

EVOLVING STUDENT PERCEPTIONS OF MATHEMATICAL IDENTITY:
A CASE STUDY OF MINDSET SHIFT

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree

of

Doctor of Education

in

Curriculum and Instruction with Mathematics Education Emphasis

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2017

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DEDICATION

This dissertation is dedicated to my father, Wilbert (Toby) MacKinder, who shared his passion for education, mathematics, broadening perspectives, and the outdoors with me before he died in 1980. This dissertation is also dedicated to my mother, Genevieve (Cookie) MacKinder-Hayes, who impressed upon me the importance of childhood, learning and growing, and playfulness before she died in 2006. I hope I have made them both proud.

ACKNOWLEDGEMENTS

I would like to thank my husband, Todd Clyatt, for believing in me when I did not and for his encouragement, patience, and humor throughout this entire higher education journey.

I would also like to thank Dr. William Ruff, my dissertation chairperson, for his continued support, inspiration, and patience. His heartfelt reassurance, insightful feedback, and gentle guidance during this process have been instrumental. I would also like to thank my dissertation committee: Dr. Beth Burroughs, Dr. David Henderson, and Dr. Fenqjen Luo. Their unique personalities, personal strengths, and broad perspectives have been influential in the direction and completion of this dissertation, as well as in the deepening of my own identity as an educator and researcher.

To Dr. Kurt Laudicina, I could not have asked for a better friend to have as a guide on this journey with me. His invaluable wisdom, feedback, humor, and encouragement made writing a dissertation enjoyable. Thank you for keeping me laughing and on track.

To my wise, adventurous, and beautiful daughters: Thank you for believing in me, encouraging me to go ever deeper, and challenging my own areas of fixed mindset. It's your turn now and I believe in you!

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ABSTRACT

This qualitative study documented the perceptions mathematics students at an alternative high school had during a shift in mindset from fixed to growth in a dual credit math course. The purpose of this study was to capture student perceptions of their own mindset shift and how their perceptions of mathematics changed. The conceptual framework used to interpret the findings was grounded in attribution theory. A case study research design bounded the perceptions of the students and the meanings they gave to these experiences. Data were collected and analyzed from multiple sources: participants' responses to writing prompts, focus group interviews, research field notes, and student artifacts. The grounded narrative that revealed itself from the student perspective over the course of this study was one of growing student trust in self and others as well as a deepening of student mathematical identity. It also showed that student perceptions of mathematics can shift in a short period of time (20 weeks) from a position of fear, shame, apprehension, and defeat to willingness, perseverance, joy, and overcoming challenges into a growth mindset. The recorded focus group discussions and various writing prompts captured the students' perceptions of their mindset shift in relationship to learning and deepening their understanding of mathematics. This study documents the power in individuals to shift out of a truncated learning cycle into a mathematical mindset. If the ability of students to shift from a fixed mindset into a growth mindset is dependent upon an educational environment, an educator's striving for a growth mindset becomes an important component.

CHAPTER ONE

INTRODUCTION

Mindset is the established set of attitudes and beliefs held by someone. When in a fixed mindset, students believe their basic abilities, their intelligence, their talents, are unchangeable traits. When in a growth mindset, students believe learning abilities are malleable with effort (Dweck, 2006). Research reveals positive effects of growth mindset interventions on students' abilities to learn and grow in education (Boaler 2013; Dweck, 2006; Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlich, 2003). Students who experience interventions aimed at moving from a fixed to a growth mindset often begin to persevere in disciplines where they had not succeeded, therefore deepening learning (Trzeniewski, & Dweck, 2007; Good, Aronson, & Inzlich, 2003; Boaler, 2016). A growing body of research supports the positive effects of a growth mindset on student learning in mathematics in general. There is a dearth of research looking at mindset shifts from the student perspective and in alternative high school settings. This study aimed to fill the gap in research through a qualitative case study from the student perspective. It explores the alternative high school students' fixed to growth mindset shift during the fall, 2016, semester of a dual credit math course in Oregon.

Student Identity and Mathematics Education

Student achievement, growth, learning successes, and failures in the study of mathematics are a convergence of many interconnected threads: attitudes and perceptions

about learning generally or mathematics specifically, socioeconomic variables, parent, peer, and community influences, self-identification as a learner, and school related variables (Singh, Granville, & Dika, 2002; Anderson, 2007). Those that are home or family factors are largely outside the influence of educators in academic settings.

However, there are some success variables that may be under the influence of educators such as student academic engagement, motivation, attitudes, learning mindsets, and student knowledge of the role that mathematics achievement takes in creating potential future opportunities. Uncovering the role these latter variables have on student engagement in mathematics has captured great attention in recent years (Ames, 1990; Kargar, Tarmizi & Bayat, 2010; Boaler, 2013; Benken, Ramirez, Li, & Wetendorf, 2015).

One notable aspect of mathematics learning is for students to develop an identity as a mathematics learner and as a member of the mathematics classroom community. Through social-emotional relationships and interactions with peers, teachers, family, and community, students come to know who they are in relationship to mathematics (Anderson, 2007).

Student identity, confidence, attitudes, beliefs, and anxiety are all linked to perseverance and motivation in the study of mathematics (Ames, 1990; Kargar, Tarmizi & Bayat, 2010; Benken, Ramirez, Li, & Wetendorf, 2015; Boaler, 2016). Students with positive attitudes about learning math report being more motivated to think mathematically, understand class content, and dedicate extra effort toward the study of mathematics than students who have negative attitudes toward mathematics (Ames, 1990; Garii, 2002; Kargar, Tarmizi & Bayat, 2010; Benken, Ramirez, Li, & Wetendorf, 2015;

Boaler, 2016). An essential objective of mathematics education over the last two decades has been to develop students' confidence and perseverance to engage challenging math problems as well as positive dispositions toward learning mathematics (Ames, 1990; National Council of Teachers of Mathematics, 2000; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). These variables create a student's own personal mathematical identity or mathematical mindset and can have a powerful and long lasting impact on a student learning and achieving in mathematics and related STEM fields (Bishop, 2012; Boaler, 2016). A student's self-worth is said to be intricately tied to their self-concept of ability in school (Ames, 1990). For example, success and enjoyment in mathematics early on often leads to the same in high school followed by enrollment in higher level mathematics courses as well as advanced science courses in higher education and STEM career fields. (Benken, Ramirez, Li, & Wetendorf, 2015; Singh, Granville, & Dika, 2002). As a student works deeply with the study and learning of mathematics, they develop their own identity as a member of the mathematics classroom community. Through connections with content and experiences with their peers, teachers, and community, students come to know who they are in relation to mathematics and this further impacts their learning (Bishop, 2012; Anderson, 2007).

Early student successes in math are additionally important because courses in mathematics are typically sequential in offering. Therefore, early learning successes in math curricular opportunities and course choices further influence a student's access to higher education and occupational opportunities later (Singh, Granville & Dika, 2002;

Benken, Ramirez, Li, & Wetendorf, 2015). The opposite can also be true: repeated math failure often leads to lack of opportunities down the road. Ihendinihu (2013) found, even when students understand the effect math has on future academics and career opportunities, they may still demonstrate careless attitudes toward the study of math. Such students who have already decided mathematics is a difficult subject and not for them are usually noncommittal to the learning process of mathematics, therefore performing poorly on examinations, shying away from challenges, and advancing in the discipline (Garii, 2002; Ihendinihu, 2013). Learning to mastery before moving on is a powerful and transformative source influencing student motivation, attitudes, and self-efficacy, therefore increasing student achievement in mathematics (Ihendinihu, 2013; Ozdemir & Pape, 2013), although some students still do not enter the cycle of positive learning to gain its reported benefits (Garii, 2002).

Metacognition and Student Mindset

Research has shown that the role of student metacognition during the learning of mathematics has a positive influence for students (Zimmerman, 1989; Garii, 2002; Karaali, 2015). These studies define metacognition as students' perceptions of their own thinking in terms of how they learn and when they know that they know. Results indicated most students are able to define and articulate some of their metacognitive processes and their path to learning, and this ability to reflect upon learning deepens the process of learning. The development of student metacognition in the learning of mathematics as a tool to propel learners forward was found to advance students in their

studies. However, there was still a portion of students who described their metacognitive experiences differently from students who are typically successful in mastering mathematics. This other group of students reflected many of the definitive characteristics of a fixed mindset (Dweck, 2006). Some students identified in Garii's (2002) research disliked the subject of mathematics and were reluctant to concede there might be a positive purpose to learning mathematics. Moreover, these students made minimal efforts to improve their skills or understanding and became frustrated with their inability to follow steps and procedures. They described a trap in which their dislike of mathematics only increased over time. Garii (2002) illustrated this finding graphically showing that students who disliked formal learning moved forward on a learning path to not seeing a point in learning, and then having no interest in learning, mathematics. This was followed by an "I can't" or "I won't" attitude, as illustrated in Figure 1. Therefore, these students became stuck in a cycle of truncated learning depicted in the far right side of the illustration.

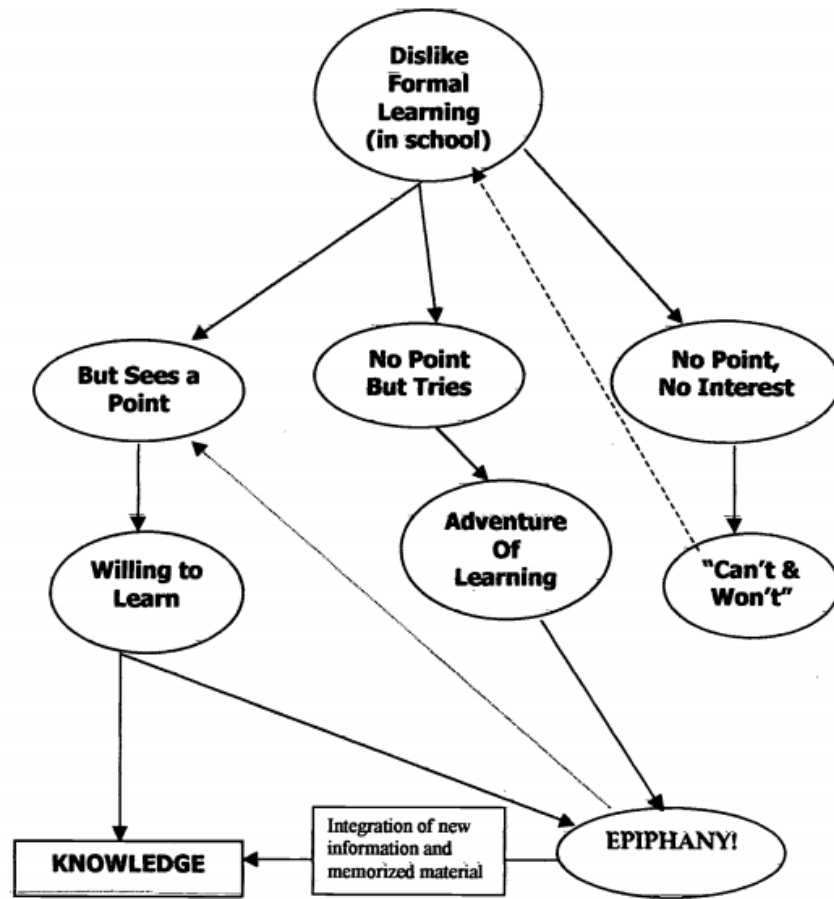


Figure1. The Path to Knowledge (Garii's 2002, p. 21)

Students stuck in a negative math learning cycle frequently have poor/low academic engagement and achievement in this discipline. A fixed mindset in mathematics occurs when students come to believe, although new learning might be possible, the basic level of intelligence is unchangeable, either smart or not (Boaler, 2016). High achieving math students can also have a fixed mindset. These students personally identify as math smart, and their performance is linked to a belief in an innate ability to perform with little or no effort. When a failure occurs for a high math achiever, it can damage their

mathematical identity. This “being smart” belief gives this student a fixed identity and, when failing, they mercilessly judge themselves (Dweck, 2006).

Student mindset about their own learning is critically important for long term academic success. Research shows fixed and growth mindsets lead to different learning behaviors which, in turn, create different learning trajectories for students (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016). When students who become stuck in a negative learning cycle are able to shift their mindset, they begin to believe they can learn at higher levels; they can change their learning trajectories (Boaler, 2016). Additionally, research has found students who have a growth mindset generally react to mistakes and challenges with more optimism and perseverance than students who have a fixed mindset (Boaler, 2016).

In 2006, Dweck summarized findings from her research on the nature and impact of a fixed mindset compared to a growth mindset in a learning environment. Dweck identified that students with a growth mindset work and learn more efficiently, show a desire for challenge, and are resilient when mistakes are made. She states a growth mindset is a “world of changing qualities—it’s about stretching yourself to learn something new. Developing yourself” (Dweck, 2006, p. 15). Alternatively, “those with a fixed mindset believe that you can learn things, but you can’t change your basic level of intelligence” (Boaler, p. viiii, 2016). In a fixed mindset identity, “success is about proving you’re smart or talented. Validating yourself” (Dweck, 2006, p. 15). Dweck (2006) stated, “Failure has been transformed from an action (I failed) to an identity (I am a failure)” (p. 33). This is especially true in the fixed mindset. Because our identity is

defined as how we see ourselves or how others see us (Anderson, 2007), being seen as smart or dumb in a fixed mindset can be limiting and form false self-beliefs adding to a self-perception of being stuck.

Statement of Problem

Recent research studies have demonstrated the positive effects of growth mindset interventions on students' learning (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Dweck, 2006; Boaler, 2016). Boaler (2016), a researcher and educator in the field of mathematics education, states the discipline often transfers the strongest fixed mindset message to students about their capacity to learn and grow. Teachers, parents, and media repeatedly imprint upon children fixed mindset messages such as, "math is a gift that some people have and others don't," or "people who can do math are the smartest or the cleverest people," or "it is not for cool, engaging people, and it is not for girls" (Boaler, 2016, p. xii). Conversely, Boaler identified the incredible natural potential the brain has to grow and change over time and the powerful impact of a growth mindset message upon students' attainment for growth and change. When students undergo interventions to move from a fixed to a growth mindset, these students started performing at higher levels in school and learning deepens (Boaler, 2016).

In alternative high school settings, many students arrive with a fixed mindset for learning in general, but with mathematics specifically, feeling disappointed with their academic interactions with previous institutions and teaching faculty. Currently, there is a

dearth of research studying alternative high school student mindset shifts in the studying and learning of mathematics.

Studies in Mindset

Although mindset has been researched and explored from many perspectives over the last decade, including coaching, leadership, interpersonal relationships, and education (Dweck, 2007; Dweck, 2009), mindset in math education from the students' perspective in alternative high school settings is relatively unexplored.

Boaler (2016) reported on middle school students who transformed their relationship with math during a summer long algebra course. Students moved from initial disaffection and low achievement to engagement, excitement, and high achievement through a mindset shift from fixed to growth. When students are exposed to mindset interventions, they often start performing at higher levels in the classroom almost immediately (Dweck, 2006). The understanding of this type of learning shift is necessary in most high schools in the United States as most classrooms have a sprinkling of students stuck in a fixed mindset or in a negative learning cycle. However, it is especially needed for students who have already experienced math failings or deep academic disappointments, such as those who often populate alternative educational settings.

Purpose of Research

The purpose of this qualitative case study was to capture and analyze, from the student perspective, how high school students in an alternative educational setting moved

from a fixed mindset to a growth mindset in mathematics. This case study was bounded by three students' experiences within the dual credit math course. Each cohort participant lived in the same city within the school district in Oregon. All were enrolled in the fall of 2016 in a dual credit mathematics course through the alternative high school and local community college.

The focus of this study was, from student perspective, the identification and description of high school mathematics students in an alternative school shift from a fixed mindset to a growth mindset. Figure 2 depicts this focus in terms of a reexamination of Garii's (2002) Path to Knowledge.



Figure 2. Conceptual Focus of this Dissertation Modified from Garii's (2002) "The Path to Knowledge"

The following research questions were used to focus this qualitative study:

RQ 1: How do high school students attending an alternative program describe their mathematics mindset?

RQ 2: How do their descriptions of their perceptions about mathematics change during a mindset shift?

Overview of Methodology

This was a qualitative case study with artifacts. The purpose of this study was to capture and analyze how high school students attending an alternative program described their mathematics mindset and how their descriptions of their perceptions about mathematics changed during a mindset shift.

A case study approach was used to assess how high school mathematics students describe content mastery experiences and, ultimately, student success through deepened learning. Writing prompt responses, observations and conversations with students, and artifacts were the primary data collection sources. For additional data, participants were asked to take part in a short in person focus group interview that was recorded and transcribed. Semi-structured interview protocols were utilized to draw out descriptions and perceptions of the participants during the focus group discussions. The recorded discussions clarified themes found in the written responses and classroom observations. Data was triangulated from these sources.

Data was gathered from students from one dual credit, high school mathematics course at an alternative learning center for high school students serving a low socioeconomic, predominantly Hispanic community, in the state of Oregon. Data collection occurred during the fall, 2016, academic semester. Participants were initially contacted in the classroom during school hours and the research study was described for them. Participation was voluntary, and those involved could decline to answer any question or withdraw from the study at any time. Participants gave their time in contribution to the study through questionnaires and interviews. There were no rewards

for participant service. My role in this study was that of participant observer as I was the math teacher at the school in which the data was collected. Digital data was stored on a password protected computer and stored in a password protected Internet storage provider.

I established reliability in this study by rich and thick descriptions, triangulation, and member checking. Detailed field notes and direct quotes from student journals and interviews created the rich and thick descriptions in this qualitative research study. Triangulation occurred through collection of data at various points over the course of the fall, 2016, academic semester and through multiple points of view: student, teacher, and artifacts. Member checking in this research study occurred through the use of small focus groups, interviews, and writing prompts where personal quotes were fed back to the participants to identify or adjust common themes in the collected data. The themes collected over time from the participants' quotes and research field notes were then checked against the themes identified for verification and refinement.

Theoretical Framework

In attribution theory (Heider, 1958), an attribution refers to a person's explicit and implicit understanding of the cause of an event and of responsibility for that event. Attribution theory defines how people come to explain the behavior of themselves or others. Weiner (2005) added to this with an educational attribution theory model that focused on student learning in school settings. He reported evidence of the influence of causal beliefs on both teacher and student behaviors and the effects of attributions on

achievement striving in education. Therefore, attribution theory allows the information gathered in this study to be viewed through the students' perceptions of their own mindset shift combined with perceptions of other students' mindset shifts in an educational setting.

Role of Researcher

My role in this study was participant observer. I was the mathematics instructor of the dual credit math course studied. According to Bonner and Tolhurst (2002), in qualitative research, it is common for a researcher to be part of the group studied. In their research, Bonner and Tolhurst cite a number of benefits to being an "insider" to the study of researcher: "Having a greater understanding of the culture being studied, not altering the flow of social interaction unnaturally, and having an established intimacy between the researcher and participants which promotes both the telling and the judging of truth" (p. 9). These researchers asserted being an insider to research allows for the process to unfold and be studied rather than outcomes of practice to be explored. The role of participant observer allowed me to recognize when a participant changed their normal patterns in relationship to math, their classmates, or the instructor, which might have indicated a shifting in mindset.

Summary of Teaching Experience. I began my teaching career as a high school vocational educator in a regional occupation program and an adult education instructor in the early 90s. I then moved into the private sector as a corporate computer software trainer and technical writer of software training manuals. In 2001, I began teaching high

school mathematics for a private, Waldorf school. Over the last 20 years, I have taught mathematics and computer technology in middle schools, high schools, adult education, summer camps, tutored fifth through twelfth grade levels of math, and instructed in higher education at community colleges and a university. My current position is a high school mathematics and dual credit instructor at an alternative high school in Oregon.

My Philosophy as a Teacher. During my first year as a high school mathematics teacher, I found myself wondering, “How do students actually learn?” and “How can I help students *want* to learn?” One of the classes in which these initial questions were pondered at that time was a small, slower-paced, lower level tracked math class of 12 students in their senior year of a Waldorf high school. Noticing that even when a well-rounded, seemingly interesting curriculum was developed for the day, which included an engaging delivery, these 12 students would demonstrate little knowledge of the course material afterwards. This was where the quest to deepen student learning began. What I found through observation, listening, mindfulness, trial/error methods, and lots of prayer was that learning began within a student as an openness or a willingness. This openness sometimes looked like curiosity, interest, or active attention, and it was followed by the acquisition of knowledge or skill leading to doing or thinking in a new way. It is as if a readiness to change met newness and then a gaining of ability or transformation occurred. Realizing that the magic was in helping the students get to a place of openness or active interest, I then shifted my focus to growing individual connections with each student uniquely. Brown, Collins & Duguid (1989) shared that social interactions support subject interest and learning, and this is the backbone on which I built and strengthened my

classroom environments year by year—interpersonal student connection. As Johnathan Erwin wrote, “Everyone knows the first three rules of real estate: Location! Location! Location! Less well known, yet far more important, are the first three rules of education: Relationships! Relationships! Relationships!” (Erwin, 2010, p. 13).

I believe true teaching is fully encompassing and engages my whole selfhood to provide a safe and welcoming learning environment, interesting and engaging learning materials, curiosity in newness, comfort in chaos, modeling learning and personal growth, seeing challenge as opportunity, and an encouragement to take steps into the unknown. When teaching is done effectively, to the outsider it looks fluid, easy, connected, and seamless. Parker Palmer, renowned educator and speaker, is known for saying, “we teach who we are” (Palmer, 2007, p. 1). As I strive for authenticity, depth of self, reverence of student, and curiosity in the moment, then the students follow suit and experience inquisitiveness, a desire to create, and a delight in their own learning process. As a teacher facilitating students’ learning, my philosophy is about striving to become a guide on students’ educational journeys and, most importantly, be an active listener in relationship along the way.

My core beliefs in teaching originated from early experiences in the Waldorf high school as well as the concurrent teacher education I was undertaking in Waldorf (Rudolf Steiner) methods curriculum, instruction, and research. My initial draw to this method of teacher training was the deep emphasis on spirituality, personal freedom, and reverence for childhood experiences.

Waldorf teachers strive to transform education into an art that educates the whole child – not just their thinking or intellectual life, but their emotional

and moral life, as well. Since 1919, the Waldorf movement has spread worldwide, with over 1,000 schools on five continents. Waldorf teachers embrace their vocation with a sense of enthusiasm and seriousness of purpose. Their task is to educate with a deep respect and love for each child, making it their primary responsibility to answer questions such as:

- How do I establish within each child his or her own high level of academic excellence?
- How do I instill enthusiasm for learning and work?
- How do I promote a healthy self-awareness, as well as a genuine interest and concern for people from all cultures and traditions?
- How do I teach a healthy respect for the earth?
- How can I help my students find meaning in their lives? (Price, 2003)

Instructional Practices. My role as a teacher has evolved over the years to a teacher interested in encouraging students' shared collaboration and problem solving. Rigor is an important aspect of teaching and learning. A low floor/high ceiling teaching method in my classrooms allows all students to learn, digest, argue their way to owning their own learning at their individual level. As a teacher, I strive to challenge students intellectually and support them academically by asking deeper questions and helping students discover ways to reach out for help when needed. When different learning preferences emerge within the student body, as a teacher, I listen and observe through the lens of assessment and adjust my classroom teaching style accordingly.

Additionally, students do a fair amount of group activities in my classroom and, therefore, must become well acquainted with each other in communities as well as with the material presented. I believe it is the grappling with one another in community that deepens empathy. Furthermore, I have found that when the varied biographies and personalities of students work together, perspectives are broadened in a way that they cannot be by the instructor alone.

No teacher can be truly effective without on-going professional growth and development, and it is the professional duty of all educators to constantly examine and evaluate their knowledge and skills and their commitment to student learning (Brownridge, 2008). Therefore, I strive to be in a constant state of research and learning attending workshops and conferences, reading various genres of books, collaborating with colleagues, requesting and integrating feedback, and earning advanced educational degrees. I have operationalized my philosophy of teaching in the classroom by sharing new information with students and asking them to share their newly acquired knowledge with me as well.

Limitations

Several limitations in this study were evident. For example, perhaps one semester was not long enough to build deep trust with the participants in order for them to share deeply and honestly and, therefore, it's possible the student data shared is not at the core of the longitudinal study.

A specific limitation could have been bias of the participants due to trying to please or punish me as the researcher who was also their mathematics teacher. Additionally, that I was a participant researcher could be a limitation due to blind spot biases innate to interpersonal relationships. Bonner and Tolhurst (2002) remind that being an insider to a research study can cause routine participant practice to be missed (because it is overly familiar).

Definitions of Terms

Aha: An “aha” moment or “aha” experience was previously known as the eureka effect or eureka moment (Auble & Franks, 1978) and is currently also known as insight or epiphany. Graii (2015) refers to a common human experience of the illuminative flash of understanding or magical moment of a previously perplexing concept (Ernst, 1987). Auble & Franks (1978) proposed an “aha!” reaction occurs when an initially ambiguous stimulus is suddenly comprehended.

Alternative education: The National Center for Education Evaluation and Regional Assistance (2014) broadly defines alternative education as “educational activities that fall outside the traditional K-12 curriculum—it frequently serves students who are at risk of school failure. Because individual states or school districts define and determine the features of their alternative education programs, programs may differ in key characteristics, such as target population, setting, services, and structure” (Porowski, O’Conner, & Luo, 2014, p.i). Alternative high school in this case study refers to one high school offering the majority of alternative education options for students in a large, suburban, northwestern Oregon school district. The high school has a 90-student capacity with eight full-time teachers.

Dual credit: In this study, it refers to courses that offer high school level students both high school credits toward high school graduation and college credits through a local, higher education institution at the same time with one curriculum, one set of requirements, and offered in one set location. College credits earned through dual credit

can usually also be transferred to various colleges or universities toward higher education degree programs.

Metacognition: When one becomes aware of their learning through reflecting on what they have learned (Flavell, 1976). Metacognition is defined as the “active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective” (Flavell, 1976, p.232). This term was thought to be introduced by John Flavell in the early 1970s based on the term “metamemory.”

Mindset: The established set of attitudes or beliefs held by someone. When in a fixed mindset, students believe their basic abilities, their intelligence, their talents, are unchangeable traits. When in a growth mindset, students believe learning abilities are malleable with effort (Dweck, 2006).

Achievement in Mathematics: The National Center for Education Statistics (2010) defines mathematics achievement as cumulative levels of competencies associated with acquired student skills and knowledge in the subject area of mathematics.

STEM: A focused academic set of programs designed to ready primary and secondary students for college study in the disciplines of science, technology, engineering, and mathematics (STEM). In addition to subject specific learning, STEM aims to foster student curiosity, reasoning skills, and teamwork.

Identity or Mathematical Identity: “Learning mathematics involves the development of each student’s identity as a member of the mathematics classroom community. Through relationships and experiences with their peers, teachers, family, and

community, students come to know who they are relative to mathematics” (Anderson, 2007, p. 7).

Summary of Chapter One

Students stuck in a negative learning cycle in mathematics often also have poor/low achievement in mathematics (Garii, 2002) and limitations in their trajectories of future STEM fields both academically and career wise (Dweck, 2007). Students in a fixed mindset may shy away from challenges out of fear and a belief they cannot succeed because they were not born with a math aptitude (Boaler, 2016). Student mindset is critically important in education because research has shown mindsets lead to different learning behaviors, which in turn create different learning paths in students’ futures (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016). When students shift their mindsets and start believing they can learn and grow in the face of mistakes and challenges more consistently with effort and help, they start engaging at higher levels in the classroom almost immediately (Dweck, 2006). This type of learning shift is needed in most high schools in the United States, but especially for students who have already experienced math failings or a stuck learning cycle such as those commonly found in alternative educational settings.

In the next chapter, the existing literature surrounding student achievement in mathematics, student metacognition in the learning process, math achievement nationally and locally, history and definition mindset, and attribution theory will be explored and discussed as it relates to this current research study.

CHAPTER TWO

REVIEW OF THE LITERATURE

Student self-perception, confidence, attitudes and beliefs, and anxiety are all linked to persistence and motivation and achievement in the study of mathematics in school (Ames, 1990; Kargar, Tarmizi & Bayat, 2010; Benken, Ramirez, Li, & Wetendorf, 2015; Boaler, 2016). Students with positive attitudes about learning math are more motivated to think mathematically, put forward effort to understand class content, and dedicate extra time toward the study of mathematics than are students who have negative attitudes toward mathematics (Ames, 1990; Garii, 2002; Kargar, Tarmizi & Bayat, 2010; Benken, Ramirez, Li, & Wetendorf, 2015; Boaler, 2016). Additionally, achievement and engagement in learning mathematics in early grades is important as it can determine high school and college academic choices and enrollment in upper level mathematics courses as well as other advanced STEM courses. (Singh, Granville, & Dika, 2002; Benken, Ramirez, Li, & Wetendorf, 2015).

Most academic courses in mathematics and sciences are sequential. Therefore, early successes in math may further influence a student's access to higher education and occupational opportunities in the future (Benken, Ramirez, Li, & Wetendorf, 2015; Singh, Granville, & Dika, 2002). The opposite is also true to some extent; early math failure often leads to lack of opportunities. Ihendinihu (2013) reported that, even though students may understand the need for math and the influence studying math has on academics and future career fields, students often demonstrate careless attitudes toward

the subject. Such students decide mathematics is a difficult subject and are usually noncommittal to the learning process of mathematics, therefore performing poorly on math examinations and shying away from challenges and advancing in mathematics (Garii, 2002; Ihendinihu, 2013).

This latter population of students, who at some point stop rising with their peers in academic achievement in mathematics, are seemingly held in a learning cycle that includes a fixed math mindset that does not move the learner forward in their studies. The delineated paths of success that would normally lead to higher student achievement through mastery experiences and self-efficacy will not materialize for students who stop seeing a point in learning mathematics, who lost interest in the subject matter, or who no longer engage in the simple adventure of learning new concepts (Garii, 2002). For these students, a shift is needed to get back into a positive learning cycle and into a growth mindset relationship with mathematics.

The introduction of a growth mindset in the classroom by the teacher may be a key component for shifting students. In some cases, research is limited on the use of growth mindset in alternative high school mathematics classrooms as a tool to move students out of negative attitudes and back into engaged, self-motivated learning. However, research has established (Kesici & Erdogan, 2009; Middleton & Spanias, 1999; Howard & Whitaker, 2011) that students' own perceptions of self-success capability are greatly influential to student achievement. Understanding more clearly how the mindset perceptions of high school mathematics students in alternative school settings are formed and changed, as well as understanding what influences alter those perceptions, can

provide useful information for teachers committed to helping such students increase achievement and deepen learning.

The focus is the shift a fixed mindset math student makes to become an engaged student with a growth mindset from their own perspective. This shift is thought to occur through a self-perception of content mastery: student “aha” moments followed by student metacognition, as illustrated in Figure 3.

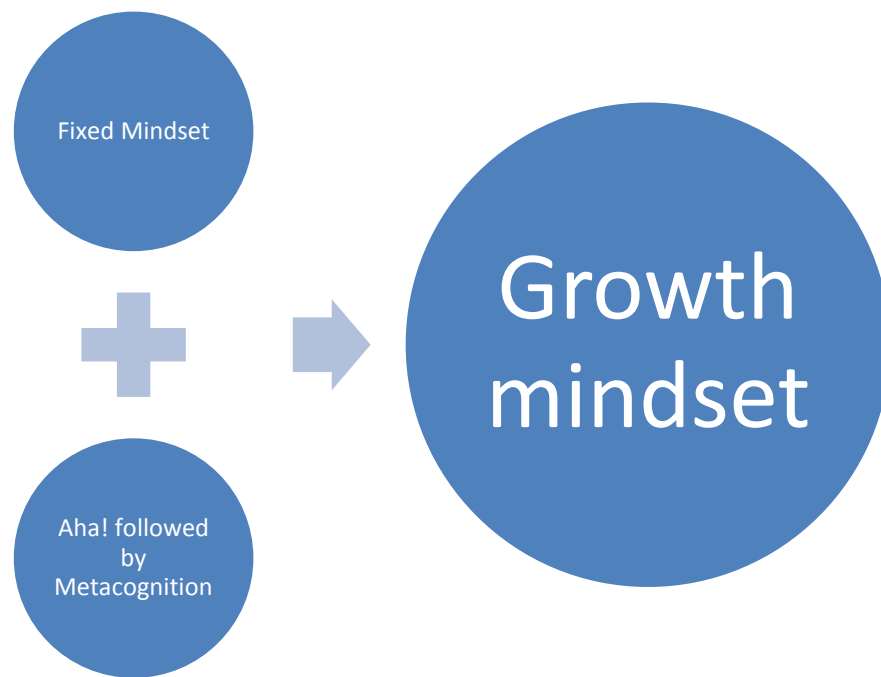


Figure 3. Model of Literature Review

Therefore, the focus of the literature review for this case study will proceed with a brief overview of student achievement research in the field of mathematics. This will be done through defining mindset and providing a brief history of the psychology of mindset, defining a learner’s “aha” experience, as well as defining metacognition and

providing a brief history as it relates to education. Further, it will include defining a method of gathering data from the student's perspective (attribution theory), and summarizing the literature review.

Student Achievement in Mathematics

A student's successful future in the adult world often weighs on his or her academic achievements while in school (Jiang, Song, Lee & Bong, 2013). Raising student achievement in mathematics is not a new topic in the field of education (Ames, 1990; Chouinard, Karsenti, & Roy, 2007; Rohde, & Thompson, 2007; Schunk, 1989) nor is how a student's mindset is related to their mathematical abilities (Ames, 1990; Good, Aronson, & Inzlicht, 2003; Dweck, 2006). In reality, the number of research studies conducted in math education over the last 50 years has only continued to increase (Kilpatrick, 1992; Grouws & Cebulla, 2000). This is, in part, because both teaching and learning mathematics are complex tasks (Grouws & Cebulla, 2000). The major question is: how do educators graduate students who are inspired, engaged learners of mathematics while concurrently preparing them to meet unidentified challenges and flourish in unknown career fields of the future? Routine skills include the recall of a fact, definition, term, or a simple procedure, performing a simple algorithm, or applying a formula. These have historically been the focus of math lessons; although easy to teach and easy to test, they are also easiest to digitize, automate and are, therefore, not educationally deepening for students. Additionally, procedural skills generally do not build creative or strategic thinking and, therefore, are not as helpful for students once in

the career world, creating difficulties. As new careers are being created, it is difficult to identify with certainty what students will need to know. However, one thing students need to know in the future is how to learn and how to meet challenges openly (Schleicher, 2015; Boaler, 2016).

Literature shows that student engagement and achievement can be increased by several varied inputs providing a complicated myriad of possibilities. Some natural, important predictors of students' academic achievement are students' cognitive abilities, intelligence, memory, and information processing skills (Rohde & Thompson, 2007). However, research has consistently established other factors also playing a role in student achievement such as family background, learning environment characteristics, student motivation and emotion, and learning through mastery.

Family Background

Among the many, non-cognitive factors relating to student achievement is the family background of students (Coleman, 1966; Jencks & Mayer, 1990). In large scale studies, Coleman and his associates and, later, Jencks and Mayer (1990) found socioeconomic factors to be powerful shapers of student performance. Both sets of researchers argued that schools, teachers, curricula, and other forces had only a negligible effect on student performance, but socioeconomic status (SES) was the single most powerful shaper of student achievement. SES is often measured as a combination of family education, income, and occupation. Research indicates that children from low SES households and communities develop academic skills more slowly compared to children from higher SES groups (Jencks & Mayer, 1990).

Learning Environment Characteristics

Edmonds (1979) and Hoy, Tarter, & Hoy (2006) added, beyond SES, other non-cognitive characteristics of student achievement, such as school characteristics. Some of these school characteristics were strong leadership from school administration, high expectations for student performance, a strong focus on basic skills, a well ordered school environment, frequent and systematic student evaluations, and a school philosophy of academic optimism. These all are shown to be powerful contributors in raising student achievement in mathematics when controlled for SES and previous achievement (Hoy, Tarter & Hoy, 2006).

Hoy and associates' (2006) study on academic optimism of schools as a force for student achievement focused on academic optimism consisting of a triad: school academic optimism, collective self-efficacy, and faculty trust. These researchers discovered that, when tightly woven together, this triad formed a strong path for increased student achievement.

Student Motivation and Emotion

Self-Efficacy. Given the Hoy et al. (2006) report of academic optimism, collective self-efficacy, and faculty trust influencing student achievement, perhaps the most potent of the three as a stand-alone factor is self-efficacy. Psychologist Albert Bandura (1994) defined self-efficacy as a person's belief in their own ability to succeed in specific situations or with a given task. Self-efficacy can play a major role in how students approach goals, tasks, and challenges, and has been well established as one of the most

powerful predictors of motivation and student achievement in various academic domains, according to Hoy et al. (2006).

In mathematics education, Ames (2009) reported that student achievement appeared linked to positive self-beliefs about math ability. Self-efficacy in mathematics has been linked to students' higher levels of thinking, persistence in acquiring new information, effort, and achievement (Schunk, 1989). Students with strong self-efficacy are found more likely to be additionally self-motivating, self-regulating, and strategic in their learning of new material as compared to students who do not believe in their skills and abilities (Seifert, 2004). Klassen (2004) reported a direct correlation in student self-efficacy beliefs strongly predicting mathematics performance.

Increasing a student's self-efficacy is not simply a matter of persuading or convincing a student they can do well. Teachers cannot directly influence a student's level of self-efficacy. However, teachers inject change through helping students reach mastery of mathematical topics. This involves giving students repeated, short-term, ever deepening, obtainable goals and strategies for making progress (Ames, 1990).

Moods, Emotions, and Attitudes. Researches contend that the feelings students develop toward learning can significantly influence not only what is learned but how and where learning occurs (Ames, 1990; Bishop 2012; Dweck, 2006). For students to be successful they often must overcome fears and believe in their own ability to learn (Dweck, 2006; Boaler, 2016). Further, students who understand the value and applicability of learning mathematics are more likely to be well engaged (Boaler, 2016). Developing students' positive attitudes, confidence, and perseverance in order to engage

with challenging math problems has been an essential objective of mathematics education over the last two decades (National Council of Teachers of Mathematics, 2000; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Positive attitudes in the math classroom, according to Bishop (2012) and, later, Boaler (2016), work to create and support a student's emerging personal mathematical identity or personal mathematical mindset and can have a powerful and long-lasting impact on a student's learning and growth in mathematics as well as other related STEM fields (Bishop, 2012; Boaler, 2016).

Motivational-emotional regulation refers to students' thoughts, actions, and behaviors when learning, which affects their efforts, persistence, and emotions when performing mathematical tasks (Tzohar-Rozen, 2014). However, many students have been traumatized by math, are debilitated by these feelings about math and, therefore, develop math anxiety and decline in engagement and achievement (Kargar, Tarmizi & Bayat, 2010; Boaler, 2016). Math anxiety is perhaps the most common emotional and motivational concern in mathematics education regarding student achievement (Kargar, Tarmizi & Bayat, 2010).

General moods and specific emotions have been reported to affect certain aspects of self-regulation in the math classroom, including strategy selection in math problem solving (Tzohar-Rozen, 2014). Negative student feelings and moods have, on the upside, been said to lead to more detailed, analytical, and careful processing of information. They also, at times, lead to inflexible thinking, mathematics avoidance, and anxiety; whereas,

positive feelings are said to generate creative, flexible, and holistic thinking (Tzohar-Rozen, 2014; Boaler, 2016).

Mastery Experiences. “Students who are interested in learning new things and developing their skills and ability have been described as mastery-oriented. These students are willing to expend the necessary effort to learn something” (Ames, 1990, p. 414). Students who interpret their skill level in mathematics as an acquired ability that is built upon with time, effort, and help, go on to develop learning goals and are more motivated to expand and deepen their knowledge base and capabilities (Chouinard, Karsenti, & Roy, 2007). A mastery orientation has consistently been associated with adaptive academic beliefs and behaviors. These include greater persistence and effort during challenging tasks, increased use of deep-level cognitive processing strategies, greater academic self-efficacy, and attribution of success in school to effort rather than ability (Ihendinihu, 2013; Ames, 1992). Mastery experiences in the classroom are important for students and teachers alike. Student mastery experiences have direct links to self-efficacy, deepened learning, and higher achievement. Unlike self-efficacy, a mastery experience may be an entry point for a teacher to directly raise student achievement (Ihendinihu, 2013; Boaler, 2016).

However, in recent years, less reliance is being placed with the teacher to raise student achievement and more on the student to be responsible and accountable for their own learning (Siegal McIntyre, 2015). Centered on the concept and execution of self-directed learning, some high schools operate in a way in which each student creates his or her own curriculum, timing, and then completes the program they have designed. As

teachers transfer the power of learning over to their students, mathematically successful students will begin to integrate the information they have learned in previous years with new ideas and concepts. This knowledge then begins to grow and further connections are made (Garri, 2002). However, achievement, self-efficacy, mastery of learning, and the connections from prior to current learning are not available to struggling students who do not have the requisite knowledge or motivation on which to stack new learning (Garri, 2002). This creates a slowed or stuck learning cycle in these latter students that has a tendency to block current and future achievement, self-efficacy, and mastery learning for these students in mathematics education.

History and Definition of Mindset

Mindset has its root in incremental theory of intelligence (Elliot & Dweck, 2005). The first writings on mindset are said to date back to 1909 by a French psychologist named Alfred Binet. It was in his work with the original IQ test where Binet asserted an individual's intelligence is not a fixed quantity without the ability to increase. Years of research have reported that students who think of learning capability as a fixed trait (entity theory) rather than as a potential to be developed (incremental theory) are in danger of undesirable academic outcomes and lowered confidence, enjoyment, motivation, and performance when faced with increasing levels of challenge or obstacles (Ames, 1990; Ames 1992; Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Henderson & Dweck, 1990).

Currently, Dweck, a psychologist from Stanford University, is the foremost researcher on mindset. In 2006, she summarized findings from her research of student achievement and motivation and the nature and impact of students' fixed mindset compared to a growth mindset in a book *Mindset: The New Psychology of Success*. Dweck describes mindset as the established set of attitudes held by someone based on previous experiences. She posits every person has a basic mindset, either fixed or growth, which is a core belief about how they learn (Dweck, 2006). Dweck reported about 40% of the students studied had a detrimental fixed mindset, 40% had a growth mindset, and the remaining 20% wavered between the two mindsets.

Fixed Mindset

When in a fixed mindset, Dweck (2006) shares that students believe their basic abilities, intelligence, and talents are unchangeable traits that students are either born with or are not. She says this world of fixed traits is about repeatedly proving smartness, talent, and worthiness of self. Effort, failure, and loss are believed to compose an undesirable cycle pointing to a lack of some attribute that should be innate. Fixed mindsets believe personal qualities are carved in stone and a predetermined fixed amount of intelligence, a definite personality, and a certain moral character exist (Dweck, 2006). Finally, a focal point in Dweck's work with mindset is that those with a fixed mindset believe in either having intelligence or not and, when a mistake is made, they believe it means they are simply not smart enough and, therefore, give up trying and often try to hide their errors to avoid perceived judgement. Students with fixed mindsets believe their intellectual ability is a fixed trait: either smart or not (Dweck, 2006). These students

believe, on some level, skills are innate and their focus is on performance outcomes in avoidance of looking bad.

Low-effort in school is often another way students with a fixed mindset protect themselves. When facing hard transitions, these stuck students can seemingly minimize any threats that might unmask their believed flaws by non-performing, thereby turn them from winners into losers (Dweck, 2006). Ames (1990) states:

Ability is important in most classrooms; when students' self-concept of ability is threatened, they display failure-avoidance motivation. They engage in failure avoiding tactics such as not trying, procrastinating, false effort, and even the denial of effort. Why would they do this when these behaviors most assuredly will increase the likelihood of failure? What these behaviors accomplish is reducing the negative implications of failure. From the students' point of view, failure without effort does not negatively reflect on their ability" (p. 413).

Boaler (2016) points out, even when a student believes they are smart, this is also a damaging fixed mindset and this student is less willing to try challenging work at greater levels because they are afraid of slipping up and no longer being seen as smart. One reason so many students in the United States have fixed mindsets is the praise they are given by parent and teachers; students believe they are smart and, therefore, do not need to apply effort to succeed (Boaler, 2016).

Praise feels good, but when people are praised for who they are as a person ("You are so smart") rather than what they did ("That is an amazing piece of work"), they get the idea they have a fixed amount of ability (Boaler, 2016, p. 8).

In short, when in a fixed mindset, students often display the following: giving up when leaning becomes difficult, avoiding challenges, often becoming defensive when feedback is provided, and avoiding making mistakes and looking bad.

Growth Mindset

A growth mindset is believing learning abilities are malleable with effort and can be built upon with time and with effort (Dweck, 2006). Here, learning for students becomes interesting and rewarding. Dweck (2006) shares that failure followed by increased assistance and effort is what makes someone smart or talented. Research has shown when learning happens, a synapse fires and, in order for structural brain changes to occur, the new idea must be revisited repeatedly, learned deeply, and the new concepts must be used creatively multiple times (Boaler, 2016, p. 42). Growth mindset is about stretching self to learn something new and developing the self with each mistake or mishap, preserving in repeated practice with effort. In this mindset, the basic building blocks a student arrives with is just the starting point for continued evolution and development. This mindset is based on the belief that basic qualities are to be cultivated through work, progress, application, and experience (Dweck, 2006).

A main takeaway from Dweck's (2006) work is students with a growth mindset work to learn more efficiently, show a desire for challenge, a resilience when mistakes are made, and appreciation when feedback is received. Her research shows the importance of a growth mindset: the belief intelligence is built and the more students learn, the smarter they become. In short, when in a growth mindset, students often display perseverance when learning becomes difficult, enjoyment of challenges, often become appreciative when feedback is provided, and view making mistakes as part of the learning process.

Movement from a fixed to a growth student mindset is possible with effort, practice, and help (Dweck, 2006; Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016). Blackwell et al. (2007) conducted a mindset intervention study with minority students who were making their transition from sixth to seventh grade, with some who had declining grades. The growth mindset intervention given to the middle schoolers stopped their decline in grades and started the students on an improved path of learning and increased achievement.

Good et al. (2003) created a mindset intervention for middle school students as well. The growth mindset intervention in Good's study led to a gain in mathematics achievement test scores for the students involved. The control group in the research showed a highly significant gender difference in mathematics scores, but in the growth mindset group, the gender gap was mostly eliminated.

Perhaps the most common misconception is simply equating the shift from fixed to growth mindset through the use of effort alone (Dweck, 2015). A growth mindset is not about effort alone. Dweck (2015) added that students need to try new approaches to problem solving in mathematics and seek input from peers and teachers when they find themselves stuck. She reminds that effort is a path to the end goal of learning and improving and not to effort alone.

Mindset and Mood

Dweck (2006) researched student depression and how it relates to mindset. She found that different students handle depression in dramatically different ways depending on their mindset. First, she learned that students with the fixed mindset had higher levels

and frequency of depression and tended to ruminate over their problems and setbacks longer. These students were more likely to give up easily with regards to academic endeavors. On the other hand, the more depressed students with the growth mindset became, the more they took action to confront their problems, keep up with schoolwork, and keep up with their lives in general. These latter students became more determined and more persistent the worse they felt.

Mindset and Math Education

Research found that a student's mindset about learning and achieving in mathematics, a traditionally challenging discipline, is suggestive of future academic performance (Dweck, 2006; Boaler & Sengupta-Irving, 2006). Boaler (2010) has worked with mindset mostly in the field of mathematics and reported this subject area often transfers the strongest fixed ability message and thinking to students. This is partly due to many elementary teachers feeling anxious about learning and teaching mathematics themselves, usually because they were given fixed and stereotyped message about the subject and their limited individual potential (Boaler, 2016).

Conversely, Boaler (2016) also found both the incredible, natural potential students have to grow their learning capacities and change themselves as students over time and the powerful impact of a growth mindset message upon students' attainment for growth and change. Boaler and other researchers reported that students who undergo interventions to move from a fixed to a growth mindset start performing at deeper levels in school, sometimes immediately (Dweck, 2006, Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016).

Inequality. Fixed mindsets in math education have been shown to lead to inequality in math education (Boaler & Sengupta-Irving, 2006; Boaler, 2016). Boaler states, “Fixed mindset beliefs contribute to inequities in education as they particularly harm minority students and girls; they also contribute to overall low achievement and participation” (Boaler, 2013, p. 150). Boaler (2016) also discovered society has favored an elitist approach to mathematics and holds it as being harder than other subjects and, therefore, suitable for only a gifted few, which is detrimental to minority students, including females (Boaler, 2016).

Studies of brain processing do not support the idea that females are genetically inferior to males in mathematical potential, yet this construct exists in education. Ideas such as these can be damaging as they concern the intellectual potential of students and have contributed to the gender differences that prevail today with males continuing to outnumber females in mathematics (Boaler & Sengupta-Irving, 2006).

Females may be more likely to consider math abilities as innate skills rather than abilities that are built, suggesting that females may be less open to continuing math advancement as they encounter challenges (Dweck, 2007; Boaler & Sengupta-Irving, 2006; Boaler, 2016). Experimental studies evaluating mathematics performance found high performing females were the most likely to experience “debilitation” effects of fixed mindsets (Licht & Dweck, 1984; Boaler & Sengupta-Irving, 2006). These studies reported once female students had been labeled as smart, they were less likely to take on challenges out of fear of appearing not smart.

Speed in Learning. Further, Boaler (2016) strongly believes, in order to cultivate a growth mindset for students, mathematics classrooms around the world need to change the idea that math speed is more important than learning depth. Boaler reasons, the field of math suffers from this misnomer more than other academic subjects and the learners of math suffer alongside. Boaler wrote that valuing quickness in problem solving in the math classroom often leads to fixed mindsets among students. Additionally, “we know that students who are pushed to go through content faster are usually the ones to drop out of mathematics when they get the opportunity” (Boaler, 2016, p. 192).

Practice. The concept that students practicing mathematics to a point that skills become routine as a path to a student growth mindset and deepened understanding was presented by Garii (2002). In Garii’s study, secondary school students were asked to consider their own thinking in terms of how they learn and when they know that they know; in other words, metacognition. Students in her study articulated parts of their metacognitive processes and shared how memorization and conceptualization worked symbiotically, and the "aha" experience occurred when their learned material moved into a useable and explainable concept. Learning occurred over time for some students through repetition and practice.

Mistake Making. Both Dweck (2006) and Boaler (2016) work to reorient educators to value correct work less and mistakes more. These researchers state it is best for students to be making mistakes while learning new topics and for educators to be giving students challenging work that is difficult but also accompanied by positive

messages about mistake making that enable student to feel comfortable working on harder problem, making mistakes, reflecting then adjusting, and persevering on. Boaler (2016) shared, “when we teach students that mistakes are positive, it has an incredibly liberating effect on them” (p. 15).

Mathematical Mindset

Mathematics is the subject “most in need of a mindset makeover” (Boaler, 2016, p. viiii). Boaler stated this is due to trauma many students have endured while learning math from poor teachers, and students have become somewhat weakened and debilitated from these experiences. However,

Scientific evidence suggests the actual difference between students who succeed and those who don’t in mathematics is not their individual brain capacities that each were born with but instead about the student’s approach to life, the message they receive about their potential, and the opportunities they have to learn (Boaler, 2016, p. 5).

Boaler calls a growth mindset in the subject of mathematics and in the math classroom a “mathematical mindset” (2016, p. 9). It is a “knowing that math is a subject of growth and (a student’s) role is to learn and think about new ideas” (Boaler, 2016, p. 34). Students will know they are in a mathematical mindset when they approach learning math with a desire to understand and to think deeply about math concepts with confidence that they will be able to understand it.

For educators and students alike to maintain a mathematical mindset, Boaler (2016) suggests learning about neuroplasticity of the brain and how the brain continues to be able to grow and learn over time. She also emphasizes the growth opportunities available for learners in making mistakes and in learning from struggles, recognizing and

cultivating the creativity and beauty of mathematics, and the importance of engaging in rich mathematical tasks while maintaining flexibility of thinking.

False Growth Mindset

A false growth mindset also exists (Dweck, 2015). This is where educators, parents, or students claim to have a growth mindset, but whose words and actions do not reflect growth in action. The path to a growth mindset is a journey, not a proclamation (Dweck, 2015; Boaler, 2016). To allow acceptance of the gray area between a fixed and growth mindset, Dweck (2015) suggests the following: acknowledge we're all a mixture of fixed and growth mindsets given a variety of tasks and topics, create compassion around the idea that no one will ever be in a growth mindset all of the time, ever, and the most productive way to move closer to a growth mindset in thoughts and practices is to stay aware with the inner fixed mindset thoughts and deeds.

Defining the “Aha!” Moment

An “aha!” moment or experience was previously known as the eureka effect or moment (Ernst, 1987). It is also known as an insight, a quick moment of discovery, or epiphany (Graii, 2015) and refers to a common human experience of the illuminative flash of understanding of a previously perplexing concept (Liljedahl, 2004). An “aha!” reaction occurs when initially unclear information is suddenly comprehended. In the case of this research, an “aha!” will be used to identify this moment.

Liljedahl (2004) describes the mathematical “aha!” moment or experience as the following:

Suddenly, it's all illuminated. In the time it takes to turn on a light the answer appears and all that came before it makes sense. A problem has just been solved, or a new piece of mathematics has been found, and it has happened in a flash of insight, in a moment of illumination, in an AHA experience. From Archimedes to Andrew Wiles, from mathematicians to mathematics students, the AHA experience is an elusive, yet real, part of “doing” mathematics. Although it defies logic and resists explanation, it requires neither logic nor explanation to define it. The AHA experience is self-defining. At the moment of insight, in the flash of understanding when everything seems to make sense and the answer is laid bare before you, you know it, and you call out—AHA, I GOT IT! However, the AHA experience is more than just this moment of insight. It is this moment of insight on the heels of lengthy, and seemingly fruitless, intentional effort. It is the turning on the light after six months of groping in the dark (Liljedahl, 2004, p 1).

The “aha!” experience in mathematics is coined as illumination or the rapid coming to mind of an idea (Liljedahl, 2004). Liljedahl summarizes the “aha!” sequence that happens for students of mathematics as beginning with an initiation phase during which the math student attacks the problem with focused intention with making connections to past experiences, intuition, and imagination while concurrently deciding on a direction to proceed. Next is the incubation phase during which the conscious mind of the student is distracted or focused away from the problem. This culminates with the illumination phase where an idea as to the solution or method toward a solution suddenly appears, filling the student with a sense of confidence, relief, and delight (2004).

Students who experience this “aha!” sequence in the learning of mathematics are said to develop positive attitudes about the subject (de Lourdes Mata, Monteiro, & Peixoto, 2012). Students with positive feelings about learning math report to be more motivated to think mathematically, understand class content, and dedicate extra effort toward the study of mathematics than students who have negative

attitudes toward mathematics, as discussed earlier (Ames, 1990; Garii, 2002; Kargar, Tarmizi & Bayat, 2010; Benken, Ramirez, Li, & Wetendorf, 2015; Boaler, 2016).

Barnes (2000) wrote that “aha!” moments are important enough for educators to be concerned about recognizing and encouraging these experiences within students. Barnes’ (2000) evidence suggests “aha!” experiences are motivating though the excitement and enthusiasm for learning these moments create in students. The feelings of pleasure and exhilaration that the “aha!” events produced were of value both for their own sake and because they influenced students' continued participation and performance in mathematics (Barnes, 2000).

Metacognition

Metacognition is when one becomes aware of their learning through reflecting on what they have learned (Flavell, 1976). Metacognition is defined as the “active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective” (Flavell, 1976, p.232). This term was introduced by Flavell in the early 1970s based on the term meta-memory. It is usually related to learners' knowledge, awareness, and control of the processes by which they learn. Flavell's definition was followed by others, often highlighting different understandings of processes associated with metacognition.

In mathematics research, Cardelle-Elawar (1992) defines metacognition as an “aspect of critical thinking that includes the student’s abilities to (a) develop a systematic

strategy during the act of problem solving and (b) reflect on and evaluate the productiveness of his or her own thinking processes” (p. 110).

Metacognition as it relates to student learning ranks highest in the revised 2001 Blooms’ Taxonomy of Cognitive Tasks for Students. This is sometimes referred to as a form of self-regulated learning (Palincsar & Brown, 1987). Metacognitive knowledge has become of increasing significance in student learning as researchers continue to demonstrate the importance of a student growing in awareness of their own learning process and then using this knowledge to appropriately adapt the ways in which they think, operate, and persevere through tasks (Krathwohl, 2002).

Accurately judging one’s performance or recalling the details of an “aha!” experience in the mathematics classroom can be challenging considering most students tend to be overconfident and overestimate their actual performance (Callender, Franco-Watkins, & Roberts, 2015). Overconfidence (or denial) while learning mathematics can be problematic, leading to poor decisions such as making inappropriate choices regarding classroom focus, avoidance of practicing new skills, or not allocating study time appropriately. The ability to accurately observe and explore one’s own performance is not easily attained. The student’s use of metacognition in the classroom is particularly important as student knowledge about their own learning affects their future study choices and learning (Callender, Franco-Watkins, & Roberts, 2015).

Garii (2002) stated, “Little research has assessed the role of student-initiated metacognition in the learning of mathematics” (p. 1). Therefore, helping students understand their own metacognitive processes and how each student can attain “aha!”

experiences may help to increase their academic performance. Some researchers believe the feelings of pleasure and excitement that come with “aha!” experiences, followed by reflective activities in the math classroom, may fuel students' continued willingness, interest, and performance in mathematics (Barnes, 2000).

In terms of learning mathematics, levels of self-knowledge or metacognition can be either an important companion or a limitation. Students who know their own strengths and weaknesses can regulate their own path to learning to be more adaptive to different tasks and, thus, expedite “aha!” moments. If, for example, a mathematics student realizes they do not have the necessary requisite skills to a particular topic, they might pay closer attention while studying and use a variety of strategies to make sure they fully grasp what is being taught. In the same manner, if a student is aware they have difficulties with exams (test anxiety) then they can prepare for an upcoming mathematics test in an appropriate manner for their own specific need. Students who lack knowledge and understanding of their own strengths and weaknesses will be less likely to adapt to the variety of situations learning naturally presents and, therefore, not be able to adjust their own learning accordingly (Krathwohl, 2002). These students can easily get stuck in a nonproductive cycle of mathematics learning (Kargar, Tarmizi & Bayat, 2010; Garii, 2002). Because of this, increased student achievement, deepening of learning, and advancement through the hierarchy of math courses may be limited or unavailable to some.

Student-initiated Metacognition

Research in the area of assessing the role of student-initiated metacognition in learning mathematics in alternative high school settings is sparse. Most current research on classroom metacognition looks at how motivation affects metacognitive performance. For example, Karaali (2015) reported on the relationship of how metacognition affects the motivation of students in the classroom over the course of an academic semester. Karaali's research supports the regular use of metacognitive and self-reflective activities to keep students focused on learning and to allow students to remain engaged and motivated throughout a school semester.

Ozcan (2015) investigated self-regulated learning activities as a key to improving problem-solving. Ozcan (2015) built upon Zimmerman's (1989) description and work of self-regulated student learners and metacognition. Zimmerman (1989) found students are self-regulated learners to the degree they are metacognitively, motivationally, and behaviorally active participants in their own learning process. Ozcan (2015) added that behaviorally active students choose, form, or create environments that are ideal for their learning to take place. Ozcan's (2015) findings indicate a student's brain rewards itself with interesting information, not with results.

Attribution Theory

Researchers and educators agree, having and reflecting upon positive experiences in mathematics, including "aha!" experiences, can potentially lead to positive outlooks about mathematical learning and growth mindsets (Barnes, 2000; Liljedahl, 2004; Boaler,

2016). It was the student's point of view most sought after in this particular study. Therefore, applying attribution theory as the theoretical framework for this research allowed the lens of study to be from the students' perspectives.

Attribution theory, initially associated with Fritz Heider (1896-1988), defines how people come to explain their own behavior or the behavior of another and was used as the theoretical framework of this paper to explore how students see themselves or their classmates move from a fixed mindset to a growth mindset in mathematics. In attribution theory, an attribution refers to a person's explicit and implicit understanding of the cause of an event and responsibility for that event (Heider, 1958). Generally, a person's behavior is credited to either a disposition or to an external situation (Malle, 2011).

Generating and perceiving "aha!" experiences and moving from a fixed to a growth mindset in mathematics may be triggered by a multitude of inputs for students. Kelley's (1967) addition to Heider's original attribution theory was the adding of the covariation model. Covariation is meant to describe how a person has gathered information from multiple observations at different times and situations and can perceive the correlation between the observed effect and its causes. Kelley (1967) shared three types of causal information, which he believed influenced an individual's judgment:

1. Consensus – the extent to which other people behave in the same way in a similar situation.
2. Distinctiveness – the extent to which the person behaves in the same way in similar situations.

3. Consistency – the extent to which the person behaves like this every time the situation occurs.

Weiner (2005) furthered attribution theory and connected it to classroom motivation and student learning experiences. Specifically, Weiner (2005) delineated the processes through which learners form causal beliefs. A basic assumption of Weiner's model of attributions is that learners are affected by both environmental factors, such as characteristics of the student's home or school, and by personal factors, such as prior experiences and knowledge. His research reported on the influence of casual beliefs on both teacher and student behaviors and the effects of attributions on achievement striving, motivation, and perseverance. The benefit of Weiner's educational attribution theory model is that it allows the addition of the influence of both the teacher/researcher and student behaviors.

Attribution Theory in Action

Although fundamentally a sociology theory, attribution theory has been used in many disciplines, including mathematics education research. Di Martino and Zan (2010) found that teachers often diagnose a student's negative attitude in mathematics as a causal attribution of the student's perceived failure. This negative attitude is perceived as fixed or stuck rather than an accurate interpretation of the student's current behavior or feedback about their current stage of learning in a larger cycle of learning, both now and to come. In this study, attribution theory allowed the lens to be focused around student's beliefs about themselves and their own perceptions of learning mathematics.

Others, such as Vaughn (2012), also used attribution theory as the theoretical framework in math education research. Research focused on middle school mathematics and students' perceptions on mathematics learning. Vaughn's study used a phenomenological research design, which illumined and gave meaning to the experiences of students. The findings of Vaughn's (2012) study demonstrated students' past experiences influenced their current attitudes about the study of mathematics. Perceptions of mathematical ability, history of success or failure with grades, and the influence of the teacher and peers in the learning environment were found to influence students' attitudes about mathematics the most. Moreover, feelings were shown to impact the degree to which a student puts forth effort in the study of mathematics. Finally, Vaughn (2013) found the relationship with the mathematics teacher had the greatest impact on student attitudes of all factors. Through this research, Vaughn demonstrated the lens of attribution theory as beneficial to examining student beliefs about their own successes or failures.

Chapter Summation

The focus of this literature review was the leverage point that uncovers the shift a fixed mindset math student makes to become an engaged student with a growth mindset from the student's perspective. This shift was thought to occur through a self-perception of content mastery: student "aha!" moments followed by student metacognition. Therefore, the literature review began with a brief overview of student achievement research in the field of mathematics and the importance of deepening student learning

due to student's successful future in the adult world weighing on academic engagement. Next, a brief history of the psychology of mindset and various mindset definitions were provided to highlight how having a growth mindset in mathematics, a mathematical mindset (Boaler, 2016), leads to deeper engagement in math, learning more efficiently, an increased desire for challenge, and a resilience when mistakes are made (Boaler, 2016). Conversely, a fixed mindset was reported to be stuck under an unchangeable label of smart or dumb with fear of failure and lacking in the pleasures of perseverance and creativity (Dweck, 2006).

Following mindset came student "aha!" experiences and their significance. Students who experience "aha!" moments in the learning of mathematics are said to develop positive attitudes about mathematics (de Lourdes Mata, Monteiro, & Peixoto, 2012). Students with positive feelings about learning math report being more motivated to think mathematically, to understand class content, and to dedicate extra effort toward the study of mathematics (Ames, 1990; Garii, 2002; Boaler, 2016). In other words, the literature review points to "aha!" moments leading to a growth mindset, which then leads to increased student engagement.

Defining metacognition and providing a brief history as it relates to education, as well as sharing on a method of gathering data from the student's perspective (attribution theory), were the last sections of the literature review. Metacognitive knowledge was reported as significant in student learning as researchers demonstrated the importance of students growing in awareness of their own learning process and then using this knowledge to appropriately adapt the ways in which they think, operate, and persevere

through tasks (Krathwohl, 2002). To study a student who is reflecting upon an “aha!” experience, the lens of attribution theory is used to explore the perception of an “aha!” moment, judgment of intention, and the assigning an attribution of causality, all from the student’s perspective (Malle, 2011).

In the upcoming third chapter, the methodology of this qualitative case study of students at an alternative high school moving from a fixed to a growth mindset will be discussed in detail.

CHAPTER THREE

THE METHODOLOGY

Research has demonstrated the positive affects of growth mindset interventions on students' development in education (Dweck, 2007; Boaler 2016). Specifically, growth mindset interventions have the potential to increase students' academic persistence and performance (Boaler, 2016). Boaler (2016) reported that the subject of mathematics often transfers the strongest fixed mindset message to students about perceived educational ability, or lack thereof, and limitations in thinking. Conversely, Boaler also found that growth mindset messages had a powerful impact upon students' attainment for progress and change in math education. When students undergo interventions to move from a fixed to a growth mindset, they immediately start performing at higher levels in school (Boaler, 2016).

Additionally, student mastery experiences allow students to experience the value and attainability of academic goals and are also a source of positive feedback. Student mastery experiences are defined as repeated successes creating a strong belief in self-efficacy (Bandura, 1994). Research has shown mastery experiences are the most powerful sources influencing and predicting student self-efficacy, which directly affects student learning (Klassen, 2004; Ozdmir & Pape, 2013). Research results further indicate mastery experiences can have a profoundly transformative affect on a student who is typically resistant to learning math and in a fixed mindset. However, it is not currently known how a student moves into mastery experiences out of a fixed mindset from the

student perspective in the alternative high school environment. There is a dearth of information regarding mindset shifts from the student perspective in the mathematics alternative high school realm.

The purpose of this qualitative case study was to document and analyze from the student's perspective how mathematics high school students at an alternative educational center moved from a fixed mindset to a growth mindset in a dual credit math course.

Specifically, this study seeks to answer the following research questions:

RQ 1: How do high school students attending an alternative program describe their mathematics mindset?

RQ 2: How do the descriptions of their perceptions about mathematics change during a mindset shift?

Research Design

This research study was designed to describe a process, from the student perspective, of the shift from a fixed mindset to a growth mindset as it occurred in an alternative high school, dual credit, Intermediate Algebra course over the course of one academic semester. The qualitative design used in this research study was a case study. Yin (2014) had a twofold definition of a case study. The first begins with the scope of a case study: "A case study is an empirical inquiry that investigates a contemporary phenomenon (the 'case') in-depth and when it's real world context, especially when the boundaries between phenomenon and context may not be clearly evident" (p. 16). This case study looked closely at the students' experiences of moving from a fixed to a growth

mindset within a semester of math work at an alternative high school learning center in Oregon.

The second part of the definition deals with the phenomenon and context of the study. Yin (2014) stated:

A case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as a result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analyses (p. 17).

This case study was bounded by three students' experiences of shifting from a fixed to a growth mindset within an alternative high school math class located in an urban district of Oregon. The experiential shift in mindset was not distinguishable as a linear event. Multiple methods of data collection were relevant features of this research study.

Purposeful Selection and Context

Participant Identification

The course that defined the case was the fall, 2016, high school dual credit course, Algebra 2/Math 95–Intermediate Algebra. It included three high school student participants who attended a Title 1 alternative high school. All three of the students had overall grade point averages below 2.00 on a four-point scale and were generally unsuccessful at the traditionally oriented, comprehensive high school within the same school district. Each participant had failed at least one semester of high school mathematics prior to this course. One was 17 years old and two were 18 years old when this study took place. Two of the three participants had met their math course

requirements in order to graduate high school, but elected to take this course even though the graduation requirement was met prior to their enrollment in the course. The other student needed this course or another high school math course to fulfill the district high school graduation requirements. Every student enrolled in the Algebra 2/Math 95 math course was invited to respond to seven writing prompts during class time and participate in one to two small group interviews. The three participants who consented to participate ongoing for the duration of the study are represented with the demographic profile notes in Table 1.

This group of three students began their formal exposure to mindset psychology in the fall of 2016 in an alternative high school setting in an urban area of Oregon. Previous to the mindset information, all three students described themselves in some form or another as having a fixed mindset with regards to learning mathematics. Each student applied to, was accepted into, and attended the alternative high school due to some experiences of being unsuccessful at the large, comprehensive high schools in the same urban district. Additionally, all of the participants had earned a non-passing grade during one or more of their previous high school math courses at one of the other high schools in the same district.

Table 1. Participant Demographic Profiles

Demographic Profile	Data
Age	17 years old: 1 18 years old: 2
High School grade level	11 th grader: 1 12 th grader: 2
High school mathematics course non-pass	Algebra 1: 3students
Needed this course or another high school level math course in order to complete graduation requirements	Yes: 1 students No: 2 students

This study did not specifically address what motivated these students to enroll in the dual credit mathematics course instead of other math courses, or no math courses at all. The focus of this study was on the fixed to growth mindset shift of the students from their perspectives based on self-reports.

The alternative high school set an attendance standard for best learning—no more than eight absences per academic year. Consistent and regular high school attendance for the majority of students at this alternative high school was challenging. By week 20 of the course, two of the students were well over the district’s recommendation. This pattern was consistent throughout the semester. See Table 5 for Student Attendance Data.

Human Subject Consideration

Each student participant was invited to participate using the Research Participation Invitation Letter (Appendix D) approved by Montana State University Institutional Review Board (IRB) (Appendix A). The letter provided a brief overview of the intent of the study and was given to students in class, and sent home via the students for parents to sign if the student was a minor. The letter of participation invitation was accompanied by words of support and recommendation for the study from the alternative high school principal (Appendix E). If no response was received from the invitation, a second, identical letter was attempted. Finally, an in-person meeting with the student's guardian was attempted if the second attempt also failed. If, after these attempts, no response was received, the assumption was made that the student was not interested in participating or did not receive parental support.

The participants for this qualitative case study were selected based on their first-time enrollment in a semester long dual credit section of the midlevel developmental mathematics course, Intermediate Algebra, at an alternative high school in the fall semester of the 2016 school year. The fall, 2016, semester was the first offering of a dual credit math course at this alternative high school. Ten students total were initially enrolled in the dual credit course as Algebra II for high school credit. Halfway through the semester, when it came time to add the dual credit option of Math 95–Intermediate Algebra college credit through a local community college, eight students decided to fully enroll. These eight (of the ten) attended the daily class regularly and performed at passing levels for the entire semester. Three of these eight students returned their parent and

participant permission slips to be included in the study and actively participated in class and data collection opportunities. Participation was voluntary, participants could decline to answer any question, and were able to withdraw from the study at any time. Students gave their time to participate in the writing exercises and interviews and were not rewarded for their services. No survey software was used in the collection or analysis of the data.

Creating the Space for Learners

Instructional Methods

All of the curriculum, sequencing, rigor standard, exams, and timing for this dual credit math course were derived from or closely guided by the partnering community college. A partial course syllabus for this course can be found in Appendix F delineating the course description, course outcomes, class etiquette, course grading, outcome assessment strategies, assessment requirements, and course schedule/timing. These were all preset and agreed upon in advance between the school district and partnering community college in order to offer the course to the alternative high school students. The rigor level of each assignment and exam was determined and verified by the partnering community college. All homework sets, quizzes, and exams maintained a consistent college level rigor throughout. I was also evaluated for rigor and consistency as an instructor by the partnering community college and the completed Dual Credit Course Assessment Form may be found in Appendix H. In addition to the instructor assessment, regular communication was maintained between myself and a mentoring

community college instructor through emails, phone calls, in-person meetings, and professional development events with the community college.

Even though the curriculum and timing were preset, there was still a great amount of classroom freedom to deliver the material in my own style. As was mentioned in Chapter One, my role as a teacher has evolved over the years to a teacher interested in encouraging students' shared collaboration and problem solving through discussion. Rigor is an important aspect of student learning in my classrooms. As a teacher, I strive to challenge students intellectually and support them academically by asking deeper questions and helping students discover ways to learn in a community and also reach out for help when needed. Students do a good amount of group work in my classroom and, therefore, must become well acquainted with each other in communities, as well as with the material presented. I believe it is the grappling with one another in community that deepens empathy. I have found that, when the varied biographies and personalities of students work together, perspectives are broadened in a way that they cannot be by the instructor alone.

In order to maintain my own flavor of classroom environment within a set framework of material and time preset for our course, I did not modify my teaching style for this course. Instead, I imposed my methodology of teaching upon the community college curriculum. The partnering community college mentor instructor was able to view this teaching method during my instructor assessment. On the day of the assessment, the topic was from Section 8.3: Quadratic Equations and the material presented was a supplemental worksheet provided by the community college (Appendix G). I strive to

deliver all new material in a low floor/high ceiling method encouraged in growth mindset classrooms (Boaler, 2016) where the task is presented and worked with in a way that each individual student can begin the task and work at their own level of engagement.

For this topic specifically, I projected the pages directly onto the large classroom white board and, from my seat, I invited all of the five students in attendance to approach the board to investigate today's work. Due to the previous work in community classroom building and mutual respect, each student was attentive and engaged. They took turns reading through the tasks, making conjectures, and offering up methods of attack to begin the work. Together they discussed and argued their way through connecting their previous knowledge of lines, parabolas, inequalities, domain, range, and word problem translations into solutions to each problem on all three pages. They looked to each other for next steps, drew on the white board to illustrate their thinking to each other, corrected each other's mistakes, and used me only when completely stuck. When the students looked to me for guidance, I posed a question back to them from previous work instead of handing them the solution. The classroom was boisterous, active, and engaging. The white board progressed from empty, to incorrect ideas, to messy corrections and, finally, to beautiful solutions. Each student appeared to gain understanding from the exercise and followed up with completing their own paper copy of the assignment and turning it in for the gradebook.

Evolution of Interest in the Research Topic

In the autumn of 2005, when I was still new to teaching high school math, I wrote a short article for the Research Institute of Waldorf Education. In it, I first pondered the nature of student challenges with mathematics. “Why is the proportion of students who struggle with math so large? Who are these students and what can be done to change this? What impact might these deficiencies have on students’ futures?” (MacKinder, p. 49). These questions lay upon my heart and mind and I prayed about them over many years as I worked with various levels of mathematics students across the western United States.

Ten years later, during the winter of 2015, I was able to research a little more in depth during a graduate qualitative research course. The purpose of that particular phenomenological study was to explore teachers’ understanding of student mathematical mastery experiences and student “aha!” moments in secondary mathematics classrooms. I had read research showing that mastery experiences and “aha!” moments were some of the most powerful sources influencing and predicting student self-efficacy and student achievement whereas frequent and repeated failures lowered both for students over time (Klassen, 2004). Upon reading these, I felt all teachers, including myself, could benefit from a deeper understanding of how student mastery experiences and student “aha!” moments occur in a classroom setting. Therefore, I focused the research to examine teachers’ perceptions of students’ “aha!” moments in the classroom and what influences the creation of the mastery experiences with the expectation that I would later look

toward the student perspective of mastery experiences and “aha!” moments for the dissertation.

During a literature review process for the dissertation prospectus in early 2016, I located a paper by Garii presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 1–5, 2002) titled “‘Aha’ Experience: Meta-Cognition and Student Understanding of Learning and Knowledge”. That was when I realized the student “aha!” perspective had been reported on and further understood the gap in the literature that existed around how a student moves out of a fixed mindset and into a growth mindset in order to have an “aha!” moment. I was struck with empathy by the following section of Garii’s paper:

Several struggling students described a negative pattern that was integrated into this model: they were aware that they did not have the requisite knowledge on which to stack new learning and they volunteered that they had chosen not to learn the information that would help them develop the skills that could lead to knowledge. They were quick to point out that this lack of knowledge was not due to teacher inadequacy but in their own disinterest and their disbelief that “any of this” was really important. They recognized their own negative cycle: they disliked the subject matter, they were unwilling to accept that there could be any point, they made minimal (if any) effort to improve their skills and/or understanding and thus were frustrated with their inability to follow the steps and routines, so their dislike of the subject matter increased. Ultimately, they found themselves unable to proceed and faced continuous, unrelieved frustration in mathematics. They characterized themselves as unwilling at any time to try the one step that they perceived would help them, memorization of procedures and basic facts (p. 15).

These self-proclaimed unwilling students in a fixed mindset around mathematics as described above seemed identical to the students I was currently working with at the alternative high school in Oregon and brought me full circle back to the original questions that weighed upon my heart in my early years of teaching. I again wondered

how to help students move from an unwilling attitude and fixed mindset into curiosity, love of learning and, ultimately, their own “aha!” moments and a growth mindset.

In late May of 2016, my school district offered up an opportunity to enroll and participate in a Stanford University online course by Dr. Jo Boaler titled, “How to Learn Math: For Teachers and Parents”. The purpose of this university course was to support teachers, administrators, and parents with the integration of growth mindset research ideas that would assist all students in learning mathematics at deeper levels. The delivery was through OpenEdX platform course sessions and included interviews, classroom videos, lesson plans, and many thinking tasks. At the same time that I completed this course, I also read “Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching” by Boaler (2016) and “Mindset: The New Psychology of Success” by Dweck (2006).

Together, these new inspirations helped me confirm it was the shift in mindset from fixed to growth I wanted to study among my students at the alternative high school from students’ perspectives. I believed this could be the key for moving the unwilling students Garii reported on into willing students who would move into experiencing mastery and “aha!” moments and begin to enjoy the learning of mathematics.

Procedures

Data Collection

Creswell (2007) suggests data collection, data analysis, and report writing are not distinct steps in the process, but instead are interrelated and often go on simultaneously in

a research project. A major strength of case study data collection is the opportunity to use many different sources of evidence (Yin, 2014). This case study gathered qualitative data from student participants during the fall, 2016, semester of the dual credit intermediate algebra course. The qualitative data collected included: (1) eight student written reflections, (2) recorded/transcribed student participant focus group interview and discussion, (3) student artifacts, and (4) instructor observations and field notes taken during the course of teaching the dual credit math course. Table 2 below summarizes the types of data that were collected and a brief rationale for the collection of the data.

Table 2. Summary of Data Collected and Rationale

Data Collection Type	Rationale
Initial Participant Written Reflection	Provided individual student's initial perceptions and dispositions regarding mathematical mindset for themselves and their classmates and worked to establish a trust connection and relationship between teacher and student
Instructor Observations and Field Notes	Provided a means to anchor students' experiences and perceptions to behavioral observations, students' responses, and shared classroom interactions during the dual credit mathematics teaching and learning
Seven Additional Participant Written Reflections	Provided students' during course perceptions and dispositions regarding mindset shifts in mathematics while the course was being taught over a timeline of 20 weeks

Table 2. Summary of Data Collected and Rationale Continued

Focus Group Interview with Discussion	Provided shared and collaborated perceptions and dispositions of mindset shifts of self and of classmates and allowed the topic to be explored from various student viewpoints
Student Artifacts	Provided concrete documentation of mindset shifts of students

Direct observations and field notes were also recorded by me throughout the course of the semester of the dual credit Intermediate Algebra course. Observations of student behavior, comments or conversations, and artifacts were recorded weekly into an Excel spreadsheet. In total, the field notes sought to provide a clear and detailed picture of events that included physical description of behaviors observed in specific settings and the accurate reconstruction of events (Yin, 2011).

Data Sources

Student Writings

At the beginning of a scheduled Algebra 2/Math 95 math class, photocopies of the writing prompts were handed to each math student in attendance. The instructions were given to complete the writing to the best of the student's ability and to ask any questions as they arose regarding meaning of the questions. Students would then take the first five to ten minutes of class to complete the writing and hand it back to the teacher. Those students who were absent on the day of the writing were asked the next day back to complete the question response writing.

The initial student written reflection was in response to a question prompt given during the first week of school (Appendix B). The prompt asked students to complete a short letter to the teacher. It stated, “Dear Math Teacher, You should know this about me...” In completing this prompt, mathematics students were asked to share key points about themselves or their individual learning that would be helpful for the teacher to know. My expectation was that each student would self-report any relevant learning blocks during the writing exercise and then share with the whole class aloud if they desired. Dunn (1983) found that students in grades 3–12 can self-identify important key aspects of their own learning needs and styles and greatly benefit from being asked to share with their teacher.

In the following 19 weeks, seven reflective writing prompts were additionally given to the student participants to complete (Appendix B). The purpose for the student writing and conversational reflections were to have the students consider the process of their own learning in mathematics—their process of metacognition—critically review their own behavior, that of their classmates, build a grounded narrative from observations, generalizations, practical situations, thoughts or a mixture, engage in personal or self-development or self-evolution or empower others, and make decisions or resolve uncertainty.

Previous research supports the implementation of reflective journaling and conversing within the classroom. Meel (1999) implemented reflective journal writing within his university level linear algebra course and found benefits such as opening strong lines of communication between teacher and student.

A hardcopy packet was created by me for each student, identified by an individual student code that included their completed prompted writings and other communication with the participant. These notes and observations were then entered into a spreadsheet with the corresponding questions in order to facilitate reviewing and categorizing. No coding software was used.

Researcher Field Notes

I kept a weekly log of student activities, comments, and behaviors over the course of the semester of math studied. Each student had their own row on a spreadsheet where notes were taken after classroom events. I had scheduled class time with the students daily in one-hour increments. On occasion, I was out during the week for mandatory school district or math department meetings and, in those cases, random substitute teachers taught the course and no field notes were taken on those days. The field notes delineated my observations, student interactions with each other or with me, comments made, and other important actions or inactions of the student participants. The field notes were created, updated, and stored in a spreadsheet on a password protected computer.

Small Focus Group Interview

One of the most important sources of this case study evidence was the focus group interviews and discussions, which was not surprising as interviews are commonly found in case study research as powerful sources of data (Yin, 2014). The focus group interviews and discussions conducted in the fourteenth week of school were originally set up so that small groups of students could be interviewed at a time, and two interview

sessions would be held so that all student participants could participate. By this time, five writing prompts had been completed and the school semester was over halfway completed. Two of the four major exams had been completed and all but one of the three students were passing the course. The interviews resembled guided conversations rather than structured queries which are sometimes referred to as “in-depth interviews” or “unstructured interviews” (Yin, 2014, p 110). The first interview began with two students and a third participant joined later. The second interview began with three non-participant students who had not yet opted out of the study, and then, in the last few minutes, had two participants join when a new and very relevant question was posed regarding student perceptions of mindset shifts. Both interviews lasted about 11 minutes.

I prepared a set of four questions prior to the interview recording as noted in Table 3, but also let the students engage in a free flowing conversation once interviews began. A fifth question arose from a student who at the time was a participant, but later opted out of the study. This non-participant spontaneously posed a question for all during the last few minutes of the second interview. Therefore, five questions in total were discussed by all participants. Throughout the interviews, the students displayed relaxed postures and conversational openness during their self-reflections and discussion sharing.

The four original questions scheduled to be given to the students during the short interview and discussion were: (1) What does it take to be successful in math? (2) What changed for you such that you are now successful with math? (3) Have you seen other classmates shift into also being successful in math and, if so, what have you seen or heard

that caused their shift? (4) What have I missed or what should I have asked you about regarding students shifting their mindset from fixed to growth?

The fifth interview question raised by a student who later opted out of the study was: “When and how did you notice that you had moved from a fixed to a growth mindset?” This question was given as much time and importance as the original four questions and was open to all participants to answer and discuss.

Table 3. Focus Group Interview Questions

Interview	Q1: What does it take to be successful in math? Q2: What changed for you such that you are now successful with math? In other words, what was your biggest shift? Q3: Have you seen other classmates shift into also being successful in math? If so, what have you seen or heard that caused their shift? Q4: Looking back over the writing entries and questions in this interview and other things that we talked about in class regarding shifting from a fixed mindset to a growth mindset, is there something that you want to add to my research? Q5: (student added question) When and how did you notice that you had moved from a fixed to a growth mindset?	14 th week
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Once the focus group interviews were recorded, each interview was then transcribed into a Google Docs document with a user log in and private password. The recorded interviews and the transcriptions of the student interviews were stored on a password protected laptop within two web based, password protected applications: DropBox and Google Drive.

Data Analysis Procedure

The data analysis procedure followed the suggestions of Creswell's (2007) general spiral model and Yin's (2014) logic model. The research began by taking a general inventory of all data collected and reviewing it holistically.

Next, all student responses from student writings, interview questions, and observations over the semester were entered into a spreadsheet. The data in its entirety was reread and descriptive codes were added to margins, which attempted to summarize a primary topic of an excerpt (Saldana, 2013). The codes and data were examined across questions in search of themes or patterns. When similar codes were repeated in the data, they were then color-coded in a particular color to represent a category of repetition. A table of themes was created from the color-coded pattern. This table was then verified and supported with direct student quotes. These themes were distilled further onto notecards with accompanying definitions. This was followed by examining the data over time and for each participant individually and verified against the notecards and theme definitions. I followed Yin's (2014) recommendation that a researcher start the analysis "by playing with the data and searching for promising patterns, insights, or concepts—the

goal being to define your priorities for what to analyze and why” (p. 132). For the most part, data for this qualitative study was comprised of personal thoughts, feelings, and reflections of the student participants and was, therefore, approached and held with reverence and in gratitude.

On the last day of the academic semester, the final themes from the notecards were posted on large paper on the classroom wall for the participants to view and comment on. Each participant was invited to rewrite, add to, or remove a theme. This participant member checking added to the validity of each theme through participant additions of supporting comments to each large poster. A final discussion naturally emerged from this participant activity of member checking and data analysis. Participants were also invited to read through and redact any information from their entire hardcopy packet that had been collected over the course of the semester of dual credit math. In the final phase, the entire analysis was scrutinized for researcher bias with the assistance of the Committee Chair Person and final validation using triangulation from the various forms of the data from all three participants over the time frame of an academic semester.

Data Analysis

Creswell (2007) believes the analysis process conforms to a general contour that “is best represented in a spiral image, a data analysis spiral” (p. 150). Creswell (2007) shows:

To analyze qualitative data, the researcher engages in the process of moving in analytic circles rather than using a fixed linear approach. One enters with data of text or images and exits with an account or a narrative. In between, the researcher touches on several facets of analysis and circles around and around (p. 150).

As Maxwell (2005) offers, a “qualitative researcher begins data analysis immediately after finishing the first interview or observation, and continues to analyze the data as long as he or she is working on the research, stopping briefly to write reports and papers” (p. 95). Data analysis for this qualitative case study followed Creswell’s spiraling suggestion and consisted of preparing and organizing the data for analysis, reviewing all materials collected from the student participants as well as the field notes, then reducing the data into themes through a process of coding and condensing the codes, and, finally, representating the data in figures, tables, and a discussion (2007).

However, Yin (2014) reminds within qualitative research, “the analysis of case study evidence is one of the least developed aspects of doing case studies” (p. 133). Within Creswell’s (2007) general spiral strategy of data analysis for this qualitative case study, I also looked to the writings of Yin (2014) and used a recommend analytic technique, a logic model, in order to develop internal and external validity.

Logic models have become increasingly useful in recent years, especially in studying theories of change (Yin, 2014) such as this case study focusing on the student shift from a fixed to a growth mindset.

The logic model stipulates and operationalizes a complex chain of occurrences or events over an extended period of time. The events are staged in repeated cause-effect-cause-effect patterns, whereby a dependent variable (event) at an earlier stage becomes the independent variable (causal event) for the next stage (p 155).

In other words, logic models help to explain a sometimes mysterious outcome with a sequencing of non-linear events, for instance, a shift in mathematical mindset.

Analyzing data presents a challenging task for qualitative researchers, and deciding how to represent data only adds to that challenge (Creswell, 2007). “Data analysis in qualitative research consists of preparing and organizing the data for analysis, then reducing the data into themes through a process of coding and condensing the codes and finally representing the data in figures, tables, or discussion” (p. 148). For a case study specifically, “the analysis of case study evidence is one of the least developed aspects of doing case studies” (Yin, p. 133, 2014). Case study analysis usually consists of making a detailed description of the case, its setting and the facts about the case, or the activities of the case (Creswell, 2007).

Creswell delineates a tabled progression in analyzing and representing case study data for qualitative research that includes: organizing or managing the data through the creation of files; reading and memorizing the data, including making margin notes and forming initial codes; describing the case and its context; classifying data by using categorical aggregation to establish themes or patterns; interpreting the data through either using direct interpretations or developing naturalistic generalizations; and,, finally representation or visualizing data by presenting in-depth pictures of the case using narrative, tables, and figures (2007, pp. 156-157).

The above data analysis and representation was followed for this research and additionally pressed for high quality using Yin’s four principles that underlie all good socialscience research. These four principles were: (1) attended to all the evidence, (2) addressed all plausible rival interpretations, (3) addressed the most significant aspect of the case study, and (4) used own prior expert knowledge in the case study (2014).

Data analysis for this research began by reading and reflecting on the initial student written reflection and the additional seven student journal writings, researcher field notes, and interview transcript data looking for commonalities, a pattern, or insight to emerge to determine how the mindset shifts for the student fit into the setting—in this case, an alternative high school with students who were typically unsuccessful in the large, district, comprehensive high school.

Coding. “A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence capturing, and/or evocative attribute for a portion of language—based or visual data” (Saldana, 2013, p. 3). The coding of the data began by rereading the transcribed focus group recordings and adding digital highlighting to student statements that seemed similar in theme as to how they perceived a shift in mindset occurred for themselves and their math classmates. In all, seven initial mindset shift codes were gleaned from the transcripts: (1) self-efficacy, (2) school/teacher, (3) classmates/peer influence, (4) math topics of interest, (5) mastery experiences, (6) practicing, and (7) moods/anxiety. Next, I added descriptive memos into the margins of the participant written data responses to look for similar or additional student statements or ideas. Patterns in the codes were then gleaned. These patterns were broken down into either sub-codes of the original codes or into broader categories. An all-inclusive analysis of the data was used with the extracted codes, categories, and themes to determine specifically how a student in an alternative high school has a shift in mathematical mindset from fixed to growth following a modified version of Saldana’s “streamlined codes to theory model for qualitative inquiry” (2013, p. 13) (see Figure 4).

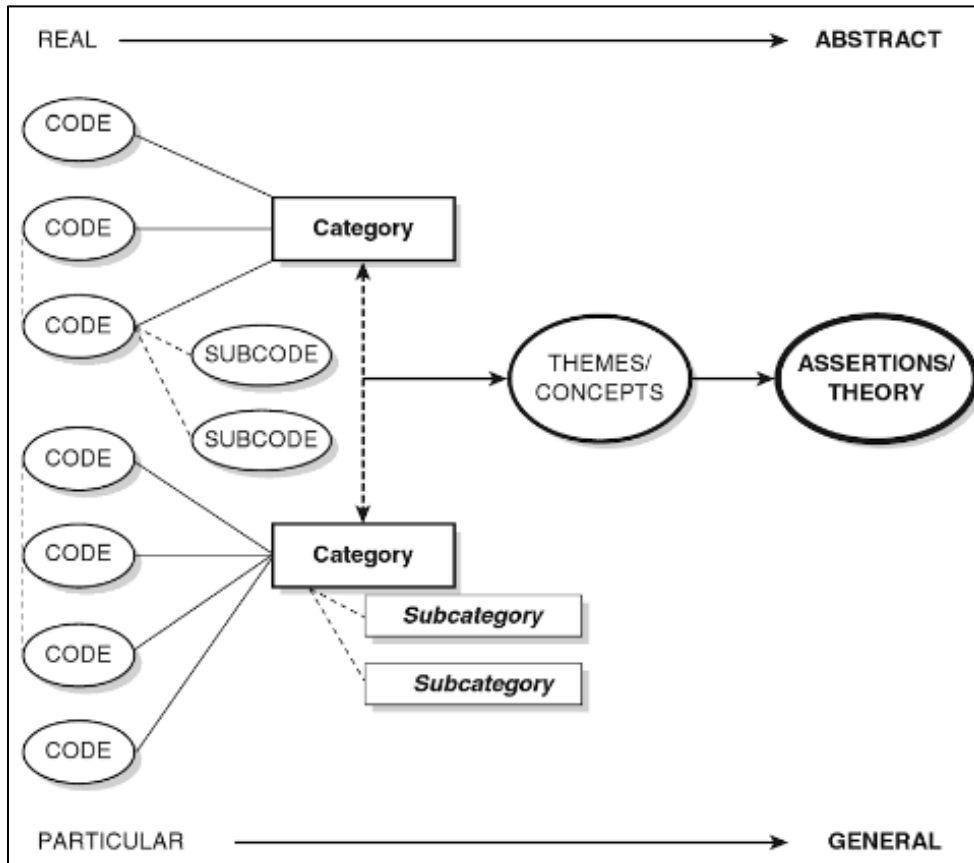


Figure 4. Saldana's (2013) Streamlined Codes to theory Model for Qualitative Inquiry

When all notes and codes from the student data and transcribed recordings had been pooled together, mindset shift themes and sub-themes were assembled. A grounded narrative was then created with rich thick descriptions in support of the mindset shift themes and underlying coding. The codes, categories, and narrative were shared back with the participants for feedback and refinement twice during the data analysis process for accuracy.

Trustworthiness

Collecting information using a variety of sources and methods is one aspect of what is called triangulation (Maxwell, 2005). This strategy reduces the risk that conclusions will reflect only the systematic bias or limitation of a specific source or method and allows for a broader and more secure understanding of the issues under investigation (p. 94). Trustworthiness in this qualitative research was created through triangulation including the rich and thick descriptions from student direct quotes taken from the written reflections, detailed researcher field notes, and quotes from focus group interviews, all supporting and revealing a mindset shift. The interviews provided additional information that was missed in the written reflections and were also used to check the accuracy of the field notes, observations, and student written reflections. Furthermore, multiple student mindset shift views were represented in each of the themes that were uncovered, which supports the possibility of the data being able to be replicated in the future.

Additionally, member checking was used twice during the process. The first time was during the nineteenth week of school and secondly in a writing prompt on the last day of the academic semester. These were done through feeding the participants' quotes taken from the transcripts, field notes, and previous writing prompt answers back to them and asking what they meant or observed in the quotes as well as asking them to elaborate or delete as they saw fit. The participants then verified themes based on the quotes and observations and added comments in support. The participants' themes were then matched up with my themes for verification of accuracy (Figure 5).

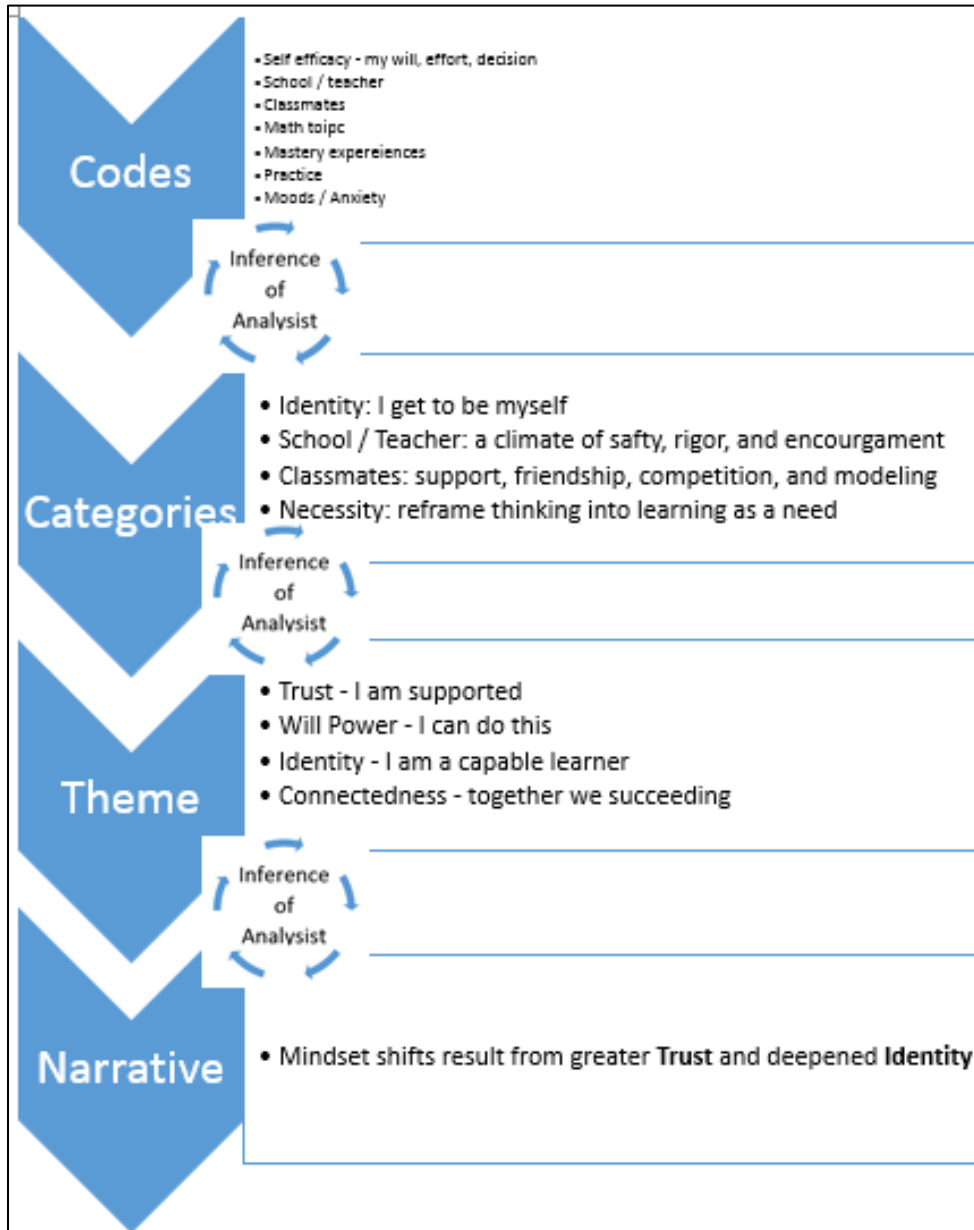


Figure 5. Coding to Themes to Grounded Narrative

Maxwell (2005) argues, “Qualitative researchers generally deal with validity threats as particular events or processes that could lead to invalid conclusions, rather than as generic variables that need to be controlled” (2005, p. 108). The two main validity threats are researcher bias and reactivity: bias, meaning an innate prejudice for or against

and reactivity, meaning acting in response instead of pre-planning. Because I was also in the role of the classroom mathematics teacher, this relationship and bias had the greatest potential for harming the validation and credibility of this current case study, while at the same time potentially serving the study. As Maxwell notes, “validity in qualitative research is not the result of indifference, but of integrity (personal communication)” (2005, p. 108). The fact that I was part of the natural environment being studied made me a potentially potent and unavoidable influence. Bearing this in mind, I strove to avoid leading questions and preventing undesirable consequences of my presence by working to understand how I may have influenced what the student participants said or did and how that may affect the validity of the inferences that were drawn from the collected data.

Limitation of the Study

A specific limitation to the study is due to a potential bias from the students in attempting to please or punish me as their daily classroom teacher. Additionally, as a participant researcher, there is the potential that neutral observations were not conducted and a bias is present throughout.

Student absenteeism was a limitation of the study. The source of the absenteeism rate and the impact of absenteeism on the course were not within the scope of this study. The absenteeism rate did however affect the ability for the student participants to answer all journal question prompts and attend the recorded focus group interview. Due to the unpredictability of the student absences, most journal prompts were given over more than

one day's time. Student absenteeism may have also limited the ability of a student to experience a shift in mindset and therefore not be able to report on a shift due to decreased contact with math classmates, teacher, school community, and curriculum.

In the following chapter (Chapter Four), the findings of the research will be reviewed and explored in detail.

CHAPTER FOUR

REVIEW OF FINDINGS

The purpose of this qualitative case study was to document and analyze from the students' perspective how high school mathematics students in an alternative education setting moved between a fixed mindset and a growth mindset.

Specifically, this study sought to answer the following research questions:

RQ 1: How do high school students attending an alternative program describe their mathematics mindset?

RQ 2: How do the descriptions of their perceptions about mathematics change during a mindset shift?

This qualitative research study explored and created awareness of what Maxwell (2005) calls “interconnections and interaction among the different design components” (p. 3) and how the awareness of moving from a fixed to a growth mindset impacted the learning of mathematics for the participants at an alternative high school learning center in Oregon.

This case study was bounded by three students' experiences during an academic semester within a Title 1 alternative high school dual credit math course. The experiential shift in mindset was not distinguishable as a clearly defined linear event. Therefore, multiple methods of data collection were relevant features of this research study.

The course defining the case was the fall, 2016, high school dual credit course, Algebra 2/Math 95–Intermediate Algebra. It originally included ten high school students

who attended a Title 1 alternative high school. Seven of the ten students returned both the Parent Consent Forms and Participant Consent Forms needed to participate. Of the seven students who returned both forms, only three of these students continued participation in the study through the end of the academic semester. The other four students, over time, dropped the course, elected to not attend interviews, or stopped answering written prompt requests for various personal reasons. Due to the private nature of these personal reasons, they will not be reported within. The three participants who remained for the duration of the course responded to the written prompts and questions throughout the fall semester and attended focus group discussions comprising the purposeful sample of students who experienced mindset shifts.

Description of Participants

Participant Identification

Every student enrolled in the Algebra 2/Math 95 course was invited to respond to seven writing prompts during class time and participate in one to two small focus group interviews. Each participant had failed at least one semester of high school mathematics at another high school within the same district prior to this course. Participant One wrote in the initial writing prompt on the first day of the course:

I struggle with math but try hard not to. I learn math slow but it's always a race. My hardest problem is remembering steps in order. Without notes, calculators, and practice, I'm hopeless in a math environment. I can't do any computer math work either.

All participants were high school level, adolescent males. One was 17 years old and two were 18 years old during the fall semester of 2016 in which this study took place. Two of

the three participants had met their math course requirements in order to graduate high school, but elected to take this course even though no more math credits were required. The other student needed this course or another high school math course to fulfill the district's high school graduation requirements. The three participants who consented to participate ongoing for the duration of the study are represented with the demographic profiles notes in Table 4.

Table 4. Participant Demographic Profiles

Demographic Profile	Data
Age	17 years old: 1 18 years old: 2
Gender	Females: 0 Males: 3
High School grade level	11 th grader: 1 12 th grader: 2
Other non-passing high school math course	Algebra 1: 3students
Needed this course or another high school level math course to complete graduation requirements	Yes: 1 students No: 2 students

This group of three students began their formal exposure to mindset psychology in the fall of 2016 in an alternative high school setting in urban Oregon. Previous to the mindset information, all three students described themselves in some form or another as

having a fixed mindset with regards to learning mathematics. For example, one participant wrote in the second week of class, “I have always had difficulties in math. I'm not good at mental math, and I not good at tests. I didn't learn anything math related in middle school and I honestly wish never had to be in math.” Each student applied and was accepted into the alternative high school due to some unsuccessful experiences at the large, comprehensive high schools in the same district. Additionally, all of the participants earned a non-passing grade during one or more of their previous high school math courses at one of the other high schools in the same district.

Attendance

The alternative high school’s district set a standard for best learning—no more than eight absences per academic year. Consistent and regular high school attendance for the majority of students at this alternative high school was challenging. By week 20 of the course, two of the students were well over the district’s recommendation. This pattern was consistent throughout the semester. See Table 5.

Table 5. Student Attendance Data

Absences	School District Recommendation	Student #1	Student #2	Student #3	Average
Week 10	< 4	7	5	2	4.666667
Week 20	< 8	11	14	7	10.66667

Emerging Self-perceptions of Mindset

From the participants' perspectives, the qualities of a growth mindset in the study of mathematics (perseverance, enjoyment of challenges, appreciative of feedback, and seeing mistakes as opportunities) matured inside each student. The participants' descriptions of their own mindset with regards to learning mathematics showed variation as the course progressed through the academic semester as trust and identity grew. The participants found themselves in and out of both growth and fixed mindsets. Each writing prompt revealed a new theme for the participants. In all, the themes shuffled to and from fixed and growth mindset over the three participants' data with an overall slow progression towards a growth mindset. These themes and the corresponding mindset are conveyed through Table 6.

Table 6. Themes from Student Data as Direct Interpretation

Data Source	Timing	Themes from Student Data	
Writing Prompt – Initial	1 st week	I get easily get derailed and stop learning	fixed
Writing Prompt - #1	1st - 2 nd week	I have math phobias and dislike math	fixed

Table 6. Themes from Student Data as Direct Interpretation, Continued

Writing Prompt- #2	3 rd week	I quit when challenged	fixed
Writing Prompt - #3	7 th week	My moods and others' affect my learning	fixed moving to growth
Writing Prompt - #4	9 th week	Teachers are a source of encouragement and support	fixed moving to growth
Writing Prompt - #7	20 th week	I have confidence that I know how I can learn challenging math	growth

Fears, Shame, Apprehensions, and Defeat

The grounded narrative that revealed itself from the student perspective over the course of this study was one of growing trust in self and deepened mathematical identity. It also showed that student perceptions of and association with mathematics can shift over time from a position of fear, shame, apprehension, and defeat to willingness, perseverance, joy, and overcoming challenges into a mathematical mindset.

Perfectionism

Participants shared not wanting to work on math or learn math at deeper levels if they could not get it correct right away. They expressed frustrations at the beginning of the semester about past math learning. For example, Participant Two shared:

I always use to think, like, there are too many steps, oh, there's too many different numbers. There's too many steps, and like, it's going to take me too long to understand it, like, I don't get it! I don't get how that number became that. What, like, you threw a letter in there?! (Participant Two, focus group discussion, 2016)

Making mistakes was initially viewed as embarrassing for the participants and should be avoided. The participants felt it made them look unintelligent. In one student's words, he shared, ever since the 6th grade, "I was too scared to like, say the wrong answer or ask for help because I felt like that I would be seen as not intellectual, I guess, and I was afraid to just kinda be wrong in class."

As the semester progressed, the students found that taking small steps forward helped eliminate the inner perfectionism self-dialogues. For Participant Two, this sounded like the following:

And then after actually figuring out like the steps are easy and practice makes perfect and all that memorization became a lot easier then you get your grade back on your test and it's like, Wow, I got, like, an A! I can do this! Then that pushes me to keep going and keep going and moving forward on it."

Participant Three concurred, "It's just like, you know, for me, it's just like little baby steps."

Fears and Anxiety

During the first three weeks, I recorded into the field notes how the students openly communicated about their fear and dislike of mathematics and about being specifically placed in the dual credit Algebra 2/Math 95 by the school academic counselors. Two participants discovered, during the first few days of the course, they had previously met mathematics requirements for high school graduation and, therefore, did not “need” this course. One said, “There's no way I will ever pass this college level math class” and both actively pursued means of dropping the course from their semester coursework load. They shared their primary goal for taking math over their years of high school was solely to meet high school graduation requirements. I wrote:

Participant One is disengaged and distracted. Says he wants out of M95 and school academic counselor will call parents to inquire about next steps or alternatives. I am encouraging him to stay. He says he is going to fail this class. He does not want to try.

On the “Dear Math Teacher” note (see Appendix B) written during the first day of school, Participant One stated, “I come into class frustrated. I won’t learn much.”

During the fourteenth week and the recorded focus group discussion, when asked what his shift was to persevere with the course and not drop it from his course load after all, Participant One shared:

Mine was like getting over my own fear of math and numbers, like, for the longest time I was afraid that I could not do anything past Algebra, but, it was kinda just a barrier that my mind had put up itself. And, like, having like, you, for example, show me that like, in math, like, you can get over that fear, and there is a lot more that opens up. And, just like I don't know, I just never liked math growing up and I just told myself that I couldn't do it.

During the data collection period, each participant wrote about how negative feelings (both theirs and classmates) got in the way of their learning of math as a block to focusing and to persevering when challenged. The willingness of the students to engage and deepen their learning was, at times, seemingly dependent upon how they were feeling. The second writing prompt revealed from Participant Two, “Math and I have a love hate relationship, but mostly dislike.” In the third writing prompt, two participants opened up with “It depends all on the mood... I know at least for me, I can't focus and don't want to” and the other wrote, “My mindset depends on the day and if my anxiety/depression is existent.”

Near the end of the semester, these same students shared: “I connect with formulas and methods more than I used to before [this alternative school setting] came into my life,” “I have more trust in my math abilities,” “I feel way more connected,” “I have learned to stay happy and focused,” “I have less math related anxiety now,” and “I have less anxiety when I come to math.”

Defeat

At the start of the course, the three participants shared how, at some point in their lives, they had given up on themselves as a mathematician and on their ability to persevere in difficult math concepts. All three previously failed Algebra 1 at the start of their high school studies. Participant Two commented in the third writing prompt, “I normally tend to give up, especially if I know I don't have to do it in order to graduate” and Participant One shared, “I try it. I don't like it, and move on before I completely give up.”

In the third week's writing, Participant One stated, "I have always had difficulties in math. I'm not good at mental math, and I not good at tests. I didn't learn anything math related in middle school and I honestly wish never had to be in math."

The fourth week, I recorded field notes describing Participant Three in this way regarding classroom, the assigned chapter math work, and problem sets:

Appears stuck or shut-down when challenged. Looks to me in order to start and complete assignment problems. Reassurance and support is needed. Student is building self-efficacy, but does not yet have his own. Not an independent learner/worker yet and still uncomfortable with classmate collaboration.

Defeatism also showed up from the students in the form of not being able to receive constructive feedback. During the first four weeks, the students were becoming familiar with the new and strict write-up standards for math solutions required from the partnering community college. The write-up standards were unfamiliar to all these students who had previously worked out problems anywhere on a homework sheet and boxed the answer for a teacher to find. Much conversation and feedback was necessary during the first third of the course for the new way of showing work and displaying answers to take hold. A section of the general field notes during week two confirms.

Quiz 1 was proctored this week and quiz 1 revisions are due as well. Students are expressing frustration with the community college write-up standards being required. "This is so much work!" seems to be Participants Three's mantra in the classroom this week. They all seem to be dreading feedback and revisions.

Two quizzes were proctored during the first third of the semester. Summative scores were low with not much gain early on and none were meeting proficiency standards yet (Table 7).

Table 7. Summative Results – First Third of Course

Participant Identification	Quiz 1: Does not meet Meets Exceeds	Quiz 2 Does not meet Meets Exceeds	Exam 1 Does not meet Meets Exceeds
#1	Does not meet	Does not meet	Does not meet
#2	Does not meet	Does not meet	Does not meet
#3	Does not meet	Does not meet	Does not meet
Average %	25%	21.67%	40%
Week Number	2	4	5

As participants earned low quiz and exam scores, defeatism continued to sneak into their reactions at times. For example, each of the participants received a personalized, encouragement, yellow sticky feedback note from me on their Exam 1, as

shown in Figure 6. The field notes for one participant during the sixth week, when Exam 1 was returned to each student reads:

Tuesday: Participant Three received his Exam 1 score today and teacher feedback exam note and ripped (the note) into tiny shreds and threw it away. He appears upset with himself and exam score and also frustrated with the note. Wednesday: Distant and disengaged, ate Cheetos chips all period long, may be high.

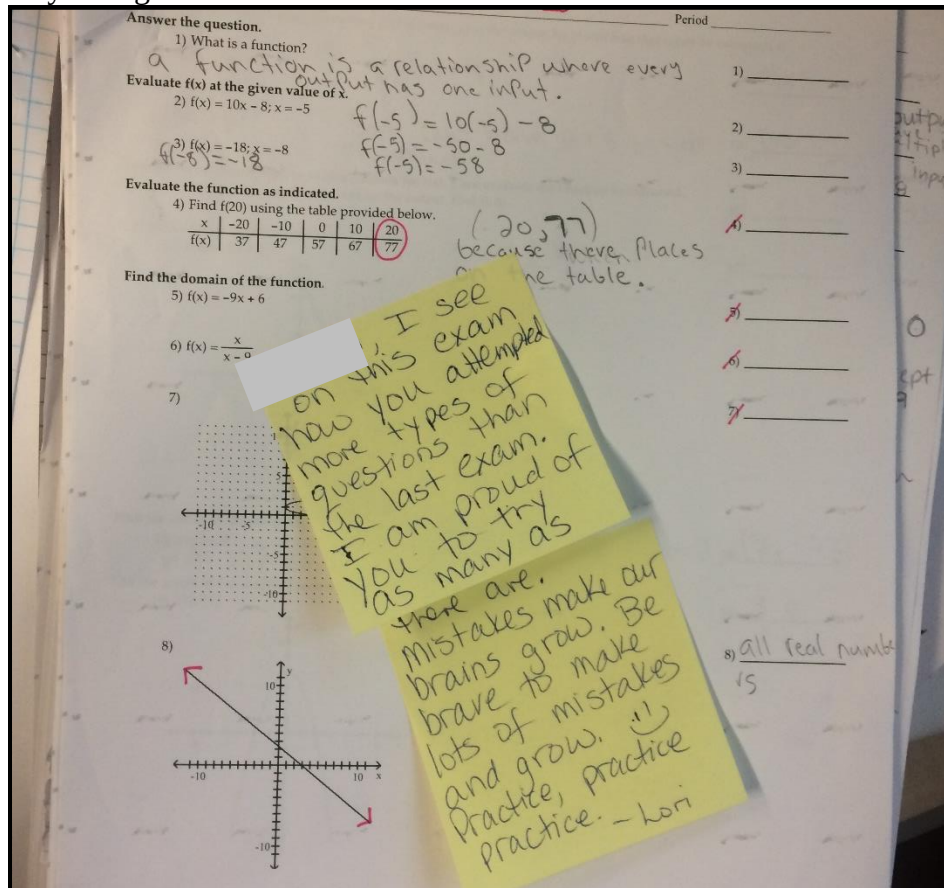


Figure 6. Exam 1 Teacher Feedback to Participant Three

As the term progressed, these defeatism attitudes subsided and were replaced by words of optimism from the participants such as Participant Two, "I've notice that it has pushed me to believe in myself more often than not and not be intimidated by questions I don't understand" and, "When I first started this class, I thought to myself, 'There's no

way I will ever pass college level math class'. Then, as the semester went on I realized that college level math wasn't as hard as I thought it was. I started to believe in myself and enjoy math and the challenge it brings."

Trust

Around the time of Exam 1, Participants One and Two were beginning to show some change in their ability to learn and grow from mistake making, receive and use feedback constructively, and redefine their mindset. They also shared how trust was concurrently shifting in themselves. The participants shared how they began to trust in new ways as their perceptions of math changed during a mindset shift: trust in self, in the math, in the teacher, and in their classmates.

Trust in Self

The trust grew for the participants and was expressed in many ways. For example, Participant One shared in response to the seventh writing prompt, "I have more trust in my math abilities." Participant Two, for the same prompt wrote, "I have more trust in my learning process" and Participant Three penned, "I have more faith in myself and my learning abilities." Participant One shared in the interview that mistakes were now internalized as helpful and a learning opportunity. "Yeah, and like, just not giving up if you get something wrong, just like, looking at that like a learning experiences and doing better next time."

Participant One shared about his emerging self-efficacy belief and developing trust in self as a core catalyst for shifting from a fixed to a growth mindset during the first small group recorded interview.

You know, but it also takes a lot of determination from yourself and wanting to succeed too because math is like something you need in everyday life and any career, and me figuring that out for myself instead of someone telling me, that kinds made me more focused on it.

Following this first student in the same interview, Participant Two added:

Um, for me it's like getting inspired in math. Like I need to like figure out a way to have fun and to see how this will help me in the future. Um. It's really about just like figuring out how to stay involved and not just looking out the window at cars passing by.

Both of these students are pointing to their own personally generated capabilities and abilities in order to execute a course of action in their math learning. They see the shift in math mindset and the ability to achieve in mathematics as their own responsibility, at least in part. Bandura (1994) defined self-efficacy as one's belief in one's ability to succeed. This was reiterated in these students' reasoning for mindset shifts among themselves and what they saw in their peers during the middle of the fall semester of this dual credit mathematics course.

Participant One wrote in week sixteen, "I was nervous and a little worried I would fail. Now I still worry whenever a new chapter is introduced or I'm not grasping the subject, but the trick is to keep trying." Participant Two shared, "When I first started this class I thought to myself 'there's no way I will ever pass college level math class.' Then as the semester went on, I realized that college level math wasn't as hard as I thought it was. I started to believe in myself and enjoy math and the challenge it brings."

In the same week's writing, Participant One shared about his new definition of mathematical mindset for himself, "A thought process built around mathematical thinking, my math mindset questions, thinks critically, and tries to never get discouraged." Participant Two wrote, "I've notice that it has pushed me to believe in myself more often than not and not be intimidated by questions I don't understand." These students were showing increased perseverance in their thoughts and classroom actions as well as a new math identity. Their description of mindset in the math classroom now included appreciation for challenges for themselves. Participant Two stated, "A mathematical mindset is someone who isn't scared of numbers, fractions or long equations. It's someone who...enjoys its challenge" and Participant One said, "A challenge that always keeps me trying and guessing." Participant Three stated it this way, "A mathematical mindset is an open mindset. You have to be open to learn new things and you have to be open to messing up."

Trust in the Relevancy and Study of Math

The participants were asked how they saw their high school math classmates shift from a fixed to a growth mindset. The responses pointed to attending class regularly as a key factor. They shared being present for the math would help them grow in math ability.

In the video recording, Participant Two said about classmates:

Their attendance and like, they won't come often enough to the point that they can get a full understanding of it so they think it's too hard, and then when they start to show up and attend classes daily, they are like, oh, if I come often enough, I can actually see where all of this connects and make a picture for it in my mind, and that makes a lot more sense for them and they start to succeed.

During the small group interview, Participant Two shared his own breakthrough from the fixed to growth mindset as the math connections he made for himself and to the life around him. He trusted in the math and how it related to “real life.” He stated, “With me it’s easier with like, pictures than with formulas and stuff like that so, I need to figure out a real life situation where I can bring the math into that.”

As this student above pointed out, sometimes the reason to move out of a fixed mindset with mathematics is a connection to the real world through a perceived use of or purpose for the materials in the student’s future.

Additionally, participants spoke of a new connection with math in a way of looking forward to surprise successes. Studying mathematics built excitement in learning, and following success came a willingness to engage further. Participant One stated during the group interview, “I just never liked math growing up and I just told myself that I couldn’t do it, and then what I found was that I actually could do it and that inspired me to keep going with it.” In this case, the success inspired more success. Another way out of a fixed mindset for some students is incremental successes followed by reflection. After a student has reflected upon what caused them to succeed, their learning typically advances.

Participant Two shared how trust in math was strengthened for him through practicing until mastery was reached.

Practice makes perfect and all that memorization became a lot easier then you get your grade back on your test and it’s like, ‘Wow, I got like an ‘A.’ I can do this!’ Then that pushes me to keep going and keep going and moving forward on it.

On the second question prompt, Participant Three also shared about practicing assisting him in meeting his personal math goals. He added, “I think I’m pretty good at math. I kinda need to practice more on all the new math so I can better.” On writing prompt three, when asked “Do you have a growth or fixed mindset in math class?” Participant Three responded, “I have a growth mindset ‘cause I’m always trying to get better at math.” For Participant Three, making errors, correcting errors, and practicing math as a source of succeeding in math came up five separate times throughout the data. His route to a growth mindset when he found himself stuck, he often answered, was to persevere and control his cognition, motivation, and behavior in math learning situations in order to grow beyond his previous state.

Trust in the Teacher

When the Exam 1 grades were returned, field notes show Participant Two commenting about growing trust in teacher feedback, “He removed his Exam-1 teacher feedback notes from the exam and placed them on the front cover of his math three-ring binder under the protective plastic cover.” See Figure 7.

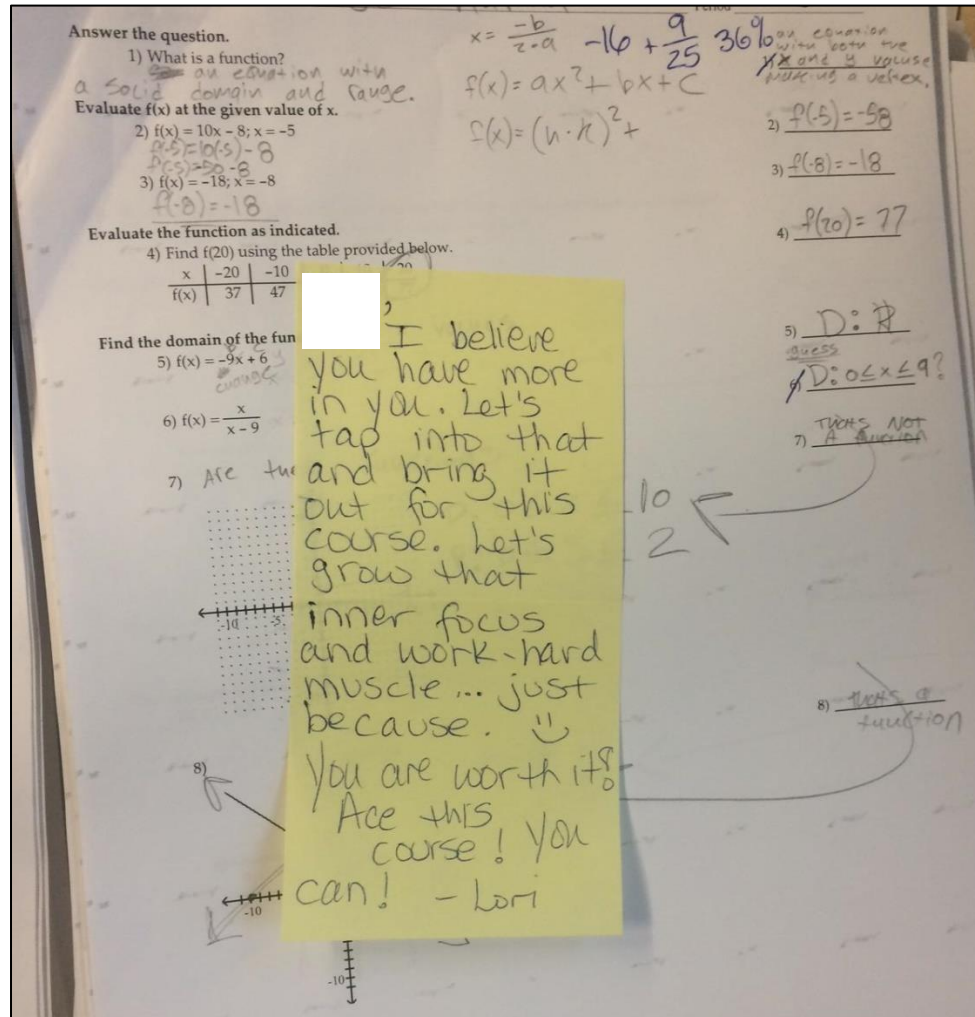


Figure 7. Exam 1 Teacher Feedback to Participant Two

Each participant specifically discussed the idea of a challenging, yet nurturing and respectful teacher believing his or her students can achieve high levels as bridges between fixed and growth mindsets for mathematics students. The students commented on the importance of being seen as an individual as in this video transcript conversation piece. For example, Participant One stated:

So I am like, ok, she's [my teacher] just not just seeing all of us as just one, but, we all learn the same but she sees our differences, I guess. And that kinda taught me as a way that where I don't have to do the exact same thing

as the classmate sitting next to me. That I can work on the problem kinda in my own thought process.

Additionally, two students were captured in the same first interview transcript as having the following discussion. Participant Two shared:

Um, for me it was um, I had that fixed mindset of I can't do it, I am not good at it, and then when you started becoming my teacher like you helped me like sit down with me, and patient with me even on my bad days and that did a lot because I just need to keep trying on my bad days and if I have that support like, I can get there.

Then Participant One, building on those thoughts, "Like, a teacher that like, cares and like, pushes you in a good way to keep trying and not like, just here is your assignment here is the formula figure it out, you know?"

Participant Two, continuing:

Um, I think just having like a strong like, connection with your teacher like an understanding like, double that, like, being able to meet your students on that level, which you do perfectly, like you meet each student like, on their own level which helps us cause you explain in a way that we can like, understand better. Other than just like, here's this, here's that, here's that, there you go. And now kinda like go around it all so we can make the connections in our own ways.

Continuing upon the same idea, Participant One's response to writing prompt four was, "I used to hate math, but this teacher specifically showed me how to love numbers."

For the students in this study, it seemed to take a teacher who modeled a growth mindset for their own mindset change to take place. It seemed as if the more I moved into a growth mindset as their teacher about their ability to soar with math, the more the participants were expanding their own mindset about themselves and their relationship to math. When respect and caring were present, and when I believed a student could achieve highly in mathematics even when the student doubted his own abilities, the student could

ride my beliefs and try new mathematical tasks. For example, from the first student video transcript, Participant Two shared about a cause of his shift from the fixed to growth mindset and progress in the courses in the alternative learning center:

Um, it was receiving respect from my teachers, which was new to me when I came here, because all the teachers at the big schools do not have time to actually get to know their students like they just kinda throw assignments at them.

Participant One, building on the conversation in the same video:

It's like when I get the respect from my teachers I, like, put that actual foot forward and like, respect their teaching, you know, I won't just check out 'cause I'll be like, you are being attentive to my needs so I am going to be attentive to, like, the teacher, and what they are doing.

Trust in Classmates

Each of the three participants shared feelings and ideas about the advantage of working with peers for the learning of new mathematics and shifting out of a fixed mindset in mathematics to a growth mindset. Participant One is documented in the week prior to Exam 1 as working outside the classroom with a classmate during a lunch period under a tree at a picnic table in field notes. Putting time towards learning the material outside of class and trusting peers to mentor and tutor was new behavior at that point.

Positive community learning added a sense of comradery, inspiration, and hope for these students when they felt stuck. When they were in a fixed mindset, one way they brought themselves back to a growth mindset was through watching and interacting with peers in the same course.

Working together as a team became more of a classroom norm during the middle third of the semester of dual credit math. During this time, student to student trust and

openness to peer feedback grew. Participant One included these thoughts in the recorded interview:

For me like, I think at least when I see students improve, it's like, for some, it's not for all, but when they have another student or someone trying to help them out and explain with them like, a study buddy, they are talking to another student, the student can give them another insight from another student learning perspective, like, to start to kinda get another understanding from another viewpoint.

Identity

As time passed through the semester of dual credit math learning, a change in personal identity occurred. Participants began to view themselves as math students and learners and therefore capable in ways they had not known previously. The seventh writing prompt reveals the inner thoughts of the participants near the end of the course:

“I feel my relationship with mathematics is stronger and I enjoy it” (Participant One).

“I feel more connected to math and myself” (Participant Two).

“I feel like I now can do anything knowing what I'm capable of” (Participant Three).

“I started to enjoy the challenge of math and it became my favorite class” (Participant One).

“While taking the final I learned that I had more effort in me than I could imagine” (Participant Two).

“I went from not really liking this class to loving this class. This class has also been an eye opener” (Participant Three).

The field notes further confirm the identity shift, noting students finding a “home” in the math classroom when class is not in session. Week eighteen field notes state, Participant Three has been attending fourth period and hanging out during my prep in fifth period. Participant Two and Participant One are often working together in the back of the room.”

The three participants wrote about their changing sense of self and their relationship with math during the course several times. They were able to share reflections of where their identity was at the start of the course and where they were at the end of the course with a level of depth of reflection. Participant One shared, “I was nervous and a little worried I would fail. Now I still worry whenever a new chapter is introduced or I'm not grasping the subject, but the trick is to keep trying.” Participant Two wrote:

When I first started this class I thought to myself “There's no way I will ever pass college level math class,” then as the semester went on I realized that college level math wasn't as hard as I thought it was. I started to believe in myself and enjoy math and the challenge it brings.”

Further, Participant Three declared, “I went from not really liking this class to loving this class. This class has also been an eye opener.”

Perseverance

All three students began to display more steadfastness with the material and rigor of learning. Toward the end of the course, they described seeing themselves as capable learners. While participating in the recorded interview, Participant One shared how his identity was deepening along with a mindset shift:

[Before attending in this alternative setting] I was afraid to just kinda be wrong in class but then when I came here it was a lot smaller classes for me and I saw all of my classmates also having trouble with the same material that I was so it gave me an chance to go up and ask the question that everyone was wanting to ask but too afraid and that's, kinda, pushed me into trying harder, which is, if you ask the wrong question it's still going to help you in the end ... And that, kinda, taught me as a way that where I don't have to do exact same thing as the classmate sitting next to me. That I can work on the problem, kinda, in my own thought process, and, then also like seeing all your other classmates do it a different way too is also kinda cool 'cause it gives you a another way to do it.

Also during the recorded interview in week fourteen, Participant One added his thoughts about what it takes to succeed in mathematics courses, and demonstrated awareness of perseverance when he asserted:

It also takes a lot of determination from yourself and wanting to succeed too, because math is like something you need in everyday life and any career and me figuring that out for myself instead of someone telling me that kinda made me more focused on it.

Participant Two added to this conversation, "Um. It's really about just like figuring out how to stay involved and not just looking out the window at cars passing by and like with me it's easier with like pictures than with formulas and stuff like that so I need to figure out a real life situation where I can bring the math into that. Yes, not getting squished." Then Participant Three added in the same vein:

Takes patience. You gotta get better at math, you can't just, like, take math and expect to just be good at it right out of the gate, so you gotta practice and take the time to get better at it.

The participants began to see themselves as mathematicians and demonstrated this through exchanging some personal weekend time to meet each other outside of school or with the teacher at the local library to work deeper with the math content. Week fifteen field notes read:

I met with Participant Three over Winter Holiday Break and we completed the exam correction #2 together and practiced recent math topics. The connection and work level done were both well done. One full hour at the library was spent working on the math. Upon returning to class this week he was more engaged and I could hear his voice louder answering open ended questions in class, popcorn style.

In preparation for exam #3 in week eighteen, the field notes delineate a second study session at the library and read:

Texted Participant Three's dad to see if Three could join the study group at the library this Sunday at noon. Dad texted back that he'd have Three there. This week Three ate lunch in my room, sometimes working on math and other times just hanging out on his phone.

The week 19 field notes add:

Participant Three came in again at lunch time, this is his second week in a row of lunches in my room. He also brought [fellow classmate] with him today. He then also asked me if he would meet me again this Sunday like he did last Sunday at the library for tutoring. Last week [non-participant students] asked for the tutoring and texted Participant Three's dad, to see if Participant Three was interested to join the study group. In the end last week, only Participant Three showed up for tutoring and we worked in the library for an hour. I told Three, yes, I could meet this Sunday and set 11am as the time.

Week 20 of the field notes adds to this ongoing narrative of the participants extending their new identity of a mathematician to outside the school walls with:

This past Saturday, Participant Three's dad texted back, "Are you still going to be at the library at 11am tomorrow? If so I will make sure he's there. His test is more important. It turned out Participant Three and [two non-participant students] came for 2.5 hours of library tutoring Sunday. It's impressive to see this new level of family support for math, student dedication, and perseverance.

Student artifacts, such as semester exam scores, show an accompanying rise in student achievement over time as well, as shown in Table 8. Although, at times,

Participant Three would describe himself as “check out a lot” or “really stressed” and “this is so much work,” he also shared, “but I still thought I could do it.”

Table 8. Participant Exam Results

Participant	Exam 1 - Week 5	Exam 2 - Week 13	Exam 3 - Week 18
1	Does not meet	Meets	Meets
2	Does not meet	Does not meet	Meets
3	Does not meet	Does not meet	Meets
Exam Averages	40.0%	56.7%	74.3%

Enjoys Challenge

By the middle of the course, the participants began to include some comments of enjoyment of work and challenges the course brought. Each participant discovered and deepened a place in themselves that enjoyed the math, such as Participant One who said, “I started to enjoy the challenge of math and it became my favorite class.”

The field notes also documented this shift with the capturing of creativity and playfulness during class sessions from the participants. Participant One began leaving behind surprise graffiti on the small classroom individual white boards shown in the photos in Figures 8 and 9, which showed a shift in mindset description was taking place. Week 11 was the date noted in the field notes as the date the green graffiti of Figure 8, “Mathematics, Gymnastics for the Mind” was discovered after the course let out. Accompanying this surprise student whiteboard art, the field notes for that week were documented as:

This week Participant One left behind some white board graffiti about math gymnastics. We had been working on “Equations Involving Radical Expressions and Complex Numbers” which were new concepts to all. Overall students were engaged and enjoyed the idea of “imaginary numbers” as though we were studying mysticism with the use of the word imaginary. They were hollering out in delight and disbelief during the video *Imaginary Numbers Are Real [Part 1: Introduction]* that I pulled off YouTube from: <https://www.youtube.com/watch?v=T647CGsuOVU>. As the narrator pulled the graph of $f(x)=x^2+1$ into (3-D) colorful imaginary numbers, the student’s chatter escalated to the point we were all laughing.

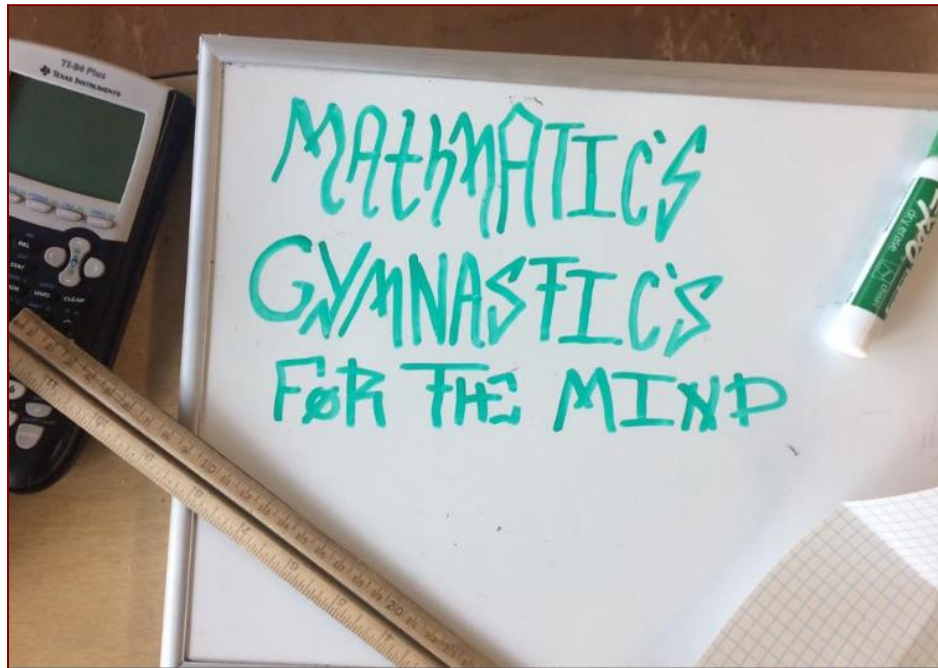


Figure 8. First Student Graffiti

Week 12 is noted as the week in which the second graffiti, written in black pen, “If you have a negative mindset square it!” was discovered in the classroom (seen in Figure 9). Although the depiction of the math equation for the graffiti in Figure 9 is mathematically incorrect by missing parentheses, the words that demonstrated a shift in mindset were most important for this research. The field notes for this Participant One’s whiteboard art state:

Another student graffiti was left in the classroom this week on squaring a negative mindset to make it positive. This was the second student quote graffiti found for dual credit students. Another student followed suit in Geometry by also making a math graffiti whiteboard quote after seeing this one from the dual credit students. This week's topic was Quadratic Functions and Equations. Of special note, this section covered the method of solving quadratic equations using "completing the square." This was the first time these students said they encountered this method of solving.

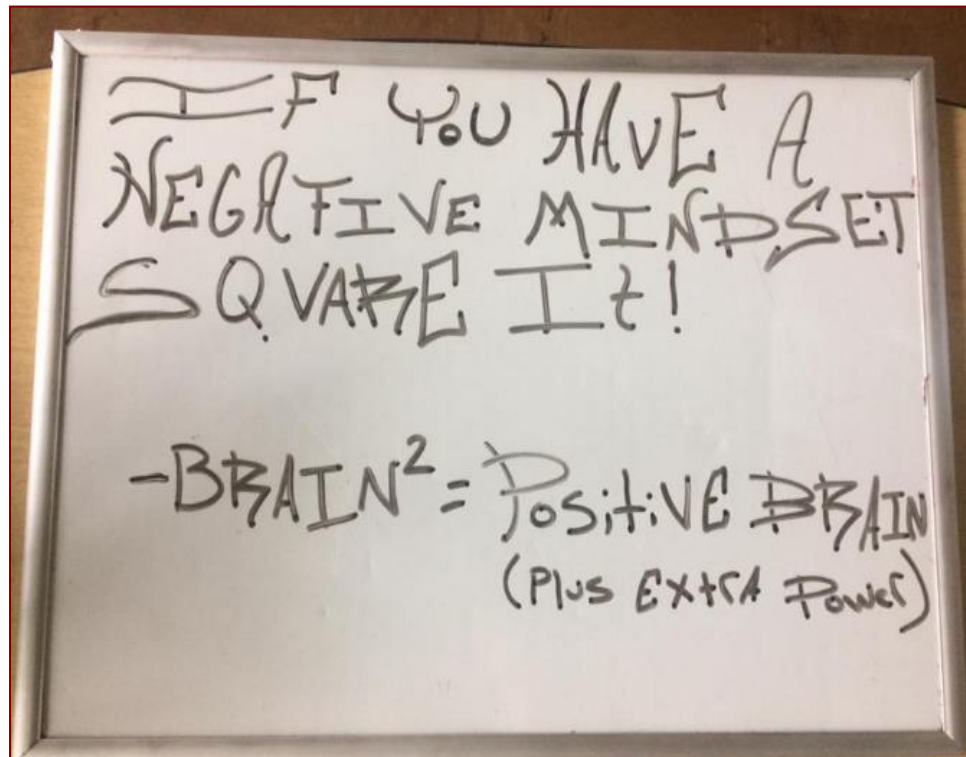


Figure 9. Second Student Graffiti

The students' mindset descriptions of themselves was now more playful and receptive. They saw themselves as able to learn and enjoy math. This was captured from Participant Two during the recorded interview, "Um, for me it's like getting inspired in math. Like, I need to, like, figure out a way to have fun and to see how this will help me in the future." Participant One added, "Um I guess for me what it takes just like focusing like on what I am doing and not letting my mind get distracted while in class."

Looking back over this middle portion of the semester, I see in writing prompt seven that Participant One wrote about himself, and this time with fondness, “Around the holidays’ my math mindset is growth, I talk about math all the time outside of school.” Participant Three wrote, “Moving from a fixed mindset to a growth mindset has helped me understand math better.”

Academic Pride and Appreciation

The students began to see themselves as valuable and competent contributors of math learning and math teaching. Over time, academic language and, specifically, correct mathematical vocabulary began to happen inside the classroom and in the outside world. This was a clear sign of the growing comfort with themselves, the mathematics of the course, and with mistake making.

Participant One shared his joy around this type of mathematical discourse at home with a sibling and math problems from our course and how that was when he knew this new behavior was a sign of the shift in mathematical mindset:

First time I noticed that I had moved from a fixed to a growth mindset was when I started thinking about math outside of school and just having discussions with my brother, just talking about math, and we’d argue for like, hours on one problem, just for the problem of trying to find the answer. And that’s when I kinda figured that I liked learning and growing with my math.

Exam revisions post exam were becoming tidy and deeper in reflection. By the middle third of the course, the participants’ ability to self-reflect using the exam corrections form, recognize and correct mistakes grew. In Figure 10, a participant’s Exam Two correction sheet from week 14 displays previous thinking as well as corrections

showing the ability to move through mistakes with a growth mindset. Previously, exam corrections were submitted to me in an unorganized, answer only manner. My field notes for that week document the shift for Participant Two:

I received Exam 2 corrections back today and his work is so much more tidy and in depth than the start of the year. When I passed back his revisions I mentioned this to him and we compared Exam 1 revisions with Exam 2 revisions. He giggled a little and he said he noticed a change too. He said he takes more time to complete revisions now and sees value in understanding his errors and making corrections.

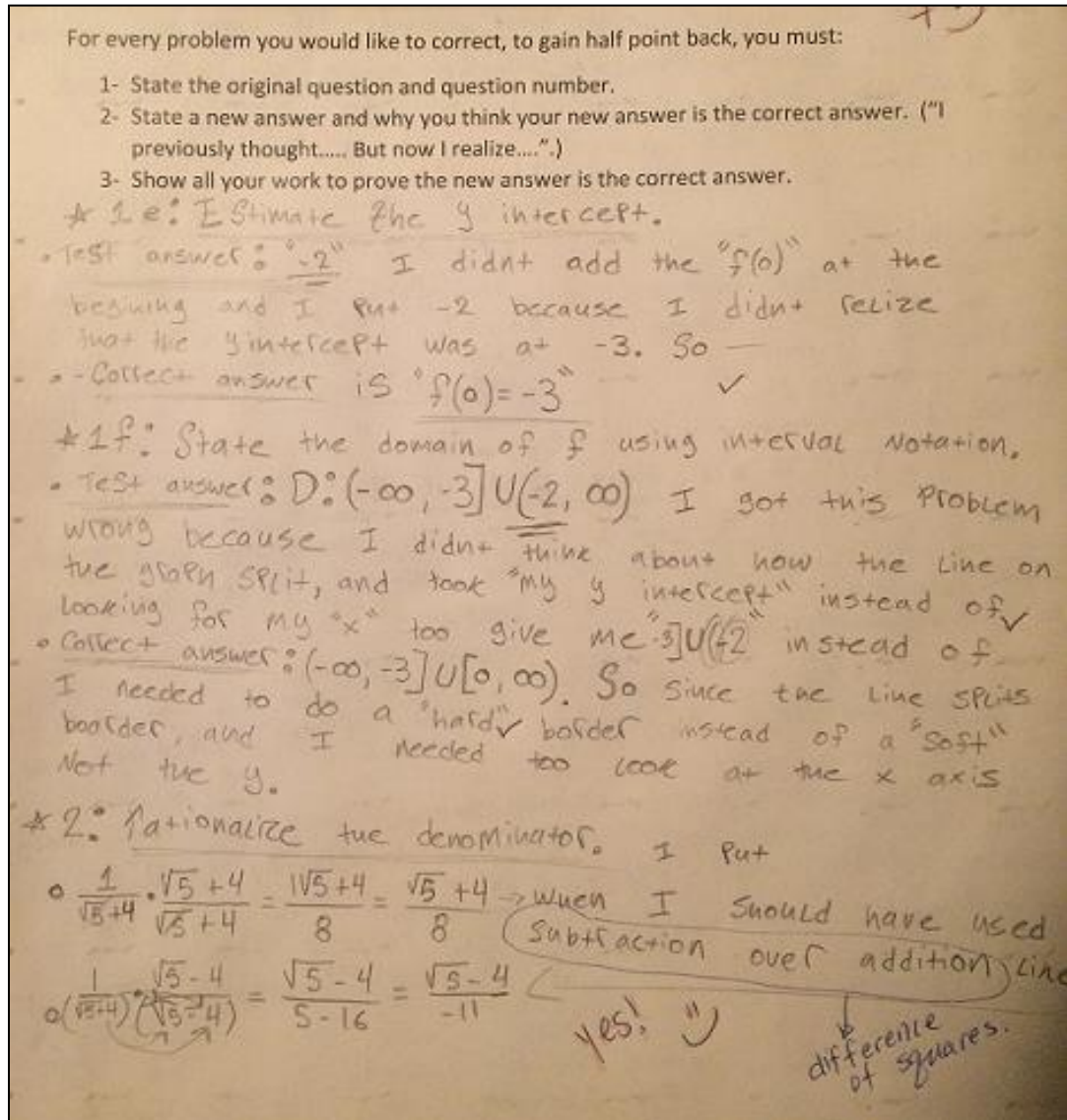


Figure 10. Student example of exam corrections

The participants were noted as becoming proud of their test correction sheets that showed developed thoughts and increased beauty in math working. The field notes documented this sharing their corrections with each other with pride and discussing various paths and possible methods to the solutions:

Participant Three and [non-participant classmate] worked together on the Exam 1 revisions. Participant Three's revisions have clearly taken a step up

in organization and depth of reflection. I am assuming this is in part to working with [non-participant classmate] who earned an "A" grade on this exam and discussing various methods to arrive at the answer. He turned in this revisions with a smile.

Breakdowns as Opportunities for Breakthrough

During the semester of dual credit math under study, each participant encountered a personal breakdown followed by breakthrough in relationship to mathematics education. I recorded these events in the field notes and noticed they may relate to a mindset shift once the breakthrough occurred. Breakdowns are defined as disruptions in the normal functioning of things forcing a person to adopt a more reflective or deliberative stance toward ongoing activity (Koschmann, Kuutti, & Hickman, 1998). Breakdowns can be opportunities for the development of new habits toward the promotion of personal growth and enriched experiences. Faced with a breakdown, many people will revert to old ways of being, even when these ways are no longer helpful (Koschmann, Kuutti, & Hickman, 1998).

Participant One's Breakthrough: Participant One was a high school senior in his last semester of high school. He had completed all required high school mathematics courses in order to graduate that winter. Just before the dual credit course began, participant one was enrolled into the course by the school's academic counselor. Over the first few weeks of the course he actively sought to drop the course and, during this time, had little to no engagement with the math topics, course materials, or class discussions. His first two written responses shared his disappointment with his math education thus far and why he did not wish to continue. I asked him in writing prompt two to think back

in time and recall when his feelings about how he saw his math ability get formed and to tell me the story. He wrote, “Ever since third grade, it really sucks when you're the only kid who never completed 60 problems in 1 minute.” I also asked him how he sees his math abilities currently and if he would describe himself in relationship to math. He wrote back, “I have always had difficulties in math. I'm not good at mental math, and I not good at tests. I didn't learn anything math related in middle school and I honestly wish never had to be in math”.

His breakthrough occurred when he learned the high school dual credit math course would satisfy the requirements for the Associate of Applied Science degree he was planning on perusing post-graduation, at no cost to him and over an extended period of time as compared to the same course offered on campus at the community college. I recorded the first sightings of a shift in mindset for him in the week four field notes, “During lunch on Thursday, I saw Participant One and a classmate working together and discussing our math work under the oak tree at the picnic table. Looks like he is getting caught up.”

Later on, in prompt three, I asked him what he felt influences math growth mindset in our classroom and he wrote, “I feel that hard work and positive group interaction is a big part of it.” He was discovering that he could enjoy learning math and, for him, this was especially true when learning math in relationship with others. He is the same participant who shared during the focus group interview and discussion, “the first time I notice that I had moved from a fixed to a growth mindset was when I started thinking about math outside of school and just having discussions with um my [other

classmate] just talking about math and we'd argue for like hours on one problem just for the problem of trying to find the answer. And that's when I kinda figured that I liked learning and growing with my math" (See Table 9).

Table 9. Participant Self Defining Mindset Quotes

	Participant One	Participant Two	Participant Three
Weeks 1-7	I struggle with math but try hard not to. I learn math slow but it's always a race. I'm hopeless in a math environment. I try it. I don't like it, and move on before I completely give up. I have always had difficulties in math. I'm not good at mental math, and I not good at tests. I didn't learn anything math related in middle school and I honestly wish never had to be in math.	I come into class frustrated. I won't learn much. Math and I have a love hate relationship, but mostly dislike. It's always taken me too long to understand math. I normally tend to give up, especially if I know I don't have to do it in order to graduate. It depends all on the mood... I know at least for me, I can't focus and don't want to. My mindset depends on the day and if my anxiety/depression is existent.	I didn't think I was gonna pass. I give up or sit there. I don't like the idea of picking things I want to learn about. My attitude / mood is in my way. People's moods influence math growth in our classroom. My mindset was slow before.

Table 9. Participant Self Defining Mindset Quotes, Continued

Weeks 8-14	Mine was like getting over my own fear of math and numbers, like, for the longest time I was afraid that I could not do anything past Algebra, but, it was kinda just a barrier that my mind had put up itself. Sometime I get discouraged but I always try to being back that good mindset.	I started to believe in myself and enjoy math and the challenge it brings. (I have) less self-doubt, anxiety and depression towards math. (I have) the feeling of 'Oh wow, I can actually do math'.	This is so much work! (I am) really stressed out.
Weeks 15-20	A challenge that always keeps me trying and guessing. I started to enjoy the challenge of math and it became my favorite class. An amazing feeling of trust. Comfort leads to effort.	Now I think that if I try hard enough I will pass. Now I try harder in math than I used to and push myself to try again before giving up. I feel more connected to math. While taking the final I learned that I had more effort in me than I could imagine.	I went from not really liking this class to loving this class. This class has also been n an eye opener. I now know I can do it. I learned that you have to put in the effort if you wanna pass. I have less anxiety when it comes to math. I feel like I now can do anything knowing what I'm capable of.

Participant Two's Breakthrough: Participant Two also did not need the dual credit math course to graduate. Similarly to Participant One, he had a slow start to the course as the impulse to drop the course was somewhat contagious early on. During the first week of the course he let me know he might be a feeling personality that may make decisions

based on his emotions. He shared, “I’m determined, but if I come into class frustrated I won’t learn much.” The next week, I gave a writing prompt that asked him how he perceived his own math abilities and if he could describe himself to me in relationship to math. He responded with a few more feeling words. He wrote, “Math and I have a love hate relationship, but mostly dislike. It’s always taken me too long to understand math, but I feel accomplished when I get things right.” In the seventh week of the course I asked him about his classmates and his perceptions for their mindsets in math class. He answered, “I think all of my classmates have a growth mindset in the classroom because every day even though its 6th period they come into class eager and excited to learn.” After witnessing the moods of his classmates being contagious to him earlier in the semester, I began to wonder if he was close to having a breakthrough into math eagerness and excitement as well. I next posed the question, what do you feel influences these math mindsets in our classroom? He reported back, “Our amazing supportive teacher pushes each student as an individual at their own pace to do their best.” I realized then that I might be the source of his breakthrough as he had put his trust in me. My moment with Participant Two did not arrive until the last day of the course while he was taking the comprehensive final exam. The final exam for this dual credit course was a longer and more rigorous exam than any of the participants had ever taken. After spending only a fraction of the allotted time with the exam, he turned the test back in to me and announced he could not do it. I saw there was some thoughtful work already on a couple of pages, but the majority remained empty. This exam was 25% of this total course grade as required by the partnering community college. Failing the final exam could have

meant not passing the course. I asked him if he trusted me and he replied, yes. I asked him to leave his test on the table and take a 10 minute walk away from the test, the room, math thinking, and everything else about this final exam. I recommended he grab a bite to eat, drink some water, walk around outside, and then come back and just see if perhaps he had more to put onto the exam. He then left the room and came back sometime after. I cannot give an accurate time because I did not see him quietly sit back down and get to work close to the 10-minute mark. He ended up working each problem and sharing with me in the last writing prompt, “While taking the final I learned that I had more effort in me than I could imagine.” Through this, I heard that his identity as a math student had shifted and his previous limits in math effort had been redefined into a more expansive version (See Table 9).

Participant Three’s Breakthrough: Participant three was a quiet, reserved, and thoughtful student. Early in the semester, I asked him in a writing prompt how he felt about challenges in the math classroom and in math assignments. He shared with me, “I think I’m pretty good at math. I kinda need to practice more on all the new math so I can be better.” In fact, he often pointed to needing more practice as a means to his success. Over the winter break I met up with him at the local library to practice further. During this time our student/teacher relationship deepened. When school resumed after the holidays, I began to hear his voice in the discussions, where I had not before, and his overall participation increased as his confidence with taking on new challenges increased. He wrote to me through prompt five during the sixteenth week of the course, “I went from not really liking this class to loving this class. This class has also been an eye

opener.” Having extra one-on-one practice time helped Participant Three with a breakthrough and, for him, this breakthrough carried with it a deeper trust in his teacher and a strong mathematical identity for himself (See Table 9).

Summary

The ability for a student to shift their mindset when they find themselves in a stuck place is vitally important to persevering in learning. Research has shown different student mindsets lead to different learning behaviors, which in turn create different learning outcomes for students (Boaler, 2016). When students shift their mindsets into a growth or mathematical mindset and start to believe they can learn at higher levels, they change their learning trajectories and achieve at deeper levels (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016), grow in trust, and develop identity as a math learner (Bishop, 2012).

Boaler (2016) stated that current research has not delineated “how teachers of mathematics and parents working with their students at home can transform student ideas, experiences, and life chances through a growth mindset approach to math” (p. xii). This study has found that the answer to Boaler’s quandary above comes from three students who attended a high school dual credit math course in an alternative education setting, and who discovered the following about themselves and their classmates as they, together, moved from a fixed mindset to a growth mathematical mindset.

“My awareness of my own growth mindset impacted my enthusiasm to learn, and my grade and effort”

“I’ve notice that it has pushed me to believe in myself, more often than not, and not be intimidated by questions I don't understand”

“I feel like I now can do anything knowing what I'm capable of”

“I have more faith in myself and my learning abilities”

“I have more trust in my learning process”

The students commented on numerous occasions that working with peers added to the enjoyment of learning and, when succeeding together on challenges, this added to their ability to persevere.

In summary, the story that revealed itself from the student perspective over the course of this study is one of trust and deepened self-identity, and how trust and identity shift over time from a position of fear, shame, apprehension, and defeat to perseverance, joy, overcoming challenges, and into a growth mindset (See Table 9).

Finally, when the students were asked what they would like other current or future math teachers to consider about students shifting from a fixed to a growth mathematical mindset, the students responded with, “A note for math teachers is sublimely show students how math is cool and also amazing.”

CHAPTER FIVE

INTERPRETATIONS AND RECOMMENDATIONS

Research has shown repeatedly that students in a growth mindset have greater perseverance, enjoy challenges, see mistakes as learning opportunities, and earn higher scores on achievement tests, especially in difficult courses (Dweck, 2006; Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Dweck, 2015; Boaler 2016). The subject of mathematics has been said to transfer the strongest fixed mindset message to students about limited ability and thinking, according to Boaler (2016). Providing students who are in a fixed mindset with growth mindset interventions has proven to increase motivation and deepen learning (Dweck, 2006; Dweck, 2015; Boaler, 2016).

The purpose of this qualitative case study was to document and analyze from the student perspective how mathematics high school students in an alternative education setting moved from a fixed mindset to a growth mindset in a dual credit math course.

Specifically, this study sought to answer the following research questions:

RQ 1: How do high school students attending an alternative program describe their mathematics mindset?

RQ 2: How do their descriptions of their perceptions about mathematics change during a mindset shift?

Theoretical Focus

Heider's (1958) attribution theory was applied as the theoretical framework for this research. Applying attribution theory as the theoretical framework for this research allowed the lens of study to be from the student perspective. Attribution theory (Heider, 1958) defines how people come to explain their own behavior or the behavior of another. It aligned with the focus of this paper to explore how students see themselves or classmates move from a fixed mindset to a growth mindset in mathematics.

Methods

This qualitative research study was designed to describe a process from the student perspective of the shift from a fixed to a growth mindset as it occurred in an alternative high school, dual credit, intermediate algebra course over the course of one academic semester. The qualitative design used in this research study was a case study.

This case study was bounded by three students' experiences of shifting from a fixed to a growth mindset within an alternative high school math class located in a school serving an at-risk, low socioeconomic community, defined by the Title 1 status of the school. All three of the students had overall high school grade-point averages below 2.0 on a four-point scale and were generally unsuccessful at the traditionally oriented, comprehensive high school within the same school district and earned a non-passing grade in one or more previous high school level math courses.

The experiential shift in mindset was not distinguishable as a linear event; therefore, multiple methods of data collection were relevant features of this research

study. The qualitative data collected included the following: (1) an initial student written reflection, (2) seven follow up student written reflections, (3) recorded/transcribed participant focus group interviews and discussions, (4) instructor observations and field notes taken while teaching the dual credit math course, and (5) student artifacts.

Conclusions

Research Question 1–The Changing Definitions of Mindset

RQ 1: How do high school students attending an alternative program describe their mathematical mindset?

The findings revealed changes over time in the students' views of themselves and their relationship to mathematics—identity. From the participants' perspectives, the qualities of a growth mindset in the study of mathematics (perseverance, enjoyment of challenges, appreciation of feedback, and seeing mistakes as opportunities) matured inside each student due to the building of trust and the deepening of self-identity in relationship to themselves and the discipline of mathematics. The participants' descriptions of their own mindsets with regards to learning mathematics showed variation as the course progressed through the academic semester as trust and identity grew. The participants found themselves in and out of both growth and fixed mindsets as feelings of trust in themselves and their learning grew as well as a deepening of their mathematical identity. Each writing prompt revealed a new theme for the participants. These themes and the corresponding mindset are conveyed through Table 10

Table 10. Themes from Student Data as Direct Interpretation

Data Source	Timing	Themes from Student Data	
Writing Prompt – Initial	1 st week	I get easily get derailed and stop learning	Fixed
Writing Prompt - #1	1 st - 2 nd week	I have math phobias	Fixed
Writing Prompt- #2	3 rd week	I quit when challenged	Fixed
Writing Prompt - #3	7 th week	My moods and others' affect my learning	fixed moving to growth
Writing Prompt - #4	9 th week	Teachers are a source of encouragement and support	fixed moving to growth
Writing Prompt - #5	16 th week	A mathematical mindset is an open mindset	Growth

Table 10. Themes from Student Data as Direct Interpretation, Continued

Writing Prompt - #6	18th week	Math is cool	Growth
Writing Prompt - #7	20 th week	I have confidence that I know how I can learn challenging math	Growth

The story that revealed itself from the student perspective over the course of this study was one of growing trust in self and deepened mathematical identity. It also showed student perceptions of and association with mathematics can shift over time from a position of fear, shame, apprehension, and defeat to willingness, perseverance, joy, and overcoming challenges into a growth mindset.

The various writing prompts over the semester captured the core of the students' perceptions of their mindset shifts in relationship to learning and deepening their understanding of mathematics. It was revealed that, alongside a mindset shift for these students was a concurrent shift in identity as a mathematician. See Table 9 in Chapter Four.

Moods and Fears as an Indicator to Shifting Mindset. Shifts in participant emotions and anxieties preceded mindset shift for the participants and were apparent over time from the student writings and researcher field notes. The students began the dual credit course with fear and self-doubt with regards to challenging mathematics. For

example, the students wrote about negative moods or emotions affecting their learning seven different times during the first third of the semester long course. The students associated feelings of moodiness as a cause of resistance to focusing or a block to persevering when challenged. On the initial writing prompt, during the first days of school, Participant One wrote, “I come into class frustrated, I won’t learn much.” A few weeks later, a journal question #3 response in mid-October from Participant Three stated, “I think people’s moods influence math growth in our classroom.” However, by week fourteen, talk of moods and emotions being in the way of learning were no longer present in the conversations without a direct researcher prompt. On the last day of the semester in study, Participant One wrote, “I started to enjoy the challenge of math and it became my favorite class.” This came from a participant who, during the first week of the semester, actively tried to drop the course from his course load and openly vocalized his dislike of the discipline. On the last day, Participant Three wrote, “I have less anxiety when it comes to math” and later added, “I learned that you have to put in the effort if you wanna pass,” followed by, “I feel like I now can do anything knowing what I’m capable of.”

Identity. When asked about their initial thoughts about their own mindsets at the start of the semester, the three participants described themselves and their relationship to mathematics in a doubtful, fearful way: “At the start of the year I didn’t think I would pass,” “I didn’t think I was gonna pass,” and “Worried but excited.” Here, the participants display uncertainty in self and concern they do not have what it takes to succeed.

As the semester went on, the participants' views of themselves as mathematicians and views of their relationship with math began to undergo a metamorphosis. When asked again about describing their mindsets in the middle of the dual credit math course, the three participants responded in this way: "Around the holidays, my math mindset is growth, I talk about math all the time outside of school," "I checked out a lot but I still thought I could do it," and "I was really stressed."

Each participant moved from an overall fixed mindset with math to an overall growth mindset with math in their own timing. The shift did not occur for all three at the same time. Over time, all participants flexed between the two mindsets given a specific topic or mathematical task. When asked on the final day of the semester to describe their mindsets currently as it relates to math specifically, the three participants answered in this way: "Now I think that if I try hard enough I will pass," "A challenge that always keeps me trying and guessing," and "I now know I can do it."

As time passed through the semester of dual credit math learning, a change in personal identity occurred. Participants began to identify themselves as math students and as mathematics learners and therefore capable in ways they had not known previously. The seventh writing prompt reveals the inner feelings of the participants at the end of the semester long course: "I feel my relationship with mathematics is stronger and I enjoy it," "I feel more connected to math and myself," and "While taking the final I learned that I had more effort in me than I could imagine."

Field notes further confirm the identity shift, noting students finding a "home" in the math classroom when math class was not in session. Week eighteen field notes state:

Participant Three has been attending 4th period and hanging out during the following prep-period, in 5th period. Participant Two and Participant One are often working together in the back of the room beyond class time and into student free time with enjoyment and engagement.

Research Question 2–By What Means Did the Shift Occur?

RQ 2: How do the descriptions of the students’ perceptions about mathematics change during a mindset shift?

Over the course of the dual credit math semester, the three participants fluctuated between fixed and growth mindsets as they moved more permanently towards a growth or mathematical mindset. When inquired upon, all three participants reported on their top reasons they believed a mindset shift occurred within them and their classmates over the course of the academic semester. They attributed the mindset shift, in their own words, to a supportive, yet challenging teacher, an understanding school, an accepting and safe school environment, personal attitude shifts to not give up, less self-doubt, anxiety, and fear toward math, an interesting and meaningful math course, seeing math as cool and a necessity, and receiving support from and collaboration with fellow students.

Impacts of Moving From a Fixed to a Growth Mindset. The three participants wrote vulnerably about their experience throughout the duration of the dual credit mathematics course. Each shared reflections of where they were in their own personal mindset at the start of the course and at the end of the course with great depth of understanding. For example, Participant One shared, “I was nervous and a little worried I would fail. Now I still worry whenever a new chapter is introduced or I’m not grasping the subject, but the trick is to keep trying.” Participant Two wrote:

When I first started this class I thought to myself “There's no way I will ever pass college level math class,” then as the semester went on I realized that college level math wasn't as hard as I thought it was. I started to believe in myself and enjoy math and the challenge it brings.

Further, Participant Three declared, “I went from not really liking this class to loving this class. This class has also been an eye opener.”

These three students were developing qualities through the process of moving from a fixed to a growth mindset. Personal qualities such as metacognition abilities, self-efficacy, teamwork, and openness emerged. They each found that, if there was a belief in their ability, a belief in self, or their teacher believed in them, and they followed this with effort and work in the math material, they would consequently have an “Aha!” moment of understanding, thus bringing enjoyment. When the participants reflected on mastery of the material and “Aha!” moments, this generated a desire to repeat successes and learn more. This reflection of success also built further belief in self when they fed the cycle forward, as shown in Figure 11.

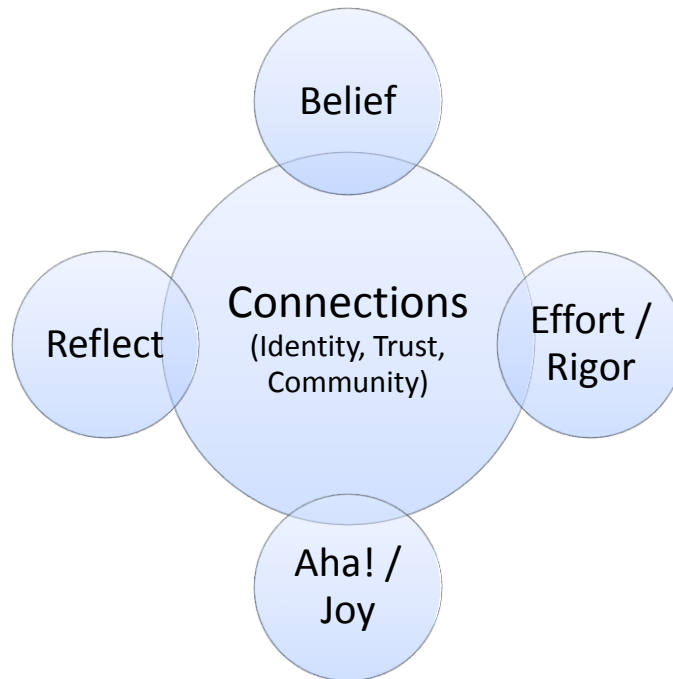


Figure 11. Students Learning Cycle in Mathematical Mindset

Effects Upon Researcher/Teacher

The purpose of the study was to examine mindset shifts from the student perspective within the alternative school setting. I chose this because the students that make up the student body population of the alternative school are students that were once sprinkled throughout the regular, comprehensive high schools within the same district. One goal was to hopefully uncover some information about student mindset shifts that could be beneficial to all levels of teachers in all types of school settings. What I did not expect was to uncover a variety of fixed mindsets within my own teaching practice. Yet, through the process of writing, reading, analyzing, and reporting on my students' shifts, I also had mindset shifts of my own.

I began the semester in a bit of trepidation myself as I wondered if my students, who had all failed a high school math course previous to this one, would be willing and able to rise to the rigorous standards and timing set forth by the partnering community college in the dual credit course. As the semester progressed and we as a group committed ourselves to trying out and then committing to all succeeding in the dual credit rigid framework, the rebellious nature that lived beneath the surface of myself and my students developed into an “us against the world” ideology as we eventually met each challenge set forth by the community college through perseverance and grit. Though the group process, struggle, and overcoming of challenges together, we became a trusting and playful community of learners. They trusted me to guide them through the framework and timing, I trusted them to rise and meet each requirement, and I began to trust myself deeper as an educator and researcher. My own identity strengthened as I met challenges with a new type of openness and playfulness. My own sense of community trust grew, not only in myself and my students, but also in my school as other teachers began to encourage and support the dual credit math students as well as me through the first time dual credit maze. During this semester of research, I grew in appreciation for the alternative school I teach for, the staff and faculty that kept us emotionally afloat, each student as they showed up again and again in this new territory with willingness to try, and myself as an ever evolving educator and continuous learner.

Interpretations

The ability for a student to shift their mindset when they find themselves in a stuck place is vitally important to persevering with learning. Research shows that different student mindsets lead to different learning behaviors, which in turn, create different learning outcomes for students (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Boaler, 2016). When students shift their mindsets into a growth or mathematical mindset and start to believe they can learn at higher levels, they in turn change their learning trajectories and achieve at deeper levels rooted in trust and develop identity as a math learner (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Bishop, 2012; Boaler, 2016).

Deepened Identity

Bishop (2012) wrote:

Who we believe ourselves to be is a powerful influence on how we interact, engage, behave, and learn. Identities are important because they affect whether and how we engage in activities, both mathematical and otherwise, and also because they play a fundamental role in enhancing (or detracting from) our attitudes, dispositions, emotional development, and general sense of self. One goal of mathematics education is to help students develop positive dispositions toward mathematics—to become persistent, agentic, and confident (p. 35).

This study was found to further support Bishop's statements above. Each participant defined not only their relationship to math differently over the course of this study, but also themselves as a learner. As a shift toward a growth mindset took place, a deepening of a mathematical identity occurred simultaneously.

Boaler (2016) stated that current research has not delineated “how teachers of mathematics and parents working with their students at home can transform student ideas, experiences, and life chances through a growth mindset approach to math” (p. xii). This study has found that the answer to Boaler’s quandary above comes from three students who attended a high school dual credit math course in an alternative education setting. These three students discovered the following about themselves and their classmates as they together moved from a fixed mindset to a growth mathematical mindset. They shared, “My awareness of my own growth mindset impacted my enthusiasm to learn, and my grade and effort,” “I’ve notice that it has pushed me to believe in myself, more often than not, and not be intimidated by questions I don’t understand,” and “I feel like I now can do anything knowing what I’m capable of.”

Trust

According to Tschannen-Moran, & Hoy (2000), the study of student trust in schools has been neglected thus far in educational research. They state, “There is intriguing evidence that trust matters in facilitating student learning, yet we know little about the structural, cultural, and individual characteristics of teachers and schools that promote student trust” (p. 585).

However, interrelationship with trust and growth mindset revealed itself in this study. For the participants in this study, trust grew at the same time mindsets expanded. This trust took the forms of deepened trust in self, trust in the process of learning, trust in the teacher and school, and trust in academic peers. The participants shared comments

such as, “I have more faith in myself and my learning abilities” and “I have more trust in my learning process.”

Brown, Collins and Duguid (1989) shared “learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge” (p. 10.). They point out, throughout most of life, students actually learn and work collaboratively, not individually, even though schools often ask student to work individually. All three participants noted that work with each other and with the teacher was instrumental to their shift in mindset from fixed to growth.

Contribution to Attribution Theory

Although researchers and educators agreed that having and reflecting upon positive experiences in mathematics can potentially lead to positive outlooks about mathematical learning (Barnes, 2000; Liljedahl, 2004), it was the student’s point of view of a shift to a growth mindset in mathematics most sought in this particular study. Therefore, having applied attribution theory as the theoretical framework for this research allowed the lens of study to be from the student’s perspective. This netted many positive results.

First, as the students listened to each other share about vulnerable experiences of shifting from and to fixed and growth mindsets during the focus group interview, each participant naturally attributed the shifts to causes that were either similar or dissimilar within themselves. This opening of inner experience generated an atmosphere of safety within the focus group. The participants shared how a fixed mindset felt personally protective, but also limiting within that protection, and shifting out of that felt vulnerable

as the opening occurred. The sharing of these common experiences aloud in the focus group created common experience within the learning community and propelled each further into a growth mindset.

Second, attribution theory, initially associated with Fritz Heider (1896-1988), defines how people come to explain their own behavior or the behavior of another and was used as the theoretical framework of this paper to explore how students see themselves or classmates move from a fixed mindset to a growth mindset in mathematics. Generally, a person's behavior is credited to either a disposition or to an external situation. As participants viewed themselves as shifting from a fixed to a growth mindset, or their classmates before them, they reflected upon what attributed to the shift. Once some plausible sources of the shift were identified, the participants then reached for more to solidify their growth mindset. For some students, this meant more tutoring time with the teacher, for another it was more peer mentoring, for another it was reaching deeper inside for more inner strength to work through emotions.

Summary

In summary, the grounded narrative that revealed itself from the student perspective over the course of this study of three students' perceptions of a mindset shift was one of growing trust in self and deepened mathematical identity. It also showed student perceptions of and association with mathematics can shift over time from a position of fear, shame, apprehension, and defeat to willingness, perseverance, joy, and overcoming challenges into a mathematical mindset.

This study demonstrates, for a student to become a great student requires the student to “know thyself” through deepening their understanding with what they know and how they have come to know it. For a student to know themselves as a deep learner, an academic risk taker, a willing mistake-maker, or a budding mathematician is a powerful and confident step towards a landscape of unknown and exciting educational opportunities. As students learn more about who they are, they learn techniques that reveal the personhood from which good learning comes. They then no longer need to use routines or procedures to mask shallow understanding (a fixed mindset) for disposable mathematical skills. Instead, students begin to use challenges as opportunities to manifest more fully the gift of self and share this part in their learning communities, from which the best and deepest learning comes.

Recommendations for Future Research

Research repeatedly shows students in a growth mindset have greater perseverance, enjoy challenges, see mistakes as learning opportunities, and earn higher scores on achievement tests, especially in difficult courses (Dweck, 2006; Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003; Dweck, 2015; Boaler 2016). Research also indicates that the subject of math may transfer the strongest fixed mindset message to students about limited ability and thinking (Boaler, 2016). The purpose of this qualitative case study was to document and analyze, from the student perspective, how mathematics high school students in an alternative education setting moved from a fixed mindset to a growth mindset in a dual credit math course.

A recommendation for future research or steps in the research surrounding mindset in math education would be to explore and analyze, from the student perspective, how high school mathematics students affect each other in moving from a fixed mindset to a growth mindset over the course of a school semester without teacher directed interventions, if the shift is able to occur from peer to peer, and perhaps how long lasting the shift in mindset is.

Further research could additionally be looking at the impact of teacher relationships with students inside and outside of the classroom connected with a student's ability to reach graduation. It is clear in this case study that not only were the mindsets shifting for the students in this study, but that the school and teacher may have been a likely variable to a greater or lesser degree. A major cause of student persistence to graduation is faculty interaction and academic trust. The research evidence supporting faculty student contact inside and outside the classroom is formidable and the positive outcomes empirically associated with it are multiple (Wilson, 1975).

According to Tschannen-Moran, & Hoy (2000), the study of student trust in schools has been neglected thus far in educational research. They state, "There is intriguing evidence that trust matters in facilitating student learning, yet we know little about the structural, cultural, and individual characteristics of teachers and schools that promote student trust" (p. 585). Therefore, further research could look closely at the impacts and factors associated with student trust in school and how trust specifically relates to mindset shifts.

Koschmann, Kuutti, & Hickman (1998) wrote on the concept of breakdown and the implications student breakdowns have for education, mind, and culture. They define breakdown as “a disruption in the normal functioning of things forcing a person to adopt a more reflective or deliberative stance toward ongoing activity” (p. 26). In their article, they state that breakdowns are an opportunity for the formation of new habits toward the promotion of growth and enriched experience. In the classroom, when faced with a breakdown, many students will revert to old behavior or old habits of disassociation, denial, or avoidance. When a teacher is attentive to a student breakdown, an intervention of support may become available for students to form new habits in a growth mindset. Research in this area of teacher interventions within a fixed mindset student’s breakdown is lacking and important research.

It seemed during this research, the students’ ability to shift into a growth mindset was somewhat dependent upon the teacher believing in the student and the teacher having a growth mindset about their own learning of mathematics and also about the capacity of students to learn mathematics. Research to explore and confirm this phenomenon might be beneficial for teacher education programs and school district development programs.

Yin (2014) reminds that, within qualitative research, “the analysis of case study evidence is one of the least developed aspects of doing case studies” (p. 133). Future research may therefore be beneficial in the area of specially delineating analysis and detailed coding complete with schematics for a qualitative case study.

Recommendations for Practice

Attentive, compassionate, and encouraging teaching is the greatest recommendation for practice I can make as an outcome of this study. Student breakdowns in the math classroom are a sometimes often occurrence with tears and upset, especially in alternative school settings. A breakdown is an opportunity for the formation of new learning habits toward the promotion of a growth and an enriched experience (Koschmann, Kuutti, & Hickman, 1998). However, student breakdowns in mathematics are often viewed by educators as an uncomfortable inconvenience. When faced with a breakdown in the math classroom due to challenging work, falling behind, or other pitfalls, many students will revert to old behaviors of disassociation, denial, or avoidance. When a teacher is attentive, compassionate, and encouraging within a student breakdown, an intervention of support may become available for students to form new habits towards a growth mindset, deepened trust, and personal identity. In this way, breakdowns become opportunities for breakthroughs.

For any teacher who may want to conduct research in his or her own classroom, there are some considerations of which to be aware. Of special note, the act of conducting classroom based research by the teacher creates a change agent upon the teacher researcher. D'Ambrosio (1998) pointed out that the impacts on teachers conducting classroom based research include: teachers better understanding their own classroom, becoming more equipped to be agents of change upon classroom practice and classroom environment, taking ownership of change initiatives, growing to better understand their students through listening to them in deeper ways and through the modeling and fostering

of an inquisitive disposition in the classroom, teachers also redefine learning as research and the act of engaging in classroom based research renews their own enthusiasm for learning and teaching. Therefore, I encourage other classroom teachers to conduct research in their classrooms and embrace the change that occurs in practice, classroom environment, and mindset.

The pursuit of a growth mindset by both students and educators is a recommendation emerging from this study. If the ability of students to shift from a fixed mindset into a growth mindset is dependent upon the educational environment, an educator's striving for a growth mindset becomes an important component.

In closing, when the participants of this study were asked what they would like current or future math teachers to consider about students shifting from a fixed to a growth mathematical mindset, they responded with, "A note for math teachers is sublimely show students how math is cool and also amazing."

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APPENDICES

APPENDIX A

REQUEST FOR DESIGNATION OF RESEARCH

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt from the
Requirement of Institutional Review Board Review
(9/23/2013)

DATE: July 25, 2016

I. INVESTIGATOR:

Name: Lori Ann Clyatt

Department/Complete Address: Department of Education, Montana State University Bozeman

Home address:

Telephone: 406-

E-Mail Address:

DATE TRAINING COMPLETED: 09/30/2013 [Required training: CITI training; see website for link]

Name of Faculty Sponsor (if above is a student; also must complete CITI training):

Dr. Bill Ruff

SIGNATURE (INVESTIGATOR or ADVISOR):

II. TITLE OF RESEARCH PROJECT: (Try to keep title on first page.)

A CASE STUDY OF HIGH SCHOOL MATHEMATICS STUDENTS MOVING From a fixed to a growth mindset

III. BRIEF DESCRIPTION OF RESEARCH METHODS (also see section VII).

The purpose of this case study is to explore understanding of student mathematical fixed to growth mindset in the mathematics high school classroom from student's point of view. Many research studies have demonstrated the positive effects of growth mindset interventions on students' achievements. Educator and researcher Jo Boaler, has worked mostly in the field of mathematics and feels that math courses specifically transfers the strongest fixed mindset message and programming to students (2010). She shared that when students undergo interventions to move from a fixed to a growth mindset, these students immediately start performing at higher levels in schools (Boaler, 2006). Data collection is anticipated to begin at the beginning of September 2016 and the end date for the research project is anticipated to November 2016. Potential student participants will be contacted through their school association in Oregon: xxx, an alternative high school. As with most phenomenological studies, I will rely heavily on student journals, small focus groups and student interviews as a primary source of data collection. Semi-structured interview protocols will be utilized to draw out descriptions

from and perceptions of participants. Study participants will be asked to take part in multiple interviews (up to 5 interviews), each lasting approximately 15 minutes. Data collection strategies may also include participant observations and academic pre and post grade and attendance comparisons. For the first interview, participants will be given a questionnaire to complete and journal about. For the second interview, participants will be asked to take part in a recorded small focus group interview session of approximately 20 minutes in length. Preliminary interview questions are attached. Electronic data will be stored on a password-protected computer and stored in a password protected Internet storage provider (Google Drive). Participation is voluntary, participants may decline to answer any question and participants may withdraw from the study at any time. Participants will be giving their time to participate in the interviews and focus groups without compensation.

IV. RISKS AND INCONVENIENCES TO SUBJECTS:

There are no foreseen risks to participation in this study. The interview questions are not of a sensitive nature and information shared should not present personal or legal risk. Participation is voluntary, participants may decline to answer any question, and participants may withdraw from the study at any time. Participants will be giving their time to participate in the interviews and focus groups without compensation. Parental consent will be obtained through email or phone call explanation of the project and followed up with a parent signature requested. Parents may also decline before and during the interview stages. Parents and students will be given their recorded transcripts to review and comment on. Parents may remove their participant data from the research.

V. SUBJECTS:

A. Expected numbers of subjects: 5-12 minors (mathematics students in high school)

B. Will research involve minors (age <18 years)? Yes No
(If 'Yes', please specify and justify.)

Questions will be asked of high school students about their perception of how they and their peers move out to a fixed mathematics mindset into a growth mindset (or not) and what their math teachers can do to enhance this opportunity in the mathematics classroom. Students will be anonymous in the study and so no personal or identifying information will be shared. It is important to gather student data for this project so that fixed to growth mindset shifts in mathematics from the student perspective may be found and shared.

C. Will research involve prisoners? Yes No

Will research involve any specific ethnic, racial, religious, etc. groups of people?

(If 'Yes', please specify and justify.) Yes No

This research study will focus specifically on students at xxx, mathematics high school students. This group was selected due to the fact that is also the location of employment of the research.

Will a consent form be used? (Please use accepted format from our website. Be sure to indicate that participation is voluntary. Provide a stand-alone copy. Do not include the form here.)

Yes, see attached.

VI. FOR RESEARCH INVOLVING SURVEYS OR QUESTIONNAIRES:

(Be sure to indicate on each instrument, survey or questionnaire that participation is voluntary.)

A. Is information being collected about:

Sexual behavior? Yes No

Criminal behavior? Yes No

Alcohol or substance abuse? Yes No

Matters affecting employment? Yes No

Matters relating to civil litigation? Yes No

Will the information obtained be completely anonymous, with no identifying information linked to the responding subjects? Yes No

Confidentiality and anonymity will be maintained. Only a number or pseudonym will identify individual recordings and transcripts. Any information shared by individuals that may be personally identifiable will not be reported.

If identifying information will be linked to the responding subjects, how will the subjects be identified? (Please circle or bold your answers)

By name Yes No

By code Yes No

By other identifying information Yes No

Does this survey utilize a standardized and/or validated survey tool/questionnaire? Yes
No

VII. FOR RESEARCH BEING CONDUCTED IN A CLASSROOM SETTING:

Will research involve blood draws? (If Yes, please follow protocol listed in the
 “Guidelines for Describing Risks: blood, etc.”, section I-VI.) No

VIII. FOR RESEARCH INVOLVING PATIENT INFORMATION, MATERIALS,
 BLOOD OR TISSUE

SPECIMENS RECEIVED FROM OTHER INSTITUTIONS:

A. Are these materials linked in any way to the patient (code, identifier, or
 other link to patient identity)? Yes No

B. Are you involved in the design of the study for which the materials are
 being collected? Yes No

C. Will your name appear on publications resulting from this research?
 Yes No

D. Where are the subjects from whom this material is being collected?

E. Has an IRB at the institution releasing this material reviewed the proposed
 project?

(If 'Yes', please provide documentation.) Yes N

F. Regarding the above materials or data, will you be:

Collecting them Yes No

Receiving them Yes No

Sending them Yes No

G. Do the materials already exist? Yes No

H. Are the materials being collected for the purpose of this study? Yes
 No

Do the materials come from subjects who are:

Minors Yes No

Prisoners Yes No

Pregnant women Yes No

Does this material originate from a patient population that, for religious or other reasons,

would prohibit its use in biomedical research?

Yes No Unknown source

IX. FOR RESEARCH INVOLVING MEDICAL AND/OR INSURANCE RECORDS

Does this research involve the use of:

Medical, psychiatric and/or psychological records Yes No

Health insurance records Yes No

Any other records containing information regarding personal health and illness Yes No

If you answered "Yes" to any of the items in this section, you must complete the HIPAA Worksheet.

APPENDIX B

STUDENT WRITING PROMPTS AND TIMING

Writing	Questions or Prompts	Timing
Writing Prompt – Initial	Dear Math Teacher (Lori), You should know this about me:	1 st week
Writing Prompt - #1	Q1: Can you tell me what grade you are in and what math course you currently take? Q2: What math course did you take last semester and how did you do? Q3: What attributed to how you did last semester? Q4: What is your goal in math this semester? Q5: What is in your way of achieving this math goal? Q6: How do you plan on achieving this math goal?	1st week and 2 nd week depending on attendance
Writing Prompt- #2	Q1: How do you see you math abilities? Describe yourself in relationship to math. Q2: Think back in time. When did your feelings about how you see your math ability get formed? What messages did you hear? Who formed this belief with you? Tell me the story. Q3: How do you feel about challenges in the math classroom and in math assignments? Tell me about you. Q4: What do you do when you feel stuck in math class or on a math assignment? Tell me about you.	3 rd week

Writing Prompt - #3	Q1: Do your classmates have a fixed or growth mindset in math class? Please tell me about those. Q2: What do you feel influences these math mindset? Q3: Do you have a growth or fixed mindset in math class? Please tell me more about that. Q4: What do you feel influences math growth mindset in the classroom setting?	7 th week
Writing Prompt - #4	Q1: Do your teachers notice your learning (or not) in the classroom? Q2: How do you know? What do they say or do? Q3: Tell me about how your teachers works to facilitate your mathematical advancement.	9 th week
Writing Prompt - #5	Q1: How do you describe a mathematical mindset? Q2: How has the awareness of moving from a fixed to a growth mindset impacted learning for you and/or your classmates? Q3: How have your (or your classmates) feeling for math or for learning math changed this semester? (How did you feel when you arrived in this course in September and how do you feel now?) Q4: What are the top 3 to 5 things that you attribute this change in feeling to?	16 th week

Writing Prompt - #6	Q1: Looking back on your math learning, when did you have a fixed mindset in mathematics? Please describe in detail. (Which grade? Which math class? And why?) Did you also have a fixed mindset at the start of this current course? Q2: What changed for you and when since that time in the previous question to have you where you are today in your feelings/doings with math learning? Q3: Are you planning on taking math courses after this one? Tell me about this... Q4: What is unique about you and your life's story that makes you amazing that you are here in this class today with math success? Q5: What do you want to tell me or add about your shift in math mindset or what do you want to make sure other math teachers around the world know about students' mindset shift?	18th week
Writing Prompt- #7 Member Checking	Q1: Beginning: What was your mathematical mindset at the start of the semester? Describe this in your own words. Q2: Middle: Describe your mathematical mindset around the holiday season in your own words.	20 th week

	Q3: End: Describe your mathematical mindset now in your own words. Q4: These are the themes that emerged from the data, please add to or cross off as you find appropriate: Trust: Trust in self, in the math, in the teacher, in my classmates, or other? Connectedness: I find I now connect to myself and math or my math classmates or a math topic or my school or my teacher in a different way? My Identity: I see or feel myself different with relation to the math, my classmates, myself, my teacher, or my school? My will or effort: I found I had more effort in me? I feel differently: How I feel (m mood or emotions) has changed or changes about math, classmates, my school, my teacher, myself has changed?	
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APPENDIX C

FOCUS GROUP INTERVIEW QUESTIONS AND DISCUSSION PROMPTS

Interview	Q1: What does it take to be successful in math? Q2: What changed for you such that you are now successful with math? In other words, what was your biggest shift? Q3: Have you seen other classmates shift into also being successful in math? If so, what have you seen or heard caused their shift? Q4: Looking back over the writing entries and questions in this interview and other things that we talked about in class regarding shifting from a fixed mindset to a growth mindset is there something that you want to add to my research? Q5: (student added question) When and how did you notice that you had moved from a fixed to a growth mindset?	14 th week
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APPENDIX D

SUBJECT CONSENT FORMS



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 0000165

960 Technology Blvd, Room 127
 c/o Microbiology & Immunology
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-4707
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-4706
 cherylj@montana.edu

MEMORANDUM

TO: Lori Ann Clyatt and William Ruff

FROM: Mark Quinn *Mark Quinn CJ*
 Chair, Institutional Review Board for the Protection of Human Subjects

DATE: August 24, 2016

SUBJECT: "A Case Study of High School Mathematics Students Moving from a Fixed to a Growth Mindset" [LC082416]

The above proposal was reviewed by expedited review by the Institutional Review Board. This proposal is now approved for a period of one-year.

Please keep track of the number of subjects who participate in the study and of any unexpected or adverse consequences of the research. If there are any adverse consequences, please report them to the committee as soon as possible. If there are serious adverse consequences, please suspend the research until the situation has been reviewed by the Institutional Review Board.

Any changes in the human subjects' aspects of the research should be approved by the committee before they are implemented.

It is the investigator's responsibility to inform subjects about the risks and benefits of the research. Although the subject's signing of the consent form, documents this process, you, as the investigator should be sure that the subject understands it. Please remember that subjects should receive a copy of the consent form and that you should keep a signed copy for your records.

In one year, you will be sent a questionnaire asking for information about the progress of the research. The information that you provide will be used to determine whether the committee will give continuing approval for another year. If the research is still in progress in **5 years**, a complete new application will be required.

Participant
SUBJECT CONSENT FORM FOR
PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY
 A CASE STUDY: HIGH SCHOOL MATH STUDENTS MOVING FROM FIXED TO GROWTH
 MINDSET

Lori Ann Clyatt, Researcher, Montana State University, Bozeman

You are being asked to participate in a research study designed to further explore and understand student perceptions of learning in the mathematics classroom at Education Center, West. Results from this study may provide classroom teachers with a better understanding of how to create and enhance student mathematical achievement. Data collection is anticipated to begin and end in the 2016 fall semester. Study participants will be asked to complete a brief survey and take part in interviews, each lasting approximately 15 minutes. Data collection strategies may also include participant observations, journal writing, and focus groups. If you agree to participate in this study you may be asked to complete journal entries based on the topic and participate in multiple interviews. Additionally, you may be asked to be a part of a small focus group discussion to share your experiences and ideas about your perceptions on learning math. Data from all interview and focus groups will be recorded and securely stored. The focus groups will be audio recorded. The recorded focus group discussion will then be transcribed verbatim and any information that might identify you personally (including your name) will be removed from the transcription. Only the interviewer will have access to the tape from your interview.

Your participation in this research is voluntary. Non-participation will not impact the quality of education nor impact your relationship with the school or school officials. You are free to stop participating in the research at any time, or to decline to answer any specific questions. Your participation in this research study is confidential. The transcription of your interview will be identified by a code number and this number will not be connected with your name in any fashion. If information you disclose is uniquely identifiable, this information will not be disclosed. There are no foreseen risks to participation in this research study.

If you have any questions regarding this research project you can contact me at . Any additional questions about the rights of human subjects can be answered by the Chair of the MSU Human Subjects Committee, Mark Quinn, (406) 994-4707, mquinn@montana.edu.

AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risk of this study. I, _____, agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed: _____ Date _____

Investigator: _____

APPROVED
MSU IRB
08/24/2016
 Date approved

Parent

SUBJECT CONSENT FORM FOR
PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY
 A CASE STUDY: HIGH SCHOOL MATH STUDENTS MOVING FROM FIXED TO GROWTH
 MINDSET

Lori Ann Clyatt, Researcher, Montana State University, Bozeman

Your child is being asked to participate in a research study designed to further explore and understand student mindset in the mathematics classroom at Education Center, West. Participation is completely voluntary and your permission as well as your child's permission is required for participation. Non-participation will have not impact the quality of your child's education or your or your child's relationship with the school.

Results from this study may provide a better understanding by classroom teachers on how to enhance student mathematical achievement. Data collection is anticipated to begin and end in the 2016 fall semester. Study participants will be asked to complete a brief survey and participate in multiple interviews, each lasting approximately 15 minutes. Data collection strategies may also include participant observations, journal writing, and focus groups. If you agree to allow your child to participate in this study he/she may be asked to participate in multiple interviews and complete journal entries based on the topic. Additionally, he/she may be asked to be a part of a small focus group discussion to share their experiences and ideas about learning mathematics. Data from all interviews and focus groups will be recorded (audio only) and securely stored. The recorded focus group discussion will then be transcribed verbatim and any information that might identify you personally (including your name) will be removed from the transcription. Only the interviewer will have access to the tape from the interviews.

Your child's participation in this research is voluntary. They are free to stop participating in the research at any time, or to decline to answer any specific questions. Their participation in this research study is confidential. The transcription of their interview will be identified by a code number and this number will not be connected with your name in any fashion. If information they disclose is uniquely identifiable, this information will not be disclosed. There are no foreseen risks to participation in this research study.

If you have any questions regarding this research project you can contact Lori Clyatt at 406-

Any additional questions about the rights of human subjects can be answered by the Chair of the MSU Human Subjects Committee, Mark Quinn, (406) 994-4707, mquinn@montana.edu.

AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risk of this study. I, _____, parent of _____ agree to participate in this research. I understand that I may later refuse participation, and that I may withdraw my child from the study at any time. I have received a copy of this consent form for my own records.

Signed: _____
 Investigator: _____
 Date: _____

APPROVED
MSU IRB
 08/24/2016
 Date approved

APPENDIX E

ALTERNATIVE SCHOOL APPROVAL LETTER

[REDACTED] SCHOOL DISTRICT

[REDACTED] EDUCATION CENTER

[REDACTED]

DATE: August 8, 2016

TO: Montana State University

RE: Approval for Dissertation Research Project

To Whom It May Concern,

[REDACTED] Education Center and the [REDACTED] School District give Lori Ann Clyatt approval to use [REDACTED]

Education Center and our students to conduct her research in the area of growth mindset in mathematics in the high school classroom from the perspective of the students.

I will work with Lori Ann Clyatt to obtain parent permissions were needed and ensure that all aspects of her IRB are followed.

If Montana State University as any questions regarding her research please contact me at your convenience.

Sincerely,

Gregg O'Mara
Director of Alternative Programs

[REDACTED]

APPENDIX F

PARTIAL DUAL CREDIT COURSE SYLLABUS

(PARTIAL) Course Syllabus for Math 95: Intermediate Algebra



(Partnering) Community College

CRN _____ 4.0 Credits

Offered through the (Partnering Community College) Dual Credit Program 2016-2017

Instructor: Lori Ann MacKinder-Clyatt

REQUIRED COURSE MATERIALS

Text: Intermediate Algebra with Applications and Visualization, **Publisher:** Pearson; 4th edition, ISBN-10: 0321773314

Course Supplement: Available on our course webpage

Calculator: Graphing calculator required. TI-89 Titanium recommended

Other materials: You will need graph paper, a ruler or straightedge, a pencil, and an eraser. A three ring binder is highly recommended.

COURSE INFORMATION

Course Description: Explores functions graphically, symbolically, verbally, and numerically with an emphasis on function notation. Investigates functions, equations, and graphs involving quadratic, rational, radical, and absolute value expressions. Integrates technology throughout.

Course Outcomes: The course outcomes can be found at the link below.

HSD Course Prerequisites: MHS Counselor placement or successful completion of Algebra 2.

Attendance Policy: Students are expected to attend each class meeting, actively participate and not use personal electronic device during class. If a student is absent, it is the student's responsibility to find out what was covered in class and get the work completed in a timely manner.

CLASS ETIQUETTE & POLICY FOR CELL PHONES AND OTHER ELECTRONIC DEVICES	- Remember to silence your cell phone and put it away before entering class. Cell phones must be turned off and put away during the class. In case of necessary/emergency call or text, please leave the classroom before responding. - Laptops, iPads, or other electronic devices are permitted only for work pertaining to class (taking notes, graphing, etc.) - During exams, calculators may only be used on the calculator portion. Other devices may not be used, such as cell phones, laptops, iPads, etc. - If you are late for class PLEASE be considerate, enter the room quietly and join the class. - All students are expected to act respectfully to others in the class and behave in a manner that is consistent with the college's student conduct policies.
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Course Grading: Your final course grade will be calculate on a percentage of the total points earned. There is no extra credit offered in this course. Final grades are not rounded. The scales is as follows:

A = 90% - 100% B = 80%-89% C = 70% - 79% D= 60% - 69% F = 59% - 0%

Your grade is based on:

- 10% Exam 1, Week 5
- 10% Exam 2, Week 13
- 10% Exam 3, Week 18
- 25% Comprehensive Final Exam, Week 20.
- 10% Quizzes
- 20% Practice, Activities, Assignments, and Homework,
- 15% Exam Revisions (Exam 1, Exam 2, and Exam 3).

*Note: For Dual Credit grade calculations, students will **not** be allowed to retake any examinations, tests or quizzes.*

Excused absences have 5 days to make-up missed exams. No make-up exams for unexcused absences.

All homework due before corresponding exam for credit.

Outcome Assessment Strategies:

- Develop algebraic skills necessary to accurately simplify, evaluate, and/or interpret properties of absolute value, quadratic, rational and radical expressions and/or equations.
- Participate in activities, assignments, and exams, which show an understanding of the connection between graphical, numerical, verbal, and symbolic representations of functions.
- Participate in activities, assignments, and exams which apply algebraic functions to real-life situations while showing an understanding of the creation and interpretation of a function to model the situation.
- Participate in, and contribute to, class discussions and activities.
- Take all scheduled examinations.

Assessment Requirements

- The following must be assessed in a proctored, closed-book, no-note, and no-calculator setting:
 - finding the equation of the linear function given two ordered pairs stated using function notation
 - simplifying rational expressions
 - solving rational equations
 - solving radical equations
 - graphing quadratic functions
 - determining the domain of radical and rational functions
 - evaluating algebraic expressions that include function notation
- Assessment must include evaluation of the student's ability to arrive at correct conclusions using proper mathematical procedures and notation. Additionally, each student must be assessed on their ability to use appropriate organizational strategies and write appropriate conclusions. Application problems must be answered in complete sentences.

Course Schedule

Week	Topic#	Topic Name	Section	Assignments	Assessment
1-2	1	Linear Functions and Their Representations	Section 2.1	Section 2.1: 1-12, 21-31 odd, 33, 53-59 odd, 77	
2	2	Linear Functions	Section 2.2	Section 2.1: 81-87 odd, 91-99 odd, 115-123 odd Section 2.2: 49-65 odd	
3	3	Quadratic Functions and Their Graphs	Section 8.1	Section 8.1: 1-10, 21, 29, 33, 35, 41	Quiz 2.1 to 2.2
4	4	Parabolas and Modeling	Section 8.2	Section 8.2: 3-6, 15-23 odd, 39, 51, 61-75 odd 8.2 Supplement Section 8.1: use graphing calc.: 87, 89	Quiz 8.1 to 8.2
5	Topics 1-4		Review All	Exam 1	Exam 1
6	5	Linear Inequalities	Section 3.3	Section 3.3: 19-33 odd, 39, 45, 49, 67, 69, 79, 83	
7	6	Compound Inequalities	Section 3.4	Section 3.4: 7, 15, 21, 29, 35, 41-47 odd, 49-57 odd, 59-73 odd, 77, 115	

8	7	Absolute Value Equations and Inequalities	Section 3.5	Section 3.5: 9, 11, 15, 27-37 odd, 45, 47, 49, 61-77 odd, 87, 95, 119	Quiz 3.3 to 3.5
9	8	Radical Expressions and Functions	Section 7.1, 7.3, 7.4	Section 7.1: 1-4, 15-27 odd, 45, 47, 57, 61, 65, 79, 83, 85, 87, 111 Section 7.3: 11-19 odd Section 7.4: 97-102	
10	9	Radical Exponents	Section 7.2, 7.5	Section 7.2: 17-35 odd, 41, 43, 45-57 odd, 63, 69, 75-91 odd, 103 Section 7.5: 17, 19, 21, 26, 35, 51	
11	10	Equations Involving Radical Expressions and Complex Numbers	Section 7.6, 7.7	Section 7.6: 17-41 odd, 71, 77, 119 Section 7.7: 3, 4, 13-22	Quiz 7.1 to 7.7
12	11	Quadratic Equations and Quadratic Formula	Section 8.3, 8.4	Section 8.3: 41-44, 47, 53-61 odd, 71-81 odd, 113 Section 8.4: 15, 17, 19, 25, 49, 51, 55, 57-63 odd, 71-79 odd, 85, 89, 91, 92, 113	Quiz 8.3 to 8.4
13	Topics 5-11		Review All	Exam 2	Exam 2
14	12	Rational Functions and Equations	Section 6.1	Section 6.1: 1-4, 11, 13, 21-29 odd, 39, 51, 57, 59, 61, 65, 69, 73, 85, 103	
15	13	Multiplication and Division of Rational Expressions	Section 6.2	Section 6.2: 23-39 odd, 43, 49, 53-59 odd, 61, 67-75 odd, 85-89 odd	
16	14	Addition and Subtraction of Rational Expressions	Section 6.3, 6.4	Section 6.3: 1-4, 17, 19, 33, 35, 41, 45, 51, 59, 67, 69, 73, 83, 91 Section 6.4: 1-7, 11, 13, 19, 21, 23, 27, 29, 35, 37, 43, 45, 47, 65, 71, 93	
17	15	Complex Fractions and Rational Equations	Section 6.5, 6.4, 7.6	Section 6.5: 11, 15, 19, 27, 29, 31, 33, 39 Section 6.4: 73-83 odd Section 7.6: 83, 85	Quiz 6.1 to 6.5 and 7.6
18	Topics 11-15		Review All	Exam 3	Exam 3
19	Topics 1-15		Final Review	Review Exam 1-3 and Exam Revisions	Practice Final
20	Topics 1-15	Final Exam			Comprehensive Final Exam

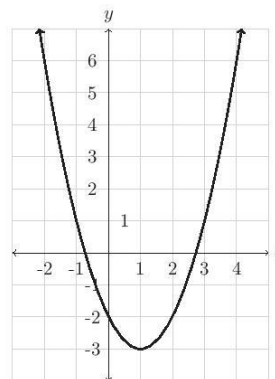
APPENDIX G

SAMPLE COMMUNITY COLLEGE CURRICULUM

SUPPLEMENT TO §8.3

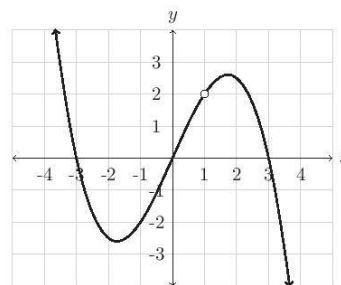
1. The graph of $y = w(x)$ is given in the figure to the right. Use it to do the following exercises.

- Solve $w(x) < 1$.
- Solve $w(x) \geq -2$.
- Solve $-2 < w(x) \leq 6$.
- Solve $w(x) < -3$.
- Determine the domain and range of w . State your answer using interval notation.



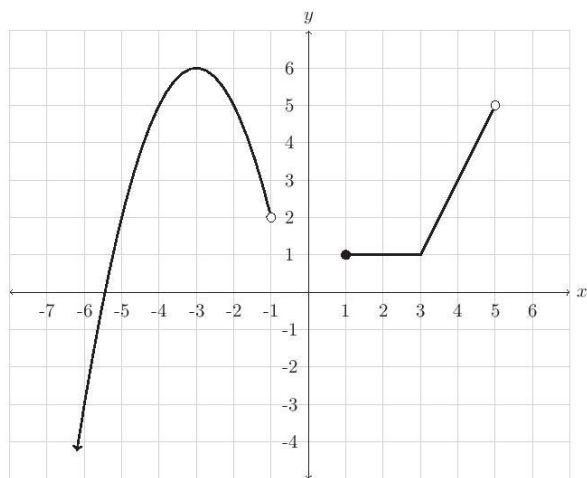
2. Use the graph of $y = f(x)$ to answer the following.

- Evaluate $f(-1)$.
- Solve $f(x) = 0$.
- Solve $f(x) > 0$.
- Estimate solutions to $f(x) = 1$.



- What are the domain and range of f . Use interval notation.

3. Use the graph of $y = m(x)$ to answer the following questions.



a. Evaluate $m(-5)$.

g. Solve $m(x) = -3$.

b. Evaluate $m(3)$.

h. Solve $m(x) = 3$.

c. Solve $m(x) = 2$.

i. Solve $m(x) \leq -3$.

d. Solve $m(x) = 6$.

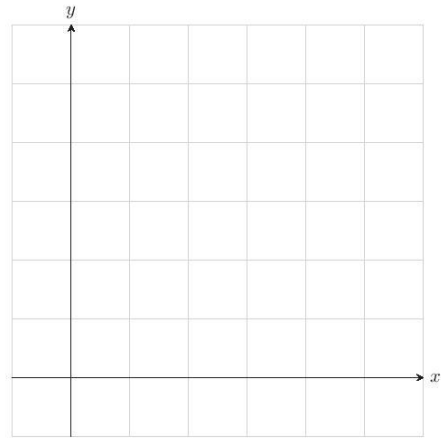
j. Solve $m(x) > 5$.

e. Solve $m(x) > 0$.

k. State the domain and range of m using interval notation.

f. Evaluate $m(-1)$.

4. The function $f(t) = -t^2 + 2t + 3$ models the depth of water in feet in a large drainage ditch, where t is measured in hours and $t = 0$ corresponds to the moment that a summer storm has ended.
- Evaluate and interpret $f(2)$ in the context of the real world function.
 - Write $f(t)$ in vertex form by completing the square. State the meaning of the vertex as a maximum or minimum in context of the situation.
 - Using the vertex form of $f(t)$ you found in part (b), solve the equation $f(t) = 0$ using the square root method.
 - What is the domain of and range of f in context of the situation? Write your answer in interval notation and explain your answer using a complete sentence.
 - At what time(s) will the water in the ditch be 1 foot deep? Round your solutions to three decimal places. Interpret your solutions in the context of the problem.
 - Make a graph the parabola $y = f(t)$ **on its implied domain** without using your calculator. Scale and label your axes.



APPENDIX H

DUAL CREDIT INSTRUCTOR COURSE ASSESSMENT FORM

PCC Dual Credit Course Assessment Form

Instructor Name: Lori Clyatt Date: 11/22/2016
 Instructor Email: Instructor Phone:
 High School Name:
 High School Course Name: Intermediate Algebra PCC Course: MTH 95
 PCC Dual Credit Liaison Name:

Purpose of visit:

- ☒ 1 year (Initial) Assessment ☐ 3 year (Renewal) Assessment

I visited the Dual Credit high school faculty's class on the date noted above, and have completed the evaluation according to the rubric included here. I affirm that:

- ☒ The curriculum, pedagogical, theoretical and philosophical approach in this Dual Credit course is consistent with the college course at PCC, and that Dual Credit students are held to the same assessment methods and grading standards as those expected in on-campus sections.
- ☐ The course is not substantially the same. Follow-up recommendations will be addressed and detailed with the high school faculty and with the Dual Credit program staff. A follow-up visit and/or meeting will occur within the current Articulation Agreement time period and issues remedied before the class can be offered again for Dual Credit.

PCC Dual Credit Liaison Signature:  Date: 1/31/2017

I have reviewed the evaluation and comments written by the PCC liaison and acknowledge the liaison's visit on the specified date noted above.

Dual Credit High School Faculty Signature:  Date: 2/14/2017

Please return completed forms to Dual Credit.
 Email to dualcredit@pcc.edu or mail to RC 3-226.

PCC Dual Credit Course Assessment Form

Performance Level » » »	Exemplary	Standard	Needs Improvement	Unsatisfactory
Instructional Delivery PCC Faculty standard: Instructor demonstrates superior knowledge of current teaching methodology and applies in ways that stimulate independent learning in the students.	☒ Instructional delivery methods effectively accommodate varying learning styles and engage students in such a way that they are able to effectively apply core concepts.	☐ Instructional delivery methods accommodate some learning styles and engage motivated students in such a way that they are able to effectively apply core concepts; less motivated students may struggle.	☐ Instructional delivery methods accommodate a single learning style that makes it challenging for even the most motivated students to remain engaged.	☐ Instructional delivery methods are significantly ineffective, seriously affecting students' ability to learn the course content.
NOTES (HIGHLIGHTS/SUGGESTIONS/COMPLIMENTS) Lori displays such a huge talent at having students learn through discovery and the Socratic method. Lori displays a mastery of questioning strategies. Her students are in charge of their own knowledge and construct the mathematical content with guidance from Lori. She is absolutely outstanding at guiding students to find their own understanding of the material. The lesson I was able to see was working through graphs of quadratic functions using the required supplement 8.3. Students were able to use their time to work through this material full class. The entire lesson was student centered and the students were engaged the entire time I was there.				
Instructional Syllabus PCC faculty standard: Is the syllabus submitted to the coordinator in a timely manner consistently by the faculty member? Is the syllabus based on the master syllabus and does it reflect the instructor's personal policies?	☐ Syllabus uses the PCC template or master syllabus for course and includes additional high school info or supplements. Syllabus is fully aligned with PCC standards.	☒ Syllabus uses the PCC template or master syllabus and is aligned with PCC standards.	☐ Syllabus meets PCC standards but does not use the PCC template or master syllabus. Syllabus is mostly aligned with PCC standards and can be brought into alignment with minor editing.	☐ Syllabus includes high school information only AND/OR is substantially out of alignment with PCC standards and requires substantial edits to align.
NOTES (HIGHLIGHTS/SUGGESTIONS/COMPLIMENTS) Lori's syllabus is close to the template.				
Textbook and Materials PCC faculty standard: Does the faculty member work with others in the discipline to choose the textbook for courses and forward request to the PCC Discipline Chair in a timely manner?	☒ Instructor uses the PCC standard text for this course.	☐ Instructor uses college-level text OR uses high school text with college-level supplements and additional material.	☐ Instructor uses high school text only, with no additional material or supplements.	☐ Instructor uses outdated, problematic or otherwise unsuitable text, supplements or materials.
NOTES (HIGHLIGHTS/SUGGESTIONS/COMPLIMENTS)				
Course Rigor & Alignment PCC Dual Credit standard: Articulated courses must provide the same content, course materials and outcomes as a PCC course.	☐ Course rigor exceeds PCC standards.	☒ Course rigor matches PCC standards.	☐ Course rigor slightly below PCC standards but can be brought to alignment with minor changes.	☐ Course rigor substantially below PCC standards and would require major revision to align OR course rigor at high school level.
NOTES (HIGHLIGHTS/SUGGESTIONS/COMPLIMENTS) Lori's students get more time, but they are absolutely being exposed to the rigor of a college course.				

Please return completed forms to Dual Credit.
 Email to dualcredit@pcc.edu or mail to RC 3-226.