45 out of 60, indicating low anxiety. This score was not extremely high but still well above the average for all Algebra 2 students. Magnolia's survey results with respect to her peers are displayed in Figure 3.

**Attitude Toward Success and Mathematics Usefulness**

Based on her survey responses, Magnolia had a relatively positive attitude about mathematics and strongly believed mathematics was useful. Her pre-interview responses to questions about her mathematics background gave more in-depth detail about her survey responses.

Magnolia had a good attitude about mathematics and her success in the subject. She strongly agreed with the statement, "I'd be proud to be the outstanding student in math" and she strongly disagreed with the statement, "I don't like people to think I'm smart in math" (Fennema & Sherman, 1976, p. 24). Though she was proud for others to believe she was good in math, she did not want to be publicly recognized for her mathematical achievements. She indicated neutral feelings about the statement, "Winning a prize in mathematics would make me feel unpleasantly conspicuous" and agreed with the statement, "If I got the highest grade in math, I'd prefer no one knew" (Fennema & Sherman, 1976, p. 24). Even though her attitude score was just one point above average, her overall attitude was positive and negative feelings were connected to spotlighting her success.

On all twelve items on the usefulness scale, Magnolia responded with the optimal answer giving her 60 out of 60 on the usefulness scale. She strongly agreed with statements such as, "I'll need mathematics for my future work" and "I will use mathematics in many ways as an adult" (Fennema & Sherman, 1976, p. 27). She also strongly disagreed with statements such as, "Mathematics is of no relevance to my life" and "Taking mathematics is a waste of time" (Fennema & Sherman, 1976, p. 27). She

spoke in detail in the pre-interview about why she had such strong feelings about the usefulness of mathematics.

Magnolia believed mathematics would be required for her future college and career interests. When I asked her what career path she planned to pursue, she said,

> I'm really interested in industrial design. And so, I've always liked problem solving, with math and with science. And so, I've been thinking about that. And then I've also always liked art. . . using math and art kind of together. (Magnolia, Interview, 12/01/21)

Magnolia was interested in a career combining her love of problem solving in mathematics and science with her interest in art. The opportunity to combine visual appeal with features and function in product design appealed to her. I asked Magnolia what she would study to become an industrial designer and she explained:

> I don't really know right now because I was thinking about getting an undergrad in applied math or in math because it seems like it'd be a good foundation for it. But then I was looking at some bigger schools that have industrial design programs, and they have a lot of different classes that you would have to take pretty much as much math as you would art. And so, I don't really know exactly what degree I would need right now. But I am figuring that out. (Magnolia, Interview, 12/01/21)

As a junior in high school, Magnolia had started to research college programs and degree paths. She originally thought a degree in applied mathematics would be a good fit for her interests, but after research, she found industrial design programs requiring as many art courses as mathematics courses.

Though she was interested in industrial design, her career plans could change before she finishes college. Therefore, I asked Magnolia about the usefulness of mathematics if she ended up pursuing a career not directly connected to the field of mathematics. She replied:

> I think it's pretty important. And whenever I have a family, I think it's important to understand math, just in general. And then just for life, kind of all the application questions that we always do in math classes are real world things that happen. And so, I think knowing how to do higher level math, even if I don't end up going into a field with math, I think is still really important, just for everyday life. (Magnolia, Interview, 12/01/21)

Magnolia believed mathematics was useful for everyday life whether she pursued a career in mathematics or not.

Magnolia's belief in the usefulness of mathematics served as motivation for her to persevere in mathematics class. When asked about the usefulness of mathematics, she said:

> I think it will be pretty important. And that's kind of what I have to remind myself of whenever we have a class that's confusing, to just remind myself I need to know how to do this for my future. It's not something I can just forget about because it'll keep on building after this after high school. (Magnolia, Interview, 12/01/21)

When mathematics was tough for her, Magnolia reminded herself that what she is learning was important to her future. She needed to make sure she learned the material at each point along the way because new concepts would build upon previous material.

**Confidence and Mathematics Anxiety**

Magnolia had a high confidence score on the survey and an above average score for mathematical anxiety, indicating high confidence and low anxiety in mathematics. Magnolia gave the most favorable response for all items in the confidence survey except two. She disagreed with the statements "I'm no good in math" and "For some reason even though I study, math seems unusually hard for me" (Fennema & Sherman, 1976, p. 21). Both responses are favorable, but they stood out because they were the only items to not receive a score of 5. On the anxiety portion of the survey, her answers were all scored with a 4 or 5 except for three questions. She was neutral about the statements, "I usually have been at ease during math tests" and "I get a sinking feeling when I think of trying hard math problems" (Fennema & Sherman, 1976, p. 28). Magnolia is not immune to being nervous about mathematics tests or feeling a bit of discomfort when the material is especially challenging. She disagreed with the statement, "I almost never have gotten shook up during a math test" (Fennema & Sherman, 1976, p. 28). Her usually high confidence and low level of anxiety about mathematics were strained when material is hard, or she was being tested. Her discussion of confidence and anxiety through her assessment reflections and interviews provide further explanation of her survey responses.

Magnolia had an eventful educational journey before she arrived at Hillside School the fall of her freshman year. In her pre-interview, Magnolia described her journey and the resulting impact on her confidence in mathematics. I opened the interview by asking her about her experience in the mathematics classroom, to which she replied:

> I didn't really like math. In elementary school, I hated subtraction because I just did not understand it. And then I moved to Switzerland. So, I started doing all of my math in German. And so that was confusing, but also really interesting to learn how to do it in a different language. (Magnolia, Interview, 12/01/21)

Magnolia described a challenging start to her mathematics journey. Subtraction was frustrating for her at a young age. Then at age ten, her family moved to Switzerland. Magnolia attended a school in Switzerland where all mathematics courses were taught in German. At thirteen, her family moved to New York City where she attended another school that taught mathematics in German. Magnolia reflected on her time in New York by saying, "and then, in New York, I started doing integrated math (so geometry and algebra) but that was also in German" (Magnolia, Interview, 12/01/21). Magnolia's elementary and middle school years were marked by transition and learning mathematics in a new language.

Magnolia's transition to Hillside School was challenging because she once again transitioned schools and for the first time since she was ten years old, she had mathematics class in English. She said:

> When I came to Hillside School, I had never… I hadn't done math in English in a really long time. So, it was confusing in that way. But then after I started to get it, then I became a lot more confident, and I started to really like math. And so, through Algebra 1, and Geometry, and now Algebra 2, I really liked math. (Magnolia, Interview, 12/01/21)

Taking mathematics class in English for the first time in years presented some challenges for Magnolia. In time, however, her confidence began to increase. When I asked her if

she thought the language change had anything to do with how she felt about mathematics she remarked:

> I think so because I mean, when I was younger, I had just started middle school. So, it wasn't really that weird to transition. And my teacher in Switzerland was really good about explaining it in English and German. I think when I had to take assessments in eighth grade for ninth grade [admission] in English, while I had only been doing basically Algebra 1 in German, I didn't know what it was asking me to do. And so that was what made it really confusing and frustrating, and why I didn't like math, when I started high school. (Magnolia, Interview, 12/01/21)

Her early transition to mathematics classes in German was not too difficult because she was young, the mathematics was simpler, and her teacher was careful to give directions in German and English while she was learning. Her transition back to mathematics class in English when she moved to Hillside School was much more abrupt. Magnolia did not know whether she had learned many of the topics before because she was unfamiliar with the English terminology. She also had no peers adjusting to learning mathematics in English, so she did not have much support for this transition.

Because of Magnolia's lack of familiarity with mathematics terminology in English, she placed into the lowest level mathematics class for freshmen at Hillside School, Algebra 1. I asked Magnolia if she felt like she had already done most of the mathematics in Algebra 1 or if she felt it was a valuable experience to repeat a course, most of which she had already taken. She replied:

> I definitely think it was good to take Algebra 1 because some stuff we had covered, and some stuff we didn't just because of what they focus on in the

> European system. And I had done integrated, so we'd do one big algebra unit, one big geometry unit, one big algebra unit, one big geometry unit, and that was our whole year in New York, in seventh and eighth grade. And so I think it was good to take Algebra 1 just to get everything because I think, if I hadn't taken Algebra 1 again, I would really be confused in Algebra 2. (Magnolia, Interview, 12/01/21)

Magnolia believed taking Algebra 1 in the ninth grade helped her transition to a new school with a different mathematics sequence than her previous institution. It also gave her the opportunity to reacclimate into learning mathematics in her first language, English. Her successes in Algebra 1 helped her to feel prepared and confident in her subsequent courses of Geometry and Algebra 2.

Just as subtraction proved difficult for Magnolia in in elementary school, negative numbers gave her trouble in middle school. This diminished her confidence. She said:

> I remember in eighth grade; I was really good at roots. And in seventh grade, we learned the concept of negative numbers. And that was kind of the first time I'd ever heard of that. So that was really confusing, learning how to add negative numbers. I was like "what?" and it didn't really make a lot of sense. But then obviously, after a while, it started to click. But that took a while to start to understand that there were numbers below zero. (Magnolia, Interview, 12/01/21)

Though Magnolia recalled the negative impact of a newly introduced concept, she also learned that with persistence, she could master challenging material. I asked if her confidence in mathematics was diminished when she encountered challenges. She replied:

> I think so. It made me less confident for a while until I would get to [a] unit where I really knew what was going on. And when I was really little and doing subtraction and didn't understand how to do it. I think that really impacted my confidence. Because especially in a class setting, when everyone gets it and you don't, you don't want [to] answer any questions or anything like that. (Magnolia, Interview, 12/01/21)

Magnolia provided further insight when she explained her lack of confidence with mathematical concepts caused her to be intimidated in a classroom setting and reluctant to ask questions or speak in class. As previously stated, Magnolia liked to be perceived by classmates as good at mathematics. As such, when her confidence waned, she was less likely to engage in mathematics class.

I asked Magnolia if she believed her confidence fluctuated from one assignment to another or if she saw her confidence as more of an overall feeling. She said:

> For me, I don't think it changes that often. I think I do have challenges when I learn something new. But I've just started going into a new unit, with the thought of "I can do it. It's just building off of what we did before. I can do it!" And I just have to sit with it for a while. And I think when I was younger, I didn't really understand that yet. And I wouldn't sit with it and really think about it to try and understand it, I would just kind of accept that I don't know how to do this. I'm confused. And then it would never work out. (Magnolia, Interview, 12/01/21)

As Magnolia matured as a mathematics student, she learned struggle was a part of the learning process. She became comfortable with the discomfort, confident in the

knowledge that she would figure it out eventually. This sentiment resonated throughout my interactions with Magnolia.

In the post-interview, Magnolia and I walked through the focal unit of the current study. She offered detailed explanations for the progression of her confidence level. The unit began just before the Thanksgiving break. To cover the desired material before the holiday, Ms. Albert asked students to watch a video introduction of the quadratics lesson for homework after the previous unit test. The next day, Magnolia gave a low confidence mark on her quadratics quick check and wrote, “I didn’t do my homework yet so I just tried my best” (Magnolia, Quadratic Functions Quick Check, 11/12/21). Despite her lack of confidence on the material, she maintained a good attitude. She knew she had not adequately prepared so she tried her best and that was okay with her. When I asked her about this remark in the post interview, Magnolia said:

> Well, that I remember being harder because I remember we did the quick check, and I hadn't watched a video yet. So that was a little difficult. But I think it's kind of the same as when my teacher explains it to me, even if it is through video that it makes enough sense where I can do it by myself. Even if I have to go back and check a couple of times to make sure that I am following the law correctly. (Magnolia, Interview, 12/13/21)

Magnolia remembered she had not watched the video, which made the quick check challenging. She also explained that she did not mind learning new material via the flipped classroom model. Whether the teacher explained a new concept in person or on video, Magnolia felt she had enough understanding to start working problems on her

own. Learning from a video also afforded her the opportunity to go back and rewatch parts of the lesson if necessary.

Magnolia had a good attitude about learning from a video; however, she did not feel comfortable learning about polynomials via the discovery exercise (See Appendix E). When I asked her how this formative experience influenced her confidence, she said:

> I thought it was a little bit difficult. Just because I didn't have my teacher telling me or teaching me what it was, I was kind of teaching myself. So I didn't know if I was like making mistakes or not catching all of the information. Because I know that when we go through the [online class notebook], Ms. Albert, will like highlight the things that are important. And we go through everything, and people can ask questions. And it's harder, when we aren't learning it as a class, and we're learning it more individually. It kind of reminded me of what we did in the spring of 2020, when we were online a lot, or all the time, I guess, when we had to teach ourselves some of this stuff. (Magnolia, Interview, 12/13/21).

Magnolia feared that without her teacher explaining the material, she would not learn all the important details. She preferred for new material to be presented by her teacher, highlighting the most essential information. According to Magnolia, the discovery exercise on polynomials was similar to virtual learning she had experienced in the spring of 2020. She was uncomfortable with material she believed she was having to teach herself. The next day, she marked her confidence level just above the halfway mark and said, “I feel better about this material but it is still a little confusing” (Magnolia, Polynomial Functions Quick Check Reflection, 11/29/21). In the follow-up interview she explained:

> I think I was less confident. And then when we did the quick check, I was less confident in it because it was kind of new. And then I think as I did it more and more by myself and I was getting there right? I think that that helped boost my confidence than when I first learned it and I was kind of unsure whether or not I was right or not. (Magnolia, Interview, 12/13/21)

Her reflection at the end of the unit included more perspective about the lesson on polynomials. She remembered being less than confident when learning the material. However, when she took the quick check, she believed the newness of the material negatively impacted her confidence rather than the method of instruction. After the quick check, she indicated that more practice allowed her to successfully completed more problems on her own. As a result, her self-doubt diminished and her confidence level increased. To clarify, I asked how she felt about this material when it was time to take the end-of-unit summative tests. She replied:

> I felt good about it. I know when I was taking it, there was one problem that I was a little bit confused about, but I had to think about it for a little while, like five minutes. And then I kind of just tried something and I realized how it all went together. Good. And so that was kind of like a moment that made me feel more confident. Because even if I didn't get it at first, I could think about it for a little while. And it would just, it kind of just came to me. And I could kind of plug in everything. (Magnolia, Interview, 12/13/21)

By the end of the unit, she felt comfortable enough with the material from the polynomials lesson that she calmly thought about a problem she was stuck on and was

able to figure out how to solve the problem. This had a positive impact on her confidence level for the remainder of the assessment.

In the post interview Magnolia further explained the reason for her improved confidence on the early material by the end of the unit. She said:

> Okay, so I know we started it before Thanksgiving break. And the first couple of sections were a little bit confusing, just because we either did them really fast, or we had to learn it from videos, which was a little bit hard. But then once we did synthetic and long division, and then like applying that, and kind of doing that in different ways that, at least for me, it all made a lot more sense. So then when I went back, and I looked at [sections] 4.1 and 4.2, then that made a lot more sense, because it was leading into the synthetic and long division. And it was like, it just made more sense that way. (Magnolia, Interview, 12/13/21).

Magnolia described her struggles early in the unit. She was not terribly worried, attributing her difficulties to the school holiday and the accompanying disruption to the normal classroom rhythm. However, in the third lesson of the unit on polynomial and synthetic division, Magnolia found a rhythm as she began to recognize the usefulness of the first two lessons. The lesson on polynomial and synthetic division seemed to be a turning point for Magnolia during this unit.

After learning how to do polynomial and synthetic division, students spent the remainder of the class completing division problems in the form of a tic-tac-toe style game. I asked Magnolia how this formative assessment impacted her confidence level and she replied:

> I really liked it. I remember we didn't have a ton of time to do it in class. But I remember specifically practicing the ones with synthetic division because we had just learned that and I was getting them right which was nice. And so even though we couldn't finish the game, then I mean, I think it helped a lot to just know that, "okay, I know how to do this. I can do it by myself." (Magnolia, Interview, 12/13/21)

Magnolia appreciated the opportunity to practice the new skill she had just learned. When the practice yielded success, she felt good about her ability to do division problem on her own.

The following class period, she marked her confidence level near the top of the scale on the division quick check and wrote, "I thought it was pretty good because I really like this division. I did have some questions about #1 though" (Magnolia, Polynomial and Synthetic Division Quick Check Reflection, 12/01/21). Despite having questions on one of the problems, she felt good about her ability to divide polynomials. In the post-interview, I asked her how she felt about this quick check and if she remembered what questions she had. She said:

> I definitely liked it a lot better. And I think the questions that I had were more about the long division, and how that would work. Because I know that was still a little bit new. So trying to figure out how that works was a little bit complicated. But once I learned it, I really liked it. And it was kind of fun. (Magnolia, Interview, 12/13/21)

Magnolia did not allow uncertainty about a new concept to negatively impact her confidence on the assessment because she felt good about what she understood and believed her comfort would continue to increase with additional material.

Magnolia's confidence marks continued to increase with each subsequent assessment in the unit. The final lesson required students to put together all of the information from previous sections and find all zeros and all factors of given polynomials. On this quick check, Magnolia marked her confidence level just below the highest possible mark and wrote, "I understand this and I think its kinda fun [smiley face]" (Magnolia, Zeros of Polynomials Quick Check Reflection, 12/02/21). When we discussed this reflection in the post-interview, I mentioned to Magnolia that she appeared to have a positive attitude about this robust, challenging section. She replied:

> I've always liked when units build on each other, or when all of the different things that we learned kind of culminate in something and you can apply everything that you've learned in one thing. And I feel like, that was what that idea was for this unit is kind of everything coming together. And it also brought in stuff that we had learned, like in chapter two or whatever, and so kind of being able to bring other things from this semester was nice. And then, for some reason, it just made a lot of sense in my brain, how it worked. And I knew, "okay, here's what I have to do with this, and then I factor it out. And if I can't factor it out, then I have to do the quadratic formula." And it was just very step by step for me, which made it a lot easier, and I think made me more confident when I was doing it, like on our test. (Magnolia, Interview, 12/13/21)

Magnolia perceived that her confidence was strengthened throughout the unit because each subsequent lesson built upon the previous ones. As she made connections between concepts and understood why each detail was important, she felt more confident with the material.

In the post-interview, I asked Magnolia if her growing confidence carried over to the end of unit assessment, the summative test. She replied:

> Yes, I think also, because before our tests, I'd practiced a lot, just with our textbook. And so I kind of knew, "okay, here's what I have to do. And if it doesn't work out, go back, try something else. Maybe you did finding the equation wrong or something like that." (Magnolia, Interview, 12/13/21)

Magnolia was confident because she felt prepared. She practiced problems regularly and developed an internal dialogue. This practice encouraged her to persist and continue trying new ways to work a problem if she was stuck. In order to get a better understanding of what helped her develop such a dialogue and feel confident about her understanding, I asked her how she prepared for the test. She said,

> Like I said before, from the synthetic division, long division part through the end, I pretty much understood. And then the beginning was what I had to go back and do. So I went back and I read through my notes, looked at my different worksheets that we did. And then we, or Ms. [Albert] told us about our [text]book and so I did some of the questions in there. And that's how I prepared for it. And I wasn't . . . I think I was nervous about the test because I'm always a little bit nervous about the test. But once I was taking it, it wasn't . . . there wasn't anything on there that really surprised me. Or that I wasn't, I mean, there was that

> one question that was a little bit more difficult. But I think, in general, because I've prepared for it and prepared for the different types of questions. I think it made me more confident when I was taking it. So then, and I kind of just understood what was going on. (Magnolia, Interview, 12/13/21)

The growth of her confidence throughout the unit as the material built caused Magnolia to realize she did not need to spend much time preparing for the most recent material but instead needed to review over the earlier sections. She admitted to always having some anxiety about tests, but beyond the normal nerves, she was not surprised by the questions she was asked. She felt she had adequately prepared and was confident when taking the test because she felt as though she understood what she was doing.

For clarity, I asked Magnolia to what question she referred when she mentioned the one question that was difficult. She said,

> So [for] the one I had trouble with, we had to find the zeros, the end behavior, and then graph it. And I was looking at the equation and then it's like, "I don't really know what I'm supposed to be doing with this, am I supposed to do synthetic division? I don't really know." And I tried it and it just didn't look right. So I was like, "maybe I should try something else." And then I just thought about it. And then I made up a list in my mind of the possible zeros, and then just like guessed on one until I got to a remainder of zero, and then I factored it out based on that. And I was like, "Oh, that makes sense." And then, I found the multiplicity. And then I knew the end behavior what it was supposed to be, which is why I knew that the one before I had tried was wrong. And so then I looked at it to see if it would make sense for that to be correct. And then it looked like it would be right.

> So I just graphed it that way. And I ended up doing it right. So that was satisfying that I got it. (Magnolia, Interview, 12/13/21)

The problem Magnolia found difficult was a polynomial with a repeated zero. She understood the role of degree knew theorems indicating that irrational and complex zeros occur in conjugate pairs for polynomials with rational coefficients. When she listed all of the possible rational zeros and tested to see which ones were zeros of the polynomial, the numbers did not work with her understanding of the material. When she performed repeated synthetic division with all of the rational zeros she had found, she was left with the final factor and discovered it was one she had already found, but it had a multiplicity of two. She felt much better at this point because she was able to graph the polynomial. Her list of zeros and their multiplicity, combined with the *x*-intercepts and end behavior of the graph, aligned with her understanding of the concepts.

Upon completion of the end-of-unit test, Magnolia gave a high confidence score on her test reflection and wrote, “I felt pretty good because I studied a lot and caught some mistakes I made when I went over everything. On the calculator part, I was less confident because I wasn’t sure I was doing everything correctly” (Magnolia, Test Reflection, 12/06/21). She questioned her work on the calculator, but overall was confident because she had caught some mistakes and corrected them herself. When I asked for more detail about this reflection in her post interview, she said,

> I was pretty confident. I know on one of the word problems, I wasn’t completely sure if I had done it right. And so I was like, “I don’t know.” But on everything else, I felt good. And after I got it back, I felt good about it. (Magnolia, Interview, 12/13/21)

The word problem she was uncertain about was on the calculator portion of the test. When the graded test was returned to her, however, she felt good because she had correctly solved the problem. Because Magnolia commented on feeling good about her uncertainties once she got the test back, I asked her if grades influence her confidence level on assessments. She replied:

> I don't think it really influences that much. I think I would have said the same thing after I got it back. But I think definitely, if you get the grade that you thought or a grade that was higher than what you thought, then I think it makes you more confident about what you did. I think if you get a grade lower than sometimes you can think that "oh maybe I was a little too confident coming out of that test." (Magnolia, Interview, 12/13/21)

Although Magnolia said her grade on an assessment does not alter her confidence, she went on to explain performing as well or better than she thought would boost her confidence. She did not, however, say a lower than expected grade would decrease her confidence but rather would draw attention to her over confidence on the material.

Overall, Magnolia described her high level of confidence that grew throughout the unit. She appreciated the way the mathematics built upon itself as the lessons progressed. She mentioned in her pre-interview, however, circumstances that impeded her usally strong level of confidence and low mathematical anxiety. She said:

> When we do a lot of topics in a week, and then like, early the next week, we have a test, then it's hard. I think it's hard to have all that information really quickly, and then have to turn around and apply it. Even if you understand how to do it. It can be like you learn it, you know how to do it, and you apply it on the test, and

> you do well on the test. But then you kind of forget how to do it. So, when the exam comes you have to relearn a lot of stuff, just because you didn't really fully understand it before a test. (Magnolia, Interview, 12/01/21)

Magnolia preferred having enough time to master material for long term retention. She said she could not feel fully confident about the mathematics learned if she had to absorb it too quickly. She may be successful on assessments in the short-term, but for Magnolia this was not enough. She wanted to feel confident enough to be able to use the mathematics when she needed it in the future.

**Other Influential Factors**

Although Magnolia gave lengthy, thoughtful answers during our post-interview, she was always focused on the question she was asked. She did not describe or elaborate on other influential factors unless I specifically asked. As mentioned in a previous section, Magnolia was less open to discovery activities because she had negative memories of having to teach herself mathematics while learning from home in the spring and fall of 2020 amidst shutdowns associated with the COVID-19 pandemic. When describing her experience with the discovery exercise on polynomial functions, she said:

> I thought it was a little bit difficult. Just because I didn't have my teacher telling me or teaching me what it was, I was kind of teaching myself. So I didn't know if I was like making mistakes or not catching all of the information. Because I know that when we go through the [online class notebook], Ms. [Anderson], will like highlight the things that are important. And we go through everything, and people can ask questions. And it's harder, when we aren't learning it as a class, and we're learning it more individually. It kind of reminded me of what we did in the spring

> of 2020, when we were online a lot, or all the time, I guess, when we had to teach ourselves some of this stuff. (Magnolia, Interview, 12/13/21)

Magnolia was not comfortable with the format of the discovery exercise because it was too similar to the way she experienced mathematics class remotely during 2020.

The other possible influence on Magnolia's attitudes towards mathematics was the growth and maturity she experienced as she transitioned between schools and between languages of instruction in her mathematics classes. She described:

> I think I do have challenges when I learn something new. But I've just started going into a new unit, with the thought of I can do it. Like, it's just it's building off of what we did before. I can do it. And I just have to have to sit with it for a while. And I think when I was younger, I didn't really understand that yet. And I wouldn't, I wouldn't sit with it and really, like, think about it to try and understand it, I would just kind of accept that I don't know how to do this. I'm confused. And then it would never work out. (Magnolia, Interview, 12/01/21)

Magnolia described a transformation in the way she faced learning new mathematics. When she was younger, she was not patient with herself as she was learning. She gave up easily and was frustrated by the mathematics. As she matured, however, she grew in her confidence, attitude, and patience with her learning process. She was more willing to sit with challenging concepts and was patient as she worked through them. She also realized how mathematics knowledge is cumulative and she began to use prior knowledge to help build understanding of new material.

**What Magnolia Needs**

Magnolia was clear about classroom experiences that either boosted or impeded her confidence. She described a need for time to process new material without graded assessments to allow her to gain confidence in her understanding. The time between exposure and assessment has been insufficient at times, concerning Magnolia. She said:

> Sometimes there's a really quick turnaround between when we learned something and when we have homework due on it. So especially on the days, at least here where we have a back-to-back. I think sometimes that can be hard, because sometimes I feel like I just don't have enough time to sit with the information. (Magnolia, Interview, 12/01/21)

Most of Magnolia's Algebra 2 homework was assigned in an online environment associated with her textbook. She was allowed multiple attempts on each problem without penalty; however, the homework was graded daily for accuracy.

Magnolia's class met four out of every seven school days and therefore once in a rotation, she had Algebra 2 on subsequent days. She wished she had more time to practice and absorb new material before graded homework was due, especially when she had mathematics class two days in a row. Magnolia offered a solution idea to this problem when she said:

> I think at least on the days where we go back-to-back to maybe have homework due after that class, but to maybe keep going or like go over it again, and then start something new. And so, you have more time to finish the homework, so that you can understand it. (Magnolia, Interview, 12/01/21)

She proposed that when the class meets two days in a row, the students should have an extra night to complete the homework assignment. She said it would be okay if the teacher continued with the pace of the class and moved on to new material, if necessary. Having a more flexible homework due date was her suggestion for increasing the time for mastery of new material before a graded assessment.

One characteristic of the unit in this study which was a departure for the norm in Magnolia's Algebra 2 class was the lack of a mid-unit quiz. In the follow-up interview she reflected on how this helped her confidence. She said:

> I really liked not having a quiz this unit. I felt like the daily quick checks were kind of like a quiz and I think it helped that when we had a quick check Ms. [Albert] said, "Okay, this is probably what it's going to look like on your test." And so when I was studying for my test, I could go back and look at them and see, "oh I got this one wrong because of this," and kind of figure out how I did it, and how I should have done it that I could do it correctly on the test. . . but I really liked having a quick check instead of like a graded quiz, because I think sometimes, if there's a quiz in the middle of the unit, and maybe you don't do as well on it, it can bring down your confidence when you're going into the test over that material. (Magnolia, Interview, 12/13/21)

Magnolia valued the opportunity to work problems on quick checks and use them to guage her undersanding of the unit. She appreciated the regular, ungraded opportunities for feedback. They offered similar learning opportunities as her mid-unit quizzes from earlier in the year without the blow to her confidence dealt by some of these quizzes.

I wondered if it was the frequency of the quick checks or the lack of a grade had a greater affect on Magnolia's assessment preferences. I asked if her confidence would have been negatively impacted if the quick checks had been graded. She said:

> I think so. Yeah. Because I think people in my class and I know, for me, I would be much more on edge about it if I knew that they were going to be graded, and would be in my grade, especially if maybe I didn't understand the material as well at that point as I could, or that I would by the end of the unit. (Magnolia, Interview, 12/13/21)

She felt grades should only be taken when students have been given ample time and opportunity to master the material. Graded intermediate assignments given soon after introduction to the concepts made her nervous.

I was curious about nonchalance that students might develop if quick checks were never graded. I asked Magnolia if they would be meaningful if she was given a quick check after every lesson for the rest of the year and they were never graded. She said:

> I feel like [if] it was like an all year thing, then I think, occasionally, they would have to be graded just because I think, probably, at some point, you wouldn't really try and learn the material as well. I think in this unit, it really helped just because we were learning a lot of new things and combining a lot of Algebra 2 things that we've learned this semester. So it was good to not have them be graded. (Magnolia, Interview, 12/13/21)

Magnolia reasoned that for brand new material, it seemed fair to give ungraded formative assessments, though she did acknowledge some motivation to learn new material right away would be lost if there were no stakes for any intermediate assessments. I thought

she suggested it would be fair to grade assessments like quick checks on material introduced in previous courses or units. Whereas for brand new material, grading such assessments should be withheld until the students had time to digest the material. I asked if this was what she was trying to say and she said, “yeah” and continued:

> Or like we do a quick check every class and they're not graded, but we still would have a quiz that would be graded just to make sure that we're learning the material. And if we're not [given a quiz] to go back and go over the stuff that we might not understand. (Magnolia, Interview, 12/13/21)

Once again, Magnolia offered a solution balancing a need for accountability with the need for feedback and time to grow.

**Case Summary**

Magnolia was selected as a participant in this study because of all students willing to be interviewed, she had the highest overall score on the survey. Her confidence and usefulness scores were the highest of all regular level students. Magnolia’s past experiences in mathematics helped her learn to adapt to new situations and to be comfortable with the discomfort of learning new mathematics.

Magnolia’s confidence in the material strengthened throughout the unit. She showed patience with herself and trusted the learning process. She was not worried about challenges along the way and did not allow them to negatively impact her confidence. She appreciated the way mathematics content builds on prior concepts, and she believed making these connections was important for her learning. This positive outlook on learning mathematics helped her to persevere with confidence throughout the learning process.

Magnolia believed she needed to learn new material from her teacher, whether face-to-face or virtually. Regardless of delivery, he wanted the teacher to explain the mathematics. Exploring and questioning without direct instruction caused her to doubt her understanding and lowered her confidence. She appreciated opportunities to practice a new skill before being assessed on the material and it was important for her to have adequate time separation between learning new material and taking a graded assessment.

Magnolia admitted she was often nervous on tests but knowing she was prepared lifted her confidence and helped her to move past the nerves. As she encountered challenges on the unit test, she was able to try different solution methods and when she found something that worked, her confidence was boosted. Magnolia did not believe grades impacted her confidence. However, she argued assessments should only be graded if they are assessing material students have reviewed or have had sufficient time to practice. Overall, Magnolia had a big picture perspective and worried less about small setbacks along the way. Instead, she focused on learning the mathematics she would need for her future. This long-sighted view of learned helped her confidence to remain steady and even grow stronger throughout the learning process.

## Cross Case Analysis

In the previous sections, I described the confidence of five students, Susie, Hilda, Yuliana, Magnolia, and Teagan, throughout a unit of study in Algebra 2. I will now share the results of the cross-case analysis, discussing similarities, differences, and patterns across the five cases (Yin, 2009). First, I will include a mathematics attitudes summary and comparison of the five cases. Next, I will describe the ways students perceived that mastery experiences influenced their confidence on assessments. I will then compare

student perceptions of the ways vicarious experiences and social persuasion influenced their confidence on assessments. Finally, I will share the physiological, emotional, and other factors for which students described connections with their confidence on mathematics assessments.

**Mathematics Attitudes**

Based on the results from the selected subset of scales on the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976), five students were selected to participate in interviews to offer insight into the mathematical confidence of a variety of students. Of the five students interviewed, two were enrolled in Honors Algebra 2 and the other three were students in the regular level Algebra 2 course. Three of the students were in the $10^{th}$ grade and the other two were in the $11^{th}$ grade. The students had career aspirations ranging from child psychology to business to industrial design. The survey results and demographic information for the five students interviewed are included in Table 5. The variety of interests, experiences, and attitudes about mathematics represented by these five cases helped to give voice to the perceptions of a variety of girls about their confidence in mathematics.

**Table 5**

*Student Case Information and Survey Results*

| Variable | Teagan | Susie | Hilda | Yuliana | Magnolia |
|---|---|---|---|---|---|
| Course | Algebra 2 | Honors Algebra 2 | Honors Algebra 2 | Algebra 2 | Algebra 2 |
| Year in School | 11th grade | 10th grade | 10th grade | 10th grade | 11th grade |
| Career Interest | computer science | child psychology | business | music business | industrial design |
| Confidence Score | low | very low | average | very high | very high |
| Attitude Score | average | high | average | very high | high |
| Usefulness Score | average | low | low | high | very high |
| Anxiety | very low [a] | very low [a] | low [a] | high [b] | high [b] |
| Overall Score | very low | low | very low | high | very high |

Note: Scores for Susie and Hilda are given relative to the Honors Algebra 2 students. Scores for Teagan, Yuliana, and Magnolia are given with respect to all Algebra 2 students.

a A low anxiety score indicates high anxiety.

b A high anxiety score indicates low anxiety

**Mastery Experiences**

The Algebra 2 unit that was the focus of this study included a variety of mastery experiences and remain the most influential sources of self-efficacy (Bandura, 1997). Quick checks, online homework, a mid-unit quiz, and an end-of-unit summative test comprised the list of mastery experiences intended to provide the students with evidence that they could successfully learn the mathematics in this unit. There was no mid-unit quiz given in the regular level classes, however, some of the regular level students discussed the possibility of having such a quiz.

Homework was assigned daily in an online platform associated with the textbook. Homework was graded and was a small percentage of the students' course grade. In general, students used homework to help them learn new material. Yuliana did homework assignments the nights they were assigned and felt as though they included enough problems to get sufficient practice on a new topic. She and Teagan used their class notes when they were stuck on a problem, and if they still could not resolve the problem, they sought outside help from their teacher. Teagan and Hilda used the scores they earned on homework assignments to assess their understanding of new material. When the score was high without much outside help, they felt good about their understanding. Otherwise, low homework scores or assignments that required asking the teacher an excessive number of questions caused their confidence to wane. Susie preferred to save the homework and use it as a study tool in preparation for larger assessments. Though the students valued the homework for different reasons, they all agreed it was valuable for their confidence in mathematics.

There were aspects of homework that students believed could be improved. Magnolia and Susie both mentioned the time from initial exposure to material until the homework due date felt too fast for them at times. Susie suggested the teacher require half of the homework to be turned in the next class period and the other half due by the summative test. She believed this would work because students would likely be able to do some of the work, even if they needed time for the rest of the material to be absorbed. Magnolia concurred that a more flexible due date would help increase the time for mastery before having a graded assessment, even though homework grades were low stakes assessments. Susie's suggestion also allowed her to continue using homework as test review because she could finish all the assignments while studying for a quiz or test.

Yuliana also liked to do homework problems in preparation for a larger assessment. Rather than saving homework problems for this purpose, Yuliana liked to search her textbook for similar problems to ones she had completed for homework because she felt good about the breadth of material the homework problems covered, though doing these on her own was challenging and left her wondering if she did them correctly. She suggested it would be better for the teacher to give problems similar to the homework to be completed in class with the teacher there to help if needed and to confirm correct solutions.

Teagan agreed with this suggestion when she compared homework in Geometry with homework in Algebra 2. When left to check their own solutions in the back of the book, Teagan suggested that students rarely had time for this step and therefore were unable to check their understanding until they took a larger assessment. The instantaneous feedback provided by the online homework in Algebra 2 helped Teagan to

gauge her understanding early and gave her an opportunity to gain confidence. She even suggested another online homework platform that gave example problems with instantaneous feedback. The student perceived benefits and hindrances that homework provided to their confidence in mathematics are summarized in Table 6.

**Table 6**

*Students' Perceived Benefits and Limitations of Homework to Confidence*

| Mastery Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Homework | Instantaneous feedback of online homework<br>Flexible due dates balancing accountability with time to absorb new material<br>Opportunity to practice many problems representing ways students should apply their learning<br>Access to notes, examples, or teacher outside of class for help when stuck | Textbook problems with no feedback<br>Graded homework that is due the next day<br>Access limitations for online homework after the due date |

"Quick check" can be described as short, three question assessments given at the beginning of the class period. Quick checks were ungraded, formative assessments designed for the students and teacher to see how well they understood material learned the previous class period. Students described different ways quick checks impacted their confidence. Susie and Yuliana appreciated the opportunity quick checks provided for them to assess their understanding of new material. Susie saved homework assignments for test review and therefore used quick checks as the first opportunity to assess her understanding while the other four students completed graded homework problems

before taking quick checks. Susie, Magnolia, and Teagan believed the quick checks helped them to feel more confident on future assessments because they were exposed to the types of questions that might be on the larger assessments. It helped them focus their practice and feel more prepared.

Though quick checks helped students feel more confident on future assessments, there were mixed feeling about confidence on the quick checks. Susie, for example, did not feel confident with the material before taking a quick check. She was able to do more problems correctly than anticipated so she began to feel as though she could master the material as a result of the quick check. Hilda and Yuliana did not feel confident about quick checks because they were given soon after learning new material. Hilda said even though she may have known the material for the quick check just as well as she did for the test, not having time to establish a comfort level with the new material made her less confident for the quick checks. Yuliana was not comfortable having her teacher assess her work so soon after learning the material. She did not mind doing the work but was not yet confident sharing it with her teacher.

There was a consensus that quick checks should not be graded. Susie, Hilda, and Magnolia said if they were graded, they would be more stressful. The opportunity to make mistakes, learn from them, and not have her grade negatively impacted improved Hilda's confidence. She was comfortable with some uncertainty on the quick checks only because she would not be penalized for mistakes. Hilda and Magnolia both admitted that if quick checks were given all year, they may become commonplace and lose their effectiveness if they were not graded. They had other suggestions, however, to fix this problem besides grading quick checks.

To motivate students to do well on regularly administered quick checks, Magnolia suggested they be graded occasionally. She clarified that this was only appropriate when the material on the quick check was review from a previous unit or previous course. Quick checks on new material should not be graded. Magnolia, who was in the regular Algebra 2 class, described another alternative. She described quick checks as being quiz-like in nature but without the pressure of a grade. Therefore, she suggested a unit have daily, ungraded quick checks so students can grow comfortable with the material. Then students would be prepared for a graded assessment and teachers would have a summative assessment of the material to that point. The student perceived benefits and hindrances homework provided to their confidence in mathematics are summarized in Table 7.

**Table 7**

*Students' Perceived Benefits and Limitations of Quick Checks to Confidence*

| Mastery Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Quick Check | Frequent opportunities for students to gauge their understanding of new material | Occur too soon after exposure to new material for students to be confident |
| | Exposure to questions similar to those students may see on future assessments | Graded quick checks would increase anxiety and negatively impact confidence |
| | Improved confidence with successes on quick checks and opportunity to learn from mistakes | |

A mid-unit quiz was only given in the honors course, however, students enrolled in the regular level course also mentioned the idea of having a mid-unit quiz. Susie and

Hilda were the only two students to take a mid-unit quiz during this study and they both described a lack of confidence and high anxiety while taking the quiz. However, when they discussed the results in the post-interview, they both admitted they performed reasonably well. Thus, there was no reason for anxiety about their performance.

Magnolia did not take a mid-unit quiz and mentioned that she was pleased by this situation because performing poorly on a quiz can lower students' confidence for the test when they are next assessed on the material. If a teacher felt a mid-unit quiz was a necessary assessment, Magnolia suggested the use of ungraded quick checks to help students monitor their progress in combination with a mid-unit quiz. The teacher would still be able to assess the students' mid-unit, and the students would have ample formative feedback to feel prepared for a graded assessment at that point in time.

Teagan also did not take a mid-unit quiz but lamented her experience taking quizzes in Geometry class the previous year. She noted that without feedback on homework from the textbook, periodic quizzes were here first opportunity to assess her understanding and she found this situation to be problematic. Table 8 includes a summary of the students' perceptions of the benefits and hinderances of quizzes to their confidence.

**Table 8**

*Students' Perceived Benefits and Limitations of Quizzes to Confidence*

| Mastery Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Quiz | Ample opportunities for formative assessment or low-stakes, graded assessments before a quiz may bolster confidence on a quiz | The graded, summative nature of a quiz can raise anxiety and lower confidence regardless of a students' understanding of the material<br>Without any opportunity to gauge understanding prior to taking a quiz, students lack confidence in their preparation for the quiz |

A summative test was given at the end of the unit in both the honors and regular level Algebra 2 courses. Test grades accounted for at least 50% of the course grade in both classes and were therefore high-stakes assessments. In this study, students spoke about their confidence on the test as well as the impact tests have on their overall confidence in mathematics.

Hilda and Magnolia both explained that the high-stakes nature of a test automatically made them feel nervous and less confident than other assessments. These feelings were independent of their understanding of the material and preparation for the test. Once Magnolia worked past the initial nerves, her confidence grew throughout the test. She remained calm when stuck on a problem and her ability to figure out next steps bolstered her confidence throughout the test. Hilda described her feelings before a test as preparing "for the worst," (Hilda, Interview, 12/17/21) even though she had performed well on test review. Unlike Magnolia, her confidence did not improve while taking the

test or even after the test when she learned she scored well. Susie, on the other hand, felt much more confident on the unit test than on any other assessment. She was confident because by the time she took the test, she had completed sufficient practice, asked her teacher any necessary questions, and had time to absorb and truly understand the material.

For Teagan, her experience with practice influenced her confidence on the test as did her overall standing in the course. If she completed practice with instantaneous feedback, she could figure out the answers without seeking too much help from her teacher. This led to greater confidence while testing. If she did not have feedback on her practice or if she had to ask her teacher for help on many problems, her confidence was low. The potential impact of a test on her course grade also influenced how much pressure she felt to perform well on the test. If her grade could not be raised by the test grade, she felt more confident because she knew the test grade would not affect her grade substantially.

Grades were important to the students in this study and were referenced often by Hilda and Susie. Magnolia and Susie cared about grades but when they discussed their confidence, they referred to sufficient preparation and their comfort level with the material. Hilda, on the other hand, was clear that her confidence fluctuated with her performance on major assessments, namely tests. A high-test score raised her confidence and a subpar score brought down her confidence level. Students' perceived benefits and hindrances of tests to confidence are summarized in Table 9.

**Table 9**

*Students' Perceived Benefits and Limitations of Tests to Confidence*

| Mastery Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Test | Sufficient time and interaction with the material on a test can help students feel more confident regardless of actual performance<br>Prior success with the material from multiple classroom activities can improve confidence on a test | The high stakes nature of tests causes students to be nervous and can lower their confidence<br>Prior mathematics, even on unrelated material, setbacks can influence students' confidence while testing. |

**Vicarious Experiences**

To provide students with vicarious experiences (Bandura, 1997) to gauge their relative level of ability, small and large group activities were incorporated into this unit. Such activities included the discovery exercise on polynomials (see Appendix E), the polynomial division tic-tac-toe game (see Appendix F) in the regular level course, and test review game in the honors level course.

The discovery exercise on polynomials was designed as a vicarious experience allowing students to work with their peers. Susie, Hilda, and Yuliana believed this exercise was beneficial to their confidence. For Susie and Yuliana, it provided a different way to learn than they experienced with other lessons and learning in this way helped to reinforce their confidence. Yuliana also appreciated the opportunity to work and then check in with her teacher. She never mentioned working with a peer, so the influence on her confidence was likely social persuasion by way of feedback from her teacher. Hilda's

confidence was boosted because she was able to work with a partner and through their collaboration, she felt the exercise was straightforward.

Magnolia and Teagan did not believe the discovery exercise helped their confidence though their reasons varied. They both cited the lack of desired feedback from the teacher. Magnolia felt as though she was having to teach herself new material. The experience was reminiscent of the Spring of 2020 when she attended school virtually as a result of the COVID-19 pandemic. Without confirmation of success or redirection from a teacher, Teagan did not realize what she did not understand until her first graded assessment. Lists of student perceived benefits and hindrances of the discovery exercises are given in Table 10.

**Table 10**

*Students' Perceived Benefits and Limitations of Polynomials Discovery Exercise to Confidence*

| Vicarious Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Discovery Exercise on Polynomials | Working with peers to discover mathematics and make connections can help to build confidence in their understanding. | The high stakes nature of tests causes students to be nervous and can lower their confidence<br>Prior mathematics setbacks, even on unrelated material, can influence students' confidence while testing. |

The tic-tac-toe practice exercise for long and synthetic division (see Appendix F) was a vicarious experience designed to help the regular level Algebra 2 students succeed in working with their peers before having to use the new skill alone on the homework. Only Magnolia and Teagan commented on the tic-tac-toe activity. Magnolia appreciated

the opportunity to practice what she learned, which increased her confidence. However, she did not mention working with her classmates. Teagan did not feel the exercise helped her confidence because she had been absent and was not secure in her understanding. She wanted to try the problems for homework and ask her teacher questions before having to work with her peers. A summary of student perceived benefits and limitations of the tic-tac-toe game to confidence is given in Table 11.

**Table 11**

*Students' Perceived Benefits and Limitations of Tic-tac-toe Division Exercise to Confidence*

| Vicarious Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Tic-tac-toe division practice | The opportunity to practice new material in a classroom setting before attempting it alone supports confidence in the material. | Some students are intimidated by having to work unfamiliar mathematics with their peers. |

In the honors sections of Algebra 2, a test review game was designed to offer the students a vicarious experience to gauge their preparedness for the test and as a result, positively influence their confidence on the test. Susie and Hilda had positive experiences with the test review but for different reasons. Susie felt that exposure to types of problems she might be expected to solve on the test was helpful for her confidence. Hilda benefited from the vicarious experience as intended. During the review game, she realized that she remembered concepts from early in the unit more readily than her peers. Therefore, she was confident in her preparedness for the test. Hindrances and benefits of the test review are given in Table 12.

**Table 12**

*Students' Perceived Benefits and Limitations of Tests Review Activity to Confidence*

| Vicarious Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Test Review | Practicing problems similar to what students might expect on a major assessment helps them to build confidence for the assessment.<br>Reviewing for a test in a social setting can help students to gauge their preparedness and know how what they need to do to be ready for the test. | None were noted |

**Social Persuasion**

Whole class, large group, and small group activities were included in this unit so students could receive encouraging feedback from others. Bandura (1997) referred to this source of self-efficacy as social persuasion. The participants in this study referred to instances where feedback from teachers or peers influenced their confidence.

Students discussed the various ways new material was presented in class and their perceptions of the influence each of these had on their confidence. Yuliana and Teagan strongly emphasized the importance of teachers providing guided notes on new material. They connected their feelings of confidence about learned material to the teacher's ability to explain material and students' ability to ask questions and receive feedback on their understanding. For this reason, Teagan did not find value in learning through discovery. She believed her retention of the material would be improved by direct instruction from

her teacher. She and Yuliana also did not like learning from videos. Whether videos were used in a flipped classroom or for virtual learning, they felt strongly that it was important to hear their teacher explain the material in person. Magnolia, on the other hand, did not mind learning from a video. She believed that like in-person instruction, the teacher would provide the necessary information for her to work problems on her own. She also liked that she could refer to videos if she needed to review. Students believed that instruction and feedback from the teacher were important for helping them feel confident in their understanding.

Students also discussed the impact of in class practice on their confidence. Yuliana preferred in class practice to practicing problems at home because the teacher was available for questions. Similarly, Teagan appreciated when her teacher would go over the solutions with the class immediately after a quick check. It was helpful for her to get feedback from her teacher to help her fill in any gaps discovered by her performance on the quick check. Magnolia, on the other hand, described times when she was struggling with the mathematics and lacked confidence in her ability to engage in class. She worried about having to answer a question for fear of embarrassed by answering incorrectly. Magnolia described a fear of negative feedback from social persuasion.

Teagan explained that social interactions with peers in math class could be helpful, but she believed it depends on who one sits beside in class. Seeking help from her teacher and finding other students struggling with the same questions helped Teagan feel she was not alone in her struggles. This was not always the case for Teagan, however. When she transitioned to Hillside School, she felt that there was no one in her class with the same mathematics background as her and this left her feeling as if she was

behind her peers with no one to struggle beside her. Magnolia had a similar experience when she transitioned to Hillside School. When she moved to a German middle school, her teacher helped her and her classmates by repeating the mathematics in both English and German. When she moved to Hillside, she did not experience the same support as the only student to transition to learning mathematics in English. The lack of peers experiencing the same difficulties made her feel isolated in her struggles. In class social interactions with teachers and peers were commonly referenced and important to the students' level of confidence in mathematics.

Students also referred to the importance of seeking help from their teacher outside of class time. Teagan would always visit her teacher outside of class before submitting her last attempt on homework problems because earning a 100% score on homework was important for her confidence. If achieving a 100% required too many questions to the teacher, however, the act of getting help was detrimental to her confidence in her ability to do the work on her own. Teagan also expressed her frustration with teachers who answer student questions with another question. She felt strongly that if she knew the answer, she would not be seeking help in the first place. She said she needed teacher support in the form of helpful answers to feel confident in her understanding. Teagan had perhaps the most devastating blow to her confidence when her Geometry teacher, who believed she was misplaced, told her she would be moved back to Algebra I. She took this abrupt pronouncement with no discussion as a lack of confidence in her and her self-confidence was severely damaged in the process. Unlike Teagan, who shared both positive and negative influences on her confidence, Yuliana and Susie described positive experiences when seeking help from teachers outside of class. Yuliana made a habit of

visiting her teacher any time she needed help with her homework. Susie described visiting her teacher the morning before the summative test to clarify concepts with her. She stated that this encouraging feedback helped her feel more confident when taking the test.

For test review in the regular sections of Algebra 2, the teacher outlined review strategies and showed students where to find additional practice and accompanying solutions in their online resources. Yuliana and Magnolia both indicated that this strategy helped them prepare well for the test. Because Ms. Albert suggested the problems, they felt confident they were practicing the right types of problems. They practiced until they believed they were well prepared to successfully complete the test. While practicing, Magnolia developed an internal feedback dialogue, encouraging herself to persist when stuck.

The girls in this study had much to say about the way social interactions with peers and teachers both in and out of the classroom influenced their confidence in mathematics. Through examples of both positive and negative experiences, they described the importance of positive social interactions to their confidence. These influences are summarized in Table 13.

**Table 13**

*Students' Perceived Benefits and Limitations of Social Interactions to Confidence*

| Social Persuasion | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Teacher Interactions | Learning material from explicit in-class instruction fosters student confidence in their learning.<br>Ability to ask teachers questions in person and receive immediate feedback supports student confidence.<br>Encouraging feedback from a teacher supports student confidence.<br>Teachers' inside knowledge of the assessments and the mathematics leads students to value their feedback for the insight it provides about what they need to know. | Leaving questions open or unanswered for exploration or discovery leaves students wondering and fosters self-doubt.<br>Teacher doubt may lead to self-doubt.<br>The need to ask teachers too many questions may cause students to believe they require help to be successful and thus negatively impact their confidence. |
| Peer Interactions | Peer feedback can support confidence through shared experience. | Fear of embarrassment or feelings of inferiority can make peer feedback negatively impact students' confidence. |

**Physiological, Emotional, and Other Influences**

When students discussed their confidence on mathematics assessments, they often referred to the state of their body or their emotions which Bandura (1997) claimed can influence how individuals assess their capabilities. Students also cited other factors outside of the mathematics classroom which impacted their confidence in mathematics.

Susie, Yuliana, Magnolia, and Hilda all discussed their emotional states and the resulting impact on their confidence though each of them talked about very different

influences on their emotions. Susie, for example, discussed her tendency to overthink and panic. She was filled with self-doubt unless she was sure she did everything within her power to succeed. She discussed the fragility of her self-confidence and how a small amount of self-doubt could diminish her confidence and exacerbate her panic. Susie also described her tendency to lose focus in class and how, as a result, she lacked confidence in her understanding because she knew she had missed some of the material. Yuliana and Magnolia, on the other hand, described the importance of a positive mindset to high confidence in mathematics. Yuliana believed in the importance of having determination and motivation as a student to want to understand to succeed.

Similarly, Magnolia used positive self-talk to motivate herself. She reminded herself of the importance of mathematics and how the subject builds and culminates into applications in the real world. Teagan also had a helpful perspective on the cumulative nature of mathematics, using the understanding that new topics build upon old ones to help her figure out what to do when she was stuck on challenging problems. Hilda mentioned the anticipation of an upcoming school holiday during the unit. This realization lightened her mood, lessened her stress level, and helped her feel more confident.

Students discussed stressors on their time outside of the mathematics classroom which influenced their confidence in mathematics class. Susie, Yuliana, and Magnolia all emphasized the importance of having sufficient time to practice and digest new mathematics, so outside influences on their time had a negative impact on the development of their confidence with the mathematics. Susie mentioned a part time job which left her insufficient time to study and complete the amount of practice necessary to

make her feel confident on assessments. Hilda cited homework from other classes and extracurricular activities which took much of her time and left her insufficient time to prepare for mathematics assessments or get adequate sleep before the assessments. Magnolia stressed the importance of having enough time to master material not only for an assessment but for long term retention so she could use it in the future. She also lamented the fact that often assignments piled up and many things ended up being due at the same time. And finally, Teagan's multiple absences from class during the unit hurt her confidence, though she experienced the greatest success on some of the material she missed which she attributed to the flexibility and helpfulness of her teacher. A summary of the benefits and limitations of these physiological, emotional, and other influences are compiled in Table 14 below.

**Table 14**

*Students' Perceived Benefits and Limitations of Other Factors to Confidence*

| Other Factor | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Emotional States | Having a positive mindset helps students feel more confident.<br>Having determination and motivation as a student to succeed helps support confidence.<br>Positive self-talk can convince a student they can succeed.<br>A positive view of the cumulative nature of mathematics can help a student rely on their experience for future success. | A tendency to panic can lower student confidence.<br>Even the smallest amount of self-doubt can raise anxiety and have a negative impact on student confidence level. |
| Physiological States | Students may associate adequate sleep with a higher likelihood of success and therefore feel more confident if they are well rested. | A lack of focus can cause students to worry they missed important information and thus lowering confidence.<br>A lack of sleep can lower confidence because students may worry about their ability to perform their best on insufficient rest. |
| Outside Factors | When students are excited about events outside of the classroom such as holidays, school breaks, or extracurricular activities, they may be less inclined to worry and feel more comfortable and confident. | During busy times during the school year, the workload can be heavy in multiple classes which makes it hard for students to feel confident they spent sufficient time on any of the material. |

## Chapter Summary

In this chapter, I detailed the cases of Teagan, Susie, Hilda, Yuliana, and Magnolia using results from survey data, interviews, and assessment reflections. A rich description of each participant was developed including their mathematics background and mathematics attitude survey responses (see Appendix A). Their assessment reflections and interview responses provided a more detailed description of their survey responses. This analysis revealed additional insight about their attitude towards mathematics, perception of the usefulness of mathematics, mathematics anxiety, and confidence in mathematics. Additional commentary was provided for the students' perceived influences on their confidence and what they believed helped improve their confidence in mathematics. The within case analysis was followed by a cross case analysis of the five cases. Differences between the girls' perceptions were highlighted and connections were made across the five participants. In Chapter V, I will provide a summary, discussion, and implications of these results and recommendations for future research.

# Chapter V: DISCUSSION AND IMPLICATIONS

## Introduction

Women are considerably less likely than men to pursue a degree or a career in the mathematically intensive STEM fields (Buck et al., 2020; Cheryan et al., 2017; Hill et al., 2010; Leslie et al., 1998; Noonan, 2017). Research has focused on various points along STEM pathways (Buck et al., 2020) and found factors contributing to the removal of women emerge as early as adolescence (Geary et al., 2019; Leslie et al., 1998). Early mathematics education gender studies focused on achievement disparities (e.g., Aiken, 1971; Parsley et al., 1964), but the research has shifted in recent years to large-scale assessment studies focused on differences in affective factors (Fennema & Sherman, 1977; Leder, 2019; Sherman & Fennema, 1977). Some researchers have questioned the validity of gender comparison studies pulling from large-scale examination data (Leder, 2019; Leder & Forgasz, 2018). Although boys' large-scale achievement scores have been higher than those of girls, girls earn higher grades than boys in school (O'Dea et al., 2018; Reardon et al., 2019; Voyer & Voyer, 2014). The classroom is a setting that privileges girls. As such, classroom experiences present research opportunities to look deeply at what happens in school mathematics in a way that resonates with girls and affects their decisions not to dismiss mathematics as a future career possibility.

The purpose of this study was to ask girls what connections they perceive between classroom activities and assessments and their confidence in mathematics. Included in this final chapter is a restatement of the research problem, a review of the methodology employed in this study, and a summary of the study results. These synopses will be followed by a discussion of the study results to include connections to prior

research, theoretical implications, suggestions for practice, and considerations for future research.

## The Research Problem

Gender, the socially constructed characteristics of females and males, is a differentiating factor in the STEM pipeline from the middle grades to the workplace privileging one group and leaking others from the stream (Bergeron & Gordon, 2017; Cheryan et al., 2017). Though large-scale assessment studies once indicated boys performed better in mathematics than girls (e.g., Aiken, 1971; Parsley et al., 1964), this achievement gap disappeared when controlled for prior experience (Fennema & Sherman, 1977). In fact, girls earn grades equivalent to or higher than boys in the mathematics classroom (Voyer & Voyer, 2014).

In other words, girls do not fall behind in mathematical performance because of ability or capability but rather because of affective factors such as self-efficacy and confidence (Zander et al., 2020). This gap is especially pronounced among high achievers (Zhou et al., 2017). Gender differences in both ability and affective factors were explored in many studies using large-scale assessment data, yet the literature lacks exploration of gendered influence of assessments on self-efficacy and confidence within the classroom, a place where girls are known to perform well. A multi-case study was designed to explore connections between classroom activities, including assessments, and girls' confidence in mathematics. The methodology for this study will be described in the next section.

## Review of Methodology

For this study, an exploratory multiple case study (Yin, 2009) was used to capture the voices of five girls enrolled in Algebra 2 as they reflected on their confidence in mathematics as it related to the classroom activities and assessments in which they engaged. Teagan, Susie, Hilda, Yuliana, and Magnolia (pseudonyms) were the students on which the study focused. Multiple data sources were collected including: (a) a case selection survey on confidence, attitude, anxiety and usefulness in mathematics, (b) assessment reflections collected after each written assessment in the unit capturing a confidence score, (c) an accompanying explanation for the score, and pre- and post-interviews with each case study participant. The third component also provided a deeper understanding of the characterization of the students and further clarified their written reflection and survey responses.

These data supported the development of rich descriptions of the five participants' perceptions of the connections between the activities and assessments they encountered in mathematics class and their level of confidence in mathematics. Bandura's (1997) four sources of self-efficacy served as a lens through which themes were developed, connections were made between the cases, and discrepancies were identified in cross-case analysis. These findings are summarized in the following section of this report.

## Summary of Results

Chapter IV of this dissertation presented the cases of Teagan, Susie, Hilda, Yuliana, and Magnolia. Each case was analyzed separately and then a cross-case analysis was presented across the five cases. Bandura's (1997) four sources of self-efficacy framed these results: mastery experiences, vicarious experiences, social persuasion, and

physiological and emotional factors. The overall findings for each of these four sources and other important results will be presented briefly in the next sections.

**Mastery Experiences**

The first mastery experience analyzed across the five cases was daily homework. Students perceived homework's utility in different ways. Yuliana believed homework was a good way to practice new mathematics. Teagan and Hilda viewed homework as a tool for self-assessment of their understanding of mathematics concepts. Susie preferred to use homework as review practice before an assessment. These four students agreed, however, daily homework was helpful for their confidence.

The discussion of homework included suggestions for improvement. Magnolia and Susie, for example, commented on needing more time to process new information before homework was due. The suggested modifications and flexibility of due dates to allow necessary time for absorption of new ideas. Yuliana and Teagan also pointed out that homework with instantaneous feedback was the most helpful type of practice. A summary of the benefits and limitations of homework to confidence is included in Table 6.

Quick Checks were the second mastery experience to be analyzed. The discussion included commentary on the usefulness of quick checks for confidence on future assessments as well as students' confidence on the quick checks themselves. Susie and Yuliana appreciated that quick checks helped them to assess their understanding of new material. However, Susie, Hilda, and Yuliana did not often feel confident while taking the quick checks because the students believed these assessments were given too soon after learning the material and the students were not yet confident. Susie, Magnolia, and

Teagan found value in taking the quick checks for future assessments because they provided exposure to the types of questions they might encounter on a larger assessment. The students agreed that quick checks should not be graded because they would become more stressful and less effective. Students offered suggestions that might make quick checks more effective if given long term. Magnolia said perhaps quick checks on review material could be graded, but quick checks on new material should not be graded. She believed quick checks should only be used for self-assessment in preparation for a graded mid-unit quiz. A summary of the benefits and hindrances of quick checks to confidence is included in Table 7.

The third mastery experience discussed was a mid-unit quiz given only in the Honors Algebra 2 course. Susie and Hilda took a mid-unit quiz, and both described high anxiety and a lack of confidence on the quiz. Magnolia and Teagan both referred to past quiz experiences and described stress and negative feelings as well. The high stakes impact of quizzes on the course grade increased their level of stress and self-doubt even when, as was the case with Susie and Hilda, the students perform well. Magnolia emphasized the usefulness of quick checks for smaller, low stakes assessments. She believed quick checks helped students know what to expect and feel more prepared and less anxious for quizzes. Table 8 includes a summary of the students' perceptions of the benefits and limitations of quizzes to their confidence.

The final mastery experience to be analyzed was the summative unit test. As with quizzes, several students mentioned the high-stakes impact of test grades on their course grade as a catalyst for anxiety and lack of confidence. The students differed broadly, however, on what additional factors influenced their confidence on the summative test.

Hilda prepared for the worst when taking a test and did not feel confident in her understanding until she received the graded assessment with a grade she deemed satisfactory. Magnolia, on the other hand, overcame initial nerves and her confidence built as she was taking the test, bolstered by her ability to work through challenging problems successfully. Susie claimed her confidence was highest on the end of unit test because by the end of the unit she was comfortable with the amount of practice she had completed and felt she had done all she could do to prepare. Teagan's confidence level on the summative test was influenced by the quality of practice she had completed. If she felt good about her work leading up to the test, she felt confident during the test. A summary of the students' perceived benefits and limitations of tests to confidence are included in Table 9.

**Vicarious Experiences**

The first vicarious experience analyzed was a discovery exercise on polynomials. Three students indicated the activity boosted their confidence. Susie and Yuliana appreciated the opportunity to learn the material in a different way and Hilda benefited from the collaboration with a peer. Yuliana also liked being able to work with her peers and still have the teacher there to confirm they were on the right track. The other two students did not indicate the discovery exercise helped their confidence. Magnolia and Teagan both expressed discomfort with the unknown without a teacher ensuring they were practicing the mathematics correctly. Table 10 gives a summary of the benefits and limitations of this vicarious experience to student confidence in mathematics.

The second vicarious experience to be analyzed was a tic-tac-toe game to practice polynomial division. Only two students completed this activity. Magnolia felt this

exercise benefited her confidence because she had an opportunity to practice what she had learned immediately. Teagan, however, did not feel this assignment helped her confidence because she was insecure with her knowledge of the concepts and wished she had been able to practice and answer questions before having to work with her peers. These results are summarized in Table 11.

The final vicarious experience to be analyzed was a test review game designed for students to gauge their preparedness for the test and to help them with what they needed to study or practice most. This was a positive experience for both Susie and Hilda. Susie's confidence was boosted because she gained exposure to the types of problems she might see on the test. Hilda, on the other hand, benefited from the vicarious experience of realizing she remembered more of the material than most of her peers, causing her to feel confident about her preparedness for the test. These results are included in Table 12.

**Social Persuasion**

Throughout the data collected for this study, there are descriptions of social interactions providing insight into the factors that aided or impeded case study participants' confidence levels in mathematics. Though teacher feedback and peer feedback were both references, the majority of the data referred to teacher feedback and the resulting influence on confidence.

Students commonly referred to things the teacher did to help their confidence. For Yuliana and Teagan, the teacher providing guided notes for a new lesson helped them feel confident about what they were learning. Magnolia said she did not mind if the teacher presented the material via video as long as the teacher delivered the material—therefore ensuring its accuracy. In terms of practice, students preferred when the teacher

was in the room to answer questions or when the teacher went over assignments right after they were completed to ensure the students had done them correctly. Yuliana and Magnolia reported their confidence was boosted when preparing for a test, if they were able to practice review problems recommended by their teacher. Several students mentioned seeing their teacher outside of class for help and reported the positive impact of these meetings on their confidence level.

There were also instances when teacher moves had a negative impact on the students' confidence. Teagan and Yuliana believed strongly that learning material on video, even if the video was created by their teacher, was not helpful to their confidence. Teagan also expressed frustration with teachers who answer students' questions by asking them a question. The students perceived the lack of teacher assistance or guidance had a negative impact on their confidence.

Though students mostly discussed social persuasion with respect to the teacher, there were a few references to peer social interactions and feedback. Teagan believed social interactions with peers in mathematics class could be beneficial to her confidence, but it depended on the peer with whom she was interacting. Magnolia and Teagan both described negative social situations with peers. Magnolia worried about negative feedback from her peers when she was unable to answer a question in class. She and Magnolia were also both socially uncomfortable when they come to Hillside because they believed they were struggling alone and there was no one to commiserate with their experience. A summary of the benefits and limitations of social persuasion experiences to confidence are included in Table 13.

**Other factors**

The fourth source of self-efficacy in Bandura's (1997) framework is physiological and emotional states. In the data collected for this survey, the students referred to physiological and emotional influences on their confidence but there were also some additional influences from outside of the classroom experience. Therefore, I grouped the fourth source of self-efficacy with these other influences and am calling them other factors.

Students referenced how their emotional state, at particular moments, influenced their confidence in mathematics. Susie referenced emotional tendencies such as overthinking, panic, and self-doubt and explained how small doses of these inhibitors could have a large impact on her fragile confidence. Yuliana, Magnolia, and Teagan referred to positive emotional states having a direct relationship with their confidence. They mentioned a positive mindset, determination and motivation, positive self-talk, and a positive view of the nature of mathematics.

The physiological state of the students and the corresponding connection with their confidence was rarely discussed. However, Hilda mentioned the importance of sleep for her confidence many times. She cited lack of sleep as the reason her confidence marks were low for some assessments. She believed getting enough sleep was essential to success and when she did not achieve the appropriate amount of sleep the night before an assessment, her confidence suffered. The only other allusion to physiological states was Susie's mention of her tendency to lose focus in class. This departure from attention to learning created doubt about how much information she absorbed in class.

Additional factors that affected the students' confidence were outside influences on their time such as work and other classes. Susie noted that her part time job took time she could have otherwise been practicing or studying mathematics. Because she was unable to devote the amount of her time to her studies, she perceived necessary for her success, her confidence was lowered. Hilda referred to similar stressors from homework in other classes and extracurricular activities, both taking away from time she believed she should have been studying mathematics.

The natural ebb and flow of the school calendar also brought some positive and negative influences on the students' confidence. Magnolia pointed out that the workload increased at busy times and made it hard to feel confident she had sufficient time to prepare for mathematics. Hilda also mentioned the upcoming Thanksgiving Holiday and how the excitement generated around the looming break from school allowed her to feel less anxious and more confident. A summary of the benefits and limitations of these other factors to confidence are given in Table 14.

The benefits and limitations of classroom experiences to student confidence were summarized in Tables 6 – 14 in Chapter IV. As an aide to the reader, those tables were combined to consolidate the benefits and limitations to confidence into one table. This summary of results can be found in Table 15 below.

**Table 15**

*Students' Perceived Benefits and Limitations of Classroom Experiences to Confidence*

| Classroom Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Homework (Mastery Experience) | Instantaneous feedback of online homework<br>Flexible due dates balance accountability with time to absorb new material<br>Opportunity to practice many problems representing ways students should apply their learning<br>Access to notes, examples, or teacher outside of class for help when stuck | Textbook problems with no feedback<br>Graded homework due the next day<br>Access limitations for online homework after the due date |
| Quick Check (Mastery Experience) | Frequent opportunities for students to gauge their understanding of new material<br>Exposure to questions similar to those students may see on future assessments<br>Improved confidence with successes on quick checks and opportunity to learn from mistakes | Occur too soon after exposure to new material for students to be confident<br>Graded quick checks would increase anxiety and negatively impact confidence |
| Quiz (Mastery Experience) | Ample opportunities for formative assessment or low-stakes, graded assessments before a quiz may bolster confidence on a quiz | The graded, summative nature of a quiz can raise anxiety and lower confidence regardless of a students' understanding of the material<br>Without any opportunity to gauge understanding prior to taking a quiz, students lack confidence in their preparation for the quiz |

(continued)

| Classroom Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Test (Mastery Experience) | Sufficient time and interaction with the material on a test can help students feel more confident regardless of actual performance<br>Prior success with the material from multiple classroom activities can improve confidence on a test | The high stakes nature of tests causes students to be nervous and can lower their confidence<br>Prior mathematics, even on unrelated material, setbacks can influence students' confidence while testing. |
| Discovery Exercise on Polynomials (Vicarious Experience) | Working with peers to discover mathematics and make connections can help to build confidence in their understanding. | The high stakes nature of tests causes students to be nervous and can lower their confidence<br>Prior mathematics setbacks, even on unrelated material, can influence students' confidence while testing. |
| Tic-tac-toe division practice (Vicarious Experience) | The opportunity to practice new material in a classroom setting before attempting it alone supports confidence in the material. | Some students are intimidated by having to work unfamiliar mathematics with their peers. |
| Test Review (Vicarious Experience) | Practicing problems similar to what students might expect on a major assessment helps them to build confidence for the assessment.<br>Reviewing for a test in a social setting can help students to gauge their preparedness and know how what they need to do to be ready for the test. | None were noted |

(continued)

| Classroom Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Teacher Interactions (Social Persuasion) | Learning material from explicit in-class instruction fosters student confidence in their learning.<br>Ability to ask teachers questions in person and receive immediate feedback supports student confidence.<br>Encouraging feedback from a teacher supports student confidence.<br>Teachers' inside knowledge of the assessments and the mathematics leads students to value their feedback for the insight it provides about what they need to know. | Leaving questions open or unanswered for exploration or discovery leaves students wondering and fosters self-doubt.<br>Teacher doubt may lead to self-doubt.<br>The need to ask teachers too many questions may cause students to believe they require help to be successful and thus negatively impact their confidence. |
| Peer Interactions (Social Persuasion) | Peer feedback can support confidence through shared experience. | Fear of embarrassment or feelings of inferiority can make peer feedback negatively impact students' confidence. |
| Emotional States (Other Factors) | Having a positive mindset helps students feel more confident.<br>Having determination and motivation as a student to succeed helps support confidence.<br>Positive self-talk can convince a student they can succeed.<br>A positive view of the cumulative nature of mathematics can help a student rely on their experience for future success. | A tendency to panic can lower student confidence.<br>Even the smallest amount of self-doubt can raise anxiety and have a negative impact on student confidence level. |

(continued)

| Classroom Experience | Benefits to Confidence | Limitations to Confidence |
|---|---|---|
| Physiological States (Other Factors) | Students may associate adequate sleep with a higher likelihood of success and therefore feel more confident if they are well rested. | A lack of focus can cause students to worry that they missed important information and thus lowering confidence.<br>A lack of sleep can lower confidence because students may worry about their ability to perform their best on insufficient rest. |
| Outside Factors (Other Factors) | When students are excited about events outside of the classroom such as holidays, school breaks, or extracurricular activities, they may be less inclined to worry and feel more comfortable and confident. | During busy times during the school year, the workload can be heavy in multiple classes which makes it hard for students to feel confident that they spent sufficient time on any of the material. |

## Discussion of the Results

The results of this study are significant in four ways. First, the results connect to prior research by providing evidence supporting the four sources of self-efficacy (Bandura, 1997) as influential to girls' confidence in mathematics by asking girls for their perceptions (Burton, 1995) from their individual way of knowing (Belenky et al., 1986), as outlined in the theoretical framework. Second, this study offers theoretical implications as to how Women's Ways of Knowing (Belenky et al., 1986) informs the four sources of self-efficacy (Bandura, 1997). Third, the results provide suggestions for practice for secondary mathematics teachers concerning selection, timing, and grading of classroom activities and assessments to support girls' confidence in mathematics. Finally,

questions and considerations for future research emerged from the results of this study. The final sections of this chapter include a discussion of each of these significant results. These results came from a particular study in the context described and therefore more research is necessary to extend beyond this context.

## Connections to Prior Research

The results of this study support the literature in three ways. First, the characterizations of the case study participants align with the categories for Women's Ways of Knowing as described by Belenky et al. (1896). Second, the results extend the use of Burton's (1995) feminist perspective of knowing in mathematics by asking the girls to describe their experience in mathematics class using interview questions aligned with the framework and yielding rich descriptions of the girls perceived connections with their confidence. Third, the research supports the four sources of self-efficacy as important contributors to girls' confidence in mathematics.

**Support for the utility of Women's Ways of Knowing as epistemological perspectives.** Chapter IV provided a thorough characterization of the five student participants in this study and their perceptions of the connections between classroom activities and confidence. Each participant described their perspective in ways that aligned with the categories for Women's Ways of Knowing (Belenky et al., 1986). These five epistemological categories include: silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge. In a position of silence, women adhere to the expectations of external authority insecure about using their own mind or voice. The received knowledge category describes women who believe they are capable of receiving knowledge from external authorities but not generating knowledge

themselves. Women in the subjective knowledge position view knowledge as personal, intuitive, and subjective. Procedural knowledge describes women who intentionally apply demonstrable procedures for acquiring knowledge. Finally, women in a constructed knowledge position value both subjective and objective ways of knowing and regard themselves as creators of knowledge. In this section, I will give evidence for the participants' alignment with these categories.

Teagan alluded to experiences that align with multiple ways of knowing. Women in a position of Silence believe blind obedience to authority is important (Belenky et al., 1986). Teagan described a scenario from her 9th grade year when her Geometry teacher decided she needed to repeat Algebra 1:

> I came in to ask [my teacher] a question about something on homework, but before I could talk, [my teacher] was just like, "oh, I saw that you can move." And it was just like, a lot happened that day. And then I had an advisor meeting. And instead of just talking with my advisor, I just started crying. (Teagan, Interview, 12/02/21)

Teagan did not feel she had a voice in the conversation and yielded to the authority of others. At the time, two years before the present study, Teagan appeared to be in a place of silence. Her reflections and responses to interview questions at the time of this study, however, placed her in a position of Received Knowledge. Women in such a position learn by listening to the words of others and have little confidence in their own ability to speak (Belenky et al., 1986). Teagan explained that she did not like it when she asked a teacher a question about mathematics, and they answered by posing a question back to her. She asked questions because she needed to know the answer. She also

needed to have immediate feedback to know if she understood the material. She was uncomfortable when asked to explore mathematics, she needed to practice what she was taught and receive feedback on the accuracy of her work.

Teagan appeared to be on the verge of moving into a place of Subjective Knowledge. According to Belenky et al. (1986), women with this perspective begin to listen to their inner source of strength. They do not necessarily share their ideas broadly but may begin to share them with trusted individuals. Teagan expressed a career interest in computing. When I asked if her interest in a career in computing would involve coding, she said, “I don't know because math, I don't want to do it and not be good at it” (Teagan, Interview, 12/01/21). She still had reservations about whether she could pursue her interest, but she was processing these ideas internally and sharing her thoughts with a few others. Therefore, Teagan is in a place of Received Knowledge, but may be moving towards Subjective Knowledge.

Based on her interview responses, Susie is in the category of Procedural Knowledge as a way of knowing mathematics. Women in this category do not trust intuition or feel they can look within themselves for answers. Instead, they believe they must dig deep to find the truth (Belenky et al., 1986). Susie expressed a lack of confidence throughout the unit of study citing a variety of reasons why she did not believe she knew the material. She said, "I don’t have a very strong mental game” (Susie, Interview, 12/13/21).

By the end of the unit, however, she said, “for the test, I was like, I’ve done the work, I’ve asked the questions, I’ve done the practice problems . . . I understand this. And so, I felt like I was more confident on all of that” (Susie, Interview, 12/13/21). She

believed she had to do all within her power to ensure her firm knowledge of the material before she was confident in her understanding. Belenky et al. (1986) said women in the procedural knowledge category do not need to know exactly what equations a teacher will ask but rather what kind of questions might be asked. Susie expressed such a desire when she said:

> I can go through the book. . .but I don't really know which ones I should be doing. So the review problems that you put on [the online class notebook] were super helpful to go through all of them just to know if I understood the concepts in general. (Susie, Interview, 12/13/21)

Susie did not need to know exactly what would be asked, but needed some guidance from the teacher about what she needed to know. Central to the position of procedural knowledge is understanding there are different ways to look at things (Belenky et al., 1986). Susie expressed this understanding when she said, "I felt really confident about it going into the test becaues I felt like there was a lot of new ways that we learned about the units other than just what was in the textbook" (Susie, Interview, 12/13/21). Susie not only understood there were different ways to look at the material, but felt more confident in her success as a result. The evidence points to Susie's position in the epistomological perspective of Procedural Knowledge.

Hilda also exhibited similar characteristics of the Procedural Knowledge perspective. Belenky et al. (1986) described two distinct forms of procedural knowledge, separate and connected knowledge. Separate knowledge is based on impersonal rules or standards; connected knowledge, or understanding, is based on relationship. Specifically, separate knowers are "suspicious of ideas that feel right" (Belenky et al., 1986, p. 104). It

was evident that Hilda aligned with this perspective when she said, “when I feel bad about a test, I usually end up doing good and when I feel good about a test, I don’t do as well” (Hilda, Interview, 11/22/21). Doubting is a key characteristic of separate knowledge and the description of Hilda’s case in Chapter IV is filled with examples of self-doubt. Therefore, Hilda was in a position of Procedural Knowledge, specifically separate knowledge.

Two themes emerging from my conversations with Yuliana helped me to situate her in a position of Received Knowledge (Belenky et al., 1986). First, Yuliana relied on her teacher to learn mathematics. She did not like to learn from videos, she wanted her teacher to explain steps and procedures so she could mimic them. Belenky et al. (1986) characterizes Received Knowledge as “listening to the voice of others” (p. 35). Second, Yuliana believed once she learned information from the teacher, she needed to practice until she was certain she could do similar problems on her own. She discussed her appreciation for the daily homework, “because the homework, it’s like 20 problems. You really get the hang of it” (Yuliana, Interview, 12/17/21). As a follow-up question, I asked about the quantity of problems she did to prepare for the summative unit test. She said, “yeah, like the zeros and everything… it was just a lot of practice” (Yuliana, Interview, 12/17/21).

Her absorption “in the business of acquiring and applying procedures for obtaining and communicating knowledge” (Belenky et al., 1986) led me to question whether Yuliana might have been moving towards a position of Procedural Knowledge. Like Susie, Yuliana aligned with the Procedural Knowledge notion that “the point was not to hit upon the exact questions the exam would contain, but rather to ask the *kind* of

questions the teacher asked" (Belenky et al., 1986) when she said, "it helps me to see different types of problems that could show on a test which helps me feel more confident" (Yuliana, Interview, 12/17/21). However, I concluded that although she was moving towards Procedural Knowledge, Yuliana was still in a position of Received Knowledge when she followed the previous comment by explaining when she sought help from her teacher. She said, "there's sometimes where it's a problem that I haven't really seen . . . something I haven't seen in my notes, because I really refer to my notes in my homework a lot to [see] similar problems" (Yuliana, Interview, 12/17/21). She was still very dependent on receiving knowledge from her teacher and therefore Yuliana was in the category of Received Knowledge.

Of the five student participants, Magnolia was the closest to being in a position of Constructed Knowledge (Belenky et al., 1986). In her interviews she spoke of using reasoning to figure out how polynomial division worked when she said, "trying to figure out how that works was a little bit complicated, but once I learned it, I really liked it" (Magnolia, Interview, 12/13/21). She also relied on her intuition. "There was one problem that I was a little bit confused about, but I had to think about it for a little while, like five minutes. And then I kind of just tried something" (Magnolia, Interview, 12/13/21). Yet, she still relied on her teacher to "highlight the things that are important" (Magnolia, Interview, 12/13/21).

In alignment with the category of Constructed Knowledge she had found, "a place for reason *and* intuition *and* the expertise of others" (Belenky et al., 1986). Another characteristic of Constructed Knowledge possessed by Magnolia was, she was articulate and reflective. It is evident when reading her interview responses, many of which are

included in Chapter IV, Magnolia was reflective of the learning process, giving thorough, well-reasoned responses to my questions. She said:

> I've always liked when units build on each other, or when all of the different things that we learned kind of culminate in something and you can apply everything that you've learned in one thing. And I feel like, that was what that idea was for this unit is kind of everything coming together. And it also brought in stuff that we had learned, like in chapter two or whatever, and so kind of being able to bring other things from this semester was nice. (Magnolia, Interview, 12/13/21)

Once again, Magnolia demostrated a characteristic of Constructed Knowledge here because she was able to "make connections that help tie together pockets of knowledge" and demonstrated an "excitement about learning and the power of the mind" (Belenky et al., 1986, pg. 140). These examples provide evidence that Magnolia is situated in a place of Constructed Knowledge.

The interview and reflection data collected from the five case participants in this study aligned each of them with one of the five epistemological perspectives for Women's Ways of Knowing (Belenky et al., 1986). A summary of each girl's way of knowing and a brief description of the category are included in Table 16. A girls' way of knowing may have theoretical implications towards her sources of self-efficacy, to be disucssed in the following section.

**Table 16**

*Summary of Participants' Ways of Knowing*

| Student Participant | Way of Knowing | Description of a Woman in this Way of Knowing |
|---|---|---|
| Teagan | Received Knowledge | Believes herself capable of receiving knowledge from external authorities but not generating knowledge herself |
| Susie | Procedural Knowledge | Intentionally applies objective procedures for acquiring knowledge |
| Hilda | Proecdural Knowledge | Intentionally applies objective procedures for acquiring knowledge |
| Yuliana | Received Knowledge | Believes herself capable of receiving knowledge from external authorities but not generating knowledge herself |
| Magnolia | Constructed Knowledge | Values both subjective and objective ways of knowing and regards herself as a creator of knowledge |

**Support for listening to the voices of girls and asking them questions from a feminist perspective.** Chapter III describes the use of Burton's (1995) recommendations for attending to a feminist perspective when inviting women to discuss mathematics. This framework was followed in response to calls to lift up the female voice (Boaler, 1997) and attend to feminist perspectives in each step of the research process (Fennema & Hart, 1994). As a result, five rich descriptions of girls' perceptions of connections between classroom activities and their confidence were captured and analyzed. The voices of the five case participants were uplifted and the theoretical and practical implications of the results will be described in the following sections.

Through their voices, these girls' expressed ideas contrary to accepted practices in the field of mathematics education. Chapter IV includes discussions during which the girls insisted they learned best by direct instruction from their teacher. Yuliana and Teagan preferred guided notes. Teagan and Magnolia did not like the discovery exercise (see Appendix E) because they felt as if they had to teach themselves the material. These perspectives do not align with the Effective Teaching Practices (NCTM, 2014) of implementing tasks to promote reasoning and problem solving or supporting productive struggle. Teagan also expressed frustration when her teacher asked her additional questions to help her figure out the answer to a question she had posed. Research says purposeful question posing is an effective teaching practice (NCTM, 2014) but Teagan did not see it that way. Although their perspectives are misaligned with the research, their perspectives make sense to them. Implications of this result for future research are discussed in a later section.

**Support for the four sources of self-efficacy as influential for girls' confidence in mathematics.** Bandura's (1997) four sources of self-efficacy served as both the analytical framework and a component of the theoretical framework for this study. By ensuring this study provided students with classroom activities and experiences to encounter all four sources of self-efficacy, the data collected contain rich descriptions of the connections the girls perceived between these activities and their confidence.

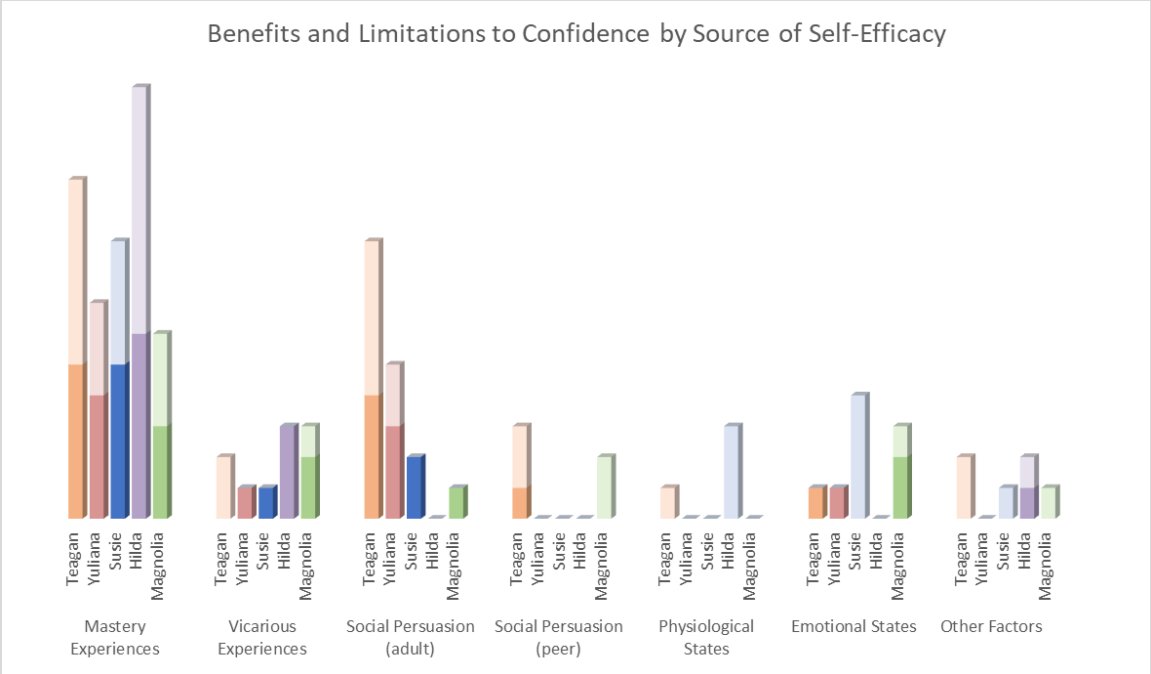
Bandura (1997) posited that mastery experiences are the most influential of the four sources of self-efficacy. Many later studies have confirmed this claim for school age students in STEM subjects (e.g., Britner & Pajares, 2006; Usher & Pajares, 2008; Zander et al., 2020). The data from the present study also align with this theory.

shows a tally of positive and negative influences of each of the four sources of self-efficacy reported by the student participants in this study. For all students, mastery experiences accounted for most comments about their confidence and there were a similar number of positive and negative influences for mastery experiences. Usher and Pajares (2008) also found that the strength and influence of the four sources of self-efficacy vary according to different circumstantial factors, one of which is gender. The data from this study align with this finding and positions a girls' way of knowing as a possible contextual factor that impacts the effects of the four sources on her confidence in mathematics.

In Figure 9, the number of positive and negative influences of each source of self-efficacy differs for each student. The two students who fall in the Received Knowledge category (Belenky, 1986), Teagan and Yuliana, seemed to be more heavily influenced by social persuasion than the other students. This aligns with the description of Received Knowledge as "listening to the voice of others" (Belenky et al., 1986, p. 35). Magnolia falls in the category of Constructed Knowledge (Belenky et al., 1986) and her reflections were the most balanced of all the student participants. This aligns with the description of Constructed Knowledge as a balanced integration of one's intuition and reason with the expertise of others. Theoretical implications of these connections will be discussed in the following section.

**Figure 9**

*Student Perceived Benefits and Limitations to Confidence by Source of Self-Efficacy*




## Theoretical Implications

The results of this study present at least two theoretically important implications. First, by approaching research on girls in mathematics from a feminist perspective a more detailed understanding of girls' confidence can be developed. Second, the strength and impact of Bandura's (1997) four sources of self-efficacy may have gendered effects informed by Women's Ways of Knowing (Belenky et al., 1986). This section contains a discussion of these implications.

**Investigating affective factors from a feminist perspective.** As previously stated, following the recommendations of Boaler (1997), Burton (1995), and Fennema and Hart (1994) to ask the girls about their perceptions in mathematics class proved to be useful in developing rich descriptions of the connections between mathematics classroom

activities and their confidence level. The use of Burton's (1995) five categories for knowing in mathematics from a feminist perspective helped to uncover how girls feel about and connect with the activities they encounter in mathematics class. Throughout this study, I was afforded a window into the ways they thought about the mathematics. I learned about the girls' different approaches to mathematics. The use of this framework may be beneficial in future work investigating the influence of affective factors on girls in mathematics.

**Four sources of self-efficacy informed by Women's Ways of Knowing.** The data collected for the present study was analyzed using the four sources of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states. Two theoretical considerations emerged from these results. While mastery experiences remained the most influential towards self-efficacy in mathematics for these five cases as previous research indicated (e.g., Bandura, 1997; Britner & Pajares, 2006; Usher & Pajares, 2008; Zander et al., 2020), the effect of the other three sources of self-efficacy (Bandura, 1997) differed depending on the way of knowing (Belenky et al., 1986) in which the girl was situated. Therefore, the categories for Women's Ways of Knowing (Belenky et al., 1986) may inform future research conducted on girls using the four sources of self-efficacy (Bandura, 1997).

Second, there were other influences on confidence in mathematics cited by the participants in this study that did not fall neatly into one of the four sources of self-efficacy (Bandura, 1997). These included factors outside of the classroom such as work from other classes, a part-time job, absences, school breaks, holidays, etc. Though some of these events may alter the girl's physiological or emotional state, the girls did not cite

those states as the component which impacted their confidence, but instead cited the outside factor directly. When conducting research, it may be important to consider additional factors that may fall in another category not included in Bandura's (1997) four sources of self-efficacy.

**Suggestions for Practice**

The results of this study offer suggestions for classroom teachers to inform their classroom practices. These ideas are centered around supporting the mathematical confidence of girls. This section will address the practical application to the results of this study.

For high school mathematics teachers, although research indicates effective teaching practices (e.g., NCTM, 2014) the girls in the classroom may not perceive the value in these practices. This study showcased students who believe direct instruction from the teacher helped them feel more confident about their ability to learn the material. It is important to help these girls see the value in effective teaching practices. Clearly communicating learning goals when students are expected to learn through reasoning tasks, problem solving, or productive struggle (NCTM, 2014), for example, may help the girls contextualize the experience and support their confidence.

All of the girls in this study clearly indicated that their confidence was impacted by whether or not an activity or assessment was graded. They recommended teachers allow them time to absorb new material and ample opportunity to practice before assigning a graded assessment, especially a high stakes assessment. Considering these suggestions and developing a thoughtful grading strategy that is clearly communicated to students can mitigate some unneccary negative influences on the girls' confidence.

Events outside of the mathematics classroom were cited by the girls in this study for their impact on their confidence. It is important for teachers to consider the whole girl and be mindful of her life outside of mathematics class. Inviting students to share when external factors are influencing their mathematics confidence is a likely first step. With knowledge of the situation, teachers can then consider flexibile solutions to support the student's confidence.

Finally, this study followed five students who were in a variety of categories of Women's Ways of Knowing (Belenky et al., 1986). Of these five girls, the one with the highest confidence score and highest overall score on the attitudes survey (Fennema & Sherman, 1976) was positioned in the category of Constructed Knowledge. Teachers might consider the characteristics of this way of knowing for which students integrate the voices of reason, intuition, and the expertise of others (Belenky et al., 1986). Belenky et al. (1986) suggested "educators can help women develop their own authentic voice if they emphasize connection over separation, understanding and acceptance over assessment, and collaboration over debate" (p. 229). Teachers can use their knowledge of teaching strategies to help draw their girls into this constructed way of knowing.

**Questions and Considerations for Future Research**

This study explored five girls' perceptions of the connections between activities and assessments in the mathematics classroom and their confidence in mathematics. The results uncovered similarities and differences in the perspective of these five girls, some of which may be connected to their epistemological perspective of knowing (Belenky et al., 1986). These connections could be explored further in a future study.

The mid-level framework used in the study design intentionally exposed the students to pedagogy focused on feminist ways of knowing mathematics (Burton, 1995). However, the influence of this feminist perspective did not emerge in the coding process. Future work may explore connections between attention to feminist ways of knowing mathematics and girls' confidence in mathematics.

Authority was not a focus of this study, but the students' reliance on the teacher emerged as a major influence on their confidence. This was especially true for those girls in a place of received knowledge. Future research may explore connections between authority in the mathematics classroom and girls' confidence in mathematics.

In their pre-interviews, all five participants cited their transition to Hillside school as influential on their confidence in mathematics. Some girls described a lowering of their confidence when transitioning from a school where mathematics was easy to a more challenging environment. However, others appreciated the growth their experience afforded having successfully navigated the transition. Future research on the impact of school transitions on girls' confidence may yield helpful suggestions for teachers to ease negative impact on confidence.

A discrepancy between what research says are effective mathematics teaching practices and some students' perceptions of teaching practices that help them learn mathematics emerged as a theme in this study. Helping students to see the benefits of research-based teaching practices may help improve confidence in their ability to learn and understand mathematics. Additionally, this understanding could help them transition to a less dependent way of knowing in mathematics. More research on this topic is needed to explore these connections.

The present study was conducted using girls as subjects and, therefore, the results are bounded to this group. It is possible that some of the findings may generalize to all students, regardless of gender. However, this study makes no such claim. It is left to future research to determine if any of the results may be extended beyond the boundary of girls.

## Chapter Summary

Girls are less likely than boys to pursue a degree or career in mathematics-based STEM fields. Although their performance levels are similar, girls report lower mathematics attitudes and beliefs, including confidence. Girls' confidence in mathematics has not been closely examined at the classroom level in connection with the activities and assessments experienced. This multi case study examined five girls' perceptions of connections between the activities and assessments they participated in as a part of their Algebra 2 class and their confidence in mathematics. A rich description of these perceived connections was developed for each case and was analyzed across the five cases.

This chapter included a summary of the background for the research problem, a review of the methodology, and a discussion of the results. This study sought to understand the girls' perspective: investigating sources of self-efficacy from a feminist perspective by asking the girls and listening to what they had to say. As a result, connections to prior research were made and a possible relationship emerged between a girl's way of knowing and the influence various classroom activities have on her confidence. The results yielded possible theoretical and practical implications, all of which were explored in this chapter. Investigating connections between confidence and

other school related phenomena was a recommendation for future research. Additionally, future research may extend the findings of this study beyond the five case study participants and beyond the boundary of all girls with hopes that each new study will help increase the likelihood that girls choose mathematics-based STEM careers.

## References

Aiken Jr, L. R. (1971). Intellective variables and mathematics achievement: Directions for research. *Journal of School Psychology*, *9*, 201-212.

Almukhambetova, A., Torrano, D. H., & Nam, A. (2021). Fixing the leaky pipeline for talented women in STEM. *International Journal of Science and Mathematics Education*, 1-20. https://doi-org.ezproxy.mtsu.edu/10.1007/s10763-021-10239-1

Archard, N. (2012). Adolescent girls and leadership: The impact of confidence, competition, and failure. *International Journal of Adolescence and Youth*, *17*(4), 189-203.

Aysel, T., Ann, O. S., & Breen, S. (2020). Students' attitudes to mathematics learning and assessment in Turkey and Ireland. *International Journal of Educational Studies in Mathematics*, *7*(1), 26-38.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Freeman.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*(1), 1-26. https://doi: 10.1146/annurev.psych.52.1.1

Becker, J. R. (1981). Differential treatment of females and males in mathematics classes. *Journal for Research in Mathematics Education*, *12*(1), 40-53.

Becker, J. R. (1995). Women's ways of knowing in mathematics. In P. Rogers & G. Kaiser (Eds.), *Equity in mathematics education: Influences of feminism and culture*, (pp. 163-174). The Falmer Press.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind*. Basic Books.

Bergeron, L., & Gordon, M. (2017). Establishing a STEM pipeline: Trends in male and female enrolment and performance in higher level secondary STEM courses. *International Journal of Science and Mathematics Education, 15*(3), 433–450. https://doi-org/10.1007/s10763-015-9693-7

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM education*, *5*(1), 1-15.

Boaler, J. (1997). Reclaiming school mathematics: The girls fight back. *Gender and Education*, *9*(3), 285-305.

Brandell, G., & Staberg, E. M. (2008). Mathematics: A female, male or gender-neutral domain? A study of attitudes among students at secondary level. *Gender and Education*, *20*(5), 495-509.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *43*(5), 485-499.

Buck, G. A., Francis, D. C., & Wilkens-Yel, K. G. (2020). Research on gender equity in STEM education. In C. C. Johnson, M. J. Mohr-Schroeder, T.J. Moore & L.D. English (Eds.), *Handbook of research on STEM education* (pp. 787-850). Routledge.

Burton, L. (1986). *Girls into maths can go*. Holt, Rinehart and Winston.

Burton, L. (1995). Moving towards a feminist epistemology of mathematics. *Educational Studies in Mathematics*, *28*(3), 275-291.

Burton, L. (2004). "Confidence is everything" – perspectives of teachers and students on learning mathematics. *Journal of Mathematics Teacher Education*, *7*(4), 357–381.

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143*(1), 1–35. https://doi-org/10.1037/bul0000052

Chionh, Y. H., & Fraser, B. J. (2009). Classroom environment, achievement, attitudes and self-esteem in geography and mathematics in Singapore. *International Research in Geographical and Environmental Education, 18*(1), 29-44.

Dorman, J. P., Adams, J. E., & Ferguson, J. M. (2003). A cross-national investigation of students' perceptions of mathematics classroom environment and academic efficacy in secondary schools. *International Journal for Mathematics Teaching and Learning*, *15*, 123-176.

Fennema, E. (1979). Women and girls in mathematics—equity in mathematics education. *Educational Studies in Mathematics, 10*(4), 389-401.

Fennema, E., & Hart, L. E. (1994). Gender and the JRME. *Journal for Research in Mathematics Education*, *25*(6), 648-659.

Fennema, E., & Sherman, J.A. (1976) Fennema-Sherman mathematics attitude scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Catalog of Selected Documents in Psychology*, *6*(1).

Fennema, E., & Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization and affective factors. *American Educational Research Journal, 14*(1), 51-71. https://doi-org/10.2307/1162519

Flammer, A. (2015). Self-Efficacy. *International Encyclopedia of the Social & Behavioral Sciences*, 504–508. https://doi-org/10.1016/B978-0-08-097086-8.25033-2

Fox, L. H., Fennema, E., & Sherman, J. A. (1977). *Women and mathematics: Research perspectives for change*. US Department of Health, Education and Welfare.

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007). Girls and mathematics—A "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. *European Journal of Psychology of Education*, *22*(4), 497-514.

Frost, L. A., Hyde, J. S., & Fennema, E. (1994). Gender, mathematics performance, and mathematics-related attitudes and affect: A meta-analytic synthesis. *International Journal of Educational Research*, *21*(4), 373-385.

Geary, D. C., Hoard, M. K., Nugent, L., Chu, F., Scofield, J. E., & Ferguson Hibbard, D. (2019). Sex differences in mathematics anxiety and attitudes: Concurrent and longitudinal relations to mathematical competence. *Journal of Educational Psychology*, *111*(8), 1447–1461.

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles*, *66*, 153-166.

Hart, L. E. (1989). Classroom processes, sex of student, and confidence in learning mathematics. *Journal for Research in Mathematics Education*, *20*(3), 242-260.

Hill, C., Corbett, C., & St. Rose, A. (2010). Why so few? Women in science, technology, engineering, and mathematics. Washington, DC: AAUW Research Report.

Huang, X., Zhang, J., & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: The gender moderating effect. *European Journal of Psychology of Education*, *34*(3), 621-640. https://doi.org/10.1007/s10212-018-0403-z

Inglis, M., & Foster, C. (2018). Five decades of mathematics education research. *Journal for Research in Mathematics Education*, *49*(4), 462-500.

Jean, V. A., Payne, S. C., & Thompson, R. J. (2015). Women in STEM: Family-related challenges and initiatives. In M. Mills (Ed.), *Gender and the work-family experience: An intersection of two domains* (pp. 291-311). Springer. https://doi.org/10.1007/978-3-319-08891-4_15

Leder, G. C. (2019). Gender and mathematics education: An overview. In G. Kaiser & N. Presmeg (Eds.), *Compendium for early career researchers in mathematics education* (pp. 289-308). Springer. https://doi.org/10.1007/978-3-030-15636-7

Leder, G. C., & Forgasz, H. J. (2018). Measuring who counts: Gender and mathematics assessment. *ZDM*, *50*(4), 687-697. https://doi-org/10.1007/s11858-018-0939-z

Lee, J., Moon, S., & Hegar, R. L. (2011). Mathematics skills in early childhood: Exploring gender and ethnic patterns. *Child Indicators Research*, *4*(3), 353-368.

Leslie, L. L., McClure, G. T., & Oaxaca, R. L. (1998). Women and minorities in science and engineering: A life sequence analysis. *The Journal of Higher Education*, *69*(3), 239-276. https://doi-org/10.2307/2649188

Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics

education. *Journal for Research in Mathematics Education, 48*(4), 397-433. https://doi-org/10.5951/jresematheduc.48.4.0397

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Sage.

Lincoln, Y. S., & Guba, E. G. (2000). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin, and Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 163–188). Sage.

Lips, H. M. (2020). *Sex and gender: An introduction*. Waveland Press.

Miele, D. B., Browman, A. S., Shen, C., Vasilyeva, M., & Tyumeneva, Y. A. (2022). Domain-general and math-specific self-perceptions of perseverance as predictors of behavioral math persistence. *The Journal of Experimental Education*, *90*(3), 593-614.

National Council of Teachers of Mathematics. (2014). Principles to actions: Ensuring mathematical success for all. Reston, VA: National Council of Teachers of Mathematics.

Noddings, N. (1998). Perspectives from feminist philosophy. *Educational Researcher*, *27*, 17-18.

Noonan, R. (2017). *Women in STEM: 2017 Update. ESA Issue Brief# 06-17*. US Department of Commerce. https://www.esa.gov/reports/women-stem-2017-update

O'Dea, R. E., Lagisz, M., Jennions, M. D., & Nakagawa, S. (2018). Gender differences in individual variation in academic grades fail to fit expected patterns for STEM. *Nature Communications*, *9*(1), 1-8.

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory Into Practice*, *41*(2), 116-125.

Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice. Sage.

Parsley Jr, K. M., Powell, M., & O'Connor, H. A. (1964). Further investigation of sex differences in achievement of under-, average-, and over-achieving students within five IQ groups in grades four through eight. *The Journal of Educational Research*, *57*(5), 268-270.

Penuel, W. R., & Shepard, L. A. (2016). Assessment and teaching. In D. Gitomer & C. Bell (Eds.) Handbook of research on teaching, 5, (pp. 787-850). American Educational Research Association.

Perry, W. (1970). *Forms of intellectual and ethical growth in the college years.* Holt, Rinehart and Winston.

Preckel, F., Goetz, T., Pekrun, R., & Kleine, M. (2008). Gender differences in gifted and average-ability students: Comparing girls' and boys' achievement, self-concept, interest, and motivation in mathematics. *Gifted child quarterly*, *52*(2), 146-159.

Reardon, S. F., Fahle, E. M., Kalogrides, D., Podolsky, A., & Zárate, R. C. (2019). Gender achievement gaps in US school districts. *American Educational Research Journal*, *56*(6), 2474-2508. https://doi-org/10.3102/0002831219843824

Reyes, L. H. (1984). Affective variables and mathematics education. *The Elementary School Journal*, *84*(5), 558-581.

Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd ed.). SAGE.

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific,

interpretive, and critical research paradigms. *English Language Teaching, 5*(9), 9-16.

Seo, E., & Lee, Y. K. (2021). Stereotype threat in high school classrooms: how it links to teacher mindset climate, mathematics anxiety, and achievement. *Journal of Youth and Adolescence*, *50*(7), 1410-1423.

Shepard, L., Penuel, W., & Davidson, K. (2016). Using formative assessment to create coherent and equitable assessment systems.

Sherman, J., & Fennema, E. (1977). The study of mathematics by high school girls and boys: Related variables. *American Educational Research Journal, 14*(2), 159-168. https://doi-org/10.2307/1162708

Stake, R. E. (2005). *Multiple case study analysis.* Guilford Press.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *The American Psychologist, 6*, 613.

Stinson, D. W., & Walshaw, M. (2017). Exploring different theoretical frontiers for different (and uncertain) possibilities in mathematics education research. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp.128–155). National Council of Teachers of Mathematics.

Streitmatter, J. (1997). An exploratory study of risk-taking and attitudes in a girls-only middle school math class. *The Elementary School Journal*, *98*(1), 15-26.

Tarampi, M. R., Heydari, N., & Hegarty, M. (2016). A tale of two types of perspective taking: Sex differences in spatial ability. *Psychological science*, *27*(11), 1507-1516. https://doi-org/10.1177/0956797616667459

Tellhed, U., Bäckström, M., & Björklund, F. (2017). Will I fit in and do well? The importance of social belongingness and self-efficacy for explaining gender differences in interest in STEM and HEED majors. *Sex Roles, 77*(1-2), 86-96. https://doi-org/10.1007/s11199-016-0694-y

Tomasetto, C., Alparone, F. R., & Cadinu, M. (2011). Girls' math performance under stereotype threat: The moderating role of mothers' gender stereotypes. *Developmental Psychology, 4*, 943. https://doi-org.ezproxy.mtsu.edu/10.1037/a0024047

Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of educational research, 78*(4), 751-796.

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: does gender make a difference?. *Educational Studies in Mathematics, 56*(2), 287-312.

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: a meta-analysis. *Psychological Bulletin, 140*(4), 1174. https://doi.org/10.1037/a0036620

Webster, J. (2021). [Unpublished raw data on Girls' Confidence in Mathematics]. Middle Tennessee State University.

Wiliam, D. (2007) Lester, F. K. (Ed.). (2007). *Second handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics*. IAP.

Yin, R. K. (2009). Case Study Research (4th ed.). Sage.

Zander, L., Höhne, E., Harms, S., Pfost, M., & Hornsey, M. J. (2020). When grades are high but self-efficacy is low: Unpacking the confidence gap between girls and boys in mathematics. *Frontiers in Psychology*, 11, 2492.

Zhou, Y., Fan, X., Wei, X. Tai, R. (2017). Gender gap among high achievers in math and implications for STEM pipeline. *The Asia-Pacific Education Researcher, 26*(5), 259–269. https://doi.org/10.1007/s40299-017-0346-1

Zohar, A., & Gershikov, A. (2008). Gender and performance in mathematical tasks: Does the context make a difference? *International Journal of Science and Mathematics Education*, *6*(4), 677-693.

# APPENDICES

# APPENDIX A: EXERPTS FROM FENNEMA SHERMAN

## DIRECTIONS
## FENNEMA-SHERMAN MATHEMATICS ATTITUDE SCALES

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On the following pages is a series of statements. There are no correct answers for these statements. They have been set up in a way which permits you to indicate the extent to which you agree or disagree with the ideas expressed. Suppose the statement is:

Example 1. I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, choose A. If you agree but with reservations, choose B. If you disagree with the idea, indicate the extent to which you disagree by choosing D for disagree or E if you strongly disagree. But if you neither agree nor disagree, that is, you are not certain, choose circle C for undecided.

Example 2. Math is very interesting to me.

Do not spend much time with any statement, but be sure to answer every statement. Work fast but carefully.

There are no "right" or "wrong" answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help you make a choice.

THIS INVENTORY IS BEING USED FOR RESEARCH PURPOSES ONLY AND NO ONE WILL KNOW WHAT YOUR RESPONSES ARE.

Developed under a grant from the National Science Foundation.

Name of survey participant: _____

Are you willing to participate in an **optional** follow-up interview with the researcher?

Please check one:
_____ YES I am willing to participate in an optional follow-up interview.
_____ NO I would prefer not to participate in a follow-up interview

| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|
| 1. | Generally I have felt secure about attempting mathematics. | A | B | C | D | E |
| 2. | I am sure I could do advanced work in mathematics. | A | B | C | D | E |
| 3. | I am sure that I can learn mathematics. | A | B | C | D | E |
| 4. | I think I could handle more difficult mathematics. | A | B | C | D | E |
| 5. | I can get good grades in mathematics. | A | B | C | D | E |
| 6. | I have a lot of self-confidence when it comes to math. | A | B | C | D | E |
| 7. | I'm no good in math. | A | B | C | D | E |
| 8. | I don't think I could do advanced mathematics. | A | B | C | D | E |
| 9. | I'm not the type to do well in math. | A | B | C | D | E |
| 10. | For some reason even though I study, math seems unusually hard for me. | A | B | C | D | E |
| 11. | Most subjects I can handle O.K., but I have a knack for flubbing up math. | A | B | C | D | E |
| 12. | Math has been my worst subject. | A | B | C | D | E |

| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|
| 1. | It would make me happy to be recognized as an excellent student in mathematics. | A | B | C | D | E |
| 2. | I'd be proud to be the outstanding student in math. | A | B | C | D | E |
| 3. | I'd be happy to get top grades in mathematics. | A | B | C | D | E |
| 4. | It would be really great to win a prize in mathematics. | A | B | C | D | E |
| 5. | Being first in a mathematics competition would make me pleased. | A | B | C | D | E |
| 6. | Being regarded as smart in mathematics would be a great thing. | A | B | C | D | E |
| 7. | Winning a prize in mathematics would make me feel unpleasantly conspicuous. | A | B | C | D | E |
| 8. | People would think I was some kind of a grind if I got A's in math. | A | B | C | D | E |
| 9. | If I had good grades in math, I would try to hide it. | A | B | C | D | E |
| 10. | If I got the highest grade in math, I'd prefer no one knew. | A | B | C | D | E |
| 11. | It would make people like me less if I were a really good math student. | A | B | C | D | E |
| 12. | I don't like people to think I'm smart in math. | A | B | C | D | E |

| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|
| 1. | I'll need mathematics for my future work. | A | B | C | D | E |
| 2. | I study mathematics because I know how useful it is. | A | B | C | D | E |
| 3. | Knowing mathematics will help me earn a living. | A | B | C | D | E |
| 4. | Mathematics is a worthwhile and necessary subject. | A | B | C | D | E |
| 5. | I'll need a firm mastery of mathematics for my future work. | A | B | C | D | E |
| 6. | I will use mathematics in many ways as an adult. | A | B | C | D | E |
| 7. | Mathematics is of no relevance to my life. | A | B | C | D | E |
| 8. | Mathematics will not be important to me in my life's work. | A | B | C | D | E |
| 9. | I see mathematics as a subject I will rarely use in my daily life as an adult. | A | B | C | D | E |
| 10. | Taking mathematics is a waste of time. | A | B | C | D | E |
| 11. | In terms of my adult life it is not important for me to do well in mathematics in high school. | A | B | C | D | E |
| 12. | I expect to have little use for mathematics when I get out of school. | A | B | C | D | E |

| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|
| 1. | Math doesn't scare me at all. | A | B | C | D | E |
| 2. | It wouldn't bother me at all to take more math courses. | A | B | C | D | E |
| 3. | I haven't usually worried about being able to solve math problems. | A | B | C | D | E |
| 4. | I almost never have gotten shook up during a math test. | A | B | C | D | E |
| 5. | I usually have been at ease during math tests. | A | B | C | D | E |
| 6. | I usually have been at ease during math classes. | A | B | C | D | E |
| 7. | Mathematics usually makes me feel uncomfortable and nervous. | A | B | C | D | E |
| 8. | Mathematics makes me feel uncomfortable, restless, irritable, and impatient. | A | B | C | D | E |
| 9. | I get a sinking feeling when I think of trying hard math problems. | A | B | C | D | E |
| 10. | My mind goes blank and I am unable to think clearly when working mathematics. | A | B | C | D | E |
| 11. | A math test would scare me. | A | B | C | D | E |
| 12. | Mathematics makes me feel uneasy and confused. | A | B | C | D | E |

# APPENDIX B: SURVEY FOLLOW-UP INTERVIEW PROTOCOL

Girls' Confidence in Mathematics

Semi-structured Interview Protocol

Survey Follow-Up Interview

Opening questions (the same for all participants):

1. Tell me about your experiences in mathematics.

2. What career are you currently interested in pursuing?

Questions from the survey.

I will ask follow-up questions that relate to specific questions on the survey.

For example:

What were you thinking about when you answered this question in this way?

Why do you think you feel this way?

Can you think of events in the past that led you to answer this way?

# APPENDIX C: END OF UNIT INTERVIEW PROTOCOL

Girls' Confidence in Mathematics

Semi-structured Interview Protocol

End of Unit Interview

Opening questions (the same for all participants):

1. Tell me about you experience with the unit we just completed.

2. Please comment on your confidence as a mathematics student throughout the unit.

Questions from the assessment reflections.

I will show each girl her reflections from each of the unit's assessments and ask her to explain her answers in greater detail.

For example:

What were you thinking about when you answered this question in this way?

Why do you think you feel this way?

What about the assessment made to respond in this way?

# APPENDIX D: ASSESSMENT REFLECTION

Name: _____

Assessment Reflection

Directions: Please answer the following questions in response to the assessment that you just completed.

1. Place an arrow on the following scale to indicate your level of confidence on this assessment:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|

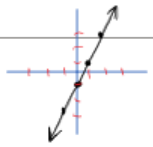
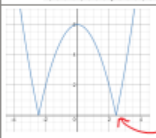
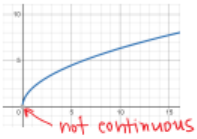
Less Confident More Confident

2. Explain your reasoning for your answer to question 1, please be as specific as possible.

# APPENDIX E: POLYNOMIAL FUNCTIONS DISCOVERY EXERCISE

## 3.2 Graphs of Polynomial Functions

What is a polynomial?

| | Polynomial function | Graph of a polynomial |
|---|---|---|
| Characteristics | • sum of monomials<br>• each term has positive integer degree<br>• coefficients are real numbers | • continuous curve<br>• smooth curve |
| Examples | $f(x) = 2x - 1$<br><br>$f(x) = x^4 + x^3 - 6x^2 + x - 10$ |  <br>  |
| Non-examples<br>i.e. NOT polynomials | $f(x) = \lvert x^2 - 6 \rvert$ absolute value<br><br>$f(x) = 2x^{\frac{1}{2}}$ fractional power |  not a smooth curve<br>  not continuous |

Do problem 1 on your worksheet.

MAKING CONNECTIONS BETWEEN A POLYNOMIAL AND ITS GRAPH

Connection 1: Degree and Sign gives End Behavior

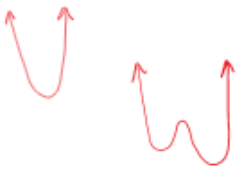
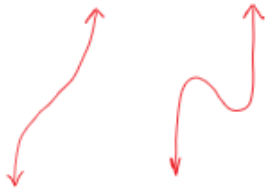
$-4x^5 + 2x^3 - x^2 - 3x + 1$

the leading term of a polynomial is the term with the highest degree

the leading coefficient of a polynomial is the coefficient of the leading term

Remember, the degree of a polynomial is the same as the degree of the leading term.

The degree of a polynomial and the sign of the leading coefficient can tell us what shape the polynomial will have.

| | Polynomial with Even Degree (both ends point the same way) | Polynomial with Odd Degree (ends point in opposite directions) |
|---|---|---|
| Polynomial with Positive Leading Coefficient (right end points up) |  |  |
| Polynomial with Negative Leading Coefficient (right end points down) |  |  |


Do problem 2 on your worksheet.

## Connection 2: Zeros and Multiplicity tells where the graph Touches and Crosses the x-axis

When finding zeros of a functions, we set $y=0$ and solve for $x$. If these zeros are real numbers, they give $x$-intercepts on the graph. Such zeros can be found by factoring a polynomial.

For example: $f(x) = x(x-3)(x+2)$ has 3 factors

when we set y to zero and solve we get

$0 = x(x-3)(x+2)$

$x=0 \quad x-3=0 \quad x+2=0$

$x=3 \quad x=-2$

So the zeros of the polynomial are $0, 3, -2$

because these are real numbers, they are x-intercepts

The multiplicity of a zero: when a polynomial is factored completely, the number of times a factor is repeated gives the multiplicity of the corresponding zero.

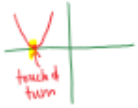
For example: $f(x) = x^2(x-3)(x+2)^3$ as we saw in the example above the zeros are $0, 3, -2$.

the zero is $x=0$ with a multiplicity of 2

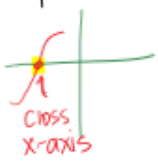
the zero is $x=3$ with a multiplicity of 1

the zero is $x=-2$ with a multiplicity of 3

real zeros that have even multiplicity give x-intercepts that DO NOT cross the x-axis but the touch the x-axis & turn.




real zeros that have odd multiplicity give x-intercepts that CROSS the x-axis





Do problem 3 on your worksheet.

Now, let's put it all together.

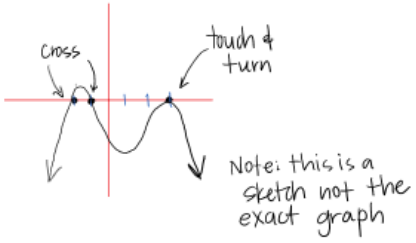
If you are given a factored polynomial, you can sketch the curve.

$f(x) = -4(x-3)^2(x+2)^0(x+1)^0$

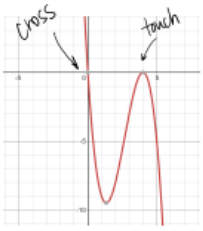
degree is 4

negative → so end behavior is ↓ even negative

zeros: $x=3$ multiplicity 2 touch
$x=-2$ multiplicity 1
$x=-1$ multiplicity 1




If you are given the graph of a polynomial, you can write an equation.




zeros: $x=4$ (even multiplicity)
$x=0$ (odd multiplicity)

end behavior: negative (b/c points down to right)
odd (b/c ends point opposite)

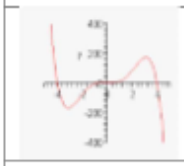
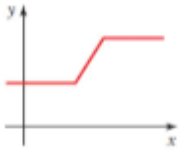
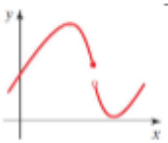
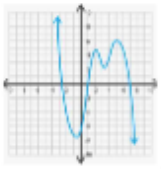
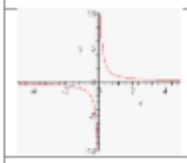
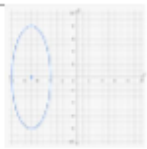
$f(x) = -1x(x-4)^2$


Do problem 4 on your worksheet.

## Graphs of Polynomials Exploration

### Graphs of Polynomials Worksheet

1. Determine whether the given expressions or graphs are polynomial functions or not. If it is not a polynomial function, indicate why not.

| | Polynomial or not? | | Polynomial or not? |
|---|---|---|---|
|  | |  | |
| $10x^{-1}+6x^2$ | | $-x^3+9$ | |
|  | |  | |
| $2x^2+6x-9$ | | $\sqrt{x}-2$ | |
|  | |  | |
| $\frac{3}{x}+5$ | | $4x^4+5x^3-8x^2+12x+24$ | |

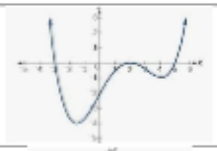
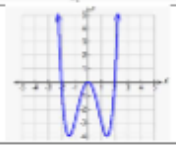
2. For each polynomial, use the degree and sign to determine the end behavior.

| Polynomial | Degree | Sign | End Behavior |
|---|---|---|---|
| $y=-3x^2+2x+1$ | | | |
| $y=x^2-4x-7$ | | | |
| $y=(x-2)^2(x-1)$ | | | |
| $y=-5x^4$ | | | |

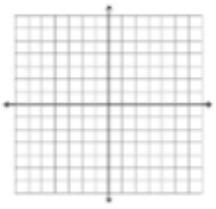
3. Zeros and Multiplicity
   a. For each polynomial, list the zeros and their multiplicity. Use the multiplicity to determine whether the graph will touch or cross the x-axis at each zero.

| Polynomial | Zeros | Multiplicity | Touch or Cross? |
|---|---|---|---|
| $y=-3(x-4)(2x+3)^2$ | | | |
| $f(x)=x(x-1)^3$ | | | |
| $g(x)=2x^2+7x-15$ | | | |
| $h(x)=(x-5)^4(x+3)^2(x-2)$ | | | |

   b. For each graph, list the zeros and determine whether each one has even or odd multiplicity.

| Graph | Zeros | Even or Odd Multiplicity? |
|---|---|---|
|  | | |
|  | | |

4. Putting it together
   a. Sketch the graph of the polynomial $y=-(x-1)(x+3)^2$

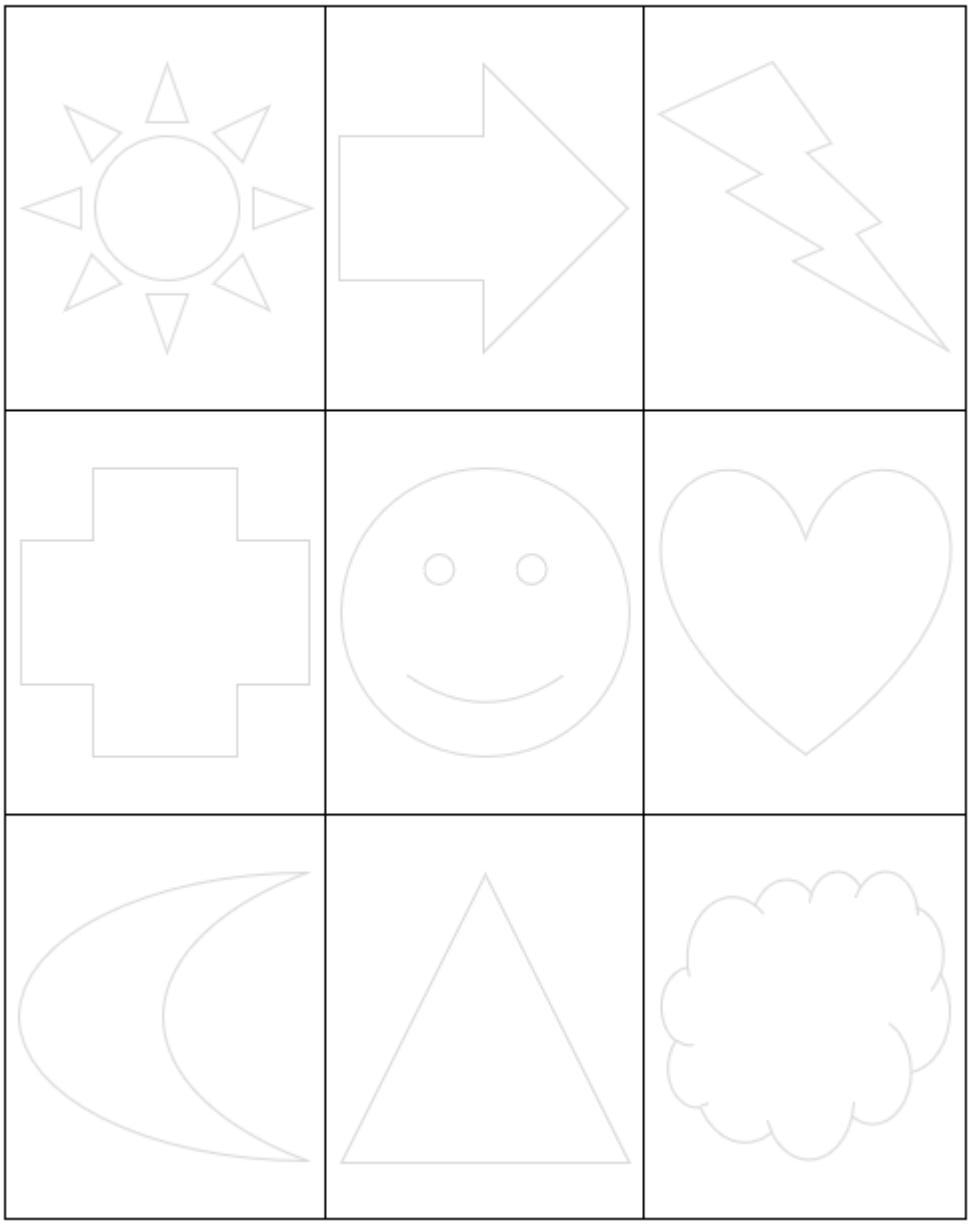


   b. Write a function whose graph is negative with even degree and has zeros that cross at $x = 4$ and $x = -3$ and a zero that touches at $x = 1$.

## APPENDIX F: POLYNOMIAL DIVISION TIC-TAC-TOE

Name: _____

Polynomial Division Tic-Tac-Toe



| | |
|---|---|
|  | $(x^4 - 3x^2 + 4x + 5) \div (x^2 - x + 1)$ |
|  | $(x^4 + x^3 - 11x^2 - 5x + 30) \div (x - 2)$ |
|  | $(4x^4 - 5x^3 + 2x^2 - x + 5) \div (x^2 + x + 1)$ |
|  | $(x^3 + 9x^2 + 12x - 27) \div (x + 3)$ |
|  | $(x^6 + 2x^5 + 5x^3 + 4x^2 + 6) \div (x^3 + 2)$ |
|  | $(3x^3 - 2x^2 - 150) \div (x - 4)$ |
|  | $(x^3 - x^2 + 4x - 3) \div (x^2 - 1)$ |
|  | $(x^4 - 2x^2 + 3x + 1) \div (x - 3)$ |
|  | $(2x^4 + 5x^3 + 8x^2 - 7x + 5) \div (2x^2 - x + 3)$ |

# APPENDIX G: INSTITUTIONAL REVIEW BOARD APPROVAL

**IRB**
**INSTITUTIONAL REVIEW BOARD**
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129
*FWA: 00005331/IRB Regn. 0003571*

MIDDLE TENNESSEE STATE UNIVERSITY

## IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Tuesday, October 26, 2021

| | |
|---|---|
| *Protocol Title* | ***Girls' Perceptions of the Connections Between Classroom Assessments and Confidence in Mathematics*** |
| *Protocol ID* | **22-2055 7im** |
| *Principal Investigator* | **Jennifer Webster** (Student) *Faculty Advisor:* Alyson Lischka |
| *Co-Investigators* | NONE |
| *Investigator Email(s)* | *jmw2dh@mtmail.mtsu.edu; Alyson.lischka@mtsu.edu* |
| *Department* | Mathematical Sciences |
| *Funding* | NONE |

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU IRB through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior*. A summary of the IRB action is tabulated below:

| | |
|---|---|
| *IRB Action* | APPROVED for ONE YEAR |
| *Date of Expiration* | 10/31/2022 *Date of Approval:* 10/27/21 *Recent Amendment:* NONE |
| *Sample Size* | ONE HUNDRED (100) |
| *Participant Pool* | *Target Population:*<br>Primary Classification: **General Minors (13 to 17 years of age)**<br>Specific Classification: **Students of The Harpeth Hall School, Nashville, TN** |
| *Type of Interaction* | ☐ Non-interventional or Data Analysis<br>☐ Virtual/Remote/Online interaction<br>☒ In person or physical interaction – Mandatory COVID-19 Management |
| *Exceptions* | Contact information is permitted to coordinate the research |
| *Restrictions* | 1. Mandatory SIGNED Parental Consent and independent Child Assent.<br>2. Other than the exceptions above, identifiable data/artifacts, such as, audio/video data, photographs, handwriting samples, personal address, driving records, social security number, and etc., MUST NOT be collected. Recorded identifiable information must be deidentified as described in the protocol.<br>3. Mandatory Final report (refer last page).<br>4. COVID-19 Management.<br>5. CDC guidelines and MTSU safe practice must be followed |
| *Approved Templates* | *IRB Templates:* Combined Parental Consent & Child Assent<br>*Non-MTSU Templates:* Recruitment script(s) |
| *Research Inducement* | NONE |
| *Comments* | NONE |

## Post-approval Requirements

The PI and FA must read and abide by the post-approval conditions (Refer "*Quick Links*" in the bottom):

- ***Reporting Adverse Events:*** The PI must report research-related adversities suffered by the participants, deviations from the protocol, misconduct, and etc., within 48 hours from when they were discovered.
- ***Final Report:*** The FA is responsible for submitting a final report to close-out this protocol before 10/31/2022 (Refer to the Continuing Review section below); REMINDERS WILLNOT BE SENT. **Failure to close-out or request for a continuing review may result in penalties** including cancellation of the data collected using this protocol and/or withholding student diploma.
- ***Protocol Amendments***: An IRB approval must be obtained for all types of amendments, such as: addition/removal of subject population or investigating team; sample size increases; changes to the research sites (appropriate permission letter(s) may be needed); alternation to funding; and etc. The proposed amendments must be requested by the FA in an addendum request form. The proposed changes must be consistent with the approval category and they must comply with expedited review requirements
- ***Research Participant Compensation:*** Compensation for research participation must be awarded as proposed in Chapter 6 of the Expedited protocol. The documentation of the monetary compensation must Appendix J and MUST NOT include protocol details when reporting to the MTSU Business Office.
- ***COVID-19:*** Regardless whether this study poses a threat to the participants or not, refer to the COVID-19 Management section for important information for the FA.

### Continuing Review (Follow the Schedule Below)

This protocol can be continued for up to THREE years by requesting a continuing review before 10/31/2022. Refer to the following schedule to plan your annual progress report; **REMINDERS WILL NOT BE SENT**. Failure to obtain an approval for continuation will result in cancellation of this protocol..

| Reporting Period | Requisition Deadline | IRB Comments |
|---|---|---|
| First year report | 9/30/2022 | NOT COMPLETED |
| Second year report | 9/30/2023 | NOT COMPLETED |
| Final report | 9/30/2024 | NOT COMPLETED |

### Post-approval Protocol Amendments:

The current MTSU IRB policies allow the investigators to implement minor and significant amendments that would fit within this approval category. ***Only TWO procedural amendments will be entertained per year*** *(changes like addition/removal of research personnel are not restricted by this rule).*

| Date | Amendment(s) | IRB Comments |
|---|---|---|
| NONE | NONE. | NONE |

### Other Post-approval Actions:

The following actions are done subsequent to the approval of this protocol on request by the PI/FA or on recommendation by the IRB or by both.

| Date | IRB Action(s) | IRB Comments |
|---|---|---|
| NONE | NONE | NONE |

### COVID-19 Management:

The PI must follow social distancing guidelines and other practices to avoid viral exposure to the participants and other workers when physical contact with the subjects is made during the study.

- The study must be stopped if a participant or an investigator should test positive for COVID-19 within 14 days of the research interaction. This must be reported to the IRB as an "adverse event."
- The MTSU's "Return-to-work" questionnaire found in Pipeline must be filled by the investigators on the day of the research interaction prior to physical contact.
- PPE must be worn if the participant would be within 6 feet from the each other or with an investigator.
- Physical surfaces that will come in contact with the participants must be sanitized between use
- **FA's Responsibility**: The FA is given the administrative authority to make emergency changes to protect the wellbeing of the participants and student researchers during the COVID-19 pandemic. However, the FA must notify the IRB after such changes have been made. The IRB will audit the changes at a later date and the FA will be instructed to carryout remedial measures if needed.

**Data Management & Storage:**
All research-related records (signed consent forms, investigator training and etc.) must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data must be stored for at least three (3) years after the study is closed. Additional Tennessee State data retention requirement may apply (*refer "Quick Links" for MTSU policy 129 below*). The data may be destroyed in a manner that maintains confidentiality and anonymity of the research subjects.

**The MTSU IRB reserves the right to modify/update the approval criteria or change/cancel the terms listed in this letter without prior notice.** Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

- Post-approval Responsibilities: http://www.mtsu.edu/irb/FAQ/PostApprovalResponsibilities.php
- Expedited Procedures: https://mtsu.edu/irb/ExpeditedProcedures.php
- MTSU Policy 129: Records retention & Disposal: https://www.mtsu.edu/policies/general/129.php