MINDSET OVER MATTER: HOW DOES PARENT MATHEMATICAL MINDSET RELATE TO STUDENT MATHEMATICAL EXPERIENCE?

by

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ABSTRACT

MINDSET OVER MATTER: HOW DOES PARENT MATHEMATICAL MINDSET INFLUENCE STUDENT MATHEMATICAL EXPERIENCE?

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This study explored the relationship between (1) parent mathematical mindset and student mathematical experience (as determined by student mathematical mindset, student mathematical achievement, and student mathematical grit), (2) participant general mindset and participant mathematical mindset, and (3) student general grit and student mathematical grit. Participants included 14 high school seniors and their active parent(s) or guardian(s) (N=38). The research followed a hermeneutical phenomenological approach – a qualitative research methodology characterized by finding meaning through the subjective interpretation of participants. Both quantitative and qualitative data were collected to describe the phenomenon of student mathematical experience, as well as the internal consistency of mindsets as applied to general intelligence and mathematical intelligence.

A moderate positive association was found between participants' general mindsets and mathematical mindsets. Despite the consistencies, 37% of participants had mathematical mindsets that were in tension with their general mindset. The present study advocates that general mindsets and mathematical mindsets are not as closely associated, thereby supporting the theory that mindsets can vary by subject domain.

In contrast, a strong positive association was found between students' general grit and their mathematical grit. To that effect, the study contributed to the field in two ways: (1) by exposing further variability in mindsets dependent on subject domain; and (2) by exposing grit as more fundamentally consistent than mindset when applied to different subject domains.

Additionally, parent mathematical mindset is not associated with student mathematical mindset. It's possible that (1) parents' mathematical mindsets are not visible to their children, (2) parents suppress their beliefs regarding mathematical intelligence, or (3) external factors, such as cultural influences, compete in shaping students' mindsets.

Finally, although no relation was found between parent mathematical mindset and both student GPA and SAT score, an inverse relationship was observed between parent mathematical mindset and student highest-level mathematics course taken. Markedly, students of parents with a mathematics-fixed mindset appear to take more advanced mathematics courses, whereas students of parents with a mathematics-growth mindset appear to take lower-level courses. This suggests that student effort may be in tension with the evaluation of effort by their parents.

TABLE OF CONTENTS

LIST OF TABLES …….……vi

LIST OF FIGURES …….....……viii

CHAPTER I : INTRODUCTION..... 1

Need for Study 1

Purpose of Study 6

Procedure 7

Participants..... 8

Data Collection. 9

Data Analysis. 10

Research question 1. 10

Research question 2. 11

Research question 3. 11

Research question 4. 12

Analysis from Open, Axial, and Selective Coding. 12

CHAPTER II : LITERATURE REVIEW 14

Views of Intelligence 15

Measuring Intelligence..... 15

Singular Intelligence. 17

Multiple Factors of Intelligence..... 17

Defining Intelligence. 19

The Malleability of Intelligence..... 20

Implicit Theories of Intelligence 23
Thoughts About Intelligence 25
Entity Theory. 25
Incremental Theory. 27
Performance Goals vs. Learning goals. 27
The Helpless and Mastery-Oriented Responses to Failure. 29
Incremental Theory Interventions. 33
The Development of Attributions. 36
Ability Attributions and Effort Attributions. 39
Mindset. 40
Grit. 41
Grit and the Growth Mindset. 45
Parent Mindset and Student Academic Achievement 46
Feedback Practices 47
Mathematical Mindsets 53
Focus of Study 58
CHAPTER III : METHODOLOGY 62
Research Questions 62
Field Setting 62
Participants 63
Measures 67
Mindset Surveys 69

Grit Scale 70
Student Demographic Survey 70
Interviews 71
Research Design 72
Procedure 73
Phase 1 73
Phase 2 75
Parent Interviews. 75
Student Mindset Survey. 77
Student Grit Scale. 77
Student Interviews. 79
Mindset interviews. 79
Grit interviews. 80
Data Analysis 82
Research Question 1 82
Research Question 2 86
Research Question 3 87
Parent Mathematical Mindset and Student GPA 87
Parent Mathematical Mindset and SAT Score. 87
Parent Mathematical Mindset and Highest Level Mathematics Course. 88
Research Question 4 88
CHAPTER IV : RESULTS 90
Research Question 1 90

Participant General Mindset 90
Participant Mathematical Mindset 92
Mathematics-Fixed-High Mindset Category. 94
Mathematics-Fixed Low Mindset Category. 95
Mathematics-Growth-High Mindset Category. 96
Mathematics-Growth-Low Mindset Category. 97
Mathematical Mindset Results. 98
Analysis. 99
Research Question 2 103
Parent Mathematical Mindset and Student Mathematical Mindset 103
Research Question 3 106
Parent Mathematical Mindset and Student Overall GPA 106
Parent Mathematical Mindset and Student Mathematics SAT Score 109
Parent Mathematical Mindset and Student Highest Mathematics Course 111
Research Question 4 113
Student Mathematical Grit 113
Very Mathematically Gritty. 114
Moderately Mathematically Gritty. 115
Fairly Mathematically Gritty. 116
Not Mathematically Gritty. 116
Parent Mathematical Mindset and Student Mathematical Grit 117
Student General Grit 119

General Grit and Mathematical Grit 119

CHAPTER V : CONCLUSION 122

Research Question 1 122

Participant General Mindset and Participant Mathematical Mindset 122

Research Question 2 126

Parent Mathematical Mindset and Student Mathematical Mindset 126

Research Question 3 127

Parent Mathematical Mindset and Student Mathematical Achievement 127

Research Question 4 129

Parent Mathematical Mindset and Student Mathematical Grit 129

Student General Grit and Student Mathematical Grit 130

Discussion 132

Recommendations 136

Limitations 139

REFERENCES 142

APPENDIX A : ADULT MINDSET SURVEY 151

APPENDIX B: STUDENT MINDSET SURVEY 152

APPENDIX C: STUDENT GRIT SCALE 153

APPENDIX D: STUDENT DEMOGRAPHIC SURVEY 154

APPENDIX E: PARENT INTERVIEW PROTOCOL 156

APPENDIX F: STUDENT INTERVIEW PROTOCOL 157

LIST OF TABLES

Table 1. Frequency of Parent Mindset Types Accepted into Phase 2 of the Study. 66

Table 2. Weighted GPA system for HS1 and HS2. 67

Table 3. Measures Used to Answer Each Research Question. 68

Table 4. Parent Interview Protocol: Mathematics Mindset Questions 76

Table 5. Summary of Scores for Each Scale. 78

Table 6. Student Interview Protocol: Mathematics Mindset Questions 79

Table 7. Student Interview Protocol: Mathematics Grit Questions 80

Table 8. Grit Rubric for Determining Mathematical Grit 81

Table 9. Evans' (1996) Verbal Descriptions for the Strength of Rho 86

Table 10. General Mindset Frequencies for Participants. 90

Table 11. General Mindset Frequencies for Families. 91

Table 12. Main Categories of Codes and Subcategories of Codes. 92

Table 13. Rubric for Determining Mathematical Mindsets 93

Table 14. Mathematical Mindset Frequencies for Participants. 98

Table 15. A Comparison of Mathematical Mindset and Gender 100

Table 16. Parent Mathematical Mindset and Student Overall GPA 107

Table 17. Parent Mathematical Mindset and Student Mathematics SAT Score 109

Table 18. Parent Mathematical Mindset and Highest Mathematics Course 111

Table 19. Grit Rubric for Determining Level of Mathematical Grit 113

Table 20. Sample Responses 115

Table 21. Parent Mathematical Mindset and Student Mathematical Grit..... 117

Table 22. A Comparison of Student General Grit and Student Mathematical Grit..... 120

LIST OF FIGURES

Figure I-1. Factors that influence student mathematics achievement. Solid lines indicate previously researched relationships. Dotted lines represent those connections missing in current studies. 3

Figure I-2. This study explored the relationship (if any) between parent mathematical mindset and student mathematical mindset, student mathematical achievement, and student mathematical grit. 5

Figure II-1. Entity theory and performance goals. This figure illustrates the causal relationship between entity theory and performance goals. 28

Figure II-2. Incremental theory and learning goals. This figure illustrates the causal relationship between incremental theory and learning goals. 29

Figure II-3. The characteristics of a fixed intelligence. An entity theorist pursues performance goals which lead to a helpless response to failure which in turn solidifies his belief in a fixed intelligence. 31

Figure II-4. The characteristics of a malleable intelligence. The incremental theorist pursues learning goals which lead to a mastery-oriented response to failure which in turn solidifies his belief in the expandability of intelligence. 31

Figure II-7. A relationship between mindset and grit as explained by Duckworth (2016). Grit and the growth mindset are highly correlated, but not the same constructs: the one-way arrows describe the way in which they are related. 46

Figure II-8. Factors that influence student mathematics achievement. Solid lines indicate previously researched relationships. Dotted lines represent those connections missing in current studies. 59

Figure III-1. Description of the participant selection process..... 65

Figure III-2. Description of the purpose of each phase of research..... 73

Figure IV-1. Spectrum of mathematics-specific mindset categories. 99

Figure IV-2. Distribution of general mindset to mathematical mindset for participants. The data displayed compares the adult/student numbers..... 100

Figure IV-3. Distribution of participant general mindset and participant mathematical mindset. Numbers inside data points represent the frequency of each general-mathematical mindset pairing. Most participants were F-FH or G-GH (red circles). Of note is the dispersion of participants with a general-growth mindset (dashed red lines)..... 101

Figure IV-4. A comparison of general mindset to mathematical mindset for participants.104

Figure IV-5. Weighted GPA system for HS1 and HS2. The source has been excluded to protect the privacy of the district. 107

Figure IV-6. Scatter plot comparing parent mathematical mindset to student overall GPA. Student GPA is shown on the x-axis, and parent mathematical mindset is shown on the y-axis. 108

Figure IV-7. Scatter plot comparing parent mathematical mindset to student SAT score. Student SAT score is shown on the x-axis, and parent mathematical mindset is shown on the y-axis. 110

Figure IV-8. A comparison of parent mathematical mindset to student highest mathematics course. 112

Figure IV-9. A comparison of parent general mindset to student highest mathematics course. 113

Figure IV-10. A comparison of parent mathematical mindset to student mathematical grit. 118

Figure IV-11. Scatter plot comparing student general grit to student mathematical grit. Student general grit is shown on the x-axis, and student mathematical grit is shown on the y-axis. 121

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DEDICATION

I would like to dedicate this dissertation to my students for continuing to question mathematics and mathematics practices and thereby making me a better educator, researcher, and mathematician.

CHAPTER I : INTRODUCTION

Need for Study

Conflicting beliefs concerning the acquisition of mathematical knowledge dichotomize our perception of mathematics. Is there a mathematics gene at the core of all mathematics success? Or is mathematics a learnable skill, a proclivity towards which depends on environmental circumstances? In other words, is mathematical ability fixed and bestowed by nature, or is it a mutable practice encouraged by nurture?

The malleability of intelligence is a lingering topic of debate amongst scholars. However, regardless of the outcome research has shown that what students *think* about intelligence has an enormous impact on their academic achievement (Aronson, Fried, & Good, 2002; Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 2000; Good, Aronson, & Inzlicht, 2003). Dweck (2006) classifies these implicit theories of intelligence as *mindset.* She uses mindset to describe one's thoughts about his or her intellectual potential. A fixed mindset, related to entity theory, is the belief that one's intelligence is immutable, i.e. an inherited and static trait. A growth mindset is significantly more flexible, and is aligned with incremental theory. Those with a growth mindset believe that intelligence can be improved upon by dedication and hard work. In relation to mathematics, one with a fixed mindset would likely believe in a mathematics gene, whereas one with a growth mindset would likely believe mathematics to be a learnable skill.

The *growth mindset* has been linked with increased levels of academic achievement: students with a growth mindset receive higher grades, are reported to enjoy and value academics more, have increased motivation, choose more positive, effort-based responses to failure, and

experience greater overall gains than those with a fixed mindset (Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007).

Mindset is also linked with resiliency and *grit*; specifically, growth mindset and grit are highly correlated (Duckworth, 2016). A term coined by Duckworth (2016), grit is the quality of being able to sustain your passions (or goals) over an extended period of time. Grit has emerged as both a significant predictor of – and essential for high – academic achievement (Duckworth & Gross, 2014; Duckworth, Peterson, Matthews, & Kelly, 2007; Rimfeld, Kovas, Dale, & Plomin, 2016). Additionally, grit has been shown to influence student engagement, retention, and matriculation (Duckworth & Quinn, 2009; Maddi, Matthews, Kelly, Villarreal, & White, 2012; Strayhorn, 2013; Wolters & Hussain, 2014).

Adult feedback practices have also been shown to affect student performance and resiliency (Blackwell et al., 2007; Dweck, 2008; Plaks & Stecher, 2007). People's reactions to positive and negative feedback depend on the expectations derived from their implicit theories of intelligence (Plaks & Stecher, 2007). Parents with fixed intelligence theories are more likely to view their child's intelligence as fixed and, as a result, are more likely to give their child praise that emphasizes product over process (Dweck, 2008; Mueller & Dweck, 1998). Additionally, parents' failure mindsets can predict their child's implicit theory of intelligence. Failure mindsets – the view that failure is either enhancing or debilitating – are separate from intelligence mindsets and play a role in parents' responses to their children's setbacks. Parents who view failure as debilitating communicate their beliefs through either verbal or behavioral cues; as a result, they tend to have children with fixed mindsets (Haimovitz & Dweck, 2016).

Thus, it has been shown that *student mindset, student grit,* and *parent feedback practices* affect students' mathematics achievement (Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007; Blackwell et al., 2007; Dweck, 2008; Plaks & Stecher, 2007; Duckworth & Gross, 2014; Duckworth et al., 2007; Rimfeld, Kovas, Dale, & Plomin, 2016). However, research has yet to show whether parent general mindset relates to student general mindset, student general grit, and student mathematics achievement.

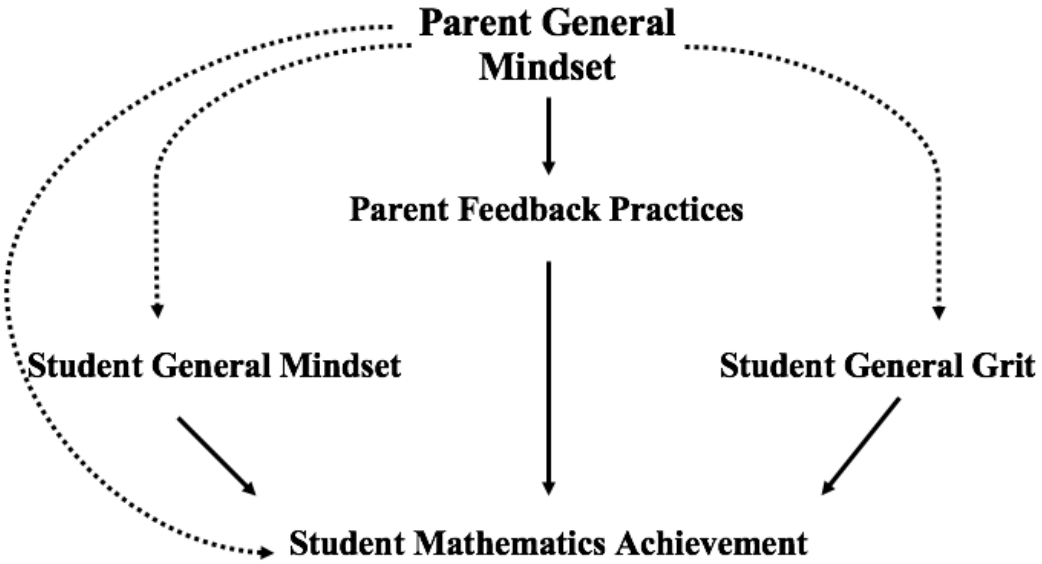

Figure I-1. Factors that influence student mathematics achievement. Solid lines indicate previously researched relationships. Dotted lines represent those connections missing in current studies.

The domain-specificity of mindsets is also a topic of contention in recent literature, for it is possible for people to have a more specific implicit theory within a particular domain (Yeager & Dweck, 2012); however, whether that specific theory is consistent or inconsistent with the general implicit theory is unclear. According to Molden and Dweck (2006), peoples' implicit

theories "serve as core assumptions that created a larger system of allied beliefs and goals" (p. 201). To that effect, one would expect one's general mindset to transcend different domains – for all subject-specific mindsets to be unified under a common theme. This universal theory of mindsets is supported by a study conducted by Hughes (2015) in which participants with fixed or growth mindsets held concurrent beliefs regarding other facets of intelligence. In stark contrast is the theory that mindsets fluctuate when applied to different domains; for instance, some studies have shown that mindsets can vary by subject, and are often influenced by pedagogical practices, classroom climate, and epistemological beliefs (Yeager & Dweck, 2012; Myers, Nichols, & White, 2003; Jonsson, Beach, Korp, & Erlandson, 2012; Altendorff, 2012; Rattan, Good, & Dweck, 2012; Paunesku, Yeager, Romero, & Walton, 2007; Buehl et al., 2002). Notably, those in favor of the variable mindset theory have yet to evince *why* a person who has internalized a certain mindset may not consistently apply it to all domains: why someone might have growth beliefs regarding general intelligence but fixed beliefs regarding mathematical intelligence.

This study examined mathematical mindsets specifically. According to Boaler (2016), having a mathematics-growth mindset is not only recognizing mathematics as a subject of growth, but having growth beliefs about the nature of mathematics and one's own role in it. In contrast, having a mathematics-fixed mindset is recognizing limitations in mathematical ability; the belief in a conceptual threshold that restricts one's intellectual progress in the subject. Markedly, mathematical mindsets have been targeted in recent studies with respect to incremental theory interventions (Rattan et al., 2012; Paunesku et al., 2007); however, mathematical mindsets were viewed as a subgroup of general mindset (e.g. as an instantiation of

general mindset rather than a separate entity), and the mathematical mindsets of participants were not analyzed.

This study considered how general mindset relates to mathematical mindset, and explored the relationship between parent mathematical mindset and student *mathematical experience*. By *mathematical experience*, I refer to three aspects: i) the student's mathematical mindset; ii) the student's mathematical achievement; and iii) the student's mathematical grit. "Student" in this study will refer to high school seniors, the rationale for which is discussed in the methodology section.

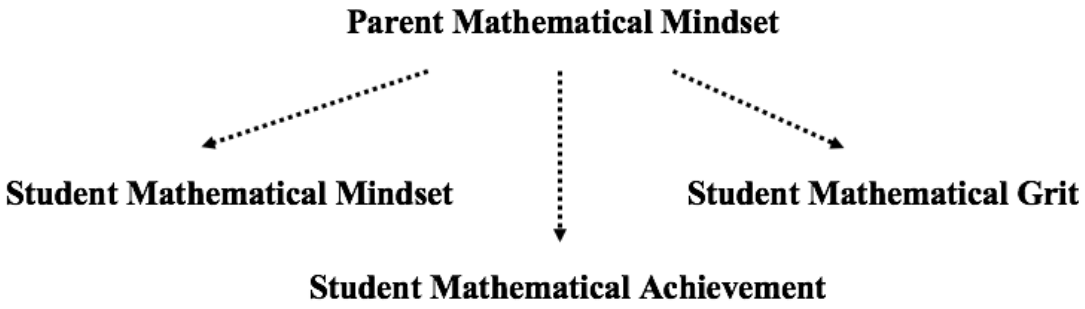

Figure I-2. This study explored the relationship (if any) between parent mathematical mindset and student mathematical mindset, student mathematical achievement, and student mathematical grit.

If it is determined that parent mathematical mindset relates to student mathematical mindset, student mathematical achievement, and student mathematical grit, then interventions – such as those pertaining to incremental theory, feedback practices, or resilience training – can be used to teach parents how to positively influence their student's mathematical achievement.

Incremental theory interventions have been shown to have positive effects on academic achievement; students receive higher grades, have increased intrinsic motivation, stronger

learning goals, more positive beliefs about effort, and were reported to enjoy academics more (Hong, Chu & Dweck, 1995; Dweck, 2000; Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007). If it is found that parent mathematical mindset relates to student mathematical mindset, then interventions aimed at teaching parents the incremental view of mathematical intelligence may produce similar results.

Additionally, adult praise of ability or effort emanates powerful messages to students (Dweck, 2000). Parents with fixed intelligence theories are more likely to praise ability (Dweck, 2008). Teaching parents an incremental theory of mathematical intelligence may result in a change in their feedback practices towards their praising effort over ability. Praise for effort can promote effort attributions, learning goals, and an incremental view of intelligence, resulting in higher achievement motivation and positive postfailure striving (Diener & Dweck, 1980; Mueller & Dweck, 1998).

Further, since parents' views of failure are visible to their children, parents who view failure as debilitating convey to their children that intelligence is fixed (Haimovitz & Dweck, 2016). Resilience training for adults can be used to combat their learned helpless response to failure that is communicated to their children through verbal or behavioral cues.

Finally, although anxiety can be evoked in all subjects, mathematics anxiety can be more severe – and affect performance more – than other subjects (Punaro & Reeve, 2012; Dowker, Sarkar & Looi, 2016). If parents can be taught to view mathematics as a conceptual domain (i.e. taught a mathematics-growth mindset), then it is likely that their student's mathematics anxiety could dissipate and their performance in mathematics could improve.

Purpose of Study

The purpose of this study was to explore the internal consistency between general mindset and mathematical mindset, as well as to determine the relationship between parent mathematical mindset and (1) student mathematical mindset, (2) student mathematics performance, and (3) student mathematical grit. The research questions are as follows:

1. What relationship exists, if any, between general mindset and mathematical mindset for high school seniors and their parents or guardians?

2. What relationship exists, if any, between high school seniors' mathematical mindsets and their parents' or guardians' mathematical mindsets?

3. What relationship exists, if any, between high school seniors' mathematical achievement and their parents' or guardians' mathematical mindsets?
4. What relationship exists, if any, between high school seniors' mathematical grit and their parents' or guardians' mathematical mindsets?
    a. What relationship exists, if any, between general grit and mathematical grit for high school seniors?

Procedure

The research followed a hermeneutical phenomenological approach (Creswell, 2015) – a qualitative research methodology characterized by finding meaning through the subjective interpretation of participants – in which the phenomena to be studied were *consistency of mindsets across specific domains* and *student mathematical experience*. The specific domain to which general mindset was compared was mathematical mindset. By *mathematical experiences,* I refer

to three aspects: i) the student's mathematical mindset; ii) the student's mathematical achievement; and iii) the student's mathematical level of grit.

There were two phases to this study. The purpose of Phase 1 was to collect quantitative data to determine general parent mindset and student mathematics performance. The purpose of Phase 2 was to determine general student mindset, general student grit, and to collect qualitative data to determine the mathematical mindsets of all participants as well as the mathematical grit of students. Relationships were examined between (1) general mindset and mathematical mindset for all participants, (2) parent mathematical mindset and student mathematical mindset, (3) parent mathematical mindset and student mathematical achievement (as measured by GPA, SAT score, and highest level mathematics course taken), and (4) parent mathematical mindset and student mathematical grit. A relationship was also examined between general grit and mathematical grit for students.

Participants. The term "participant" refers to both parents and students. "Parents" will be used when referring to parents only. "Students" will be used when referring to students only.

The study took place at two high schools in the same district of an affluent suburban city in the northeast where the researcher is currently a teacher. Stratified and purposeful sampling was used to select high school seniors from the class of 2018 and their active parents or guardians. A parent was considered "active" in a student's life if he or she lived with the student in some capacity. If both parents were active in the student's life then both were asked to participate in the study. If a parent was inactive or deceased, he or she was excluded from the study. A step parent

or other primary guardian was likewise asked to participate if he or she was active in the student's life.

In Phase 1 of the study, Dweck's (2000) 8-item Adult Mindset Survey was sent out electronically to all registered parents of high school seniors using the online Qualtrics tool. The researcher determined the general mindset of each parent (and their active spouse – if applicable) using the mindset scale (fixed, neutral, growth) described in the studies in which it was validated (Levy, Stroessner & Dweck, 1998; Hong et al., 1995). Families were excluded if it was determined that the parent mindsets were different (fixed vs. growth).

All single-parent families were invited to participate in Phase 2 of the study: there were four single-parent families. For those families with two active parents, if both parents had the same mindset (fixed-fixed, growth-growth, fixed-neutral, and growth-neutral) then those families were invited to participate in Phase 2 of the study: 10 such families qualified. As part of Phase 2, all participants (adult and student) were interviewed by the researcher. Interviews were conducted on an individual basis.

Data Collection. Both quantitative data and qualitative data were collected to explore the relationship between (1) general mindset and mathematical mindset and (2) parent mathematical mindset and student mathematical experience. Quantitative data were collected first using three validated surveys (Dweck's (2000) 8-item Parent Mindset Survey, Dweck's (2000) 6-item Student Mindset Survey, and Duckworth and Quinn's (2009) 8-item Grit-S Scale) and one Student Demographic Survey. The results of the surveys served as a baseline for further qualitative analysis. Specifically, the mindset and grit surveys were used as a baseline measure of general implicit theory of intelligence (i.e. fixed, neutral, or growth mindset) and general grit

(i.e. very gritty, fairly gritty, moderately gritty, or not gritty) respectively, and the Student Demographic Survey served to collect information pertaining to the student's mathematics achievement (e.g. current overall GPA, highest mathematics SAT section score, highest level mathematics course taken). Qualitative data were then collected vis-à-vis individual interviews with each participant. The purpose of each interview was to identify the mathematical mindset of every participant, as well as the mathematical grit of students. Additionally, the purpose of each interview was to explore the extent to which parent mathematical mindsets relate to the mathematical experiences of students.

Data Analysis. Both quantitative and qualitative data were used to address the research questions. The surveys collected quantitative data pertaining to general mindset, general student grit, and student mathematical achievement (as measured by current overall GPA, highest score on the mathematics section of the 2017 SAT examination, and highest level mathematics course taken). Qualitative analysis from interviews were used to determine the mathematical mindset of all participants, and the mathematical grit of students. Tests were then run through SPSS to determine if relationships existed between (1) participant general mindset and participant mathematical mindset, (2) parent mathematical mindset and student mathematical mindset, (3) parent mathematical mindset and student overall GPA, (4) parent mathematical mindset and student SAT score, (5) parent mathematical mindset and the student's highest level mathematics course taken, (6) parent mathematical mindset and student mathematical grit, and (7) student general grit and student mathematical grit.

Research question 1. To address RQ1, data were collected from both the Parent

Mindset Survey and the Student Mindset Survey regarding general mindset: participants were assigned either a general-fixed mindset, general-neutral mindset, or general-growth mindset as determined by their mindset score. Each participant (parent and student) was then interviewed individually. As part of the interview protocols, participants were asked questions regarding their mathematical experiences. Some questions targeted mathematics-fixed mindsets, while others targeted mathematics-growth mindsets. Depending on the response to these questions, the researcher assigned a mathematics-growth-high, mathematics-growth-low, mathematics-fixed-high, or mathematics-fixed-low mindset to each participant. Once the mathematical mindset of each participant was determined, a graph was created to compare general mindset to mathematical mindset. Additionally, a Spearman's Rho correlation was run in SPSS to determine the association between the two ordinal variables general mindset and mathematical mindset. Participant interviews were then incorporated to expand upon the quantitative results of the test.

Research question 2. To address RQ2, a distribution graph was created to determine the association between parent mathematical mindset and student mathematical mindset. Participant interviews were then incorporated to expand upon the quantitative results of the test.

Research question 3. To address RQ3, two scatter plots with linear regression trend lines were created to determine the association between parent mathematical mindset and student overall GPA, and parent mathematical mindset and student highest mathematics section score on the 2017 SAT examination. Two t-tests were then run in SPSS to determine if the

correlation coefficients from the two simple regressions were statistically significant. A graph depicting the distribution of data was used to determine the association between parent mathematical mindset and student highest level mathematics course taken.

Research question 4. To address RQ4, data were collected from the Grit-S Scale to determine the general grit of students (not gritty, fairly gritty, moderately gritty, and very gritty). As part of the interview protocol for students, students were asked questions regarding their mathematical grit. Based on their responses to these questions, the researcher assigned each student a mathematical level of grit (not mathematically gritty, fairly mathematically gritty, moderately mathematically gritty, and very mathematically gritty). A graph was created to determine the association between the two ordinal variables. Participant responses from interviews were then used to explain the relationship observed from the graph. Additionally, a scatter plot with a linear regression trend line and a Spearman's Rho correlation were used to determine the association between the two ordinal variables student general grit and student mathematical grit.

Analysis from Open, Axial, and Selective Coding. Interviews were coded to (1) determine the mathematical mindset of each participant and the mathematical grit of students, and (2) to qualitatively describe the essence of the relationship (if any) between parent mathematical mindset and student mathematical experience.

First, a priori codes were used in the process of open coding done at the beginning of data analysis; the researcher used results from previous studies and measures of the present study to

create a list of predetermined codes. Much of determining mathematical mindsets and mathematical grit resulted from the process of coding participants' statements with a priori codes.

Second, during the process of axial coding, emergent codes actively evolved from participants' statements regarding their mathematical experiences. These codes emerged as the researcher searched for a relationship between parent mathematical mindset and student mathematical experience, and were needed in cases where a priori codes were insufficient in describing data. As they developed, the researcher established hierarchical relationships between new and existing codes. Some were delegated as a main category or theme while others were deprioritized as subcategories.

Finally, at the end of data analysis – during the selective coding process – the researcher synthesized the results from coding to better describe the relationship between parent mathematical mindset and student mathematical experience.

CHAPTER II : LITERATURE REVIEW

> "Your beliefs become your thoughts, your thoughts become your words, your words become your actions, your actions become your habits, your habits become your values, your values become your destiny." – Mahatma Gandhi

This chapter is composed of three major sections: i) views of intelligence; ii) implicit theories of intelligence; and iii) parent mindset and student academic achievement.

In the first section, I discuss the many attempts to measure intelligence psychometrically, the many definitions and interpretations of intelligence, and arguments for the plasticity of intelligence.

In the second section, I describe two divergent implicit theories of intelligence (entity theory and incremental theory) and the goals, attributions, and patterned responses to failures that are associated with them. Additionally, I present growth mindset and fixed mindset as the more contemporary terms for incremental theory and entity theory, respectively. Finally, I introduce grit as an indicator of resiliency and a reliable predictor of engagement and retention, and discuss the association between grit and the growth mindset (Duckworth, 2016).

In the third and final section, I discuss the impact that adult feedback practices and praise for ability or effort can have on student achievement and motivation. I then present results from previous studies which identify student mindset, student grit, and parent feedback practices as influencers of student academic achievement. Finally, I introduce mathematical mindset, and present a rational for the need to investigate the relationship (if any) between parent mathematical

mindset and student mathematical mindset, student mathematical achievement, and student mathematical grit.

Views of Intelligence

In this section, I discuss the evolution of attempts to understand intelligence. I introduce Binet and Simon (1916) as pioneers in intelligence testing. I then elaborate on the ways in which different techniques in factor analysis have been used to support either a singular intelligence (Spearman, 2004) or multiple intelligences (Thurstone, 1934; Thurstone, 1973; Cattell, 1971; Vernon, 1971; Guilford, 1932; Gardner, 2011). Additionally, I discuss the many attempts to define intelligence (e.g. as the g factor or as an entity more social in origin) (Neisser, 1997; Lave, 1988; Vygotsky, 1978).

I end this section by presenting studies in favor of a malleable intelligence (Diamond, Barnett, Thomas & Munro, 2007; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Ericsson, Charness, Feltovich, & Hoffman, 2006; Maguire et al., 2000; Karni et al., 1998).

Measuring Intelligence

To better understand *mindset*, one must first understand *intelligence* and the active debate that surrounds it. Intelligence is an evolving mental construct that has been redefined by psychologists in a myriad of ways in the past century. The often-controversial discourse surrounding this intangible entity has centered on a variety of facets regarding the nature of intelligence itself. Much of the discussion and evidence is conflicting and, at times, even contradictory, producing a wide range of psychological explanations regarding the essence of intelligence.

At the center of the theoretical discord is the attempt to measure intelligence

psychometrically: "intelligence has been defined to a large extent by the tests designed to measure it" (Suzuki, 2005, p. 321). In 1905, Binet and Simon produced a series of mental scales that assessed a variety of cognitive functions (Binet & Simon, 1916). They understood intelligence to consist of diverse components; thus, their collection of 30 cognitive tests measured several aspects of intelligence like language skills, memory, reasoning, digit span, and psychophysical judgements (Boake, 2002). In the search for a child's "mental age," the intelligence tests were administered to Paris school children with the aim of distinguishing those who were below "normal" (Boake, 2002). The Intelligence Quotient (IQ), as it was originally conceived, was not a measure of intelligence as a fixed entity, but rather a reflection of one's ability at that moment in time. The intention was to identify those students who were not "thriving" so that they could receive the help they needed (e.g. interventional educational programs) to "blossom intellectually" (Dweck, 2000). Although the tests established by Binet and Simon later became the structural model and source of content for future intelligence tests, their interpretation of the IQ score was not always shared (Boake, 2002).

"In psychometrics, the concept of general intelligence derives from the observation of ubiquitous positive correlations among different kinds of cognitive tests" (Duncan et al., 2008, p.132). Psychologists relied heavily on statistical analysis to decipher results; they used factor analysis to explain the meaning behind positive correlations between scores on various intelligence tests. "Among the models based upon factor analysis, one line of demarcation goes between models which postulate a general factor of intelligence … and models which do not allow for a general intellectual factor" (Gustafsson, 1984, p.179).

Singular Intelligence. Spearman (2004) created the Tetrad Difference method to examine a general factor of intelligence called "g" to which he attributed the reason behind such correlations (Gustafsson, 1984). He stipulated that this underlying factor of intelligence signified one's capacity to make conceptualizations and to problem solve (Gardner, 2011); in other words, it is the sole factor responsible for success in all cognitive activities (Duncan et al., 2008).

To support this singular view of intelligence, some psychologists explored the biological bases behind cognitive functioning. Duncan et al. (2000) used positron emission tomography (PET) to map the brain regions involved when performing various intellectual functions. They found a neural basis for Spearman's g in the localized results of the cognitive functioning of the brain; specifically, the brain regions utilized during both high- and low-g tasks were not diversely distributed but, rather, predominately processed in the frontal cortex of both hemispheres.

This is not the first time a biological brain basis for the singularity of intelligence has been proposed. Rather, Jensen (1980) and Eysenck (1981) attributed intelligence to properties of the nervous system and argued that it can be measured psychometrically using electrophysiology (Gardner, 2011).

Multiple Factors of Intelligence. In contrast is the statistical justification for multiple factors of intelligence, an interpretation that in and of itself is multifaceted. Thurstone (1934) referenced the fundamental factor theorem from mathematics as justification for there being multiple factors of intelligence. He used factor theory on correlations from tests to isolate independent "primary abilities" (Thurstone, 1934; Thurstone, 1973). He created a new, refined form of statistical analysis so that he could simultaneously justify the presence of Spearman's g

along with seven other specific abilities (Gustafsson, 1984). According to Thurstone, these diverse components of intelligence are equivalent members of a heterarchical system (Gardner, 2011).

As the plurality view of intelligence gained popularity, psychologists once again found themselves at a crossroads regarding how to relate the multiple factors (Gardner, 2011). "Another line of demarcation goes between hierarchical models … and models which treat all the dimensions as being of equal generality" (Gustafsson, 1984, p. 179). Rather than partitioning and equating the factors of intelligence as Thurstone had done, Cattell (1971) used factor analysis to establish a relationship between the factors that was neither independent nor mutually exclusive. In his Ability Dimension Analysis Chart (ADAC) he outlined a hierarchical association among three main intelligence domains, the dimensions within them, and a sub-level of second-order factors (Cattell, 1971; Merrifield, 1975).

Vernon (1971) similarly used factor analysis to classify a hierarchical arrangement of mental abilities. He categorized the positive correlations from performances on tests into general classes of cognition, to which he then divided into various sublevels of ability, each representing narrower ranges (Merrifield, 1975).

Guilford (1982), perhaps to methodize the multiple factor paradigm, proposed in his Structure of Intellect (SI) model an open system consisting of three main classifications: five categories of informational content, five categories of mental operations, and six categories of products (Gustafsson, 1984). Although his system could account for as many as 150 factors of intelligence, the model was expandable: if found, a new category could be incorporated into any of the three (Guilford, 1982).

Gardner (2011) was a pluralist who based his theory of Multiple Intelligences (MI) not on correlations from tests – as many of his predecessors had done – but on neurological, evolutionary, and cross-cultural information. Additionally, he did not just examine "normal" children and adults, as his predecessors did; rather, he included work with gifted students and savants (Neisser et al., 1996).

To better explain the organization of human abilities in the mind, Gardner posited that there were seven intelligences (or innate intellectual proclivities) that operate in domains (disciplines, crafts, and other pursuits) and fields (sociological constructs) (Gardner, 2011). In his theory, Spearman's g is acknowledged; however, it is regarded as equal to all the other intelligences. Further, the intelligences do not work in isolation; rather, several intelligences are often activated when performing in a single domain. Additionally, although the intelligences are neurobiological, the successful performance in a domain can be influenced by environmental factors, namely the reception of a field (Gardner, 2011). In other words, there are both biological and social components to intelligence.

Defining Intelligence. Far from a denouement, the definition of intelligence continues to be debated amongst psychologists, particularly because each contributor uses a different definition of intelligence as the backbone to his or her argument. Further, certain models of intelligence – particularly the traditional one – have been criticized as a cause of educational and societal problems (Sternberg, 1988).

Many psychometricians define intelligence as the g-factor from a variety of mental tests:

> In any test battery, the test that best measures g is - by definition - the one that has the highest correlations with all the others. The fact that most of these…tests typically involve

> some form of abstract reasoning led Spearman and his successors to regard g as the real and perhaps genetically determined essence of intelligence. (Neisser, 1997, p. 440)

However, psychologists even differ in their interpretation of g; for instance, it has been described as mental energy, a statistical trend, ability in abstract reasoning, and neural-processing speed – to name a few (Neisser et al., 1996). Additionally, average IQ scores are on the rise worldwide – a phenomenon that is too rapid to be explained by genetic changes; as a result, other psychologists have turned towards environmental changes – like those that have occurred in schooling, child-rearing practices, and nutrition – to explain the essence of intelligence (Neisser, 1997).

Consequently, many psychologists define intelligence as social in origin. Neisser (1979) depicted intelligence as a cultural invention, a fluctuating concept that varies as values do from culture to culture. In this regard, intelligence is not independent from culture. Similarly, in an attempt to explain practical intelligence, Lave (1988), a social anthropologist, examined relations between cognition, practice, culture and society to explain differences in intelligence. Finally, for developmental psychologists, intelligence can be viewed as a progression. Vygotsky believed that intelligence tests did not adequately measure a child's "mental age" because they failed to consider the Zone of Proximal Development (ZPD) in which a child can succeed in a task with help from a supportive adult (Vygotsky, 1978).

The Malleability of Intelligence. Research from the fields of cognitive psychology and cognitive neuroscience has emerged which demonstrates that aspects of intelligence can be altered through training (Dweck, 2008). Diamond et al. (2007) found that preschool children trained under the *Tools* curriculum – an executive functioning program

modeled after Vygotsky's insights into cognitive control – experienced gains in intellectual ability. Furthermore, they found executive functioning skills, especially self-discipline, to be a better predictor of academic achievement than IQ (Diamond et al., 2007).

Cattell and Horn (1978) developed a theory to account for the malleability of intelligence in which the general factor, g, of intelligence is split into two distinct concepts: *fluid intelligence* and *crystallized intelligence*. Fluid intelligence refers to the ability to reason and solve new problems independently of existing knowledge (Jaeggi et al., 2008). In fluid intelligence, analytic ability is accentuated (Cattell & Horn, 1978). In contrast, crystallized intelligence is the set of critical skills gained from applying fluid intelligence in a cultural context; in other words, it is the knowledge accumulated by an individual (Cattell & Horn, 1978; "General Intelligence Consists," 2012).

> The notion is that over the extended periods of life-span development the many influences that promote incorporation of the intelligence of a culture work in loose harmony to produce the broad patterns of abilities of Gc [crystallized intelligence], while many influences related to incidental learning and associated with neurophysiological health represent a unity that binds together a broad pattern of abilities seen in Gf [fluid intelligence]. (Cattell & Horn, 1978, p. 140)

Based on Cattell and Horn's (1978) depiction, fluid intelligence is genetically endowed, an aspect of inheritance that accounts for individual differences in intellectual ability. However, since fluid intelligence is essential to learning and is attributed to both academic and professional success, attempts have been made to try to increase it – such as through pharmacological means or via the cognitive tasks required in video games – but to no avail (Jaeggi et al., 2008).

Nonetheless, many argue that fluid intelligence and working memory are strongly related due to the attentional control involved in both skills; further, exploiting this link might increase fluid intelligence. In fact, Jaeggi et al. (2008) found that adults trained with a demanding working memory task could increase their fluid intelligence. The gains were found regardless of participants' individual pre-existing differences in fluid intelligence, which suggests that any individual can increase his fluid intelligence given the proper task regardless of his range of cognitive skills. Furthermore, the amount of time spent training was directly related to the gains in fluid intelligence (e.g. the more training the greater the gain); in other words, it is not a "threshold phenomenon" (Jaeggi et al., 2008).

Additionally, studies of geniuses revealed that intrinsic talent alone does not sufficiently account for comparative gains in their field, supporting the emerging trend that intelligence can be altered through training (Ericsson et al., 2006). Specifically, Ericsson et al. (2006) revealed that deliberate practice is what sets geniuses apart. They further argued that genius is something developed over time through focused, extended effort (Ericsson et al., 2006), a finding that bolsters the popular Thomas Edison proverb, "genius is one percent inspiration, ninety-nine percent perspiration."

Finally, "studies conducted with Black Cab drivers [in London]…showed a degree of brain flexibility, or plasticity…This led to a shift in the scientific world in thinking about learning and 'ability' and the possibility of the brain to change and grow" (Boaler, 2016, p.3). Maguire et al. (2000) examined the structural MRIs of the brains of Black Cab drivers (people with extensive navigational experience) and control subjects (people who were not taxi drivers). They found differences in the anterior and posterior hippocampal regions of the brain; primarily, the size of

the hippocampus in the posterior and anterior regions correlated with the amount of time spent as a taxi driver (positively in the posterior, and negatively in the anterior). Since one of the many roles of the hippocampus is to store spatial memory (e.g. spatial representations of the environment), their research suggests a plasticity of the hippocampus that is dependent on environmental demands.

Emerging evidence of the brain's ability to grow, adapt, and change in response to environmental factors further supports the idea of a malleable intelligence. In fact, in their study, Karni et al. (1998) provided behavioral and fMRI evidence of the fast acquisition of skilled motor performance. In response to a 10-minute mental task repeated daily over 15 weekdays, the brains of participants grew and "rewired." The structural brain changes that occurred in the primary motor cortex show that minimal training experience is sufficient to precipitate gains in performance.

> We propose that skilled motor performance is acquired in several stages: "fast" learning, an initial, within-session improvement phase, followed by a period of consolidation of several hours duration, and then "slow" learning consisting of delayed, incremental gains in performance emerging after continued practice. This time course may reflect basic mechanisms of neuronal plasticity in the adult brain that subserve the acquisition and retention of many different skills. (Karni et al., 1998, p. 861)

The potential for the brain to grow – in as little as three weeks – suggests a need for dramatic changes in pedagogical practices to take advantage of the core principle that everyone can learn.

Implicit Theories of Intelligence

In this section, I describe two implicit theories of intelligence: entity theory and incremental theory. I present studies that link entity theory with performance goals, ability attributions, and a helpless response to failure (Farrell & Dweck, 2000; Grant & Dweck, 2003; Mangels, Butterfield, Lamb, Good & Dweck, 2006). Concurrently, the same studies link incremental theory with learning goals, effort attributions, and a mastery-oriented response to failure.

I then elaborate on a study which demonstrates that implicit theories of intelligence can be influenced by external factors (Dweck & Leggett, 1998), and cite three studies in which incremental theory interventions had positive effects on academic achievement (Blackwell et al., 2007; Aronson et al., 2002; Good et al., 2003).

Additionally, I discuss the development of effort and ability attributions from a young age to adolescence (Schunk, 1996, Blackwell et al., 2007). I justify the use of high school students in my study on the premise that (i) it isn't until adolescence that children make significant distinctions between ability and effort (Schunk, 1996), and (ii) a student's theory of intelligence doesn't affect academic achievement until adolescence (Blackwell et al., 2007). I then describe how attributions can be used to modify behavior (Miller, Brickman & Bolen, 1975).

Finally, I introduce growth mindset as the more current term for incremental theory, and fixed mindset as the contemporary term for entity theory. I introduce grit and discuss studies which identify mindset and grit as indicators of academic outcomes (Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007; Duckworth & Quinn, 2009; Maddi et al., 2012; Strayhorn, 2013; Wolters & Hussain, 2014). I end the section with an explanation of the highly correlated relationship between grit and the growth mindset (Duckworth, 2016).

Thoughts About Intelligence

The malleability of intelligence continues to be a lingering topic of cogitation amongst scholars. And, in fact, a major tenet to my study is the belief that intelligence is malleable. However, although there is compelling evidence that intelligence can be expanded, there is likely a limit to its plasticity (Sternberg, 1996; Aronson et al., 2002). Yet, regardless of the outcome, research has shown that what students *think* about intelligence has an enormous impact on their academic achievement (Aronson et al., 2002; Blackwell et al., 2007; Dweck, 2000; Good et al., 2003).

> Implicit theories of intelligence are beliefs about the fundamental nature of intelligence, specifically whether intelligence is a fixed entity that cannot be changed (an *entity* theory) or a malleable quantity that can be increased through one's efforts (an *incremental* theory). (Hong et al., 1995, p.198)

Implicit theories of intelligence are statistically independent from known predictors of achievement – such as general intelligence and self-efficacy (Plaks & Stecher, 2007), and have been shown to shape students' (1) goals (performance goals vs. learning goals), (2) beliefs about effort (effort as the key to success or a sign of low intrinsic talent), (3) attributions (ability attributions vs. effort attributions), and (4) learning strategies (the helpless vs. mastery-oriented response to failure) (Yeager & Dweck, 2012). Implicit theories of intelligence are also distinct from implicit theories of personality; for instance, "it is possible for a student to believe that intelligence can change but personality cannot" (Yeager & Dweck, 2012, p.303-304).

Entity Theory. A student's implicit theory of intelligence can affect his self-

esteem and his response to academic challenges (Hong et al., 1995; Dweck, 2000; Blackwell et al., 2007). For the entity theorist, self-esteem is at the peril of performance: it flourishes with success and diminishes with failure (Dweck, 2000). As a result, he will choose less challenging tasks where success is more likely to be achieved (Blackwell et al., 2007).

The entity theorist, being overwhelmingly consumed by his performance, pursues *performance goals*: his motivation behind completing a task is to receive a high grade for he perceives the outcome of a task as measuring his limited capacity (i.e. his intelligence or ability). Upon receipt of a high grade, he will continue to receive higher grades; however, when given a low grade he will continue to receive lower grades because he credits the poor performance to his low, fixed intelligence that cannot be improved (Grant & Dweck, 2003).

His concern with appearing smart may ultimately prevent him from seeking learning opportunities in the future; he is less likely to try something new due to the potential risk of making errors. When in need of remedial work, he is likely to avoid it; despite wanting to perform well, he views effort as futile – since intelligence cannot change – and will do his best to minimize it, for he perceives the requirement of effort as a sign of low intelligence (Dweck, 2000). In other words, he will experience withdrawals in both time and effort when faced with a setback (Grant & Dweck, 2003).

To the entity theorist, an IQ score is the ultimate measure of his fixed intellectual ability; it determines his innate aptitude. However, Binet, as an incremental theorist, would disagree with such a pessimistic outlook. Binet believed that intelligence could be increased: that it could be nurtured given the appropriate educational assistance (Dweck, 2000). In this regard, an IQ score is simply a measure of one's ability at that moment in which the test was administered, and not an

indicator of one's overall potential. Although he acknowledged individual differences in intellect, he maintained that with practice we could become more intelligent (Dweck, 2006).

Incremental Theory. Many incremental theorists define intelligence as a person's skills and knowledge: something that can be cultivated through learning (Dweck, 2000). As a result, effort is not denigrated as a weakness but valued as a conduit for success. The incremental theorist pursues *learning goals* and is motivated by mastering new things. After a poor performance, a learning goal enthusiast is likely to make effort attributions (e.g. "I need to study more) over ability attributions (e.g. "I'm not smart enough") and will likely persist to the point of improvement (Grant & Dweck, 2003).

Performance Goals vs. Learning goals. The motivational goal (i.e. performance or learning) that a child pursues shapes his response to success and failure (Dweck, 1986). In a study conducted by Farrell and Dweck (1985), junior high school students were taught new material and then tested on novel problems (e.g. problems that were new but required the same principle taught in the lesson). Students who had learning goals received higher scores, worked harder when confronted with a challenge, and were more likely to try to apply the new principle they had learned (Farrell & Dweck, 1985). Other studies reported similar findings: students with learning goals engaged in more profound processing of course material, as well as applied deeper and more effective strategies to solve a problem (Ames & Archer, 1988; Dweck, 2000; Grant & Dweck, 2003).

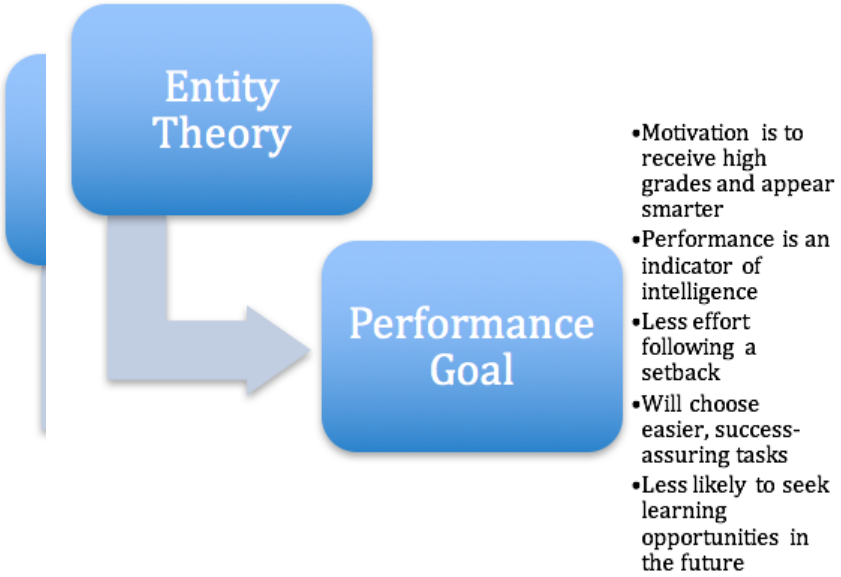

Figure II-1. Entity theory and performance goals. This figure illustrates the causal relationship between entity theory and performance goals.

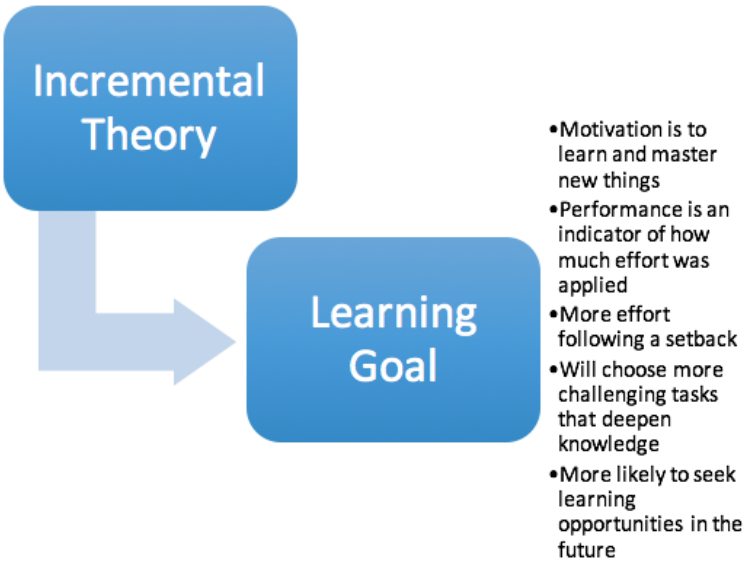

Figure II-2. Incremental theory and learning goals. This figure illustrates the causal relationship between incremental theory and learning goals.

The Helpless and Mastery-Oriented Responses to Failure. Research attributes implicit theories of intelligence to how students handle setbacks or failure (Blackwell et al., 2007; Dweck, 2000; Dweck & Leggett, 1988; Heine et al., 2001). "Those holding an entity (or fixed) theory are particularly likely to draw conclusions about their ability (vs. effort) from setbacks and to give up more readily when faced with difficulty, as compared with those holding an incremental (or malleable) theory" (Rattan et al., 2012, p.731).

There are two diverging responses to failure: the *helpless* pattern and the *mastery-oriented* pattern (Dweck, 2000). Students with the helpless response experience failure as out of their control, and attribute it to lack of ability; in other words, they make ability attributions. Those with the mastery-oriented response attribute failures to more modifiable factors – like lack of effort; in other words, they make effort attributions (Diener & Dweck, 1980).

In a study conducted by Diener and Dweck (1980), fifth- and sixth- grade students were given a series of conceptual problems to solve, the final four of which were unsolvable at their

present ability level. When faced with failure, more than a third of those students who exhibited the helpless pattern denigrated their intellectual ability; none of those students who exhibited the mastery response did so.

Furthermore, not only did the helpless group lose faith in their abilities, but they also lost perspective on the successes they had achieved on previous questions. For instance, there were eight problems that were solved correctly, and only four that were not. However, those students with the helpless response overemphasized their failures: they were so discouraged that they recalled more failures than successes. Far from doubting their intelligence, those students with the mastery-oriented pattern used self-motivating techniques that gave way to an optimist prediction regarding their ability to improve; ultimately, they embraced failure.

In their study with college students, Grant and Dweck (2003) linked learning goals with a history of mastery-oriented indicators (e.g. sustained intrinsic motivation, planning and persistence) and coping mechanisms (e.g. active coping and planning in response to setbacks). Additionally, they found that low-ability attributions were associated with drops in intrinsic motivation and loss of self-worth. Performance goals produced a susceptibility to helplessness and debilitation in the face of a challenge or a setback. In contrast, students with learning goals engaged in less time and effort withdrawal and sought positive reinterpretations and growth; quite uniquely, their perseverance made them more likely to rebound when faced with failure (Farrell & Dweck, 2000; Grant & Dweck, 2003; Mangels et al., 2006). Thus, entity theorists exhibit the helpless pattern whereas incremental theorists display the mastery-oriented pattern.

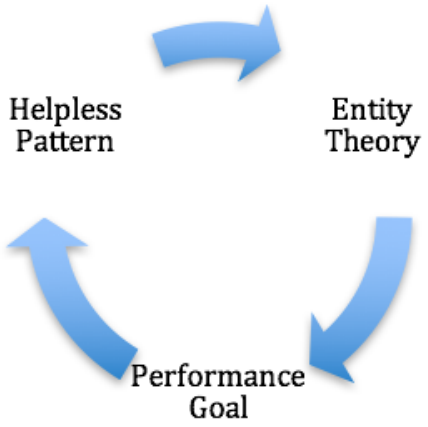

Figure II-3. The characteristics of a fixed intelligence. An entity theorist pursues performance goals which lead to a helpless response to failure which in turn solidifies his belief in a fixed intelligence.

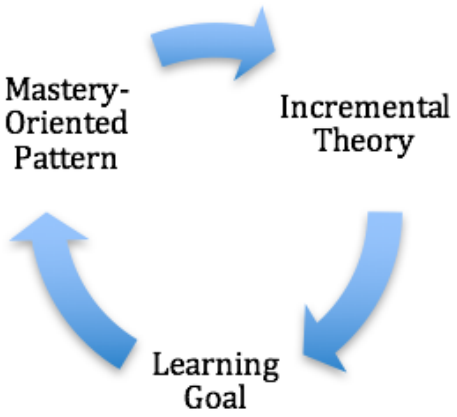

Figure II-4. The characteristics of a malleable intelligence. The incremental theorist pursues learning goals which lead to a mastery-oriented response to failure which in turn solidifies his belief in the expandability of intelligence.

Mangels et al. (2006) used event-related potentials (ERPs) to investigate how a student's beliefs and goals can influence attention to information associated with error correction. Entity theorists geared towards performance goals are concerned with proving their ability with respect to others. Following negative feedback on tests of general knowledge, Mangels et al. (2006) found that these students responded differently compared to incremental theorists, suggesting a difference in the cognitive-neural orientation of the brain. Further, as failures were corrected entity theorists were less likely to engage in sustained semantic processing when learning opportunities presented themselves; as a result, incremental theorists demonstrated significantly greater gains in knowledge. This suggests that a student's beliefs and reactions to failure can influence his learning success by manipulating his attention and conceptual processing (Mangels et al., 2006).

This is not the only instance where differences in implicit theories of intelligence affected attentional processing. In a study with undergraduate students, Plaks, Grant, and Dweck (2005) used stereotypical character profiles (e.g. the mathematics student who is a poor writer) to gauge participant response to incongruent information. They found that both groups (i.e. the entity theory group and the incremental theory group) exhibited selective processing for theory-violating information (e.g. a poor reader increasing his score on the verbal section of the SAT through deliberate practice is contrary to the entity view). In other words, participants responded faster to information congruent to their beliefs: they attended to consistencies over inconsistencies. "The present research suggests that people not only consider a behavior's consistency with a stereotype – they also consider its consistency with their theory of personality" (Plaks et al., 2005, p. 253).

It is important for one to experience confirmation of his beliefs about intelligence (Plaks et al., 2005). Differences in implicit theories of intelligence result in differences in attentional emphasis for expectancy-confirming and expectancy-disconfirming information (Plaks, Stroessner, Dweck & Sherman, 2001). Although entity theorists (much more than incremental theorists) display more attentional engagement towards stereotype-confirming information than stereotype-disconfirming information, both theorists will exhibit defensive processing (e.g. a desire to ignore or debunk inconsistent information) if the feedback from information is received negatively (Plaks et al., 2001).

Incremental Theory Interventions. Even if intelligence itself is not malleable, people's implicit theories of intelligence are (Dweck, 2000). In a study reported by Dweck and Leggett (1988), fifth-graders were divided into two groups and instructed to read a passage containing a story about a historical figure (e.g. Albert Einstein, Helen Keller) and his or her accomplishments written from the perspective of either an entity theorist or an incremental theorist. Later, those students were given the choice to choose a task on which they'd like to work. Students who read the incremental theory passage were more likely to choose the learning goal task because they wanted to *get smarter*. Students who read the entity theory passage were more likely to choose the performance goal (and easier) task because they wanted to *appear smarter*. Interestingly, students internalized the view of intelligence from the passage that they had read. Not only did it show that implicit theories of intelligence can cause a shift in goals, but it also demonstrated that it's possible to influence students' theories (at least transiently) (Dweck & Leggett, 1998; Dweck, 2000).

Research has shown that incremental theory interventions can have positive effects on academic achievement (Hong et al., 1995; Dweck, 2000; Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007). In their longitudinal study with seventh-graders, Blackwell et al. (2007) divided students into two groups to receive workshop instruction. The control group received instruction on the physiology of the brain, study skills, and antistereotypic thinking. In addition to that same instruction, the experimental group was taught that general intelligence was malleable through a variety of readings, examples, and analogies. Within a single semester, Blackwell et al. (2007) found that those students who were taught an incremental theory of intelligence not only received higher grades in their mathematics classes, but were also reported to have enhanced motivation by their mathematics teacher (who neither knew to which experimental group the students belonged, nor even that there were two distinct groups).

> This research confirms that adolescents who endorse more of an incremental theory of malleable intelligence also endorse stronger learning goals, hold more positive beliefs about effort, and make fewer ability-based, "helpless" attributions, with the result that they choose more positive, effort-based strategies in response to failure, boosting mathematics achievement over the junior high school transition. (Blackwell et al., 2007, p. 258)

Negative stereotypes disparaging the intellectual abilities of groups of people can result in their underperformance. In their study with African American college students, Aronson et al. (2002) examined the impact that one's implicit theory of intelligence can have in reducing stereotype threat. Stereotype threat undermines academic performance by inducing anxiety in tasks aimed to measure intelligence or ability (e.g. the GRE, the SAT) and by decreasing engagement through disidentification from tasks in which success is continuously elusive

(Aronson et al., 2002). For instance, "I'm not a math person" is an example of someone who has disidentified from the domain of mathematics; he has devalued the subject so that it can no longer be a basis for his self-esteem. Those who suffer from stereotype threat often view their performance as self-evaluative; as a result, they often choose easier, success-assuring tasks (Aronson et al., 2002). Thus, those vulnerable to stereotype threat may succumb to the maladaptive tendencies of entity theorists, a helpless pattern that Aronson et al. (2002) aimed to change with incremental theory interventions. Three groups of African American college students participated in the study. One group was given an incremental theory intervention designed to help them internalize the idea that intelligence is malleable and expandable. At the culmination of the study, those students who received the intervention experienced lasting and influential changes in their attitudes regarding their own intelligence. They not only received better grades, but also reported enjoying academics more.

Similarly, in their study with junior high school students, Good et al. (2003) found that when participants learned that intelligence is expandable the gender gap in mathematics and the socio-economic gap in reading both disappeared. Additionally, stereotyped students – females in mathematics classes and ability-stigmatized students in reading programs – received higher scores on standardized tests after participating in an incremental theory intervention program.

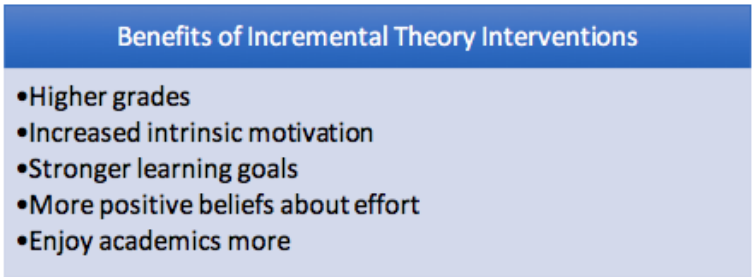

Figure II-5. Benefits of incremental theory interventions. This figure depicts the benefits of receiving an incremental theory intervention.

The Development of Attributions. Although a student's theory of intelligence plays a role in his achievement motivation, these patterns don't typically emerge until adolescence (Blackwell et al., 2007; Dweck, 2002), thus providing the rationale for using high school students in the present study. Attributions of effort and ability change throughout child development. In his paper presented to the American Educational Research Association, Schunk (1996) described the changes in conception of effort and ability among three transitional stages of development: before the age of 9, between the ages of 9 and 12, and adolescence. According to Schunk (1996), young children equate ability and effort: they believe that someone who applies more effort is smarter and, as a result, will receive higher grades. In this regard, young children believe ability is expandable; thus, they generally accept the incremental view of intelligence (Dweck & Leggett, 1988). Between the ages of 9 and 12, children begin to make minor distinctions between ability and effort. They understand that someone who applies a lot of effort may not necessarily receive higher grades due to individual differences in ability. Children's beliefs regarding their standing in class become more realistic (as opposed to excessively optimistic) (Dweck, 2002). During this age, attributions are impressionable and can be influenced by external factors; for example, adult praise for ability can result in children adopting performance goals (Mueller & Dweck, 1998).

Kun (1977) reached similar conclusions for the attributions made by younger children, but with slightly different age ranges. In her study, first-graders associated high effort with high ability, and high ability with high effort. However, by the third-grade children made different inferences when outcomes were presented as the result of high effort or high ability; specifically, less effort was inferred for outcomes attributed to high ability, whereas high ability was inferred for outcomes attributed to high effort (Kun, 1977). In other words, third graders reached varying

conclusions when making effort attributions vs. ability attributions. Nicholls (1978) confirmed this finding, and extrapolated that "because ability is not clearly differentiated from effort and outcome at these levels, ability related terms may be more closely associated with effort or with outcome depending on the situation" (p. 808).

According to Schunk (1996), by adolescence the distinctions made between effort and ability are absolute; as a result, adolescents' implicit theories of intelligence become more robustly set and defined. For instance, adolescents who are entity theorists perceive effort and ability as inversely related: low effort is an indication of high ability, and vice versa. As a result, their emphasis on ability increases and their value in effort decreases. In contrast, adolescents who are incremental theorists view effort as a conduit for expanding ability; as a result, their value in effort increases.

Interestingly, causal changes in academic performance due to implicit theories of intelligence do not typically occur until junior high school (Blackwell et al., 2007); in other words, entity theorists perform just as well as incremental theorists before adolescence. In fact,

> In a supportive, less failure-prone environment such as elementary school, vulnerable students may be buffered against the consequences of a belief in fixed intelligence. However, when they encounter the challenges of middle school, these students are less equipped to surmount them. (Blackwell et al., 2007, p.258)

Dweck (2002) describes this phenomenon as a consequence of tenable connections formed within a network of motivational beliefs. She argues that entity beliefs and goals can be highly motivating when things are going well because "some children hold an entity theory of ability long

before it hooks up with its network of other motivationally relevant beliefs (such as effort beliefs and attributions) and with persistence and performance" (Dweck, 2002, p.81).

In conjunction with other research, Blackwell et al. (2007) found that those students who endorsed an incremental theory of intelligence developed more adaptive responses to setbacks. In their longitudinal study with junior high school students, Blackwell et al. (2007) used incremental theory interventions to reverse the trajectory of junior high students' declining mathematics grades, an upward trend that had long lasting effects and remained predictive over time. Their findings supported the claim that divergent achievement patterns caused by differences in implicit theories of intelligence don't emerge until adolescence (i.e. during the challenging transition from elementary school to secondary school) (Blackwell et al., 2007).

Since changes caused by a student's implicit theory of intelligence don't culminate in academic performance until adolescence, it is even more important that students receive incremental theory interventions during this pivotal stage in development; in other words, the ideal population for which interventions would be most successful is middle school students. In contrast, the ideal population for which to study the relationship between parent mindset and student mindset is high school students because: (i) their own mindsets have crystallized (allowing a researcher to more accurately capture their mindsets); and (ii) the impact on academic performance will have occurred in adolescence, perhaps culminating with indicators such as GPA, SAT, and highest level mathematics course taken. Thus, the present study uses high school students to explore the relationship between the mathematical mindsets of parents and the mathematical experiences of students (as measured by mathematical mindset, mathematics performance, and mathematical grit).

Ability Attributions and Effort Attributions. Attribution (i.e. effort attributions or ability attributions) can be used to modify student behavior (Miller et al., 1975). In a study with fifth-graders, students were divided into three groups: an attribution group, a persuasion group, and a control group. The objective was to teach all students to be neat and tidy, and not to litter. After monitoring their behavior, the three groups were given different feedback: the attribution group was told that they were already neat and tidy; the persuasion group was told that they *should be* neat and tidy; and the control group was given no such treatment. Attribution proved to be the most effective means to modify student behavior.

The study was then repeated in second-grade classrooms with respect to mathematics achievement in which attributions of ability and attributions of motivation were also compared. All students were given a mathematics pretest, and then divided into four groups: attribution, persuasion, reinforcement and a control group that received no treatment. The ability attribution treatment for students consisted of verbal comments (e.g. "You're a very good arithmetic student"), written notes on assignments (e.g. "Excellent work"), letters from the teacher (e.g. "Very good student") and letters from the principal (e.g. "Excellent ability"). In contrast, the motivation attribution treatment for students consisted of verbal comments (e.g. "You really work hard in arithmetic"), written comments (e.g. "Keep trying harder!"), and letters from the teacher and principal which accentuated the child's effort in mathematics (e.g. "Working hard," "Trying," "Applying himself"). The persuasion ability treatment for students involved feedback like "You should be doing well in arithmetic" and "You should be good at arithmetic," and the persuasion motivation treatment for students involved feedback like "You should work harder in arithmetic."

Finally, the reinforcement group received reports like “I’m very happy with your work” and “Excellent grades.”

At the culmination of the study students were given a post-test that assessed their mathematics skills and self-esteem. Once again, attribution treatments for students resulted in more significant changes than the persuasion treatments. Of import is the implied connotations of each group: the persuasions were negative because the feedback “You should be good at arithmetic” implies that one is not already, whereas all attributions were inherently positive. This suggests that positive feedback has longer lasting effects than negative feedback.

Additionally, there was no difference in the effectiveness of modifying the behavior between the ability attribution and motivation attribution treatments; this is consistent with Schunk’s (1996), Kun’s (1977), and Nicholls’ (1978) findings that younger children equate effort with ability. Further, these results support the claim that differences in implicit theories of intelligence only affect academic performance and self-esteem in later stages of child development.

Mindset. Dweck (2006) classified implicit theories of intelligence as “mindset.” She used the terms *fixed* and *growth* mindset to describe one’s thoughts about his or her intellectual potential. A *fixed mindset*, related to entity theory, is the belief that one’s intelligence is immutable, i.e. an inherited and static trait. A *growth mindset* is significantly more flexible, and falls in conjunction with incremental theory. Those with a growth mindset believe that intelligence can be improved upon by dedication and hard work. In relation to mathematics, one with a fixed mindset would likely believe in a mathematics gene, whereas one with a growth mindset would likely believe mathematics to be a learnable skill. For the purposes of this study, I will use the

more contemporary terms growth mindset and fixed mindset instead of incremental theory and entity theory, respectively.

The *growth mindset* has been linked with increased levels of academic achievement: students with a growth mindset receive higher grades, are reported to enjoy and value academics more, have increased motivation, choose more positive, effort-based responses to failure, and experience greater overall gains than those with a fixed mindset (Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007).

In her book *Self-Theories*, Dweck (2000) presents a variety of implicit theory questionnaires that pertain to intelligence, personality, morality, and confidence levels – to name a few. Validated by multiple studies (Levy et al., 1998; Hong et al., 1995), the scales are not correlated with other scales (e.g. measures of self-esteem, optimism, political ideology, religious inclination, motivational needs, or cognitive abilities). "Thus implicit theories represent assumptions about the self that have cognitive, motivational, emotional, and behavioral consequences, but they are distinct from other cognitive and motivational constructs" (Dweck, 2000). For the purpose of this study, I will use the validated "Theories of Intelligence Scale – Self Form for Adults" for my Adult Mindset Survey, and the "Implicit Theories of Intelligence Scale for Children – Self Form" for my Student Mindset Survey.

Grit. Mindset is linked with – but not synonymous to – resiliency and "grit." "Resilience is the optimism to continue when you've experienced some failures" ("5 Ways to Develop," 2016). Someone who exhibits a high level of resilience will respond positively to a challenge by trying new strategies, applying more effort, or finding a peaceful resolution to a conflict (Yeager & Dweck, 2012). Resilience is not to be confused with grit. Grit, a term coined

by Duckworth (2016), is the quality of being able to sustain your passions (or goals) over an extended length of time. It is the "motivational drive that keeps you on a difficult task over a sustained period" ("5 Ways to Develop," 2016). According to Duckworth, grit has two components: passion and perseverance. She describes passion as a compass; a beacon that helps you stay loyal to a goal. With respect to goals, there is a hierarchy: a small number of top-level goals, a moderate number of mid-level goals, and numerous low-level goals. Grit is holding the same top-level goal for a very long time (Duckworth, 2016). In fact, the perseverance aspect of grit is not mindlessly pursuing every low-level goal; rather, giving up on low-level goals is not only forgivable but also necessary. However, for higher-level goals such stubbornness is expected: the ideal combination of passion and perseverance.

Grit – and resilience – have emerged as significant predictors of academic achievement over time (Duckworth & Gross, 2014; Duckworth et al., 2007; Rimfeld et al., 2016; Yeager & Dweck, 2012). In fact, in five studies with adults, Duckworth et al. (2007) asserted that grit is essential for high achievement. They found that grittier individuals had higher levels of education, older individuals were grittier than their younger counterparts (suggesting that grit increases with age), and grittier individuals made fewer career changes. Additionally, in their third study with undergraduates at an elite institution, grittier students – despite having lower SAT scores – had higher GPAs than peers who were less gritty. Interestingly, they found that grit was not positively associated with IQ, a result that left them wondering if grit is a better indicator of success than IQ.

Grit has been shown to influence student engagement, retention, and matriculation (Duckworth & Quinn, 2009; Maddi et al., 2012; Strayhorn, 2013; Wolters & Hussain, 2014). For instance, in their study with West Point cadets grit was more of an indicator for completion of the

grueling summer training program than the Whole Candidate Index (an accumulation of high school rank, SAT score, and a physical exercise evaluation) (Duckworth & Quinn, 2009). Duckworth et al. (2011) reported similar findings with Spelling Bee participants: grit was a more reliable indicator of retention than GPA.

Further, in their study with Black male undergraduates at a predominately white institution, grit was positively associated with academic outcomes. When compared to peers with similar academic backgrounds, Black males earned higher grades, suggesting that "grit may prove to be an effective lever for raising Black male academic success" (Strayhorn, 2013, p.8). Finally, students who exhibit higher levels of grit along with high engagement in self-regulatory learning (SRL) exhibit greater persistence in the face of setbacks or interference (Wolters & Hussain, 2014).

The significance of grit has been contested by psychologists. In a study focused on the relationship between personality and academic achievement, Rimfeld et al. (2016) found a significant correlation (both phenotypically and genetically) between grit and conscientiousness (one of the Big Five personality factors):

> We conclude that the etiology of Grit is highly similar to other personality traits, not only in showing substantial genetic influence but also in showing no influence of shared environmental factors. Personality significantly predicts academic achievement, but Grit adds little phenotypically or genetically to the prediction of academic achievement beyond traditional personality factors, especially conscientiousness. (Rimfeld et al., 2016, p.780)

Other psychologists have similarly critiqued grit's close relationship with conscientiousness. This implication of the de-emphasis of grit's importance is great, considering the many grit-inspired curricula and grit interventions taking place in schools all over the United

States. However, supporters of grit argue that conscientiousness is not a skill but a trait; as a result, it is not susceptive to direct instruction in the same way that grit has shown to be (Kamenetz, 2016). Additionally, to further distinguish grit from conscientiousness, Duckworth described a factor of grit called "consistency of effort" (Kamenetz, 2016). "Grit overlaps with achievement aspects of conscientiousness but differs in its emphasis on long-term stamina rather than short-term intensity" (Duckworth et al., 2007, p.1089).

In light of criticism, Duckworth validated a more efficient measure of grit than her original 12-item self-reported survey (Grit-O). The short scale (Grit-S) consists of 8 items and was validated in a series of tests (Duckworth & Quinn, 2009). In a cross-sectional online study with adults aged 25 and older, Duckworth and Quinn (2009) found that, controlling for conscientiousness and other Big Five personality traits, Grit-S was still a significant predictor of educational attainment and inversely related to career changes over time. In another study, Duckworth and Quinn (2009) found the Grit-S questionnaire to be "a more efficient measure of trait-level perseverance and passion for long-term goals" (p. 172). For these reasons, it is the Grit-S scale that I will use for the present study.

Despite revisions made to the validated grit scales, additional criticism remains. Researchers question the vulnerability to bias embedded in the self-reported nature of the surveys (Sparks, 2016). Adolescents "may compare themselves more to their peers, which may also affect how accurately they report their own persistence, self-efficacy, or self-control" (Sparks, 2016, p.6). Thus, as with all self-reported surveys, it is important to bolster the results with additional indicators. In the present study, I use qualitative measures (i.e. interviews) to compare the findings

from the Grit-S scale (which measures general grit) to mathematical grit (grit in the specific domain of mathematics).

Grit and the Growth Mindset. Grit-targeted instructional interventions have been successful, especially those that target the growth mindset (Kamenetz, 2016). In fact, grit and the growth mindset are highly correlated (Duckworth, 2016). "Students with a growth mindset are significantly grittier than students with a fixed mindset" (Duckworth, 2016, p. 181). Likewise, ability praise (e.g. "You're a natural" or "You're so talented") undermines both grit and the growth mindset, whereas process praise (e.g. "You're a learner" or "Don't feel bad if you can't do it yet") promotes them (Duckworth, 2016).

Similarly, implicit theories of intelligence impact resilience; in fact, to adequately apply resilience, one's implicit mindset belief must be in conjunction with growth ideas (Yeager & Dweck, 2012). Resilience training – such as optimistic self-talk practiced in cognitive behavioral therapy – was developed to combat a learned helpless response in the face of adversity. It was found that gritty individuals with a growth mindset are more likely to engage in optimistic ways of explaining difficulties – such as those taught in resilience training. In contrast, less gritty individuals with a fixed mindset are more likely to disengage, give up, and avoid challenges in the future (Duckworth, 2016).

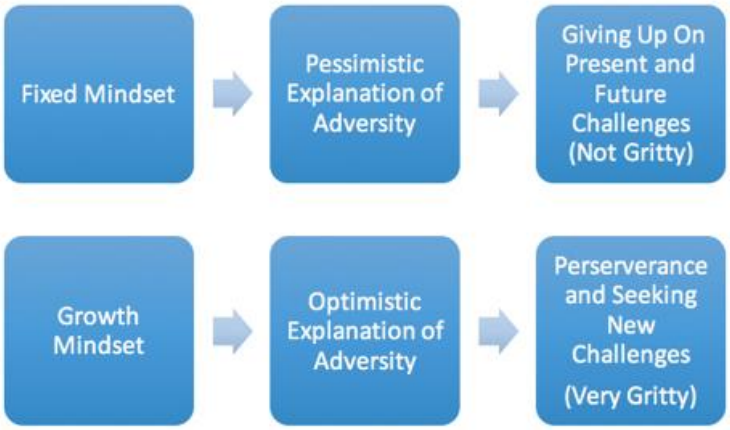

Figure II-7. A relationship between mindset and grit as explained by Duckworth (2016). Grit and the growth mindset are highly correlated, but not the same constructs: the one-way arrows describe the way in which they are related.

Although grit and the growth mindset might coincide in many regards, they are not the same concepts. Rather, those who encompass the growth mindset respond to defeat with constructive thoughts that encourage their tenacity to persist in achieving their goals; in other words, those with the growth mindset exhibit a certain way of thinking that translates to gritty behavior.

Parent Mindset and Student Academic Achievement

In this section, I discuss how praise can affect student achievement and motivation (Dweck & Leggett, 1988; Mueller & Dweck, 1998; Blackwell et al., 2007; Dweck, 2008; Plaks & Stecher, 2007; Plaks et al., 2007; Rattan et al., 2012). I also discuss how failure-mindsets differ from intelligence-mindsets, and how an adult's response to failure can impact a student's implicit theory of intelligence (Haimovitz & Dweck, 2016).

I then introduce mathematical mindsets as separate from general mindsets. In the previous studies discussed in this chapter, the psychological constructs examined (e.g. mindset, grit) were

subject-general (not subject-specific). For instance, the growth mindset and growth mindset interventions were investigated under a general subject lens. In contrast, I describe mathematics-specific mindsets as defined by Boaler (2016). Additionally, I describe two contrasting theories regarding the domain specificity of mindsets; namely, the theory that mindsets are universally applied in opposition to the theory that mindsets vary by subject.

I end this section with an emphasis on the need to examine the relationship (if any) between parent mathematical mindset and the mathematical experiences of the student (as determined by student mathematical mindset, student mathematics achievement, and student mathematical grit).

Feedback Practices

A tenet belief of the Family Math program at U.C. Berkeley is that parents – recognized as children's first and most influential teachers – are an integral instrument of support in their child's mathematical learning. Workshops, community outreach programs, and literature serve to encourage families to work together to teach children mathematics, assisting families with those aspects of parental involvement that can nurture positive mathematical self-efficacy and mathematical identities in children (e.g. by teaching parents effective methods of communication and ways to foster a positive home learning environment). A substantial way in which parents can influence their child's mathematics experience is through their feedback.

"Students' mindsets can be affected by the subtle messages they receive from adults" (Yeager & Dweck, 2012, p.310). Praise can affect student achievement and motivation. Adult praise – in particular – emanates powerful messages to students (Dweck, 2000). Praising ability or intelligence can negatively affect a student's response to achievement situations. First, it could lead students to make ability attributions and adopt a performance goal in which being challenged,

struggling, and learning are rejected in favor of appearing smart, a prerogative that leaves students with less resilience and vulnerable to a helpless response to setbacks (Dweck & Leggett, 1988; Mueller & Dweck, 1998). Second, it suggests to students that intelligence is a stable trait and that their intelligence can be discerned from their performance (Mueller & Dweck, 1998).

> Praising students for their intelligence, as opposed to praise for process (such as effort or strategy), makes students think that their abilities are fixed, makes them avoid challenging tasks (so they can keep on looking intelligent), makes them lose confidence and motivation when the task becomes hard, impairs their performance on and after difficult problems, and leads them to lie about their scores afterwards. Process praise (such as praise for effort or strategy), in contrast, leads students to seek and thrive on challenges. (Dweck, 2008, p.8)

Under conditions of success, praise for ability can benefit a student's self-efficacy and can improve the performance of older students; however, it can also have negative consequences if a student believes it to be insincere or if the student feels too much pressure to perform well in the future (Schunk, 1996; Miller et al., 1975; Mueller & Dweck, 1998). In contrast, praise for effort can promote effort attributions, learning goals, and an incremental view of intelligence regardless of the condition of the performance (i.e. success or failure). These students will attribute failure to a lapse of effort rather than an indication of low intelligence; as a result, they will display higher achievement motivation and positive postfailure striving (Diener & Dweck, 1980; Mueller & Dweck, 1998). In other words, their response to failure is adaptive rather than maladaptive. This approach to failure, in turn, may influence their academic performance in adolescence.

In a study with fifth-graders, Mueller and Dweck (1998) praised students for ability or effort and then asked them to choose tasks that reflected performance or learning goals. According

to Schunk (1996), it is at this age that students begin to make minor distinctions between ability and effort. Mueller and Dweck (1998) confirmed these findings in that those praised for ability had a proclivity towards choosing performance goals. Additionally, Mueller and Dweck (1998) found that the great value they attributed with performance outweighed their desire to seek new learning opportunities; when given the choice, students praised for ability preferred to find out how others performed on a task rather than learning a new skill that could help them solve future problems (Mueller & Dweck, 1998); these students undermined their own information-seeking interests to gauge their intelligence in comparison to others'. This disinclination to deepen their knowledge at the risk of appearing unintelligent might be another influencing factor for the academic discrepancies later found in adolescence.

Further, students praised for intelligence were so consumed by appearing smart in their performance that they were more likely to falsify or exaggerate their scores even when their reports were anonymous and unseen by the evaluators; they equated high performance with high intelligence for their own benefit, independent from the evaluator's purview (Mueller & Dweck, 1998).

Feedback practices have been shown to affect student performance and resiliency (Blackwell et al., 2007; Dweck, 2008; Plaks & Stecher, 2007; Yeager & Dweck). In their study with undergraduates, Plaks and Stecher (2007) found that feedback indicating a substantial change in performance (i.e. a major decline or improvement) triggered more anxiety from entity theorists, and feedback indicating no change in performance triggered more anxiety from incremental theorists. More anxiety was elicited when performance was incongruous with one's implicit theory of intelligence because it defied one's expectations. In fact, many participants, upon

experiencing an outcome that violated their implicit theory, reacted in self-defeating ways (Plaks & Stecher, 2007). Their research suggests that people's reactions to positive and negative feedback depends on the expectations derived from their implicit theories of intelligence (Plaks & Stecher, 2007).

"Adults holding an entity (or fixed) theory of ability are more oriented toward diagnosing people's stable traits…whereas those holding an incremental (or malleable) theory tend to be more open to information about change over time" (Rattan et al., 2012, p.731). In their comprehensive study, Rattan et al. (2012) found that instructors who embraced an entity theory regarding mathematics intelligence were quick to identify a student as having low-ability based on a single poor test score. Additionally, they adjusted their pedagogical practices to reduce student engagement, and expected very little improvement from the student in the future; for example, they might explain to a low performing student that he or she is "not a math person," and assign fewer mathematics problems for homework. These entity-praise instructors were likely to provide comforting feedback that addressed the student's low ability, as opposed to caring feedback steeped in the premise that they could improve. Compared to caring feedback, the comforting feedback decreased student motivation, undermined their resilience, and led the student to expect lower grades in the future; in other words, the consolation for low ability, even if phrased in a positive manner, generated negative outcomes for the student.

Instructors with an entity theory prefer pedagogical practices that communicate their beliefs; unfortunately, their conception of intelligence led them to communicate their beliefs in ways that backfired (Rattan et al., 2012). Educators play an influential role in shaping students' mindsets (Dweck, 2008). Children praised for intelligence run the risk of perceiving ability as a

fixed entity, whereas children praised for their hard work are likely to make attributions related to effort.

Parents with fixed intelligence theories are more likely to view their child's intelligence as fixed and, as a result, are more likely to give their child praise that emphasizes intelligence over process (Dweck, 2008; Mueller & Dweck, 1998). In fact, 85% of parents believe that praising their child's intelligence is necessary to make them feel smart (Mueller & Dweck, 1996). However,

> Fifth graders praised for intelligence were found to care more about performance goals relative to learning goals than children praised for effort. After failure, they also displayed less task persistence, less task enjoyment, more low-ability attributions, and worse task performance than children praised for effort. Finally, children praised for intelligence described it as a fixed trait more than children praised for hard work. (Mueller & Dweck, 1998, p.33)

Additionally, a parent's view of failure can predict a student's implicit theory of intelligence (Haimovitz & Dweck, 2016). In their four-part study with parents and children, Haimovitz and Dweck (2016) explored *failure mindsets* - the view that failure is either enhancing or debilitating – and the role it plays in parents' responses to their children's setbacks. Failure mindsets are distinct from intelligence mindsets; for instance, parents with a growth mindset might still praise their child's talent (behavior more characteristic of a fixed mindset) (Haimovitz & Dweck, 2016).

In their first study with parents and their fourth- and fifth-grade children, Haimovitz and Dweck (2016) revealed that parents' failure mindsets – unlike their intelligence mindsets – are visible to their children. Thus, although no clear link was found between parents' intelligence

mindsets and their children's intelligence mindsets, there was a relationship between parents' failure mindsets and their children's intelligence mindsets. Parents who viewed failure as debilitating showed that they did; as a result, their response to failure (communicated through either verbal or behavioral cues) conveyed to their children that intelligence is fixed.

In their second study with parents of students enrolled in formal education, Haimovitz and Dweck (2016) further explored the visibility of parents' failure mindsets in response to their children's setbacks. They found that parents with the failure-is-debilitating mindset endorsed performance-oriented reactions (e.g. worrying about their child's ability, pitying their child when he or she failed, comforting their child for not having enough ability) rather than learning-oriented reactions (e.g. emphasizing effort and strategies, expecting improvement). This finding further explains why parents with the failure-is-debilitating mindset have children with fixed intelligence mindsets.

In their third study with parents and children (aged 8-12), Haimovitz and Dweck (2016) found that children could accurately discern their parents' failure mindsets, but could not accurately discern their parents' intelligence mindsets. Additionally, children who more strongly perceived their parents' failure mindset as debilitating were more likely to believe intelligence was fixed. Interestingly, parents' perceptions of their own failure mindsets and intelligence mindsets were not significantly related.

Finally, in their fourth study with parents, Haimovitz and Dweck (2016) demonstrated a causal relationship between parents' failure mindsets and their reactions to their children's failures. When primed with a different view of failure (e.g. failure as an enhancing experience), parents' responses to failure changed. The implications of the study suggest that if parents could be taught

to embrace failure – to no longer see it as an indication of low intelligence – then students could learn to see intelligence as an expandable entity that could be improved upon with effort.

Mathematical Mindsets

There exists a conceptual overlap between epistemological beliefs and implicit theories of intelligence (Jonsson et al., 2012). According to Buehl, Alexander, and Murphy (2002), epistemological beliefs vary by subject domain. In their study with undergraduate students, they found statistically significant differences in students' beliefs regarding the effort required to gain knowledge in two domains that vary by structure: mathematics and history. They characterized mathematics as a well-structured domain, based on the algorithmic procedures used to answer questions and the general way in which it is treated in schools. In contrast, they characterized history as an ill-structured domain, due to the heuristic procedures used to find solutions to problems. They concluded that students' epistemological beliefs are influenced by the domain structure of the subject; specifically, students believed that mathematical knowledge required more effort to acquire than historical knowledge.

There is an inclination to perceive mathematical ability as a reflection of natural, intrinsic intelligence (Beach, 2003; Beach & Dovemark, 2007). In fact, "the beliefs that the specific discipline math requires a special inborn ability can be associated with the research results in the tradition of Thurstone and Cattell-Horn" in which fluid intelligence (Gf) – which encompasses all of the facets of mathematical reasoning – coincides with general intelligence (g) (Jonsson et al., 2012, p. 389). This perception of mathematics is prevalent in the classroom. According to Myers et al. (2003), teachers' general implicit theories of intelligence can be influenced by their discipline. In a study with 226 high school teachers in Sweden, Jonsson et al. (2012) found that a

preference for fixed mindsets is higher in mathematics teachers than for any other subject. Additionally, Jonsson et al. (2012) unearthed an interesting relationship regarding experience and age: older, more experienced teachers and younger, less experienced teachers were more likely to adhere to fixed mindset beliefs. "Experienced teachers develop their beliefs in daily transaction with students and by this acquire deeper knowledge of what factors influence achievement" (Jonsson et al., 2012, p.390; Kagan, 1992; Pajares, 1992). It's likely that for more experienced teachers, learning is viewed as dependent on factors beyond their control (Woolfolk Hoy, Davis, & Pape, 2006).

Some pedagogical methods are more likely than others to promote fixed mindset tendencies. According to Altendorff (2012), there is a dominant cultural script for teaching mathematics in English schools, characterized by teacher-centered instruction, ability grouping, outlined procedural methods, the differentiation of student work by ability, a focus on higher attaining students, and the perception of success in mathematics as finding the right answer. This dominant classroom climate encourages performance goals which, in turn, are less likely to lead to mastery oriented qualities that foster self-motivation, improvement, and overall progress in students (Dweck, 2000; Altendorff, 2012). In addition to the dominant cultural script, Altendorff (2012) found "a significant proportion of students with entity-theory frameworks and who preferred performance over challenge…[and that] the girls more than the boys and the low attaining more than high attaining students demonstrated entity theory frameworks and performance over challenge goals of learning" (p.215-216). In other words, girls and low attaining students are more likely to exhibit fixed mindset behaviors in mathematics classrooms.

Thus, it has been shown that specific subjects can influence general implicit theories of intelligence (Yeager & Dweck, 2012). More recently, studies have examined students' implicit beliefs regarding mathematics in particular. For example, Rattan et al. (2012) studied implicit theories regarding *mathematics* intelligence rather than general intelligence, and Paunesku et al. (2007) emphasized one's potential to improve *mathematics* ability in their incremental theory interventions for community college mathematics students. Notably, the aforementioned studies incorporated mathematical mindsets as an instantiation of general mindset; neither measured mathematical mindset specifically.

This study examined mathematical mindsets explicitly. According to Boaler (2016), a mathematics-growth mindset is not only recognizing mathematics as a subject of growth, but having growth beliefs about the nature of mathematics and one's own role in it. In contrast, having a mathematics-fixed mindset is recognizing limitations in mathematical ability; the belief in a conceptual threshold that restricts one's intellectual progress in the subject.

> Children need to see math as a conceptual, growth subject that they should think about and make sense of. When students see math as a series of short questions, they cannot see the role for their own inner growth and learning. They think that math is a fixed set of methods that either they get or they don't. When students see math as a broad landscape of unexplored puzzles in which they can wander around, asking questions and thinking about relationships, they understand that their role is thinking, sense making, and growing. When students see mathematics as a set of ideas and relationships and their role as one thinking about the ideas, and making sense of them, they have a mathematical mindset. (Boaler, 2016, p.34)

Mathematics is a conceptual domain not to be regarded as a memorized list of rote procedures, facts, and skills. Unfortunately, students at a very early age are taught procedural algorithms that undermine the flexible nature of the subject. For instance, they memorize multiplication facts without exploring the plethora of patterns from multiplication tables that could lead to greater mathematical understanding of multiplication properties. Or they learn the algorithm for long division without understanding the importance of place value and its role in the process. According to Boaler (2016), this is the vulnerable age where students tend to adopt a fixed, procedural mathematical mindset. She suggests counteracting this negative transition by incorporating number sense into early mathematics learning.

Additionally, the mathematics-growth mindset is often foiled by common mathematical misconceptions surrounding speed (with respect to recall of facts, the time it takes to solve a problem, and the general brevity of all mathematics solutions). When classrooms equate skill with speed and value fast recall over deep conceptual understanding, mathematics anxiety develops, and creative inquiry - a characteristic of the growth mindset in mathematics - declines (Zoido, 2016).

Mathematics anxiety is suffered by a third of all students in the United States (Zoido, 2016). Although anxiety can be evoked in all subjects, mathematics anxiety can be more severe – and affect performance more – than other subjects (Punaro & Reeve, 2012; Dowker et al., 2016). Mathematics anxiety, along with other academic-motivational constructs such as mathematics self-concept and mathematics self-efficacy, is “inevitably related to the societal and educational environment of countries” (Lee, 2009, p.363). Mathematics anxiety is the manifestation of negative physio-emotional reactions when one thinks about – or performs a task in – mathematics;

mathematics self-concept is one's perception of self in the domain of mathematics; and mathematics self-efficacy is one's conviction of his or her capability to successfully produce desirable outcomes in mathematics (Lee, 2009). Using a series of factor analyses from responses to the PISA 2003 background questionnaires for students and schools, Lee (2009) found that (i) mathematics self-concept, mathematics self-efficacy, and mathematics-anxiety are distinguishable in cross-cultural contexts, (ii) Asian countries (e.g. Korea, Japan, and Thailand) demonstrate low mathematics self-concept and mathematics self-efficacy and high mathematics anxiety, (iii) Western European countries (e.g. Austria, Germany, Sweden) demonstrate high mathematics self-efficacy and low mathematics anxiety, (iv) the United States demonstrates high mathematics self-efficacy and mathematic self-concept and middle-range ratings for mathematics anxiety, and (v) Asian countries show a weaker association between mathematics anxiety and mathematics performance. The latter finding, especially in consideration of the high mathematics scores achieved by Asian countries, suggests that additional cultural influences might be at play.

There are two contrasting theories regarding the significance of subject-specific mindsets: the consistency of mindsets verses the variability of mindsets across different subject domains. According to Molden and Dweck (2006), peoples' implicit theories "serve as core assumptions that created a larger system of allied beliefs and goals" (p. 201), and to gain a sense of who someone is one need only measure his or her mindset. "Because a given implicit theory fosters particular judgments and reactions, it can lead to relatively consistent patterns of vulnerability or resilience over time" (Yeager & Dweck, 2012, p. 304). To that effect, one would expect mindset to transcend across different domains – to be unified under a common theme. This universal theory of mindsets is supported by a study conducted by Hughes (2015) in which participants with fixed

or growth mindsets held the same beliefs regarding other facets of intelligence; specifically, individuals held concurrent beliefs regarding their general mindsets and mathematical mindsets. However, as discussed, mindsets have been shown to be influenced by subject, and are often affected by pedagogical practices, classroom climate, and epistemological beliefs (Yeager & Dweck, 2012; Myers et al., 2003; Jonsson et al., 2012; Altendorff, 2012; Rattan et al., 2012; Paunesku et al., 2007; Buehl et al., 2002). Additionally, implicit theories of intelligence and personality are decidedly distinct (Yeager & Dweck, 2012), suggesting that it is possible for implicit theories to be disparate. Thus, it is also likely that mindsets are dynamic constructs that are uniquely tailored to the subject domain in which it is studied. Notably, supporters in favor of the inconsistency of mindsets theory have yet to evince *why* a person who has internalized a certain mindset may not consistently apply it to all domains: why someone might have growth beliefs regarding general intelligence but fixed beliefs regarding mathematical intelligence.

Focus of Study

It has been shown that student mindset, student grit, and parent feedback practices affect mathematics achievement in students (Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007; Blackwell et al., 2007; Dweck, 2008; Plaks & Stecher, 2007; Duckworth & Gross, 2014; Duckworth et al., 2007; Rimfeld et al., 2016). However, research has yet to show a relationship between parent mindset and student mindset, student grit, and student mathematics achievement.

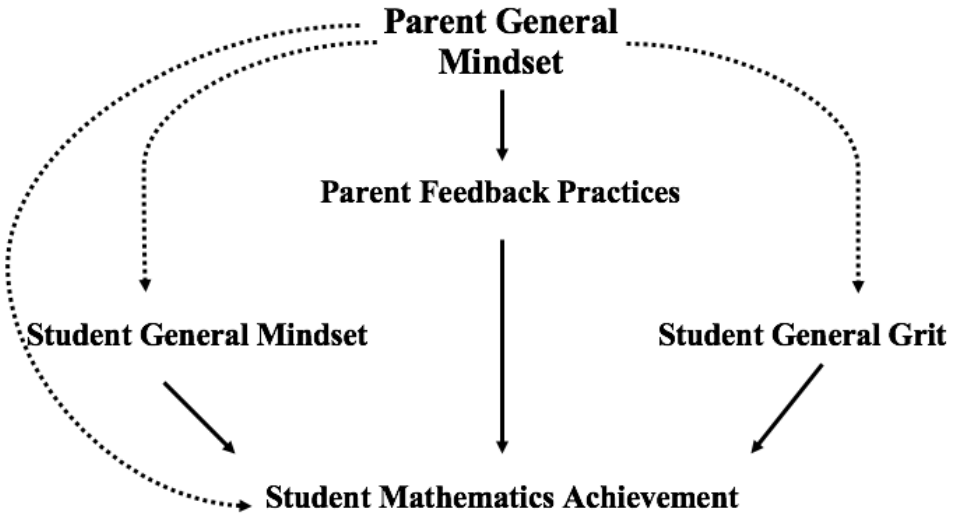

Figure II-8. Factors that influence student mathematics achievement. Solid lines indicate previously researched relationships. Dotted lines represent those connections missing in current studies.

Likewise, it has also been shown that general mindsets can be vulnerable to specific subject domains, and are often influenced by pedagogical practices, classroom climate, and epistemological beliefs (Yeager & Dweck, 2012; Myers et al., 2003; Jonsson et al., 2012; Altendorff, 2012; Rattan et al., 2012; Paunesku et al., 2007). However, research has yet to relate parent mathematical mindset to student mathematical mindset. Further, research has yet to evince if mindsets are all-encompassing or if they vary by subject.

This study explored the internal consistency between general mindset and mathematical mindset, and the relationship between parent mathematical mindset and student mathematical experience. Specifically, the students' mathematical experiences were measured by (1) student mathematical mindset, (2) student mathematics performance, and (3) student mathematical grit. If it is determined that parent mathematical mindset relates to any (or all) of the present study's indicators of student mathematical experience, then additional interventions – such as those

pertaining to incremental theory, feedback practices, or resilience training – can be used to teach parents how to positively influence their student's mathematical achievement.

For instance, it has been shown that incremental theory interventions have positive effects on academic achievement; students receive higher grades, have increased intrinsic motivation, stronger learning goals, more positive beliefs about effort, and were reported to enjoy academics more (Hong et al., 1995; Dweck, 2000; Aronson et al., 2002; Good et al., 2003; Blackwell et al., 2007). If it is found that parent mathematical mindset relates to student mathematical mindset, then interventions aimed at teaching parents the incremental view of mathematical intelligence may produce similar results. Additionally, since parents with fixed intelligence theories are more likely to praise intelligence (Dweck, 2008), teaching parents an incremental theory of mathematical intelligence may result in their praising effort over ability. Praise for effort has been shown to promote effort attributions, learning goals and an incremental view of intelligence, resulting in higher achievement motivation and positive postfailure striving (Diener & Dweck, 1980; Mueller & Dweck, 1998). Further, since parents' views of failure are visible to their children, parents who view failure as debilitating convey to their children that intelligence is fixed (Haimovitz & Dweck, 2016). Resilience training for adults can be used to combat their learned helpless response to failure that is communicated to their children through verbal or behavioral cues.

Finally, although anxiety can be evoked in all subjects, mathematics anxiety can be more severe – and affect performance more – than other subjects (Punaro & Reeve, 2012; Dowker et al., 2016). If parents can be taught to view mathematics as a conceptual domain (i.e. taught a

mathematics-growth mindset), then it is likely that their student's mathematics anxiety could dissipate and that their performance in mathematics could improve.

CHAPTER III : METHODOLOGY

This study explored the relationship between general mindset and mathematical mindset, and parent mathematical mindset and student mathematical experience. The study considered how a parent's mathematical mindset may or may not relate to student mathematical mindset, student mathematical achievement, and student mathematical grit.

Research Questions

The research questions are as follows:

1. What relationship exists, if any, between general mindset and mathematical mindset?

2. What relationship exists, if any, between high school seniors' mathematical mindsets and their parents' or guardians' mathematical mindsets?

3. What relationship exists, if any, between high school seniors' mathematical achievement and their parents' or guardians' mathematical mindsets?
4. What relationship exists, if any, between high school seniors' mathematical grit and their parents' or guardians' mathematical mindsets?
    a. What relationship exists, if any, between general grit and mathematical grit for high school seniors?

Field Setting

The study took place at two high schools in the same district of an affluent suburban city in the northeast where the researcher is currently a teacher. The majority of residents in the district are college graduates. There are approximately 750 high school seniors at both high schools combined. The first school (HS1) serves 1,519 students (grades 9-12). Minority enrollment is 15%

(majority Hispanic), which is less than the state average of 42%. The second high school (HS2) serves 1,459 students (grades 9-12). Minority enrollment is 22% (majority Hispanic), which is also below the state average. The impact of the composition of the student population (with respect to both race and socioeconomic status) will be explored later as a possible limitation to the study.

The researcher received approval from the Board of Education to conduct the study at HS1 and HS2. Additionally, the researcher received help from the principal of each high school with disseminating the initial round of online surveys.

Participants

Participants consisted of high school seniors from the class of 2018 and their parents. Elementary students and younger were excluded on the premise that mindset does not impact academic performance until adolescence (Blackwell et al., 2007; Schunk, 1996). Additionally, since performance on the mathematics section of the 2017 SAT examination, GPA, and highest-level mathematics course taken were used as indicators of academic performance, freshman, sophomores and juniors were excluded. Further, in recent years the SAT examination has undergone significant changes; specifically, changes in content, structure, and scoring were made to the SAT examination in the spring of 2016. Thus, students of an older age were excluded from this study. Finally, it was important to select only those high school seniors who had taken the updated version of the SAT examination.

I will use the term “participant” to refer to both parents and students; otherwise, the terms “parents” and “students” will be used to refer to just parents or students, respectively.

Stratified and purposeful sampling was used to select participants for each of the two phases of the study. In Phase 1 of the study, an 8-item Adult Mindset survey (see Appendix A)

(found at the end of the electronic consent and assent forms) was sent out electronically to all registered parents or guardians of high school seniors of the graduating class of 2018 in the same school district using the online Qualtrics tool. Twenty-four responses were received. The researcher determined the general mindset from each response using the validated survey scale.

Additionally, integrated into the survey was an area for parents to record the name and email of the other (if applicable) active parent or guardian as well as the name and email of their high school senior. A parent was considered "active" in a student's life if he or she lived with the student in some capacity. If both parents were active in the student's life, then an email was sent to the other parent inviting them to participate. If a parent was inactive or deceased, he or she was excluded from the study. Step-parents or other guardians were likewise asked to participate if they were active in the student's life.

Using this information, surveys were sent out to their spouses (if applicable) via the same Qualtrics tool, with an option to decline participation. Eight of the twenty-four other participants either declined participation or failed to respond. The researcher determined the general mindset of those who did respond and compared the results between parents or guardians of the same family. General mindsets were classified as fixed, growth, or mixed – as scored by Dweck's (2000) validated survey. The researcher denoted "mixed" mindsets as "neutral" due to the combination of fixed and growth beliefs.

All single-parent families were invited to participate in Phase 2 of the study: there were four single-parent families. For the two-parent families, only those with parents of the same general mindset were considered for Phase 2 of the study: 10 families qualified. Parents of the same family were determined to have the same general mindset if the parent mindset pairings were

fixed-fixed, fixed-neutral, growth-growth, and growth-neutral. Parents with growth-neural and fixed-neutral general mindsets were regarded as the same mindset because a neutral mindset indicated a small degree of both fixed and growth internalizations. The remaining families with different mindsets (growth-fixed) were immediately excluded from Phase 2 of the study because it would be difficult to determine which parent's mindset was associated (if at all) with the student's mathematical experience.

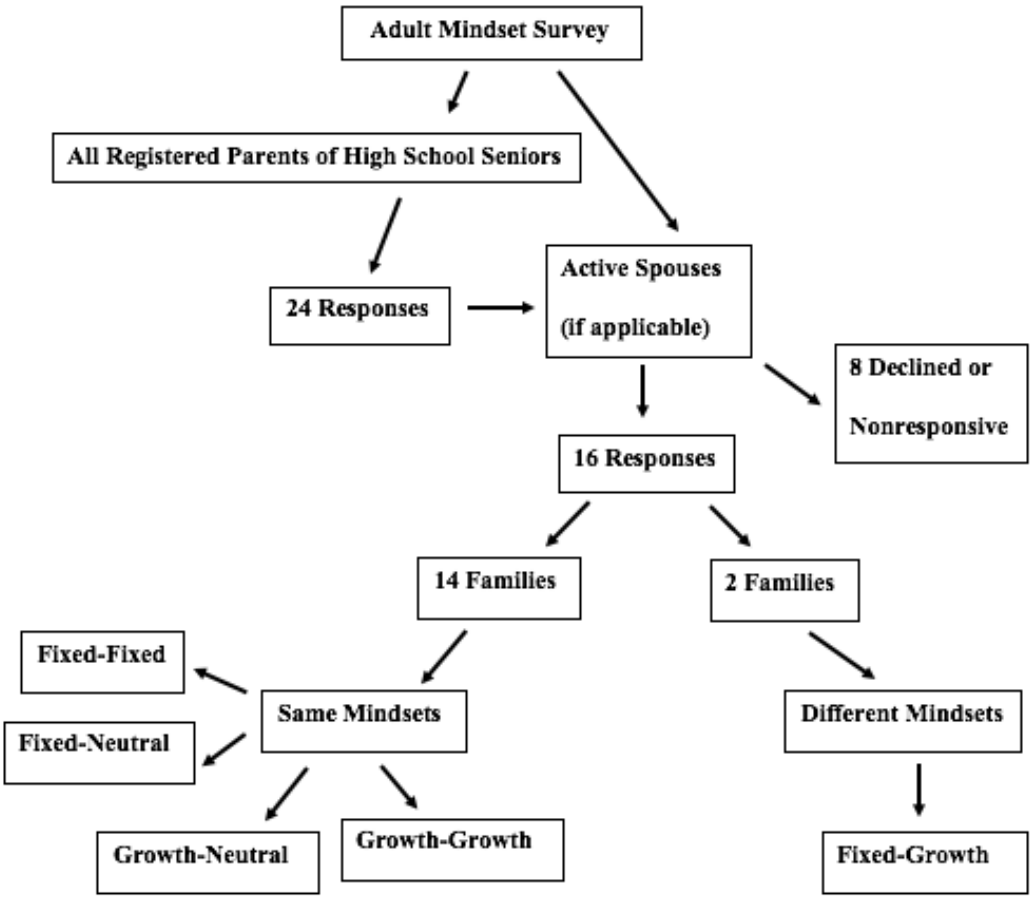

Figure III-1. Description of the participant selection process.

Table 1. Frequency of Parent Mindset Types Accepted into Phase 2 of the Study.

Fixed-Fixed	**Fixed-Neutral**	**Growth-Neutral**	**Growth-Growth**
2	3	2	7

For those 14 families who qualified for Phase 2 of the study, Student Demographic Surveys (see Appendix D) were sent out electronically (found at the end of an electronic consent form) to their high school senior via the email address provided by the parents. Students were given the opportunity to decline participation; however, no student did. Due to the limited number of qualifying participants, all 14 families were invited – and agreed – to participate in Phase 2 of the study. The small sample size (N=14) will be discussed later as a possible limitation to the study.

Of the 14 families who participated, 12 were white, one was Asian, and one identified with two or more races. Additionally, in each household English was the primary language spoken. Further, as part of the Student Demographic Survey students were asked to provide the highest-level of mathematics course taken (either currently or in the past). The researcher – as a mathematics teacher familiar with the courses in the district – classified the mathematics courses as high-level, average-level, and low-level. High-level classes included Multivariable Calculus and AP Calculus (both AB and BC). Average-level classes consisted of Intro to Calculus. Finally, lower-level classes included Financial Algebra and Mathematical Modeling. Seven

students took high-level classes, four students took average-level classes, and three students took lower-level classes. Twelve students attended HS1 and two students attended HS2.

Finally, students were asked to provide the highest score they received on the mathematics section of the 2017 SAT examination, as well as their current overall GPA. The self-reported SAT scores ranged from 350 to 800, and the GPAs ranged from 2.0 to 4.585. It should be noted that the district uses weighted GPAs based on course level.

Table 2. Weighted GPA system for HS1 and HS2.

Weighting System Used to Compute Official GPA				
Grade	Advanced Placement	Level 1	Level 0	Level 2
A+	5.00	4.67	4.67	4.33
A	4.67	4.33	4.33	4.00
A-	4.33	4.00	4.00	3.67
B+	4.00	3.67	3.67	3.33
B	3.67	3.33	3.33	3.00
B-	3.33	3.00	3.00	2.67
C+	3.00	2.67	2.67	2.33
C	2.67	2.33	2.33	2.00
C-	2.33	2.00	1.67	1.67
D+	2.00	1.67	1.33	1.33
D	1.67	1.33	1.00	1.00
D-	1.33	1.00	0.67	0.67
F	0.00	0.00	0.00	0.00

*All subjects considered except pass/fail courses and physical education/health.

Measures

Both quantitative data and qualitative measures were used in this study. Quantitative data were collected using three validated surveys (the 8-item Adult Mindset Survey, 6-item Student Mindset Survey, and 8-item Grit-S Scale) and one Student Demographic Survey. The surveys

were used to measure the general implicit theory of intelligence (i.e. growth or fixed mindset) for each participant, the general level of grit for students, and the mathematics achievement (as measured by the self-reported highest mathematics section SAT score, current overall GPA, and highest level mathematics course taken) of students. Qualitative data were then collected vis-à-vis individual interviews with each participant (parent and student). The purpose of each interview was to determine the mathematical mindset of each participant as well as the mathematical grit of students. Additionally, the purpose of the interviews was to explore the extent to which parent mathematical mindset relates to the mathematical experiences of the student.

Table 3. Measures Used to Answer Each Research Question.

Research Question	Quantitative Instrument	Qualitative Instrument
RQ1: What relationship exists, if any, between general mindset and mathematical mindset?	Adult Mindset Survey (determines general mindset) Student Mindset Survey (determines general mindset)	Individual interviews with each participant (determines mathematical mindset)
RQ2: What relationship exists, if any, between high school seniors' mathematical mindsets and their parents' or guardians' mathematical mindsets?	None used	Individual interviews with each participant (determines mathematical mindset)
RQ3: What relationship exists, if any, between high school seniors' mathematical achievement and their parents' or	Student Demographic Survey (determines SAT score, overall GPA, and highest level mathematics course taken)	Individual interviews with each participant (determines mathematical mindset and mathematical experience)

guardians' mathematical mindsets?		
RQ4: What relationship exists, if any, between high school seniors' mathematical grit and their parents' or guardians' mathematical mindsets? What relationship exists, if any, between general grit and mathematical grit for high school seniors?	Grit-S Scale for students (determines general grit)	Individual interviews with each participant (determines mathematical mindset and student mathematical grit)

Mindset Surveys

Two mindset surveys were used in this study: one for adults and one for students. Each survey took no longer than 5 minutes to complete. The Adult Mindset Survey (see Appendix A) was the 8-item "Theories of Intelligence Scale - Self Form for Adults" questionnaire validated by Levy et al. (1998) and Hong et al. (1995), and described in Dweck's (2000) book, *Self-Theories*. The Adult Mindset Survey was completed online. The Student Mindset Survey (see Appendix B) was the 6-item "Implicit Theories of Intelligence Scale for Children – Self Form" also validated by Levy et al. (1998) and Hong et al. (1995), and described in Dweck's (2000) book, *Self-Theories*. The Student Mindset Survey was completed in-person prior to the student interview. Both surveys assessed general mindset. The results from the mindset surveys were ordinal: adults and students were given a score 1.0 – 6.0. The scores were then organized into three ranges to describe the general mindsets of the participants; specifically, the ordinal results classified participants as having either a fixed, neutral, or growth general mindset. These classifications were determined by numeric values assigned to answers to questions that reflected either growth or fixed mindset beliefs. Participants rated the degree to which they agreed (strongly agreed, mostly agreed, or

agreed) or disagreed (strongly disagreed, mostly disagreed, or disagreed) with each of the statements. Their mindset was determined by the range of values in which their numeric score fell.

Neither survey is specifically designed to assess mathematical mindset. Rather, the mathematical mindset of each participant was determined qualitatively from interviews.

Grit Scale

The short scale (Grit-S) 8-item survey (see Appendix C) was used to determine the level of grit for students. The Grit-S Scale was validated in a series of tests conducted by Duckworth and Quinn (2009) and was found to be a more efficient measure than the original 12-item Grit-O scale. The results from the Grit-S Scale were ordinal; students were given a score 0-5. The scores were then organized into four ranges to describe the grittiness of students: not gritty, fairly gritty, moderately gritty, and very gritty. The Grit-S Scale took no longer than 5 minutes to complete and was taken in-person prior to the student interview.

The Grit-S Scale measures the general grit of students. To determine the mathematical grit for students, the researcher coded responses from grit-targeted interview questions.

Student Demographic Survey

The Student Demographic Survey (see Appendix D) asked questions pertaining to the student's place of birth, native language and race. It also collected information regarding the parent's (or parents' - if applicable) job. Finally, to measure the level of mathematics achievement, students were asked to record the highest score they received on the mathematics section of the 2017 SAT examination, their highest score on the mathematics section of the ACT (if applicable), their current overall GPA, and the highest-level mathematics class taken or currently being taken.

The Student Demographic Survey took no more than 5 minutes to complete and was completed online.

Interviews

The researcher conducted individual interviews with each participant (parent and student). "Interviews provide an opportunity for researchers to learn about social life through the perspective, experience, and language of those living it" (Boeije, 2010, p.62). In this regard, interviews were used as an instrument to elicit the observed phenomena of the mathematical experiences of the participants.

Interviews were done in-person and audio-recorded. Each interview took no longer than 20 minutes. The scripts were later transcribed by the researcher. The general purpose of the interviews was to determine the mathematical mindset of each participant, the mathematical grit of students, and the manner in which parent mathematical mindset relates to student mathematical experience.

Parents were asked questions regarding their implicit theories of intelligence, their own mathematical experiences, the mathematical experience of the student, and how they respond to their student's performance in mathematics. Students were asked questions pertaining to their mathematical mindset and their mathematical grit. With regards to mindset, the students were asked questions regarding their mathematical experiences and parent reactions to their successes or failures. All mindset questions aimed at assessing the extent to which their parents may have influenced their mathematical experiences. With regards to grit, the students were asked questions concerning their level of grit applied specifically to mathematics. The process by which

mathematical mindsets and mathematical level of grit were determined is described more extensively in the Procedure section of this chapter.

Research Design

The research followed a hermeneutical phenomenological approach (Creswell, 2015). Hermeneutical phenomenology is a qualitative research methodology characterized by finding meaning through the subjective interpretation of participants. The phenomena to be studied were *consistency of mindsets across specific domains* and *student mathematical experience*. The specific domain to which general mindset was compared was mathematical mindset. By *mathematical experiences,* I refer to three aspects: i) the student's mathematical mindset; ii) the student's mathematical achievement; and iii) the student's mathematical level of grit.

Since hermeneutical phenomenology is an interpretive process, it is important that the researcher be bracketed out of the study. Growing up, both my parents emphasized process over product; in other words, they valued effort over natural intrinsic ability – an attribute of the growth mindset. As a result, I faced setbacks with determination rather than despair. I viewed mathematics not as an exclusive club for the elite, but as a challenge that could be overcome with much practice. I believe that my parents' growth mindset influenced my own mindset, my level of grit, and my mathematical achievements.

The methodological framework for this study was pragmatism. As the researcher, I was free to choose both quantitative and qualitative tools to meet my needs and purposes; this, in turn, enabled me to use both inductive and deductive reasoning to construct a practical reality that reflected both my own and the participants' views and values. The central focus of all data collection and analysis was the outcome: finding the answers to the phenomena being studied.

Procedure

There were two phases to this study. The purpose of Phase 1 was to collect quantitative data to determine general parent mindset and student mathematics performance. The purpose of Phase 2 was to determine general student mindset, general student grit, and to collect qualitative data to determine the mathematical mindset of each participant as well as the mathematical grit of students. Relationships were examined between (1) participants' general mindsets and mathematical mindsets, (2) parent mathematical mindset and student mathematical mindset, (3) parent mathematical mindset and student mathematical achievement (as measured by GPA, SAT score, and mathematics course), (4) parent mathematical mindset and student mathematical grit, and (5) general grit and mathematical grit for students.

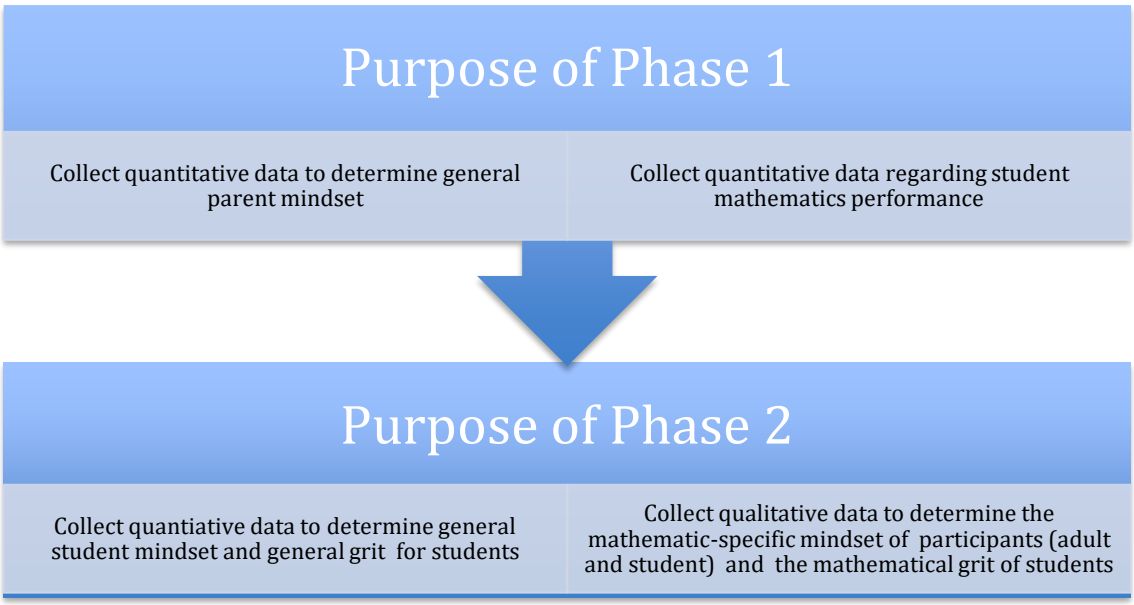

Figure III-2. Description of the purpose of each phase of research.

Phase 1

The 8-item Adult Mindset Survey (see Appendix A) was sent out electronically to all registered parents or guardians of high school seniors using the online Qualtrics tool. The scale contained four general growth mindset statements (questions 1, 2, 4, and 6) regarding general intelligence (e.g. "No matter who you are, you can significantly change your intelligence level") and four general fixed mindset statements (questions 3, 5, 7, and 8) regarding general intelligence (e.g. "You have a certain amount of intelligence, and you can't really do much to change it"). The four fixed mindset statements received a score of 6 for "Strongly Agree," 5 for "Agree," 4 for "Mostly Agree," 3 for "Mostly Disagree," 2 for "Disagree," and 1 for "Strongly Disagree." The four growth mindset statements were reverse scored. All eight items were summed and a mean theory of intelligence score was calculated. Lower scores (1-3) represented a pure general-growth mindset and higher scores (4-6) represented a pure general-fixed mindset. Scores between 3.1 and 3.9 were considered neutral (or "undecided" or "mixed"). Scoring was consistent with Dweck's (2000) survey. In some studies, those participants scored as neutral (or "undecided" or "mixed") were eliminated from the sample because those participants did not identify strongly enough with either mindset (Dweck, Chiu, & Hong, 1995); however, it was necessary for the researcher to include the neutral category so that more families could be accepted into the study. The implication of including this category will be discussed as a possible limitation to the study.

The researcher determined the general mindset of those parents who responded. Additionally, surveys were sent out to the second set of active parent participants and likewise scored. The researcher compared the results between parents or guardians of the same family. All single-parent families qualified for Phase 2 of the study: there were four single-parent families. Two-parent families qualified for Phase 2 of the study if it was determined that both active parents

had the same general mindset (fixed-fixed, growth-growth, fixed-neutral, and growth-neutral): there were 10 two-parent families that qualified. Two-parent families were excluded if it was determined that the parent mindsets were different (fixed-growth).

If parents were determined to have the same general mindset, Student Demographic Surveys (see Appendix D) were sent out electronically to their high school seniors via the provided email address. After eliminating those who declined participation as well as those families who did not have the same mindset, only 14 families qualified and were thus invited to participate in Phase 2 of the study. No family declined participation for Phase 2 of the study.

Phase 2

The Student Mindset Survey and Grit-S Scale were administered to all students. Additionally, the researcher conducted individual interviews with each of the selected participants. Interviews were done in-person at HS1 at a time that was convenient for each participant. The interviews conducted by the researcher were semi-structured interviews (Boeije, 2010). The researcher followed interview protocols for each type of participant – parent or student; however, the researcher was free to ask additional questions if warranted by the responses of the interviewees. Interviews lasted no longer than 20 minutes.

Parent Interviews. Parents were asked questions regarding their mathematical experiences. The protocol for parent interviews (see Appendix E) centered on determining their mathematical mindset. Some questions (see Table 3) targeted mathematics-specific fixed and growth mindsets. A priori coding performed with the responses to these questions was used to determine mathematical mindset. The researcher assigned a mathematics-growth (high or low) or mathematics-fixed (high or low) mindset to the parent. “High” or “low”

represents the degree to which their beliefs adhere to the mindset: the classification of "high" indicates a pure mathematical mindset, whereas a classification of "low" implies some mixed beliefs but with a greater adherence to one mindset. Specifically, parents were classified as having a mathematics-growth-high mindset if they recognized mathematics wholly as a subject of growth. Parents were classified as having a mathematics-growth-low mindset if they viewed mathematics as a subject of growth but with limitations. Parents who expressed a more static view (e.g. the belief that a predisposition towards mathematics alone dictates one's success in the subject) were classified as having a mathematics-fixed-high mindset. Those parents who viewed mathematical aptitude as mostly fixed but with a little room for growth were classified as having a mathematics-fixed-low mindset.

The mathematical mindsets are ordinal variables. Mathematics-fixed high (FH) has the lowest ordinal value, mathematics-fixed-low (FL) has the second lowest, mathematics-growth low (GL) has the second highest, and mathematic-growth-high (GH) has the highest ordinal value.

Table 4. Parent Interview Protocol: Mathematics Mindset Questions

Mathematical Mindset Targeted Questions
▪ Do you think that there is a mathematics gene that predisposes certain people to be successful in mathematics while others less successful? ▪ Do you think anyone can learn mathematics? ▪ Can anyone learn every level of mathematics? ▪ You hear people say that mathematics is either something you know or you don't. Is there any truth to this statement?

Other questions (e.g. "How would you respond to your child if s/he came home with a poor/high mathematics grade?") were aimed at determining the parent's response to the student's

performance in mathematics. Although these questions did not specifically target mathematical mindset, it was possible that the parent's response might reveal his or her mathematical mindset.

Student Mindset Survey. Before each student interview, students were asked to complete the 6-item Student Mindset Survey (see Appendix B). The survey contained three general growth mindset statements (questions 4-6) regarding general intelligence (e.g. "You can always greatly change how intelligent you are), and three general fixed mindset statements (questions 1-3) regarding general intelligence (e.g. "Your intelligence is something about you that you can't change very much").

The three fixed mindset statements received a score of 6 for "Strongly Agree," 5 for "Agree," 4 for "Mostly Agree," 3 for "Mostly Disagree," 2 for "Disagree," and 1 for "Strongly Disagree." The three growth mindset statements were reverse scored. All 6 items were summed and a mean theory of intelligence score was calculated. Lower scores (1-3) represented a pure general-growth mindset and higher scores (4-6) represented a pure general-fixed mindset (as scored by Blackwell et al. (2007)). Scores between 3.1 and 3.9 were considered neutral (or "undecided" or "mixed"). In some studies, those participants scored as neutral (or "undecided" or "mixed") were eliminated from the sample because those participants did not identify strongly enough with either mindset (Dweck et al., 1995); however, the researcher decided to include the neutral category so that the student mindset categories would be consistent with the adult mindset categories. The implication of including this category will be discussed as a possible limitation to the study.

Student Grit Scale. Following the Student Mindset Survey, students were asked

to complete the 8-item Grit-S scale before their interviews. The Grit-S scale contained four gritty statements (numbers 2, 4, 7 and 8) regarding general areas of grit (e.g. "Setbacks don't discourage me") and four non-gritty statements (numbers 1, 3, 5 and 6) regarding general areas of grit (e.g. "I often set a goal but later choose to pursue a different one"). The four general gritty statements received a score of 5 for "Very Much Like me," 4 for "Mostly Like Me," 3 for "Somewhat Like me," 2 for "Not Much Like Me," and 1 for "Not Like Me At All." The four general non-gritty statements were reverse scored. All eight items were then summed and averaged. The highest score on the scale is 5 and the lowest score on the scale is 1. The researcher classified each score as "Very Gritty," "Moderately Gritty," "Fairly Gritty," and "Not Gritty" based on the range of values that each score occupied ("Very Gritty" being the highest ordinal value, and "Not Gritty" the lowest). The Grit-S Scale was scored as determined by Duckworth and Quinn (2009). These general grit categories served as a baseline for further qualitative analysis in which the researcher used responses from grit-targeted interview questions to determine the level of grittiness in the specific domain of mathematics.

Table 5. Summary of Scores for Each Scale.

Adult and Student Mindset Survey		**Student Grit Scale**	
Score	**Category**	**Score**	**Category**
1.0-3.0	Growth	1.0 - 1.9	Not Gritty
3.1-3.9	Neutral	2.0 - 2.9	Fairly Gritty
4.0-6.0	Fixed	3.0 - 3.9	Moderately Gritty
		4.0 – 5.0	Very Gritty

Student Interviews. Students were asked questions regarding their mathematical mindset and their level of grit specific to the domain of mathematics.

Mindset interviews. Students were asked questions pertaining to their mathematical experiences (e.g. "Describe your strengths and weaknesses," "Describe your study habits," and "Describe any memorable or significant moments from mathematics class"). Some questions targeted mathematics-specific fixed and growth mindsets (Table 6). Depending on their response to these questions, the researcher assigned each student a mathematics-fixed (high or low) or a mathematics-growth (high or low) mindset. Student mathematical mindsets were assigned according to the same classifications as parent mathematical mindsets.

Table 6. Student Interview Protocol: Mathematics Mindset Questions

Mathematical Mindset Targeted Questions
▪ Describe your study habits regarding mathematics. Have your study habits changed throughout the years? How did they change? ▪ Do you think that there is a mathematics gene that predisposes certain people to be successful in mathematics while others less successful? ▪ Do you think anyone can learn mathematics? Can anyone learn every level of mathematics? What would be required of someone to reach the higher levels? ▪ How does someone become successful in mathematics?

Additionally, other questions (e.g. "Describe how you would feel after receiving a poor/high mathematics grade") aimed at discerning the attribution (i.e. ability or effort) of the students. Questions (e.g. "What would your parents say to you if you brought home a poor/high

grade on a mathematics exam?" and "Do you think your parents have any influence on how you perform in mathematics?") centered on discerning parent feedback practices and the influence it might have on student mathematics performance. Although there were some questions that did not specifically target mathematical mindset, it was possible that the student's response might reveal his or her mathematical mindset.

Grit interviews. Immediately following the Student Mindset Survey, students were also asked questions pertaining to their mathematical grit. They previously completed the Grit-S questionnaire; however, further qualitative analysis was needed to gauge the degree to which they were gritty in the specific area of mathematics. Students were asked questions regarding the obstacles they've faced in mathematics, the attributions they've made in response to success and failure in mathematics, the goals they've set for themselves in mathematics classes, and what they valued as a learner in mathematics (Table 7).

Table 7. Student Interview Protocol: Mathematics Grit Questions

Mathematical Grit Targeted Questions
▪ Have you ever faced a challenge in mathematics? What was it? Were you able to overcome this obstacle? If so, how? If not, what did you do instead? ▪ To which factors would you most attribute your mathematics performance? ▪ Have you ever given up on a mathematics problem? What was it? For how long did you work on that problem? Does this happen often? ▪ Have you ever had any goals for your mathematics classes? What are they? How long did you have to work to achieve your goals? What did you do to achieve your goals?

- Suppose you are assigned a partner to complete a mathematics project that is worth a significant part of your grade. What would you value more in a partner: someone who is naturally smart, or someone with a good work ethic?
- What would you feel more pride from: looking at a problem and immediately knowing how to do it, or having a problem that's really challenging and working really hard for a long amount of time and then finally getting it?

Unlike the Grit-S Scale, mathematical grit was not determined by an average of scores from a survey. Rather, depending on the response to the mathematical grit-targeted questions from the interviews, students were classified as "Very Mathematically Gritty," "Moderately Mathematically Gritty," "Fairly Mathematically Gritty," and "Not Mathematically Gritty" according to the rubric displayed in Table 8. As with general grit, these classifications are ordinal with "Very Mathematically Gritty" assigned the highest ordinal value and "Not Mathematically Gritty" assigned the lowest ordinal value.

Table 8. Grit Rubric for Determining Mathematical Grit

Very Mathematically Gritty	I finish all mathematics problems that I begin. Setbacks don't discourage me at all in mathematics. I set a goal in mathematics and pursue it until I meet it.
Moderately Mathematically Gritty	I finish most mathematics problems I begin, and only give up after I've tried for a long period of time. Setbacks sometimes discourage me in mathematics. I set a goal in mathematics but have difficulty maintaining it sometimes.
Fairly Mathematically Gritty	I often leave mathematics problems blank after trying for a few minutes. I have difficulty maintaining my focus in completing goals I set for myself in mathematics. Setbacks often discourage me in mathematics.

Not Mathematically Gritty	I often leave mathematics problems blank without even trying. I set goals in mathematics but often change it to pursue a different goal in mathematics. Setbacks discourage me in mathematics.

Data Analysis

Both quantitative and qualitative data were used to address the research questions. The surveys collected quantitative data pertaining to general mindset, general student grit, and student mathematical achievement (as measured by current overall GPA, highest score on the mathematics section of the 2017 SAT examination, and highest level mathematics course taken). Qualitative analysis from interviews were used to determine the mathematical mindset of all participants and student mathematical grit. Graphs were created on Excel and tests were run on SPSS to determine if relationships existed between (1) participant general mindset and participant mathematical mindset, (2) parent mathematical mindset and student overall GPA, (3) parent mathematical mindset and student SAT score, (4) parent mathematical mindset and student highest level mathematics course taken, (5) parent mathematical mindset and student mathematical grit, and (6) student general grit and student mathematical grit.

Research Question 1

To address RQ1, data were collected from both the Parent Mindset Survey and the Student Mindset Survey regarding general mindset. The mindset surveys were scored according to the rubrics described in the studies in which they were validated (Dweck, 2000; Dweck et al., 1995). The general mindset results were ordinal: general-fixed mindset (F) had the lowest ordinal value,

general-neutral mindset (N) had the intermediate ordinal value, and general-growth mindset (G) had the greatest ordinal value.

As part of the interview protocols, participants were asked questions regarding their mathematical experience. Some questions targeted mathematics-specific fixed and growth mindsets. For instance, responses to the following types of questions were used to distinguish the mathematical mindset of participants:

1. Do you think that there is a mathematics gene that predisposes certain people to be successful in mathematics while others less successful?
2. Do you think anyone can learn mathematics?
3. Can anyone learn every level of mathematics?
4. You hear people say that mathematics is either something you know or you don't. Is there any truth to this statement?
5. How does someone become successful in mathematics?

The researcher coded the responses to these questions using open coding, axial coding, and selective coding (Boeije, 2010) to determine the mathematical mindset of each participant. According to Boeije (2010), open coding is done mostly in the beginning of the data analysis with the purpose of exploring the research, managing the data and familiarizing the data. The researcher used a priori codes (predetermined codes) in the open coding process. These codes – derived from existing studies, the research questions, interview protocols, and mindset surveys – were used to organize the data to identify mathematical mindsets.

Axial coding, done halfway through data analysis, was used by the researcher to determine the sufficiency of existing (a priori) codes (Boeije, 2010). Emergent codes were created when a

priori codes were deemed insufficient. Emergent codes actively evolved from the process of data analysis. Additionally, the researcher determined hierarchical relationships between codes (both a priori and emergent). Main categories for codes were created with distinctions made between corresponding subcategories (Boeije, 2010). Since the codes were used "in a more practical or descriptive way, the value of inter-rater reliability diminishes and can even become a hindrance" (Boeije, 2010, p. 111). Thus, the researcher was the sole person in charge of creating, assigning, and organizing codes.

Finally, the researcher used selective coding during the culminating phase of data analysis to make connections between categories and reassemble the data to answer the research questions (Boeije, 2010). Specifically, the researcher used selective coding after all analyses were performed to explore the essence of the phenomenon of student mathematical experience and the role the mathematical mindset of the parents had in shaping this experience.

From the coded responses, the researcher assigned a mathematics-fixed-high (FH), mathematics-fixed-low (FL), mathematics-growth-low (GL), or mathematical-growth-high (GH) mindset to participants. Each of these variables is ordinal, the highest value assigned to mathematics-growth-high mindset, and the lowest value assigned to mathematics-fixed-low mindset. The designations "high" and "low" indicate the degree to which the participants maintained fixed or growth beliefs in the domain of mathematics.

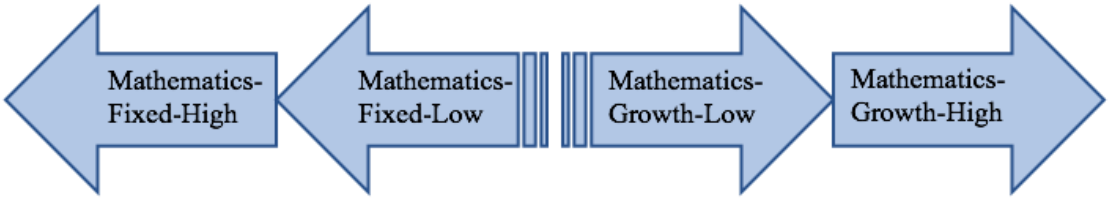

Figure III-3. Spectrum of mathematics-specific categories.

Participants were classified as having a mathematics-growth-high mindset if they recognized mathematics as a subject of growth; in other words, if they exhibited growth beliefs about the nature of mathematics as well as their own role in it (Boaler, 2016). For instance, if participants believed that anyone could learn every level of mathematics, or that someone becomes successful in mathematics through deliberate practice, then they were identified as having a mathematics-growth-high mindset. Participants were classified as having a mathematics-growth-low mindset if they viewed mathematics as a subject of growth but with limitations; for instance, if a participant believed that everyone could learn mathematics but not necessarily the highest levels of mathematics.

Participants who expressed a more static view (e.g. the belief that a predisposition towards mathematics alone dictates one's success in the subject) were classified as having a mathematics-fixed-high mindset; for example, if participants believed in a conceptual threshold that acted as a ceiling for mathematical aptitude. Those participants who viewed mathematical aptitude as mostly fixed but with a little room for growth were classified as having a mathematics-fixed-low mindset.

The distribution of data regarding participant general mindset and participant mathematical mindset were displayed in a table and a graph. The inputs for general mindset and mathematical

mindset were then recoded (F=0, N=1, and G=2 for general mindset; FH=0, FL=1, GL=2, and GH=3 for mathematical mindset) so that a scatter plot could be created to compare general mindset to mathematical mindset (N=38). A Spearman's Rho correlation was then run in SPSS, and Evans' (1996) classifications were used as a guide to determine how to verbally describe the strength of the correlation, *r*.

Table 9. Evans' (1996) Verbal Descriptions for the Strength of Rho

Value Range	Description
0.00-0.19	Very Weak
0.20-0.39	Weak
0.40-0.59	Moderate
0.60-0.79	Strong
0.80-1.0	Very Strong

Responses from participant interviews were used to expand upon the quantitative results and relationships exhibited in the graph.

Research Question 2

To address RQ2, a distribution graph was created to determine the association between parent mathematical mindset and student mathematical mindset. The mathematical mindsets of parents from two-parent families were compared, since these parents would now occupy the same cell: parents were given the shared input "MF" if their mindsets were mathematics-fixed-high or mathematics-fixed-low; parents were given the shared input "MG" if their mindsets were mathematics-growth-high or mathematics-growth-low; parents with different mathematical mindsets (mathematics-fixed and mathematics-growth) were eliminated from the data set because it would be difficult to determine which parent's mathematical mindset was associated (if at all)

with the student's mathematical mindset. The inputs for single parents were determined by the same designations. Students were given the same inputs for mathematical mindset used to answer RQ1: FH, FL, GL and GH.

There were seven mathematics-fixed parent-mindset families, four mathematics-growth parent-mindset, and three families eliminated. Due to the small sample size (N=11), relationships determined by statistical tests (i.e. a Spearman's Rho correlation) would likely not be valid. In lieu of additional statistical measures, responses from participant interviews were used to explain the relationship observed from the distribution graph.

Research Question 3

To address RQ3, parent mathematical mindsets were compared to student (1) overall GPA, (2) mathematics section score on the 2017 SAT examination, and (3) highest level mathematics course taken. The sample sizes comparing parent mathematical mindset to student GPA and mathematics course were both 11; the sample size for parent mathematical mindset to student SAT score was 10 because one student had not taken the 2017 SAT examination.

Parent Mathematical Mindset and Student GPA. A scatter plot with a linear regression trend line was created to determine if an association existed between parent mathematical mindset and overall student GPA. A t-test was then run using SPSS to determine if the correlation coefficient from the simple regression was statistically significant. Markedly, t-tests can be run even with extremely small sample sizes (de Winter, 2013).

Parent Mathematical Mindset and SAT Score. A scatter plot with a linear regression trend line was created to determine if an association existed between parent mathematical mindset and highest mathematics section score on the 2017 SAT examination. A

t-test was then run using SPSS to determine if the correlation coefficient from the simple regression was statistically significant from zero.

Parent Mathematical Mindset and Highest Level Mathematics Course. The highest mathematics courses taken were divided into three ordinal categories based on their level of difficulty: lower-level courses (Mathematical Modeling and Financial Algebra), average-level courses (Introduction to Calculus), and higher-level courses (Multivariable Calculus, AP Calculus AB, and AP Calculus BC). The inputs assigned to lower-level, average-level, and higher-level courses were LL, AL, and HL, respectively. In lieu of statistical tests, a comparison of parent mathematical mindset and highest level mathematics course was made from a graph depicting the distribution of the data. Specifically, a Spearman's Rho correlation could not be run with N=11 and a t-test could not be run with two ordinal variables.

Research Question 4

To address RQ4, students were placed into a general grit category – not gritty (NG), fairly gritty (FG), moderately gritty (MG), and very gritty (VG) – based on their Grit-S scaled score as determined by Duckworth and Quinn (2009). The general grit designations are ordinal variables, with NG having the lowest ordinal value, FG the second-lowest ordinal value, MG the second-highest ordinal value, and VG the highest ordinal value. These general grit categories served as a baseline for further qualitative analysis in which the researcher used responses from grit-targeted interview questions to determine the level of grittiness in the specific domain of mathematics. To gauge the degree to which they were gritty in the specific area of mathematics, students were asked questions regarding the obstacles they've faced in mathematics, the attributions they've made in response to success and failure in mathematics, the goals they've set

for themselves in mathematics classes, and what they valued as a learner in mathematics (Table 7).

Unlike the Grit-S Scale, mathematical grit was not determined by scores from a survey. Rather, depending on the response to the mathematical grit-targeted questions from the interviews, students were classified as "Very Mathematically Gritty (VMG)," "Moderately Mathematically Gritty (MMG)," "Fairly Mathematically Gritty (FMG)," and "Not Mathematically Gritty (NMG)" according to the rubric displayed in Table 8. VMG had the highest ordinal value, MMG had the second-highest ordinal value, FMG had the second-lowest ordinal value, and NMG had the lowest ordinal value.

A graph was created to determine the association between the two ordinal variables parent mathematical mindset and student mathematical grit (N=11). Participant responses from interviews were then used to explain the relationship observed from the graph. Statistical tests were not run: the sample size was too small for a Spearman's Rho correlation, and the assumptions were violated for t-tests because both variables were ordinal.

To compare student general grit to student mathematical grit, the ordinal variables were recoded (NG=0, FG=1, MG=2, and VG=3 for general grit; NMG=0, FMG=1, MMG=2, and VMG=3 for mathematical grit) and a scatter plot with a linear regression trend line was created. A Spearman's Rho correlation was run to test the strength of the association between the ordinal variables, despite the sample size violation to the assumptions of the test. Because the sample size was so small (N=14), too much significance should not be read into the results; as a result, the scatter plot was used to support the results from the test.

CHAPTER IV : RESULTS

Please note that the term "participant" refers to both adults and students. "Adults" will be used when referring to adults only, and "students" will be used when referring to students only.

Research Question 1

What relationship exists, if any, between general mindset and mathematical mindset for high school seniors and their parents or guardians?

Participant General Mindset

The Adult Mindset Survey and Student Mindset Survey were scored according to the rubrics described in the studies in which they were validated (Dweck, 2000; Dweck et al., 1995). The general mindset categories are ordinal variables with labels "F" for general-fixed mindset (the lowest ordinal value), "N" for general-neutral mindset (the intermediate ordinal value), and "G" for general-growth mindset (the highest ordinal value).

Table 10. General Mindset Frequencies for Participants.

		General Mindset			
		F	N	G	Total
Participant	Adult	7	5	12	24
	Student	3	2	9	14
	Total	10	7	21	38

About 55.3% of participants (21 of 38) had a general-growth mindset (G), 26.3% had a general-fixed mindset (F), and 18.4% of participants had a general-neutral mindset (N). Most adults and students had a general-growth mindset: the implications of this fact will be discussed in Chapter 5.

Of the 14 families, only four were single-parent families. Additionally, none of the four single parents were identified as having a general-neutral mindset. When comparing parents to students, the following general mindset labels were assigned: “FF” was assigned for two-parent families in which both parents had a general-fixed mindset or for single parents with a general-fixed mindset; “FN” was assigned for two-parent families in which one parent had a general-fixed mindset and the other parent had a general-neutral mindset; “GN” was assigned for two-parent families in which one parent had a general-growth mindset and the other parent had a general-neutral mindset; and “GG” was assigned for two-parent families in which both parents had a general-growth mindset or for single parents with a general-growth mindset.

Table 11. General Mindset Frequencies for Families.

		Student General Mindset			
		G	N	F	Total
General Mindset of Parents	FF	0	1	1	2
	FN	3	0	0	3
	GN	1	0	1	2
	GG	5	1	1	7
	Total	9	2	3	14

Most families (50%) (7 of 14) had either a single parent with a general-growth mindset or both parents with a general-growth mindset (GG). About 14.3% of families had either a single parent with a general-fixed mindset or both parents with a general-fixed mindset (FF). About 14.3% of families were two-parent families in which one parent had a general-growth mindset and the other a general-neutral mindset (GN). Finally, about 21.4% of families were two-parent families in which one parent had a general-fixed mindset and the other a general-neutral mindset (FN).

Participant Mathematical Mindset

In order to determine the mathematical mindset of each participant (as opposed to the general mindset), all interviews were coded according to open coding, axial coding, and selective coding procedures. A priori codes were identified prior to data analysis, and emergent codes were actively created during data analysis when a priori codes were insufficient in describing evolving themes. Hierarchical relationships were delineated, creating main categories of codes with a tier of subcategories (Table 12). The process of selective coding commenced in the culminating phase of all data analysis to synthesize the results.

There were two main categories from which hierarchical relationships among codes were created: mathematics-fixed mindset and mathematics-growth mindset. Subcategories were either combined (e.g. Mathematical intelligence/ability is fixed or limited & Mathematical brain/gene) or tiered (e.g. Mathematics-Growth Mindset and Mathematical Intelligence/Ability is Dynamic). Coded responses from these categories were used to determine mathematical mindset.

Table 12. Main Categories of Codes and Subcategories of Codes.

Mathematics-Fixed Mindset

- ◊Mathematical intelligence/ability is fixed or limited & Mathematical brain/gene
- ◊Mathematical Proclivity
- ◊Everyone can learn mathematics but not everyone can learn every level of mathematics & I hit a wall: conceptual threshold
- ◊Mathematics as magic

Mathematics-Growth Mindset

- ◊Mathematical intelligence/ability is dynamic & Mathematics as growth
  - Everyone can learn mathematics at every level
  - Effort attribution & Motivation needed for success

Based on these main categories of codes and subcategories of codes, four different mathematical mindsets (mathematics-fixed-high, mathematics-fixed-low, mathematics-growth-low, and mathematics-growth-high) were identified – which are described in Table 13.

Table 13. Rubric for Determining Mathematical Mindsets

Mathematics-Fixed-High	▪ Mathematics is a static domain ▪ Your aptitude for mathematics is predisposed and fixed ▪ Mathematics performance is attributed to an inherent ability that is beyond your control ▪ People can learn the level of mathematics that they're predisposed to learn: eventually they'll hit a conceptual threshold that they can't surpass
Mathematics-Fixed-Low	▪ Your aptitude for mathematics is mostly predisposed ▪ You are limited in your ability to increase your aptitude in mathematics ▪ Anyone can learn mathematics, but not everyone can learn every level of mathematics
Mathematics-Growth-Low	▪ There may be mathematical predispositions, but you can also increase your aptitude with effort ▪ Effort is required to improve your mathematical ability, but you are limited by how much you can improve ▪ The highest levels of mathematics are unattainable by most people

Mathematics-Growth-High	▪ Mathematics is a growth domain ▪ Anyone can learn every level of mathematics with effort: mathematics is accessible to all people ▪ Anyone can achieve success in mathematics regardless of any proclivities or predispositions ▪ If you are motivated to improve in mathematics, then you can improve in mathematics

In the next section, I first elaborate on each of these four mathematical mindsets using participant responses to exemplify the characteristics of each, before answering RQ1, which concerns the relationship between general- and mathematical-mindset.

Mathematics-Fixed-High Mindset Category. The 16 participants (13 adults, 3 students) that exuded this mathematical mindset shared the belief that mathematics was a static domain, that the capacity to increase one's mathematical aptitude was limited, and that mathematical performance was attributed to an inherent ability that was beyond their control. For instance, one student attributed her mathematics success to "natural ability," whereas another parent blamed his "nonmathematical mind" for his shortcomings. Even those who were not convinced of a mathematics gene were still passionate in their belief of a mathematical predisposition, crediting it to personality, mental disposition, and natural proclivity. They likewise acknowledged inclinations towards other domains, such as to art, music, and even an affinity to colors.

These participants were steadfast in their conviction that aptitude prevented people from reaching all levels of mathematics. One parent described others' inability to reach the highest levels of mathematics with the response "they're just incapable of it," whereas another likened it

to sports: “there’s good athletes and there’s good mathletes.” Most participants expressed their belief in a conceptual threshold as a ceiling to mathematical ability, using phrases such as “people cap out” and “I hit a wall.” For instance, one parent expressed the following:

> It’s just a question if people cap out based on their intellectual capabilities which I think is probably the case. Certain people are going to be able to go further, and certain people are gonna cap out. I see it all the time. People get to a certain level and are not capable of getting to the next level no matter how much coaching they get.

They likewise believed staunchly that aptitude was beyond one’s control, using examples of geniuses, prodigies, and savants to bolster their point. In fact, many of them described the extraordinary talents of gifted individuals in terms that suggested mathematics was almost magically endowed to certain people; for instance, comments such as “you somehow just have that understanding,” “my brain just opened up at that time,” and “you’re just not a mathy,” describe mathematical reasoning as an instantaneous process not attained by deliberate practice but rather a byproduct of good fortune.

Mathematics-Fixed Low Mindset Category. The two participants (both adults) assigned the mathematics-fixed-low mindset maintained the belief that aptitude for mathematics was limited; however, they also acknowledged small room for growth in the subject. For example, “I think everyone can get better, wherever they’re at. But I don’t think every person can do calculus or really hard math.” Or, “Anyone can get better at it, but I do think that there are levels of math that are unattainable by many people.” These comments help to distinguish between the fixed-high and fixed-low mathematical mindsets. Namely, in the fixed-high group the participants were adamant that “people are not capable of getting to the next level no matter how much coaching they get,” while in the fixed-low group they similarly suggested that some areas were “unattainable” but simultaneously also indicated that “anyone can get better at it.” That is, these

participants seemed to hold in tension the idea that anyone can get better, while simultaneously believing that some levels are not achievable.

Mathematics-Growth-High Mindset Category. The 16 participants (6 adults, 10 students) assigned this category shared the belief that mathematics was a subject of growth and that all levels of mathematics were accessible to all people. They believed that anyone could learn every level of mathematics. For example:

> You set your heart, you set a goal, you do hard work – I believe 10,000 hours of practice you can be a genius.
>
> I feel maybe someone thinks, "Oh I'm just not that good at math." I've heard that, but I don't believe that. I believe if you try and you really see what kind of learner you are, and try to work with that, then you could really be good at math.
>
> I honestly think if you teach it to someone, it might take them however long it takes them but eventually you could get it.

Many participants credited such growth – or progress – in mathematics to concerted effort: "No one is really naturally smart, they just put in the effort and get smarter." Some participants acknowledged that some people may have natural predispositions towards the subject (e.g. "some people it might come more naturally to because of their brain wiring psychology/biology"); however, they maintained that success in mathematics can be achieved regardless of natural proclivities:

> I think that if you are not naturally good at math it doesn't mean you can't be good at math. It just depends on what you do to practice it and learn it.
>
> Any level? I mean, theoretically maybe yes, but to get to that level for one person may require many more years of work and study than another person. Any person in general – whatever their original understanding lacks they have to make up for that in studying or extra help depending on where each of those points are.

Many participants recognized the role of self-motivation in expanding one's aptitude for the subject:

> I think if they're striving for it, if they want to go to college and get a degree in calculus, I think if they apply themselves anyone can do it. It's just the matter of doing it.
>
> I would say if they want to do it – if they want to take calculus and APs or any type of class like that – I would say they'd have to put a lot of effort into it because they're pretty hard classes. I hear about the kids who take them now. But I think if they wanna be successful in it they can. It's just a matter of doing it.

One such participant even admired the "hunger for learning" that drives people to succeed.

Mathematics-Growth-Low Mindset Category. The four participants (3 adults, 1 student) classified under this mindset category were steadfast in their belief that effort led to success in mathematics, while simultaneously acknowledging a small degree of limitations to aptitude. For example, when asked, "Can anyone learn any level of mathematics?" participants expressed that people can achieve higher levels of mathematics, but only when the conditions are right:

> I think that's a reflection of their tenacity, their interest, the teaching, so it would have to be a lot of factors coming together in order for everyone to be able to learn math. I think if you have no interest, poor teaching, then no. The issue is yes, but the conditions have to be right.
>
> I mean, I guess with enough time and enough effort most people can. Not necessarily every level.

These participants expressed beliefs distinct from those with a mathematics-growth-high mindset. Namely, those with a mathematics-growth-high mindset believed staunchly that any level of mathematics is attainable by anyone, and that everyone has the unlimited potential to improve their mathematical ability through effort.

Both those with the mathematics-growth-low mindset and the mathematics-fixed-low mindset held contradictory beliefs that were often in tension with each other. For example, participants with a mathematics-fixed-low mindset believed that anyone can get better at mathematics, while believing simultaneously that some levels of mathematics are not attainable by everyone. Participants with a mathematics-growth-low mindset believed that the highest

level of mathematics were unattainable by most people, while believing simultaneously that you could improve your mathematical ability through effort. The belief in limitations to mathematical ability is a characteristic that each of these mathematical mindsets has in common. However, what distinguishes these two categories is the emphasis they placed on effort and predisposed ability. Participants with a mathematics-fixed-low mindset believed mathematical ability to be mostly predisposed, whereas participants with a mathematics-growth-low mindset asserted that, although there may be some mathematical predispositions, mathematical aptitude could be improved upon most through effort

Mathematical Mindset Results. The mathematical mindset categories are ordinal, ranging on a spectrum from fixed-high (the lowest) to growth-high (the highest). Of the 38 participants, about 42.1% had a mathematics-fixed-high mindset (FH), 5.2% had a mathematics-fixed-low mindset (FL), 10.5% had a mathematics-growth-low mindset (GL), and 42.1% had a mathematics-growth-high mindset (GH). Most participants had either a FH or GH mathematical mindset. Further, most students had a GH mathematical mindset, whereas most adults had a FH mathematical mindset.

Table 14. Mathematical Mindset Frequencies for Participants.

		Mathematical Mindset				
		Fixed		Growth		
		High	Low	Low	High	Total
Participant	Adult	13	2	3	6	24
	Student	3	0	1	10	14
	Total	16	2	4	16	38

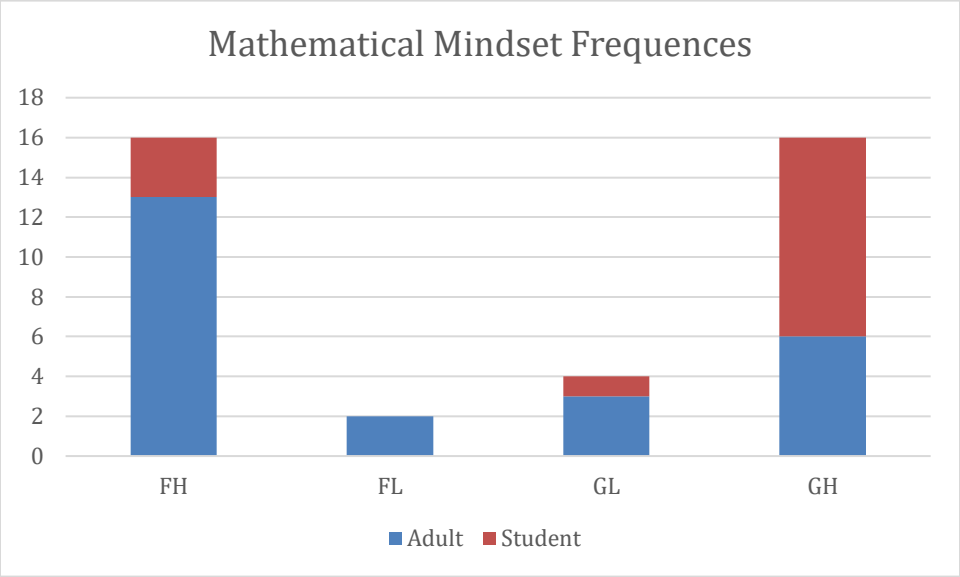

Figure IV-1. Spectrum of mathematics-specific mindset categories.

Analysis. The distribution of general mindset and mathematical mindset for each participant is displayed in Figure IV-2. Of the 38 participants, most were either G-GH or F-FH. These results are consistent with the previous findings that (1) most participants had a general-growth mindset, and (2) most participants had either a mathematics-fixed-high or mathematics-growth-high mindset. No participants were F-FL, F-GL, or N-GL. For the 14 students, most were G-GH, once again consistent with the finding that most students had a general-growth mindset and a mathematics-growth-high mindset. No students were N-FL, G-FH or G-FL. Finally, for the 24 adults, most were either F-FH or G-GH: this is to be compared with the previous finding that most adults had a general-growth mindset and a mathematics-fixed-high mindset. No adults were N-GH.

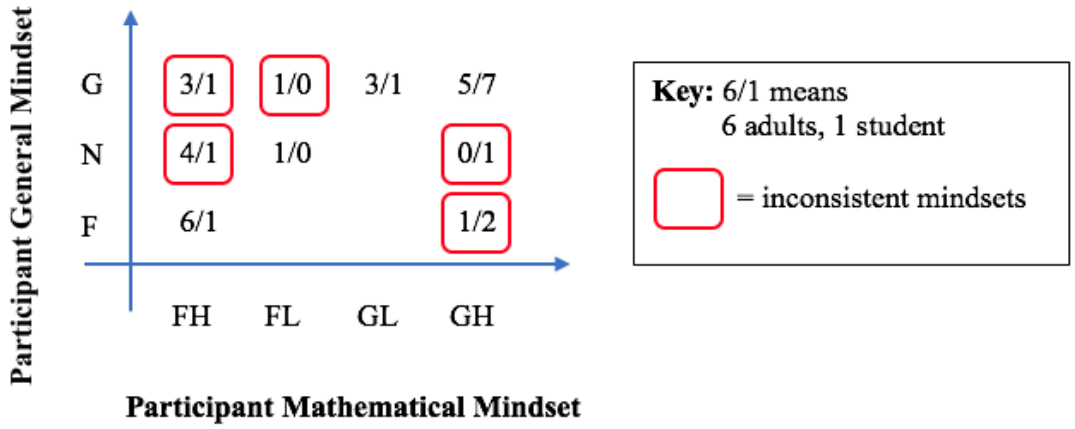

Figure IV-2. Distribution of general mindset to mathematical mindset for participants. The data displayed compares the adult/student numbers.

According to Altendorff (2012), a dominant cultural script used in mathematics classrooms encourages fixed mathematical mindset preferences in students, and girls are more likely than boys to exhibit these fixed qualities. Interestingly, of the 38 participants, less than half (18) expressed mathematics-fixed mindset views. Likewise, of the 20 female participants, less than half (9) were classified as having a mathematics-fixed mindset (Table 15). In fact, more students ascribed to mathematics-growth mindset beliefs (11 out of 14), and more female students (4 out of 6) ascribed to mathematics-growth beliefs.

Table 15. A Comparison of Mathematical Mindset and Gender

		Mathematical Mindset				
		FH	FL	GL	GH	Total
Gender	Male	9	0	1	8	18
	Female	7	2	3	8	20
	Total	16	2	4	16	38

Although most participants were F-FH or G-GH (as expected), the distribution of participants with a general-growth mindset is notable. A scatter plot was created to better view the dispersion of data points (Figure IV-3). Necessarily, the mindset labels were recoded: the general mindset labels were recoded as F=0, N=1, and G=2; the mathematical mindset labels were recoded as FH=0, FL=1, GL=2, and GH=3. An eyeball test of the scatter plot suggests a positive correlation between general mindset and mathematical mindset. However, there are data points that fall outside the range of this apparent positive trend; namely, nearly 25% of participants with a general-growth mindset have fixed beliefs regarding mathematical intelligence.

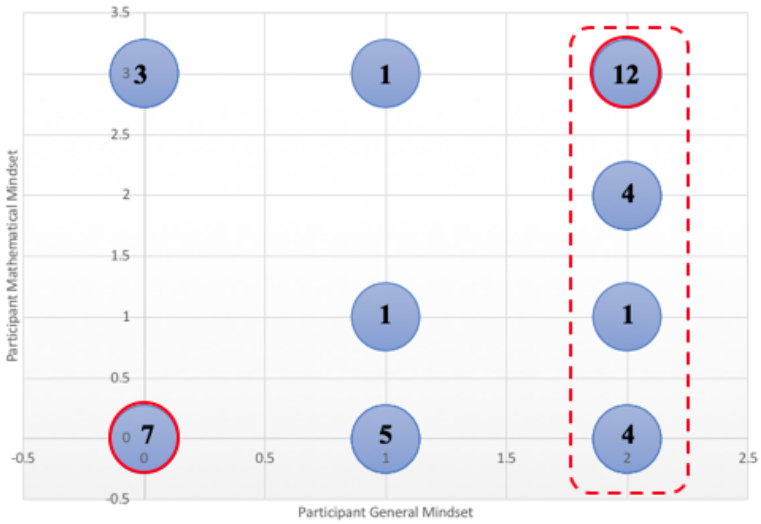

Figure IV-3. Distribution of participant general mindset and participant mathematical mindset. Numbers inside data points represent the frequency of each general-mathematical mindset pairing. Most participants were F-FH or G-GH (red circles). Of note is the dispersion of participants with a general-growth mindset (dashed red lines).

A Spearman's Rho correlation (N=38) was run to determine the association between the two ordinal variables general mindset and mathematical mindset. The nonparametric test was appropriate because the two assumptions (e.g. ordinal variables and monotonic relationship) were met. Additionally, the sample size requirement (N ≥ 25) was satisfied (Bonett & Wright, 2000). The Spearman's Rho correlation coefficient ($r_s(36) = 0.43$) indicated a moderate positive relationship (Evans, 1996) between general mindset and mathematical mindset. The result is statistically significant ($p_{value} = 0.007 < .05$).

Thus, to answer RQ1, there is a moderate positive relationship between general mindset and mathematical mindset. Of the 38 participants, 24 had consistent mindsets; in other words, their implicit theory of intelligence did not change when considering general intelligence and mathematical intelligence. In contrast, 14 participants held contradictory beliefs regarding general intelligence and mathematical intelligence (emphasized in Figure IV-2). For instance, one participant (F-GH) agreed to the following general-fixed mindset statements: you have a certain amount of intelligence, and you really can't do much to change it; your intelligence is something about you that you can't change very much; you can learn new things, but you can't really change your basic intelligence. However, she expressed mathematics-growth-high beliefs:

> Interviewer: Can anyone learn every level of math?
>
> Participant: Yes.
>
> Interviewer: How would they be able to do that?
>
> Participant: I honestly think if you teach it to someone, it might take them however long it takes them but eventually they could get it.

Another participant (G-FH) agreed with the general-growth mindset statements "No matter who you are, you can significantly change your intelligence level" and "You can always substantially change how intelligent you are," but expressed mathematics-fixed-high beliefs:

> I think if it's someone like me, I think there's a point where you just check out. Which is probably gonna be the Pre-Calc level. At that point, you just check out.

Finally, those participants determined to have a general-neutral mindset exhibited both fixed and growth beliefs regarding general intelligence. For example, they mostly disagreed with the general-fixed statement, "Your intelligence is something about you that you can't change very much," and mostly agreed with the general-growth mindset statement, "You can change even your basic intelligence level considerably." Despite these conflicting beliefs for general intelligence, one such participant (N-FH) expressed a mathematics-fixed-high mindset:

> I think it's something that you're either exceptional at because you can conceptualize and it comes easier to you versus those for whom they have to try hard and then they will make some breakthroughs. And then there are those who will never make progress. So it's like three tiers.

Although there are possible alternatives (discussed in Chapter 5), findings from these participants seem to suggest that, while there is a moderate positive association for the population at large, some people may think differently about mathematics when it comes to holding fixed or growth mindsets about intelligence.

Research Question 2

What relationship exists, if any, between high school seniors' mathematical mindsets and their parents' or guardians' mathematical mindsets?

Parent Mathematical Mindset and Student Mathematical Mindset

The mathematical mindsets of parents from two-parent families were compared. Since these parents would now occupy the same cell, they were given the shared input "MF" if their

mindsets were mathematics-fixed-high or mathematics-fixed-low, and the shared input "MG" if their mindsets were mathematics-growth-high or mathematics-growth-low. The inputs for single parents were determined by the same designations. Two-parent families in which the parents had different mathematical mindsets (mathematics-fixed and mathematics-growth) were eliminated from the data set because it would be difficult to determine which parent's mathematical mindset was associated (if at all) with the student's mathematical mindset: 3 families were excluded based on this premise. Students were given the same inputs for mathematical mindset used to answer RQ1: FH, FL, GL and GH.

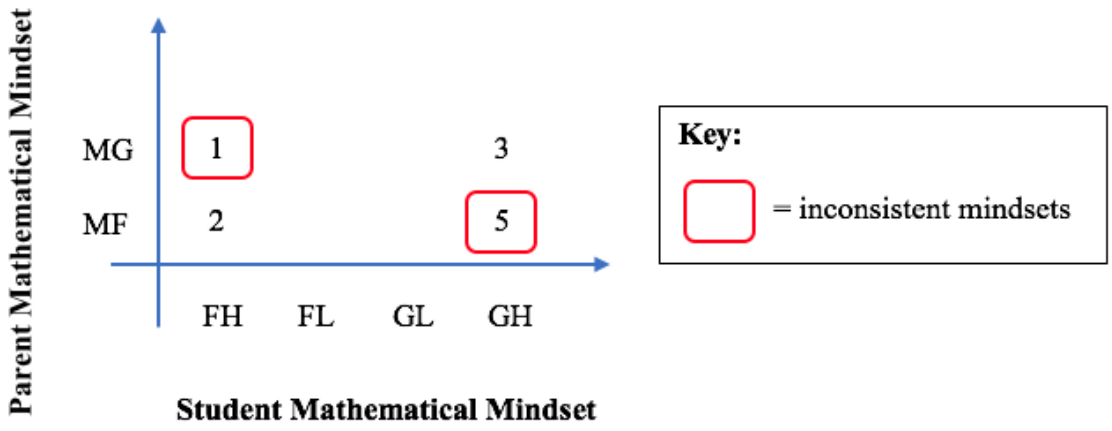

Figure IV-4. A comparison of general mindset to mathematical mindset for participants.

As depicted by Figure IV-4, there does not appear to be an association between parent mathematical mindset and student mathematical mindset. Although 5 out of 11 cases follow a trend (parent fixed, student fixed; parent growth, student growth), 5 out of 11 cases also indicate students with growth-high mathematical mindsets coming from parents of fixed mathematical mindsets.

Due to the small sample size (N=11), statistical tests would likely not be valid; for instance, despite having met the assumption for ordinal variables, the data for RQ2 were neither monotonic nor met the sample size minimum of 25 needed to run a Spearman's Rho correlation (Bonett & Wright, 2000)

Thus, to answer RQ2, there is not a clear relation between parent mathematical mindset and student mathematical mindset. In fact, only about 45% of families had the same mathematical mindset (MF-FH or MG-GH). For those families with different mathematical mindsets, starkly different language was used when describing mathematical intelligence. For instance, one parent (MF, with spouse MF) believed vehemently that mathematical ability was genetically predisposed, and that one could only reach the level of mathematical aptitude proscribed by his or her DNA. When asked, "Do you think everyone can learn every level of mathematics?" he responded:

> No. So in Good Will Hunting, there's a couple of lines in there where he talks about – the guy who won the fields medal – he talks about an Indian on a remote island who found a rudimentary math book and was able to extrapolate some of the world's most complex theorems. I think that those people exist. And those people on one end of the bell curve, - yes, they can learn any type of math that exists. Then there are other people on the bell curve that I don't think in certain lifetimes – again, if you believe in genetic proclivity – I don't think in their own lifetime or in multiple lifetimes that they can ever get to a certain piece because there's probably blockers on that gene sequence. Just like Matt Damon says to Minnie Driver in that movie, "I can't sit down and play a piano, but when I look at math it just appears to me." So there's just those proclivities.

His son (GH) agreed that not everyone can learn every level mathematics; however, for significantly different reasons. Rather than describing a genetic ceiling that inhibits one's capacity for mathematical learning, his son attributed a lack of desire as the reason for limited growth in mathematics:

> Interviewer: Do you think anyone can learn math?
>
> Son: Yes.
>
> Interviewer: Do you think everyone can learn every level of math?

> Son: No, because I feel like people won't want to and therefore won't do well on it.
>
> Interviewer: So you think it's more a matter of them not wanting to do it rather than ability to do it?
>
> Son: Yeah, I think so.

Further, he identified a strong work ethic, a perseverance to continue studying, and a willingness to learn as necessary components for success in mathematics.

In another family (MF-GH), the parents believed that "there are many levels of mathematics unattainable by many people," and that "you could take somebody who's not good at math and train them all day long, then put a person who's good at math at it, and the person who's good at math will blow them away." Each of these sentiments emphasizes the mathematics-fixed belief that mathematical performance is attributed to an innate ability that is beyond your control. In contrast, their daughter used mathematics-growth language. She believed that with enough guidance anyone could learn every level of mathematics. Further, she emphasized the role that effort has in mathematical learning: "I think some people are more naturally good at it, but I think everyone has to work hard to be good at math. Everyone has to take the time to learn the concepts."

Research Question 3

What relationship exists, if any, between high school seniors' mathematical achievement and their parents' or guardians' mathematical mindsets?

Parent Mathematical Mindset and Student Overall GPA

The student GPA used in the data set is the self-reported current overall GPA of the high school senior. The district uses weighted GPAs based on course level (Figure IV-5). The range

of the GPA (N=11) was 2.0 – 4.585 with a mean of 3.746. As before, 3 families were excluded because the parents had different mathematical mindsets.

WEIGHTING SYSTEM USED TO COMPUTE OFFICIAL GPA*

Grade	Advanced Placement	Level 1	Level 0	Level 2
A+	5.00	4.67	4.67	4.33
A	4.67	4.33	4.33	4.00
A-	4.33	4.00	4.00	3.67
B+	4.00	3.67	3.67	3.33
B	3.67	3.33	3.33	3.00
B-	3.33	3.00	3.00	2.67
C+	3.00	2.67	2.67	2.33
C	2.67	2.33	2.33	2.00
C-	2.33	2.00	1.67	1.67
D+	2.00	1.67	1.33	1.33
D	1.67	1.33	1.00	1.00
D-	1.33	1.00	0.67	0.67
F	0.00	0.00	0.00	0.00

*All subjects are considered except pass/fail courses and physical education/health.

Figure IV-5. Weighted GPA system for HS1 and HS2. The source has been excluded to protect the privacy of the district.

Table 16. Parent Mathematical Mindset and Student Overall GPA

Parent Mathematical Mindset	Student Overall Weighted GPA
MG	4.1192
MF	2.0
MG	3.2
MF	3.4
MG	3.3

MF	4.35
MF	4.3675
MF	4.585
MG	3.88
MF	4.1
MF	3.9

A scatter plot with a linear regression trend line was created to determine the association between parent mathematical mindset and student GPA (Figure IV-6). Parent mathematical mindset inputs were recoded as MF=0 and MG=1. The coefficient of determination ($R^2 = 0.0169$) indicates that only about 1.7% of the variation in student overall GPA is explained by parent mathematical mindset.

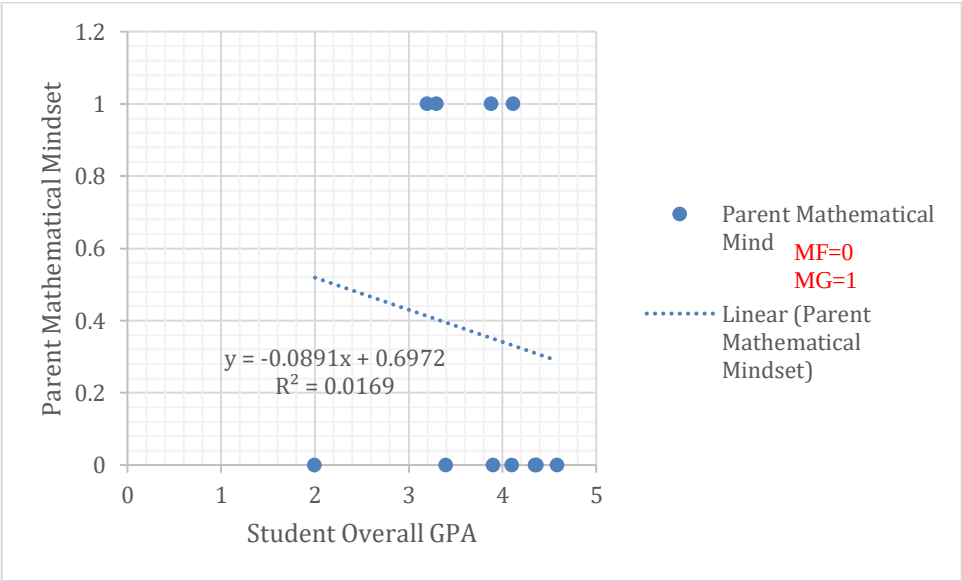

Figure IV-6. Scatter plot comparing parent mathematical mindset to student overall GPA. Student GPA is shown on the x-axis, and parent mathematical mindset is shown on the y-axis.

A t-test was run on the correlation coefficient in the simple regression to determine if the association between parent mathematical mindset and student overall GPA was statistically significant. Notably, a Spearman's Rho correlation could not be run because the minimum sample size requirement (25) was not met (N=11) (Bonett & Wright, 2000). Specifically, t-tests are feasible even with extremely small sample sizes (de Winter, 2013). The results from the t-test ($t(10) = -0.393, p = 0.7 > 0.05$) indicate that the correlation is not statistically significant.

Parent Mathematical Mindset and Student Mathematics SAT Score

The student SAT score used in the data set is the self-reported highest score on the mathematics section of the 2017 SAT examination. One additional family was excluded from the dataset because the student did not take the SAT examination. The range of the SAT (N=10) was 350 – 800 with average 647.9. The average SAT scores of the students are high compared to the district averages $\bar{X} = 548$ and $\bar{X} = 577$ as reported by HS1 and HS2 respectively, and the national average ($\bar{X} = 527$) and state average ($\bar{X} = 527$) as reported by the College Board.

Table 17. Parent Mathematical Mindset and Student Mathematics SAT Score

Parent Mathematical Mindset	Student Mathematics SAT Score
MG	800
MF	350
MG	600

MF	680
MG	599
MF	780
MF	640
MF	720
MG	680
MF	630

A scatter plot with a linear regression trend line was created to determine the association between parent mathematical mindset and student mathematics SAT score (Figure IV-7). Parent mathematical mindset inputs were recoded as MF=0 and MG=1. The coefficient of determination ($R^2 = 0.0225$) indicates that only about 2.3% of the variation in student SAT scores is explained by parent mathematical mindset.

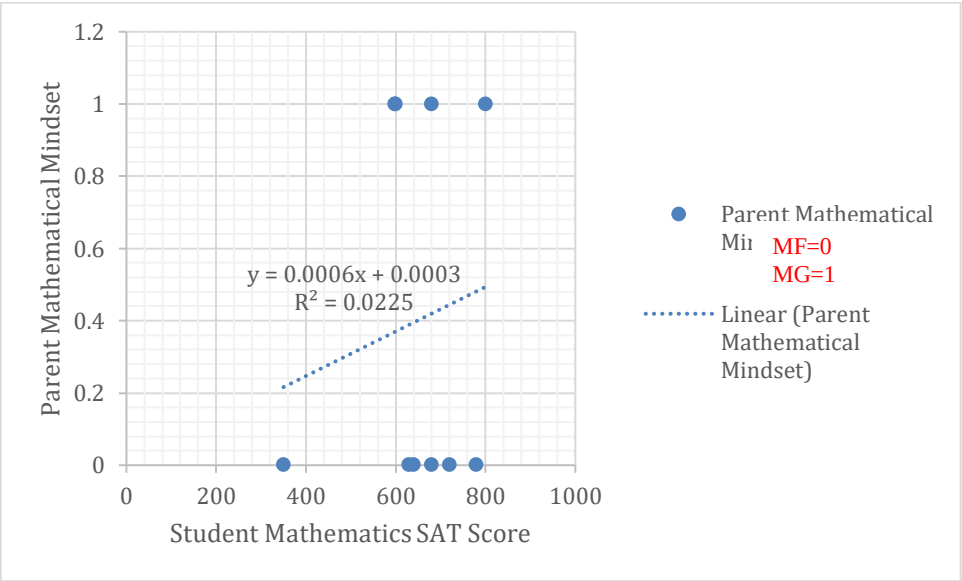

Figure IV-7. Scatter plot comparing parent mathematical mindset to student SAT score. Student SAT score is shown on the x-axis, and parent mathematical mindset is shown on the y-axis.

A t-test was run on the correlation coefficient in the simple regression to determine if the association is statistically meaningful. Once again, the t-test was the more appropriate test to run due to the small sample size (N=10). The results from the t-test ($t(9) = 0.429, p = 0.679 > 0.05$) indicate that the correlation is not statistically significant.

Parent Mathematical Mindset and Student Highest Mathematics Course

The highest mathematics courses taken were divided into three ordinal categories based on their level of difficulty: lower-level courses (Mathematical Modeling and Financial Algebra), average-level courses (Introduction to Calculus), and higher-level courses (Multivariable Calculus, AP Calculus AB, and AP Calculus BC). The inputs assigned to lower-level, average-level, and higher-level courses were LL, AL, and HL, respectively.

Table 18. Parent Mathematical Mindset and Highest Mathematics Course

Parent Mathematical Mindset	Highest Mathematics Course
MG	HL
MF	LL
MG	LL
MF	AV
MG	LL
MF	HL
MF	HL
MF	HL
MG	AL
MF	AL
MF	AL

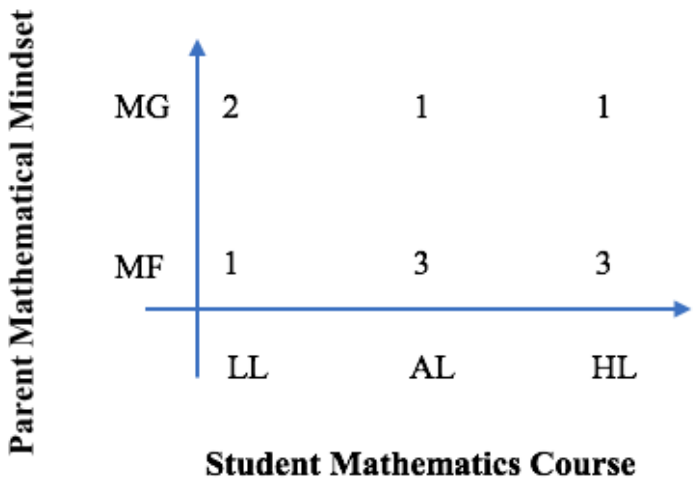

Figure IV-8. A comparison of parent mathematical mindset to student highest mathematics course.

As depicted by Figure IV-8, there seems to be an inverse relationship between mathematics course taken and parent mathematical mindset. Namely, students of parents with a mathematics-fixed mindset appear to take more advanced mathematics courses, whereas students of parents with a mathematics-growth mindset appear to take lower-level courses. Given that mathematics high school course is indicative of effort, it seems that those students from mathematics-fixed mindset parents "fight" their parents' mindsets by exerting more effort, whereas those from mathematics-growth parents didn't push themselves as hard. Interestingly, a similar trend can be seen when comparing parent general mindset to student mathematics course (Figure IV-9).

As discussed, a Spearman's Rho correlation is invalid with N=11. Additionally, the assumptions for running a t-test were violated; namely, t-tests cannot be run when both variables are ordinal.

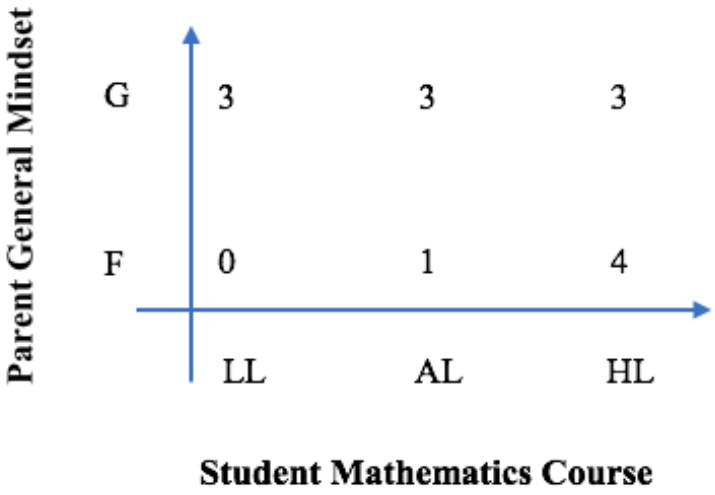

Figure IV-9. A comparison of parent general mindset to student highest mathematics course.

Research Question 4

What relationship exists, if any, between high school seniors' mathematical grit and their parents' or guardians' mathematical mindsets? What relationship exists, if any, between general grit and mathematical grit for high school seniors?

Student Mathematical Grit

The results from the grit-targeted interview questions were ordinal: depending on the response to the mathematical grit-targeted questions, students were classified as "Very Mathematically Gritty (VMG)," "Moderately Mathematically Gritty (MMG)," "Fairly Mathematically Gritty (FMG)," and "Not Mathematically Gritty (NMG)" according to the rubric displayed in Table 19.

Table 19. Grit Rubric for Determining Level of Mathematical Grit

Very Mathematically Gritty	I finish all mathematics problems that I begin. Setbacks don't discourage me at all in mathematics. I set a goal in mathematics and pursue it until I meet it.
Moderately Mathematically Gritty	I finish most mathematics problems I begin, and only give up after I've tried for a long period of time. Setbacks sometimes discourage me in mathematics. I set a goal in mathematics but have difficulty maintaining it sometimes.
Fairly Mathematically Gritty	I often leave mathematics problems blank after trying for a few minutes. I have difficulty maintaining my focus in completing goals I set for myself in mathematics. Setbacks often discourage me in mathematics.
Not Mathematically Gritty	I often leave mathematics problems blank without even trying. I set goals in mathematics but often change it to pursue a different goal in mathematics. Setbacks discourage me in mathematics.

Very Mathematically Gritty. Only one student was assigned this category. When asked, "Have you ever given up on a mathematics problem?" he responded with a resolute "no." His father confirmed the claim in his own interview:

> He doesn't stop doing his homework 'til he's done. And it can be very irritating because very often we have to go somewhere and he's like "I'm not going anywhere till I've done my homework." He's very punctilious.

All other students admitted to giving up on mathematics problems (Table 20).

Table 20. Sample Responses

Have you ever given up on a mathematics problem?
▪ Yeah, plenty of times. I've tried it and said, "I know that I don't know it." ▪ I definitely gave up on some math problems because I'd just wait for the teacher to go over it. ▪ It depends on how I'm feeling, but I would usually continue going until I really think that I'm just not going to be able to ever get it. ▪ If I don't know how to do something then it's kind of hard to figure out.

Moderately Mathematically Gritty. The nine students classified under this category admitted to giving up on mathematics problems; however, only after working on them for a long amount of time.

> I would give it probably a pretty generous amount of time. Definitely trying to figure it out, because sometimes you just have like that "aha!" moment where you're like, "oh, this is how it works," so I'd probably wait a relatively long amount of time working on it.
>
> A long time. Definitely. I think it would take me a while to get to the point where it's not worth it.

Their study habits also involved persistent effort.

> On days when we learn new notes or something I always go through them at home and I try and like remind myself of concepts and make sure I have everything down and then work on practice problems again.
>
> I think probably that I always work hard at math, I've never just assumed I'll know it or if I don't know it just give up on it. So that's probably the whole thing.
>
> I tend to just understand what I'm doing, then I just practice it over and over again and I eventually get it done easily.

They described facing setbacks, and overcoming most of them after an extended period of time.

> In the class that I wasn't doing very well in I had to study consistently, getting a higher score on tests and quizzes.

> I've faced challenges in math more than one time. As time went on, if I was struggling I started solving my problem – I started trying to fix it differently. Towards my freshman year, beginning of high school, I struggled in math a lot more than I do now. And I just got really frustrated and bitter about it. I would try to blame things that weren't my own study habit. Like "Oh I had a bad day, that's why I did bad." Or "she graded this really hard." I used to not really go to extra help if I didn't really do well, I would just be mad at it and say "I'll do better next time" instead of figuring out what I did wrong this time. But now, if I did bad on a test or didn't understand something we were doing in class, I would wanna go talk to my teacher and have someone explain it to me and then I would practice it a lot more on my own than I used to.

They also acknowledged feeling pride from pushing themselves when faced with a challenge in mathematics.

> I'm really hard on myself, and I think it's a good thing sometimes – I don't let myself settle for something. Sometimes I need to remind myself that I should be happy with this grade, but I think I definitely push myself really hard so I think that has helped me with math.

> Definitely working through [a problem] for a really long time and finally getting it because that's putting more effort in and I would feel more confident in my abilities and proud of the effort that went into it.

Fairly Mathematically Gritty. The four students assigned this category admitted to giving up on mathematics problems after very little time: "I'd look over it for maybe two or three minutes because I don't want to waste time on one problem." They described difficulty in maintaining their focus to complete their work in mathematics:

> I'm also expected to do a lot of work for the math, and usually that's the thing that brings my grade down. If I were just to take tests every day I'd probably have an A+ in every math test I take.

> The homework I would probably give up easier, of course, because there's no real incentive to get every problem right, or to complete every single one.

Not Mathematically Gritty. No students were classified as having no

mathematical grit because each of them described a length of time for which they would spend working on a mathematics problem, and described overcoming some setbacks in mathematics.

Parent Mathematical Mindset and Student Mathematical Grit

Parent mathematical mindsets were compared to student mathematical grit (Table 21). A graph was created to determine the association between the two ordinal variables (N=11). As before, 3 families (two with students who were MMG and one with a student who was VMG) were excluded because the parents had different mathematical mindsets. Notably, a Spearman's Rho correlation could not be run because the sample size did not meet the minimum requirement as outlined by Bonett and Wright (2000).

Table 21. Parent Mathematical Mindset and Student Mathematical Grit

Parent Mathematical Mindset	Student Mathematical Grit
MG	MMG
MF	FMG
MG	MMG
MF	FMG
MG	FMG
MF	MMG
MF	MMG
MF	MMG
MG	MMG
MF	FMG
MF	MMG

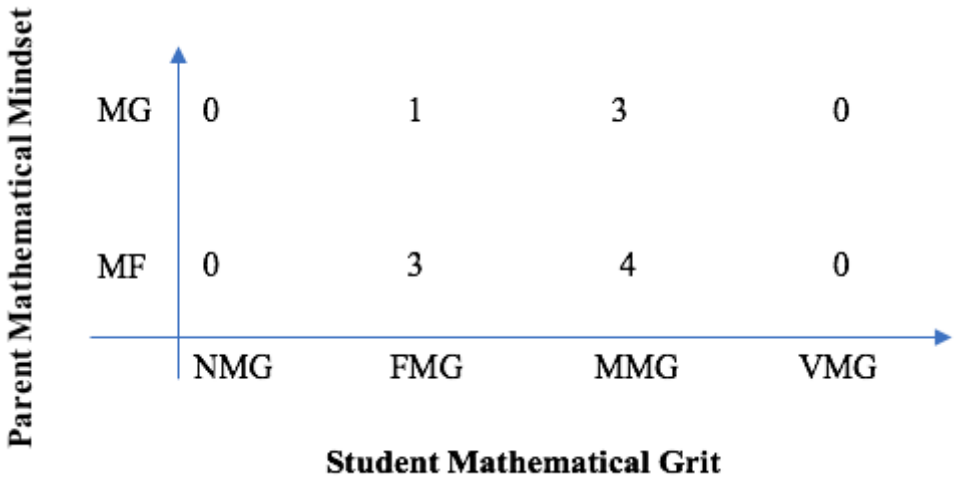

Figure IV-10. A comparison of parent mathematical mindset to student mathematical grit.

As depicted by Figure IV-10, no association was found between parent mathematical mindset and student mathematical grit. Similarly, no distinction was found between student responses regarding mathematical grit when their parents' mathematical mindsets were compared. For instance, when asked, "Have you ever had to set any goals for your mathematics classes?" a student with parents of MG mindsets responded as follows:

> **Student:** Yeah, I've had like grade goals that I wanna achieve. And also, as well as like, understanding goals, like "I wanna really understand, grasp these concepts because I know I'm gonna have to carry them into the future, in stuff in the future that I wanna do."
>
> **Interviewer:** So what did you do to achieve your goal?
>
> **Student:** Definitely studied more, definitely refocused on paying attention in class. And like also participating in class. And I found myself asking a lot of questions that other students would raise their eyebrows at kind of, because I wanted to really understand the stuff in and out and also how to like apply it to the real world, because I wanted to keep those – I wanted to understand it really well so I could do that well.

When asked the same question, another student with parents of MF mindsets responded:

> **Student:** I always have a goal to go beyond a grade to understand what we're learning and really like not just be able to do problems but understand why you're solving it this way or whatever.

> **Interviewer:** What do you do to achieve that goal?
>
> **Student:** On days when we learn new notes or something I always go through them at home and I try and like remind myself of concepts and make sure I have everything down and then work on practice problems again.

Student General Grit

The Grit-S Scale numerically determined the general level of grit. These scaled numbers were then classified into the four ordinal ranges "Very Gritty (VG)," "Moderately Gritty (MG)," "Fairly Gritty (FG)," and "Not Gritty (NG)" as determined by Duckworth and Quinn (2009).

General Grit and Mathematical Grit

Student general grit was compared to student mathematical grit (Table 22). All 14 students were used.

Table 22. A Comparison of Student General Grit and Student Mathematical Grit

General Grit Score	Student General Grit Category	Student Mathematical Grit Category
4.125	VG	MMG
2.25	FG	FMG
3.625	MG	MMG
3.125	MG	FMG
1.75	NG	FMG
3.75	MG	MMG
4.25	VG	MMG
3.75	MG	MMG
3.375	MG	MMG
2.875	FG	FMG
3.875	MG	MMG
3.625	MG	MMG
4.0	VG	VMG
3.375	MG	MMG

A scatter plot with a linear regression trend line was created to compare the association between the two ordinal variables (Figure IV-11). The coefficient of determination ($R^2 = 0.5887$) indicates that about 59% of the variation in student mathematical grit is explained by student general grit. Notably, the fact that such a significant amount of variation in student mathematical grit is explained by student general grit suggests that the positive association between the two variables is meaningful.

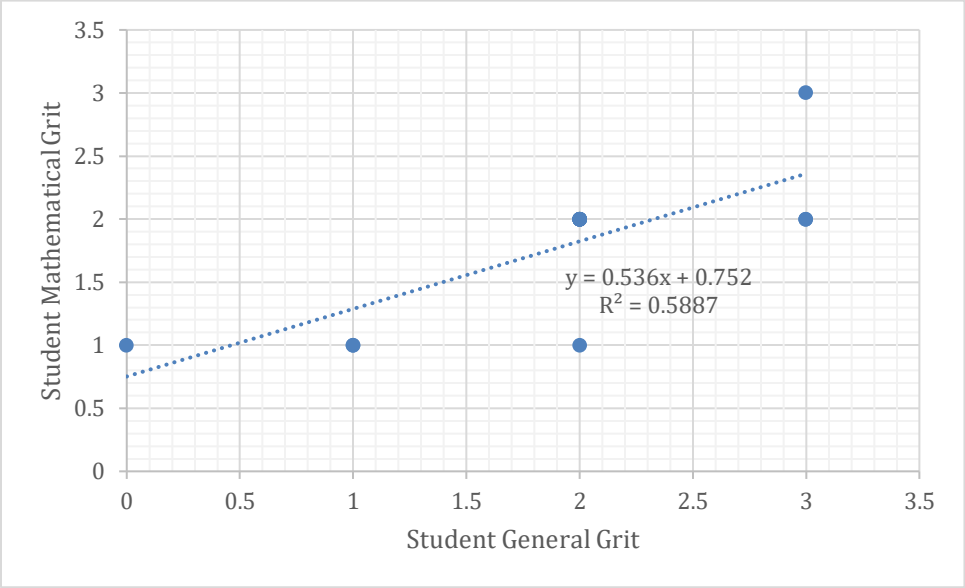

Figure IV-11. Scatter plot comparing student general grit to student mathematical grit. Student general grit is shown on the x-axis, and student mathematical grit is shown on the y-axis.

A Spearman's Rho correlation was run to test the strength of the association between the two ordinal variables. Since the assumption for sample size was violated with only 14 observations, too much significance should not be read into the results. As it is, a strong positive association (Evans, 1996) was found and the result is statistically significant ($r_s(12) = 0.781, p = 0.001 < 0.05$).

CHAPTER V : CONCLUSION

The present study investigated the relationship between parents and students in consideration of two main constructs – mindset and grit. The investigator operated under the framework of domain-specificity for both mindset and grit; as a result, participant general mindset and student general grit (measured quantitatively using validated survey instruments) were compared to participant mathematical mindset and student mathematical grit (determined qualitatively through interviews), respectively. Specifically, mathematical mindset and mathematical grit were treated as distinct from general mindset and general grit, rather than an instantiation of the general constructs. Additionally, parent mathematical mindset was compared to (1) student mathematical mindset, (2) student mathematics achievement (determined by SAT score, overall GPA, and highest mathematics course), and (3) student mathematical grit. Each of these comparisons was made in an effort to better understand the relationship (if any) between parent mathematical mindset and student mathematical experience. Fourteen families were used as participants (14 students, 24 adults). Families were the unit of study for RQ's 2-4, all participants (adults and students, N=38) were the unit of study for RQ1, and students (N=14) were the unit of study for the subquestion of RQ4.

First is a brief summary of the answers to each research question. Next is the discussion section in which themes of particular interest are described and implications to theory are explored. The recommendation section is subsequent and includes suggestions for researchers and practitioners. Finally, I discuss the possible limitations to the study.

Research Question 1

Participant General Mindset and Participant Mathematical Mindset

There is a moderate positive association between general mindset and mathematical mindset ($r_s(36) = 0.43, p_{value} = 0.007 < .05$). Of the 38 participants, most demonstrated internal consistency of mindsets across the general intelligence domain and the domain of mathematical intelligence; in other words, most participants were either G-GH or F-FH. Specifically, 70% of participants with a general-fixed mindset had a mathematics-fixed high mindset (there were no participants with F-FL) and about 76% of participants with a general-growth mindset had a mathematics-growth (high or low) mindset. Interestingly, participants with a general-growth mindset were more likely than participants with a general-fixed mindset to share concurrent beliefs regarding general and mathematical intelligence. The result is compelling, suggesting that a malleable view of intelligence is perhaps more internally consistent and transferable across different intelligence domains. However, it should also be noted that more participants (about 55%) had a general-growth mindset than any other general mindset; thus, the study should be repeated with more participants in order to determine if it is true that growth beliefs are more consistently applied across different intelligence domains than fixed beliefs.

Despite the consistencies found between general mindset and mathematical mindset, about 37% of participants had general views of intelligence that were in tension with their views regarding mathematical intelligence. In fact, about 18% of participants were identified as F-GH or G-FH – the mindset pairings that are the least similar and, as a result, most indicative of internal conflict. This finding confirms that people do not always consistently apply their general implicit theory of intelligence to all subject domains. A possible explanation for this inconsistency is the personal experiences that people attribute to their view of intelligence in a particular subject. For instance, in school people receive frequent, concrete evaluations of their performance in a subject

that can impact their own perception of intelligence for that subject. In contrast, general intelligence is less tangible and less frequently assessed, thereby making it more difficult for people to grasp; as a result, general intelligence is less likely to be affected by personal experience.

A similar inconsistency emerges when considering participants with general-neutral mindsets. Although there was no neutral category for mathematical mindset, participants identified as having either mathematics-growth-low or mathematics-fixed-low mindsets exhibited similar internal tensions that were characteristic of the general-neutral mindset. With that being said, about 86% of participants with a general-neutral mindset had either a mathematics-fixed-high or a mathematics-growth-high mindset; in other words, rather than holding consistent neutral beliefs, most participants with a general-neutral mindset possessed strong beliefs regarding mathematical intelligence, thus bolstering the finding that mathematical intelligence is viewed as separate from general intelligence, and perhaps other subject domains.

Ultimately, the positive moderate association found between general mindset and mathematical mindset is indicative of two things: (1) it provides some face validity to my construct of mathematical mindset from the qualitative data; and (2) while there is some meaningful overlap, it suggests that these two concepts are not completely analogous. In fact, with regards to the latter indication, there were some participants who evinced vastly different general- and mathematical-mindsets. As suggested, a possible explanation for the stark contrast in views could be the role that personal experiences play in fostering subject-specific mindsets. For instance, the burgeoning cases of mathematics anxiety, as well as the often inimical portrayal of mathematics in the media, contribute to the abundance of nonmathematical identities in the classroom; as a result, people may perceive mathematical intelligence as being separate from general intelligence. Further, students

perceive mathematical intelligence as requiring more effort to acquire than historical intelligence (Buehl et al., 2002), and there is an inclination to perceive mathematical ability as a reflection of natural, intrinsic intelligence (Beach, 2003; Beach & Dovemark, 2007).

It is worth noting that the results from the present study contradict those from Altendorff's (2012) study in English schools; namely, most students – and most female students – exhibited mathematics-growth tendencies. Altendorff (2012) attributed the preferences towards mathematics-fixed behaviors to a dominant cultural script in English classrooms (characterized by teacher-centered instruction, ability grouping, outlined procedural methods, the differentiation of student work by ability, a focus on higher attaining students, and the perception of success in mathematics as finding the right answer) that encouraged performance goals which, in turn, were less likely to lead to mastery oriented qualities that foster self-motivation, improvement, and overall progress in students (Dweck, 2000). It is possible that the students in the present study received mathematical instruction different from the dominant cultural script described by Altendorff (2012). The study should be repeated to explore the pedagogical methods used by the teachers in HS1 and HS2 to determine if the methods used foster learning goals, effort attributions, and mastery-oriented responses to failure (all strategies that promote mathematics-growth mindsets) (Dweck, 2000).

Finally, an interesting trend emerges when examining the mathematical mindset frequencies between adults and students (Figure IV-I); namely, most adults were identified as having a mathematics-fixed-high mindset, and most students were identified as having a mathematics-growth-high mindset. It is possible that mathematical intelligence theories seem to change in later years, after high school. In other words, it is likely that mathematical mindsets are

more malleable than previously thought, or at least shift later on in life (e.g., younger people are optimistic; as you age, you become more pessimistic). Alternatively, it is possible that the current generation of adults was mathematically instructed in particular ways that informed their intelligence theories (i.e., they have more fixed views about mathematics), and that the data suggest that students nowadays are having a very different mathematical experience in school that is shaping their intelligence views (toward more growth views).

Research Question 2

Parent Mathematical Mindset and Student Mathematical Mindset

There is no clear relationship between parent mathematical mindset and student mathematical mindset. In fact, only about 45% of families – meaning both parents and the student – had the same mathematical mindset (MF-FH or MG-GH). This result mirrors a previous finding regarding general mindset, in which no clear link was found between parents' general intelligence mindsets and their children's general intelligence mindsets (Haimovitz & Dweck, 2016). In previous studies, parents' general mindsets have been linked to other outcomes; for instance, parents' general mindsets have been linked to parent feedback practices which, in turn, have been shown to affect student mathematics achievement (Dweck, 2008; Mueller & Dweck, 1998; Blackwell et al., 2007; Plaks & Stecher, 2007). The relationship between parent mathematical mindset and parent feedback practices with respect to mathematics should be explored to determine if the same association exists. Additionally, if neither the general nor mathematical mindsets of parents is associated with the general or mathematical mindsets of the student, then future studies should explore which parent beliefs do influence their student's beliefs regarding general and mathematical intelligence.

Research Question 3

Parent Mathematical Mindset and Student Mathematical Achievement

A scatter plot revealed a weak negative association between parent mathematical mindset and student overall GPA; students with lower overall GPAs tend to have parents with mathematics-growth mindsets, and students with higher overall GPAs tend to have parents with mathematics-fixed mindsets. However, the results from the t-test ($t(10) = -0.393, p = 0.7 > 0.05$) indicate that the correlation is not statistically significant. As it is, only about 1.7% of the variation in parent mathematical mindset is explained by student overall GPA.

Additionally, a scatter plot revealed a weak positive association between parent mathematical mindset and student mathematics SAT score; students with higher SAT scores tend to have parents with mathematics-growth mindsets, and students with lower SAT scores tend to have parents with mathematics-fixed mindsets. However, results from the t-test ($t(9) = 0.429, p = 0.679 > 0.05$) indicate that the correlation is not statistically significant. Accordingly, only about 2.3% of the variation in parent mathematical mindset is explained by student SAT scores.

As expected, students with higher GPAs tend to have higher SAT scores, and vice versa. Vexingly, the slopes in the above two scatter plots contradict each other, and seem to suggest that (1) students with higher GPAs tend to have parents with mathematics-fixed mindsets, (2) students with higher mathematics SAT scores tend to have parents with mathematics-growth mindsets, and (3) students with higher overall GPAs tend to have higher mathematics SAT scores. However, neither were the correlations significant, nor the variances high. Although there's no minimum sample size required for a t-test, as the sample sizes get smaller the test

becomes more sensitive to the assumption that both samples are drawn from populations with a normal distribution; thus, the study should be repeated with a larger sample to determine if the contradictory associations hold and if the variances in parent mathematical mindset explained by student GPA and SAT score remain small.

Additionally, it is important to consider the various grades that contributed to the student's overall GPA. For instance, it's possible that a student consistently underperformed in mathematics classes, but had a higher overall GPA as a result of better performances in other classes, thereby skewing the data for mathematics achievement. The study should be repeated in which the GPA in mathematics – specifically – is used.

As it is, incorporating the highest level mathematics course taken was an attempt made by the researcher to reconcile having used overall GPA. With that being said, an inverse relationship was found between parent mathematical mindset and highest level mathematics course taken by the student: students of parents with a mathematics-fixed mindset appear to take more advanced mathematics courses, whereas students of parents with a mathematics-growth mindset appear to take lower-level courses. Interestingly, a similar trend emerged when comparing parent general mindset to student mathematics course.

In an attempt to explain the relationship between parent mathematical mindset and student highest mathematics course, it is important to consider how parent feedback is related to their own general mindset: parents with fixed intelligence theories are more likely to view their child's intelligence as fixed and, as a result, are more likely to give their child praise that emphasizes product over process (Dweck, 2008; Mueller & Dweck, 1998). Given that mathematics high school course is indicative of effort, it seems that those students from

mathematics-fixed mindset parents "fight" their parents' mindsets by exerting more effort, whereas those from mathematics-growth parents didn't push themselves as hard. Future studies should explore parent feedback practices with respect to mathematics, and how it relates to their mathematical mindsets.

Additionally, students might not always be at odds with their parents when it comes to exerting effort. For instance, parents' mindsets regarding failure (e.g. the view that failure is either enhancing or debilitating) are distinct and unrelated to their general mindsets. Unlike general mindsets, parents' failure mindsets have been shown to predict student general mindset (Haimovitz & Dweck, 2016). Thus, additional studies should be conducted to examine the relationship between (1) parents' mathematical mindsets and parents' mathematical failure mindsets, (2) general failure mindsets and mathematical failure mindsets, and (3) parents' mathematical failure mindsets and student mathematical mindset.

It should be noted that of the 14 students, 50% were enrolled in higher-level mathematics courses, whereas only about 29% were enrolled in average-level mathematics courses and 21% were enrolled in lower-level mathematics courses. Thus, it's possible that the inverse relationship observed between mindset and exerted effort is a byproduct of the uneven distribution of students enrolled in the different levels of mathematics courses. The study should be repeated with a larger population more diverse in the level of mathematics courses taken.

Research Question 4

Parent Mathematical Mindset and Student Mathematical Grit

No association was found between parent mathematical mindset and student mathematical grit. Similarly, no distinction was found between student responses regarding

mathematical grit when their parents' mathematical mindsets were compared. The result is not surprising, since grit and the growth mindset are highly correlated: in other words, since parent mathematical mindset is not a predictor of student mathematical mindset, it follows that parent mathematical mindset would also not be a predictor of student mathematical grit. With that being said, the relationship between parent mathematical mindset and (1) student mathematics course and (2) student mathematical grit should be examined concurrently: if students of parents with mathematics-fixed mindsets are more likely to exert more effort by enrolling in higher-level mathematics courses, then it is likely that these students also have higher levels of mathematical grit.

Student General Grit and Student Mathematical Grit

A strong positive association was found between student general grit and student mathematical grit ($r_s(12) = 0.781, p_{value} = 0.00097 < 0.05$). Since the sample size assumption for the test was violated (N=14), a scatter plot was created to more accurately represent the data. From the scatter plot, it was discerned that 59% of the variation in student mathematical grit is explained by student general grit. When compared to the moderate positive association found between general mindset and mathematical mindset, the finding is quite interesting: general mindset is a moderate predictor of mathematical mindset, but general grit is a strong predictor of mathematical grit. Although grit and mindset coincide in many regards, they are not the same constructs. Rather, those who encompass the growth mindset respond to defeat with constructive thoughts that encourage their tenacity to persist in achieving their goals; in other words, those with the growth mindset exhibit a certain way of thinking that translates to gritty behavior. Despite not being synonymous, grit and growth mindset are highly correlated; thus, it is not surprising that

they share a similar degree of internal consistency across different domains. However, as aforementioned, there were many inconsistencies when relating general mindset to mathematical mindset, thereby making it a less reliable predictor than general grit with mathematical grit; in fact, five students (out of 14) exhibited such inconsistencies (compared to nine adults out of 24). It appears that perseverance and passion in achieving one's goals is an attribute in a person more universally constant than their implicit views of intelligence. Future studies should explore (1) what causes people to stay steadfast with respect to their grittiness but vary in their beliefs in the malleability of intelligence, and (2) what makes general grit more transferable into mathematical contexts than general mindset.

One possible explanation for the internal stability of grit is the significant correlation (both phenotypically and genetically) between grit and conscientiousness (one of the Big Five personality factors) (Rimfeld et al., 2016). Conscientiousness is a trait; as a result, it is not susceptive to environmental factors in the same way in which mindset has shown to be. Thus, it's possible that the overlap between grit and conscientiousness is responsible for the consistency between general grit and mathematical grit. Another possible explanation, of course, is that the qualitative way in which I determined either mathematical mindset or mathematical grit is imprecise. A final possible explanation is the potential difficulty participants have in scrutinizing their own implicit theories of intelligence. Perhaps grit is more stable because it is significantly more tangible and concrete than mindset. It is visible, and can be observed. It is also vulnerable to absolutist tendencies (e.g. you either see someone pursuing their goal (to various degrees) or you do not). As a result, grit – the more "neutral" construct – is perhaps a self-evaluation more easily determined than mindset. Mindset requires significant metacognition and self-reflection.

Consequently, its variability is possibly a result of its vulnerability to experiences, emotions, and knowledge (to name a few) at any given moment of time. Mindset – in practice – is more abstract and nebulous. As a result, one's ability to determine one's own mindset, as well as that of another, is "charged" in that there are a variety of factors at play. To that regard, future studies should explore the possibility of using quantitative measures for determining mathematical mindset and mathematical grit in an attempt to make the designations more robust.

Finally, since general grit has emerged as a significant predictor of academic achievement (Duckworth & Gross, 2014; Duckworth et al., 2007; Rimfeld et al., 2016), additional studies should be conducted to examine if mathematical grit is a similar predictor of mathematics achievement. Further, since training programs aimed at teaching students to become grittier can produce more academically successful and resilient students (Maddi et al., 2012), training programs should be developed that focus on mathematical grit specifically to produce more successful and resilient mathematics students.

Discussion

This study explored the relationship between (1) parent mathematical mindset and student mathematical experience (as determined by student mathematical mindset, student mathematical achievement, and student mathematical grit), (2) participant general mindset and participant mathematical mindset, and (3) student general grit and student mathematical grit (Figure V-1).

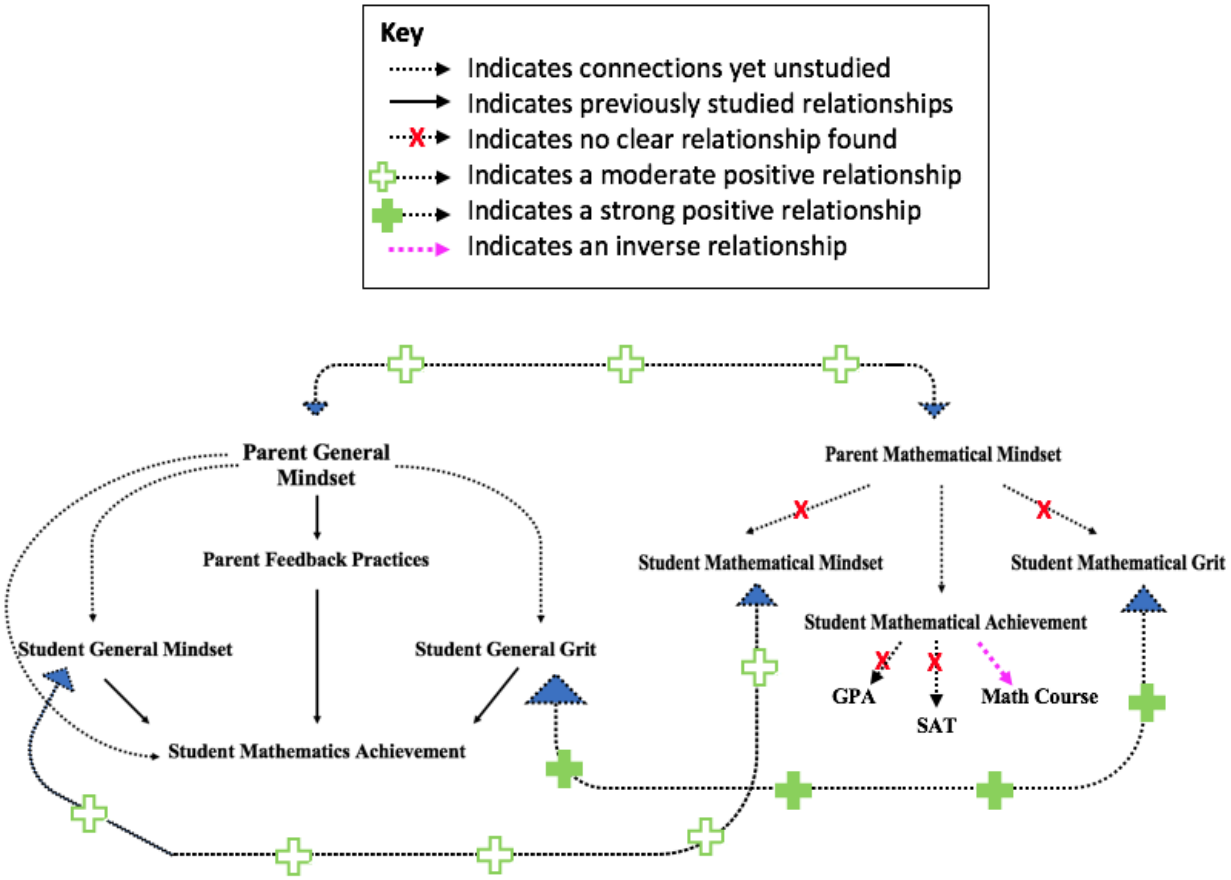

Figure V-1. Contributions of the current study.

Participant general mindset and participant mathematical mindset are not strongly correlated. This suggests that implicit theories of intelligence are not as all-encompassing as previously argued by Molden and Dweck (2006) and Hughes (2015). Although studies have utilized mathematical mindset interventions (Rattan et al., 2012; Paunesku et al., 2007), mathematical mindset was viewed as an instantiation of general mindset, and not a separate manifestation of intelligence beliefs. Further, mathematical mindset itself was not measured independently. The present study advocates that general mindsets and mathematical mindsets are not as closely associated, thereby supporting the theory that mindsets can vary by subject domain.

Notably, the inconsistent relationship established between general mindset and mathematical mindset was vastly different from the more predictive relationship between general grit and mathematical grit: general grit was strongly associated with mathematical grit. To that effect, the study contributed to the field in two ways: (1) by exposing further variability in mindsets dependent on subject domain; and (2) by exposing grit as more fundamentally consistent than mindset when applied to different subject domains. In other words, general grit and mathematical grit are significantly more analogous than general mindset and mathematical mindset. These findings suggest that grit is a more stable character trait than mindset, for in many cases participants evinced remarkably different general- and mathematical- mindsets. Additionally, these findings bolster the argument that although highly correlated, grit and mindset are, indeed, different constructs.

Additionally, parent mathematical mindset is not associated with student mathematical mindset. The result is compelling since teacher's play a role in shaping students' mindsets (Dweck, 2008). It's possible that (1) parents' mathematical mindsets are not visible to their children, (2) parents suppress their beliefs regarding mathematical intelligence, or (3) external factors, such as cultural influences, compete in shaping students' mindsets.

Firstly, parents may not explicitly express their implicit beliefs regarding mathematical intelligence. For instance, Haimovitz and Dweck (2016) found that children could not accurately discern their parents' general intelligence mindsets. With that being said, there are parent practices and actions that do shape student mindset. For instance, in the same study, Haimovitz and Dweck (2016) found that children could accurately discern their parents' failure mindsets. Contrary to mathematical (and general) mindsets, parents' failure mindsets are related to

students' general intelligence mindsets partly because parents' failure mindsets are clearly communicated to the students via verbal or behavioral cues.

Second, it's also possible that parents suppress their beliefs, and express only those beliefs that they feel would be most beneficial to their children. For example, a parent with mathematics anxiety may intentionally suppress that feeling, and in exchange express more positive feelings so as to prevent the transfer of mathematically anxious feelings along to his or her children. Additionally, parents' communicated behavior with respect to failure can be contrary to their implicit beliefs regarding intelligence. Not only can parents with a growth mindset still praise their child's talent (behavior more characteristic of a fixed mindset), but parents' perceptions of their own failure mindsets and intelligence mindsets are not significantly related (Haimovitz & Dweck, 2016)

Third, the effect of the often inimical portrayal of mathematics and mathematicians in popular culture references might play an intervening role in shaping students' mathematical mindsets. It's possible that students' mathematical mindsets are influenced by their choice of media consumption, an inclination towards which might also be shared by their peers. With that being said, it is compelling that grit is a trait immune to such cultural influences while mindset is not.

Finally, although no relation was found between parent mathematical mindset and both student GPA and SAT score, an inverse relationship was observed between parent mathematical mindset and student highest-level mathematics course taken. Markedly, students of parents with a mathematics-fixed mindset appear to take more advanced mathematics courses, whereas students of parents with a mathematics-growth mindset appear to take lower-level courses. This

inverse relationship suggests that student effort is in tension with the evaluation of effort by their parents; students from mathematics-fixed mindset parents "fight" their parents' devalued view of effort by exerting more, whereas those from mathematics-growth parents exhibit less effort despite the high esteem to which their parents perceive it. Notably, since it is unclear if parent mathematical mindsets are visible to their children, it is possible that students are not at odds with their parents' mathematical mindsets but, rather, are at odds with their interpretation of their parents' views with regards to exerting effort.

Recommendations

This study suggests that domain specific mindsets are worth investigating and may be different from general mindsets; notably, the study didn't find the same relationship regarding grit. It would be interesting to examine the ways in which other subject-specific intelligences are disparate from general intelligence. Although the present study was mathematics focused, professionals in every academic domain can benefit from the findings; namely, that implicit theories of intelligence can vary by subject, and that grit is the construct more stable when applied across different subject domains. Not only should future studies be aimed at determining why there are inconsistencies when applying implicit theories of intelligence to specific subjects, but also to determine if there are mindsets that are more dominant for certain domains. With this in mind, teachers should be more cognizant of their feedback, with regards to both the visible (and invisible) verbal or behavioral cues that are communicated to their students as well as with their feedback regarding failure. Further, if grit is more transferable across different domains, then training modules aimed at fostering grittier and more resilient students should be incorporated into classrooms.

Additionally, the study should be repeated with more participants in order to determine (1) if it is true that growth beliefs are more consistently applied across different intelligence domains than fixed beliefs, (2) if a student population more diverse in highest mathematics course taken still exhibit an inverse relationship with regards to parent mathematical mindset, and (3) if more students demonstrate mathematics-growth ideas than mathematics-fixed ideas. As to the latter suggestion, the study should be repeated to explore the pedagogical methods used by the teachers in HS1 and HS2 to determine if the methods used foster learning goals, effort attributions, and mastery-oriented responses to failure (all strategies that promote mathematics-growth mindsets) (Dweck, 2000).

Further, future studies should explore (1) what causes people to stay steadfast with respect to their grittiness but vary in their beliefs in the malleability of intelligence, (2) what makes general grit more transferable into mathematical contexts than general mindset, and (3) if student mathematical mindset and mathematical grit are accurate predictors of mathematics achievement.

The relationship between parent mathematical mindset and parent feedback practices with respect to mathematics should also be explored to determine how parents communicate their mathematical mindsets to their children (whether it is done so explicitly or implicitly, through verbal cues or behavioral cues, or whether they express their beliefs or suppress their beliefs). Having a better understanding of how parent mathematical mindsets are communicated to their children will provide valuable insight as to if parent mathematical mindsets are visible and related to their children's mathematical mindsets. In addition, since failure mindsets are visible to

children, mathematical mindsets and mathematical failure mindsets should also be examined to determine if a relationship exists between the two constructs.

Finally, the present study should be expanded to include how parent mathematical mindset affects how parents interact – in a variety of capacities – with their children regarding mathematics. A significant influencer of students' educational motivation is the social support received by parents (Cham, Hughes, West & Im, 2014). Socialization practices between parents and their children are predominantly dictated by culture. In a study with American, Chinese, and Japanese families, Stevenson et al. (1990) found that although both cultures emphasize the value of success in education, they differed significantly in terms of their emphasis on academic achievement, their views on parent involvement in education, their standards and expectations, and their belief in the influence of effort and ability – all of which are indicators of educational achievement motivation. Mathematics learning and participation can also become racialized; in a study by Martin (2009), narratives of parent interviews from African American families reflected beliefs of exclusion from mathematics along racial lines which, in turn, influenced their dialogue in communication to their children about mathematics (Martin, 2009). Therefore, the study should be expanded to include how culture plays a role in influencing parent mathematical mindset.

Since through interactions with their children parents can shape their child's mathematical experience, the role of the educator should not be viewed as confined to the classroom. Rather, educators should view their communication with parents as an opportunity to foster positive mathematical experiences at the homes of their students. For instance, educators could demonstrate to parents more beneficial ways in which to connect with their children with respect to mathematics. They could equip parents with the tools to change their own narrative in

mathematics. If students can be shown how to face their mathematical obstacles with more positive self-efficacy, then it is less likely that they disidentify and withdraw from the subject. A constructive way to change the narrative is to educate parents on the ideals of the mathematics growth mindset.

Limitations

A possible limitation to this study is the different data sources used to collect information regarding general mindset and mathematical mindset. For instance, surveys were used to determine general mindsets, and interviews were used to identify mathematical mindsets; as a result, further investigation is warranted. I have argued that the variance in mindsets suggests that participants think differently about intelligence in mathematics than they do about intelligence across other, or more general, domains. However, alternatives specific to this study likely cannot be completely ruled out; namely, the difference in methodological choices for data collection of surveys verses interviews for gathering data about general mindset and mathematical mindset may have shaped participants responses. That is, how one responds to survey items may be different from how he responds to analogous interview questions. Participants may misread a survey question (or rush through it); or they may provide more (or less) information during an interview than is possible on a survey, etc. Especially due to the small sample size, this variation in data collection cannot be ruled out. To that regard, the study should be repeated with larger sample sizes and a reassessment of the qualitative methods used to determine mathematical mindset.

Further, for RQ2-RQ4 it was important to have “families” as the unit to answer the intended research questions about the association between parents and students in the same family. However, the same sample was also used to answer RQ1, for which having such “families” was

not necessary. I cannot think of a reason for why the sample in this study would provide a biased answer to RQ1, but it is possible that having this particular sample (namely, in which parents must have the same general mindset) may have skewed the findings to RQ1.

It is difficult to come to a definitive conclusion regarding the relationship (if any) between parents' mathematical mindsets and their student's mathematical experiences due to limitations in the study regarding the participant population size and diversity. Unfortunately, various factors contributed to the diminished sample size used in the study. First, not enough participants volunteered for Phase 1 of the study. Second, due to the necessary stratified and purposeful nature of the sampling process, many participants did not qualify for Phase 2 of the study; specifically, parents with different general mindsets (fixed and growth) were excluded from participating. Finally, additional families were excluded from later statistical analysis due to parents having different mathematics-specific mindsets (mathematics-growth and mathematics-fixed). In retrospect, since there is only a moderate positive association between general mindset and mathematical mindset, families need not have been excluded on the premise that the parents had different general mindsets (i.e. the exclusion should have only existed in Phase 2 when considering mathematical mindsets specifically). Allowing families with parents of different general mindsets may have also increased the diversity of the population used.

Finally, so that more families could qualify for Phase 2 of the study, the researcher included a neutral category as part of the scale for the general mindset surveys, a practice repeated in other studies to identify participants who possessed shared beliefs from both implicit theories of intelligence. Arguably, the results of the study might have been stronger had the researcher not

created the neutral category for general mindset; however, the establishment of the neutral category was not detrimental, and, in fact, was necessary to increase sample size.

In summary, given the opportunity I would replicate the present study with a greater, more diverse population. I would revise my eliminative process of selecting participants in that I would accept those families with parents of different general mindsets. Further, I would reconsider my research methodology to include a multivariable model in which I collect more information about the participants to gain better insight into how other influencing factors might impact general mindset, mathematical mindset, general grit, and mathematical grit (such as parent education, parent socioeconomic status, student mathematics GPA, and the cultural background of the family).

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APPENDIX A : ADULT MINDSET SURVEY

Thank you for participating in this research study. This survey is an opportunity for me to understand your beliefs about intellectual ability. Your participation is voluntary and you may discontinue the study at any time. This survey should take you approximately 5 minutes.

Read each sentence below and then check the appropriate response.

Statement	**Strongly Agree**	**Agree**	**Mostly Agree**	**Mostly Disagree**	**Disagree**	**Strongly Disagree**
1. You have a certain amount of intelligence, and you can't really do much to change it.						
2. Your intelligence is something about you that you can't change very much.						
3. No matter who you are, you can significantly change your intelligence level.						
4. To be honest, you can't really change how intelligent you are.						
5. You can always substantially change how intelligent you are.						
6. You can learn new things, but you can't really change your basic intelligence.						
7. No matter how much intelligence you have, you can always change it quite a bit.						
8. You can change even your basic intelligence level considerably.						

APPENDIX B: STUDENT

MINDSET SURVEY

Thank you for participating in this research study. This survey is an opportunity for me to understand your beliefs about intellectual ability. Your participation is voluntary and you may discontinue the study at any time. This survey should take you approximately 5 minutes to complete.

Read each sentence below and then check the column that shows how much you agree with it.

Statement	**Strongly Agree**	**Agree**	**Mostly Agree**	**Mostly Disagree**	**Disagree**	**Strongly Disagree**
1. You have a certain amount of intelligence, and you really can't do much to change it.						
2. Your intelligence is something about you that you can't change very much.						
3. You can learn new things, but you can't really change your basic intelligence.						
4. No matter who you are, you can change your intelligence a lot.						
5. You can always greatly change how intelligent you are.						
6. No matter how much intelligence you have, you can always change it quite a bit.						

APPENDIX C: STUDENT GRIT SCALE

Please respond to the following 8 items. Be honest – there are no right or wrong answers.

Statement	**Very much like me**	**Mostly like me**	**Somewhat like me**	**Not much like me**	**Not like me at all**
1. New ideas and projects sometimes distract me from previous ones.					
2. Setbacks don't discourage me.					
3. I have been obsessed with a certain idea or project for a long time but later lost interest.					
4. I am a hard worker.					
5. I often set a goal but later choose to pursue a different one.					
6. I have difficulty maintaining my focus on projects that take more than a few months to complete.					
7. I finish whatever I begin.					
8. I am diligent.					

APPENDIX D: STUDENT

DEMOGRAPHIC SURVEY

This survey should take you no longer than 5 minutes to complete.

1. Please write your name in the space provided:
   _____

2. Age: _____

3. Place of birth:
   a. City: _____
   b. State: _____
   c. Country: _____

4. Primary language spoken at home: _____

5. Ethnicity: Are you Hispanic/Latino? _____ Yes _____ No

6. Race: Check all that apply
   i. American Indian or Alaskan Native
   ii. Asian
   iii. Black
   iv. White
   v. Native Hawaiian or other Pacific Islander
   vi. Other: _____

7. Guardianship: Check one
   a. Mother
   b. Father
   c. Both Parents
   d. Other: _____

8. 1st Parent/guardian name: _____

   1st Parent/guardian job : _____

9. 2nd Parent/guardian name (if applicable): _____

   2nd Parent/guardian job (if applicable): _____

10. Highest mathematics section score on the 2017 SAT exam: _____

11. Highest mathematics section score on the ACT exam (if applicable): _____

12. Highest-level mathematics class taken or currently being taken: _____

13. Current overall GPA: _____

APPENDIX E: PARENT

INTERVIEW PROTOCOL

1. What is the first word that comes to mind when I say, “mathematics?”
2. Describe any memorable or significant moments in your life regarding mathematics.
3. Describe your strengths and weaknesses in mathematics.
4. Describe your study habits regarding mathematics.
5. Do you think that there is a mathematics gene that predisposes certain people to be successful in mathematics while others less successful?
6. Do you think anyone can learn mathematics? Can they learn every level of mathematics?
7. You hear people say this about mathematics, that it’s something you either know or you don’t. Is there any truth to this statement?
8. Describe your child’s strengths and weaknesses in mathematics.
9. How involved are you when your child is working on mathematics at home? Has that involvement changed in the past?
10. How comfortable are you with the level of mathematics that your child is currently taking?
11. In your own opinion, what would be a poor grade for your child to receive in mathematics? What would be a high grade for your child to receive in mathematics?
12. How would you respond to your child if s/he came home with a poor mathematics grade?
13. How would you respond to your child if s/he came home with a high mathematics grade?

APPENDIX F: STUDENT

INTERVIEW PROTOCOL

Phase I - Mindset

1. What is the first word that comes to mind when I say, “mathematics?”
2. Describe any memorable or significant moments in your life regarding mathematics.
3. How would you describe your experiences in mathematics classes?
4. Describe your strengths in mathematics. Describe your weaknesses in mathematics.
5. Describe your study habits regarding mathematics. Have your study habits changed throughout the years? How did they change?
6. Do you think that there is a mathematics gene that predisposes certain people to be successful in mathematics while others less successful?
7. Do you think anyone can learn mathematics? Can anyone learn every level of mathematics? What would be required of someone to reach the higher levels?
8. In your own opinion, what grade would you be disappointed to receive on a mathematics exam?
9. Describe how you would feel and what you would do having just received that grade.
10. What would your parents say to you if you brought home that grade on a mathematics exam?
11. What grade would make you proud to receive on a mathematics exam?
12. Describe how you would feel and what you would do having just received that grade on a mathematics exam.
13. What would your parents say to you if you brought home that grade on a mathematics exam?
14. Do you think your parents have any influence on how you perform in mathematics?

Phase II – Grit

1. Have you ever faced a challenge in mathematics? What was it? Were you able to overcome this obstacle? If so, how? If not, what did you do instead?
2. To which factors would you most attribute your mathematics performance?
3. Do you think someone who can solve a problem quickly is necessarily smarter than someone who takes a longer time but solves it eventually?
4. Have you ever given up on a mathematics problem? What was it? For how long did you work on that problem? Does this happen often?
5. Have you ever had any goals for your mathematics classes? What are they? How long did you have to work to achieve your goals? What did you do to achieve your goals?

6. Suppose you are assigned a partner to complete a mathematics project that is worth a significant part of your grade. What would you value more in a partner: someone who is naturally smart, or someone with a good work ethic?
7. How does someone become successful in mathematics?
8. What would you feel more pride from: looking at a problem and immediately knowing how to do it, or having a problem that's really challenging and working really hard for a long amount of time and then finally getting it?