UNIVERSITY OF CALIFORNIA

Los Angeles

Anti-Stereotype Threat Pedagogy: A Neuroscience-Framed Approach to Closing Differential Learning Outcomes in High School Mathematics

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Education

by

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2023

ABSTRACT OF THE DISSERTATION

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Doctor of Education

University of California, Los Angeles, 2023

Professor Diane Durkin, Committee Co-Chair

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This exploratory mixed methods study addresses the self-perceptions and engagement of mathematics students susceptible to stereotype threat. It convenes a group of math educators to implement Anti-Stereotype Threat Pedagogy (ASTP)—an experimental intervention—to 75 high school students in four separate Integrated Math classes over six weeks. This study explores teachers' implementation experience and the impact of introducing such a methodology on learners' self-perception of math potential and engagement and instructors' beliefs around the teaching and learning of diverse students.

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2023

DEDICATION

To my lovely wife Tammy and our beautiful children Sophia, Savannah, and Josiah. Remember all things are possible. Love you all.

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Thank You, God, for Your prompting, provision, love, and guidance throughout this journey. Tammy, thank you for your love, prayers, and encouragement. I could not have done this without you. To my children Sophia, Savannah, and Josiah, this work was born out of love for you. I'm building a better world for you. Now push yourselves to new horizons. Realize your dreams through effort, planning, faith, and perseverance.

Dad, you are forever with me. I know you are watching me from heaven and can hear my words. Your love, encouragement, and vision brought me to this point. Your passion for education throughout my life made this possible. Dad, while you planted the seed of this work, Mom, you made it blossom by teaching me the power of faith. I have faith in God because of you, Mom. To my siblings Cristina, Patricia, Robert, Albert, and Maria Concepcion, your prayers and encouragement fueled me to accomplish this profound milestone for the family. As Dad would say, "It was a team effort." To my nieces and nephews, you provided me with such inspiration and hope. The light of the future shines brightly because of all of you. I love you all.

To my wonderful chairs, Felipe and Diane, I am grateful for your wisdom and guidance. This work would not have reached such quality, depth, and precision without you. I have learned so much because of you. You carved a researcher out of me. To my incredible committee, Daniel and Jennie, you inspire me. Your research and guidance were central to this work. Thank you so much.

Finally, to you, the reader, I hope you glean what is meant for you from this work. Continue to persevere toward your destiny as you engage your heart as well as your mind. All things are possible.

VITA

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CHAPTER ONE: STATEMENT OF THE PROBLEM

The achievement gap or the difference in academic performance when one subgroup outperforms another, also known as *differential learning outcomes*, remains a prevalent and growing problem in American education (Williams, 2011). Despite national legislation and state interventions over the past fifty years, differential learning outcomes continue to persist and grow between White and Asian students and their Latino and Black counterparts (NAEP, 2021). White students continue, for instance, to exceed their Black counterparts in bachelor's degree attainment by 17% (the same as it was in 1990), while this differential between Whites and Latinos has increased from 18% to 25% during the same timeframe (Cox, 2016). Differential outcomes between White and Asian and Latino and Black students permeate the literature, underscoring performance differences, particularly in math and sciences (Barlow, 1999; Ladd, 2017; Ladd & Dinella, 2009; Olszewski-Kubilius et al., 2004).

Attempts to Address Differential Learning Outcomes

Despite attempts to reduce differential outcomes, national, state and local interventions have resulted in stagnation or expansion of the achievement gap. Legislation, including No Child Left Behind (NCLB) in 2002, addressed differential outcomes by reducing funding for underperforming schools, holding schools financially culpable for low student achievement, especially for historically disadvantaged or marginalized groups. Under NCLB, however, the number of schools failing to meet Adequate Yearly Progress (AYP) paradoxically increased from 29% to 38% between 2002 and 2006 (Klein, 2015). Stakeholders and authors of this legislation admitted, in 2010, that the federal government's goal of achieving 100% proficiency by the 2013–2014 academic year remained unlikely (Klein, 2015).

Similarly, Common Core, a 2010 national education initiative, focused on calibrating states with consistent standards designed to level the instructional playing field and increase achievement (U.S. Department of Education, 2019). Albeit increases in performance on state examinations were observed for disadvantaged populations, parallel increases for advantaged populations yielded no significant impact on differential outcomes (California Department of Education, 2019).

Student Engagement and Differential Learning Outcomes

Researchers have intensified efforts to uncover variables correlated with differential outcomes (Taylor, 2006). Well-documented variables in the literature include parental socioeconomic status (SES), level of education attainment, access to highly qualified teachers, technological supports, as well as geographic location and school funding, among others. Researchers also find differential learning outcomes persist between racial groups attending the same learning institutions—despite having similar resources, instructors, and SES populations. Controlling for these variables, multiple regression analyses find positive correlations between engagement (active involvement in learning) and achievement across various learning environments (Soland, 2018).

Over the last 40 years, findings demonstrate engagement's significance and ongoing relevance. As early as the 1970s, researchers found that academic engagement, or the time students participated in assigned learning activities, measured at 75% for high achievers while low-achieving students were only engaged 51% of the time (Fredrick, 1977). More recent studies continue to find that disengagement (an antecedent to low achievement) is among the most pervasive and intensifying variables as diverse learners progress through the K-16 pipeline (Park et al., 2012). Moreover, disengagement from learning environments and differential learning outcomes (particularly in math and science) intensify between subgroups as students progress through the K-16 pipeline (Park et al., 2012).

Over the last 30 years, several strategies have emerged to increase engagement. Many of these techniques call for adapting lesson structures, analyzing student work, and modifying activities according to student learning styles. The ACT-REACT strategy, for instance, focuses on specific student-led goal setting, creating a teacher work plan, evaluating student work, and making instructional adjustments to support disengaged students (Rock & Thead, 2017). With a formulaic approach, many teacher training programs and K-12 learning communities adopt similar methodologies to improve engagement (Rock & Thead, 2017). Another commonly used method is differentiating instruction. Using this strategy, teachers modify and connect course delivery and design to the needs of students using the theory of multiple intelligences to increase engagement. However promising and productive strategies such as the ACT-REACT and differentiated instruction are, differential learning outcomes nationally persist and expand. However, some researchers have argued that such strategies, primarily focusing on teacher planning, reviewing student work, and changing instruction, are problematic as they do not address the psychological antecedents of engagement such as beliefs in one's potential (Boykin & Noguera, 2011).

Research uncovering psychological precursors to learning has yielded significant insights into what *drives* student engagement. The How People Learn (HPL) framework, the result of a joint effort between the National Research Council (NRC) Commission on Behavioral Social Sciences in collaboration with the Committee on Learning Research and Educational Practice, provides significant findings as to what drives engagement and learning based on cognitive neuroscience research (Bransford, 2000). One finding is that students come to the classroom with *preconceptions* about how the world works, and unless teachers address these preconceptions, students may fail to grasp new learning. Another finding is that to develop content competence, students must have a foundation of factual knowledge, understand facts in a framework, and organize knowledge to *facilitate retrieval and application*. The final finding is that through "metacognition," students can take control of their learning by "defining learning objectives and self-monitoring progression of these goals (Bransford, 2000). These conditions drive one of the core pillars of the How People Learn framework, underscoring a community-centered environment, and promoting psychological safety, whereby students feel secure to take intellectual risks. These environments are intentionally designed to reduce anxiety or eliminate student perceptions around any punishment, humiliation, teasing, or other psychologically negative consequences (such as anxiety) if an error is made during learning.

According to the How People Learn framework, psychological safety drives engagement behaviors such as volunteering, sharing responses, time on task, and asking questions. Additionally, to further enhance engagement, the HPL framework recommends that learning environments provide invitations for disengaged students to re-enter the "learning milieu" by fostering or redesigning environments to encourage the psychological safety necessary for engagement, learning, and achievement (Bransford, 2000; Bransford & Schwartz, 1999).

These findings consequently necessitate examining what impediments hinder students' (a) positive preconceptions around learning potential and (b) psychological safety, a known precursor to student engagement. Several studies within education psychology provide insights into significant factors that negatively impact student perceptions of learning potential and interfere with psychological safety.

Stereotype Threat: A Significant Disruptor of Student Engagement

Research indicates that Stereotype Threat (ST), a disruptor of psychological safety and engagement, significantly contributes to differential learning outcomes (Lyons et al., 2018). ST is a "socially premised *psychological threat* that arises when one is in a situation or doing something for which a negative stereotype about one's group applies" (Steele & Aronson, 1995, p. 797). ST theory posits that historically marginalized learners disengage from learning environments and underperform on standardized tests because of worry or concern about confirming a negative stereotype (Steele & Aronson, 1995). Students then fall into a self-fulfilling prophecy in accordance with the negative societal stereotype (Lyons et al., 2018). Empirical findings demonstrate this phenomenon's impact on disadvantaged learners' self-perception of capacity and levels of classroom engagement and test performance.

Negative corresponding associations with race and self-perception of academic ability erode a student's self-worth, increase anxiety, and undermine learning engagement, thus informing, and creating differential outcomes or performance gaps. Multiple regression analyses indicate that ST is a prevalent and consistent phenomenon correlating with differential outcomes aligned with race and gender (Lyons et al., 2018).

Attempts to Address Stereotype Threat

Beginning with the identification of Stereotype Threat in 1995, numerous studies have explored strategies designed to address the academically restraining effects of ST. Consequently, three separate approaches from the field of education psychology emerge. The first strategy is "self-affirmation." This strategy calls for students to reflect upon strengths and accomplishments or reinforce self-positives before a lesson, learning activity, or examination (Baker et al., 2020). Self-affirmation verbalizations, or writing prompts, engage students in the "positive self-talk," designed to counteract the “negative self-talk” students experience under ST. Self-affirmations have shown promise in providing an insulating effect against negative stereotyping whereby the learner feels safe and empowered to re-engage in the learning environment, an element directly connecting to the HPL requirements for engagement.

The second strategy is group cooperative context. This approach purposefully groups students, ensuring historically disadvantaged and advantaged groups work collaboratively (non-competitively) towards a shared learning goal. According to a study conducted in 2020, when advantaged groups and disadvantaged groups were intentionally mixed according to race and gender and were provided structures to work collaboratively towards a common goal (not a performance goal), students reported a lessening of stereotype threat effects such as disengagement (Lee et al., 2012).

The third strategy includes providing learners with “role models,” representing the students’ racial or gender background prior to or during instruction. Students engaged with this strategy are presented with speakers, presenters, or success stories from individuals representing the demographic/gender of students under ST (Aronson & McGlone, 2011). Utilizing role models has been shown to improve engagement and student academic performance.

Although promising, the aforementioned strategies do little to counter the problematic assumption underlying Stereotype Threat—*correlating race or gender (or other factors) with academic potential*. Research addressing how teachers and students directly manage this assumption has yet to emerge. To address this gap, I turn to anthropological and neuroscientific evidence refuting the correlation of race or gender with academic potential—a fundamental construct required for ST activation.

Applying Neuroscience to Elucidate and Counteract Stereotype Threat

Neuroscience, the study of the nervous system and how the brain operates, holds several keys to unlocking how learning mechanisms—motivation, perception, and cognitive potential—can address this fundamental construct of ST. Of particular interest is the brain's ability to grow neural pathways (connections between brain cells), facilitating the acquisition of new skills, a physiological ability known as neuroplasticity (Tovar-Moll & Lent, 2016). Revealing the fluid nature of the mind, the human brain, via neuroplasticity, can encode experiences and create dedicated neurons (brain cells), facilitating the acquisition of skills, memories, and specialized talents with sufficient motivation, *engagement*, and practice. This mechanism is a biological/anthropological part of being human, intersecting all ethnic, cultural, and societal constructs of "race," across species *homo sapiens*. The implication is that all learners have the physiological potential to access ever-growing learning potential via neuroplasticity. This scientific finding diametrically opposes the belief that academic potential correlates with social constructs of "race" or "gender."

Neuroscience also illuminates ST's neurological impact. Neuroscientists have obtained data on how cognitive energy (measured by blood flow to the brain) changes when students are under Stereotype Threat. Neuroscientists find that blood flow (correlated with cognitive energy) is rerouted from the prefrontal cortex (math problem-solving areas of the brain) towards the limbic system or the brain's emotional control center when participants are primed with a negative stereotype about their group when engaging math tasks. Furthermore, neuroscientific findings illuminate the cognitively restraining effects of ST. Specifically, ST's cognitively restraining effects have been shown across several neuroscientific studies to hinder working memory, retrieval, and knowledge activation. More of these findings are covered in Chapter 2.

Despite these findings, mainstream teacher training has yet to integrate neuroscientific evidence to disrupt ST. Nor have professional developments emphasized redesigning learning environments to reduce or eliminate ST, given ST's neurological impact. Needed is a study that investigates how a novel pedagogical framework can alleviate the effects of ST and overtly separate correlating race or gender with academic capacity.

Neuroscience-Related Pedagogies Addressing Stereotype Threat

Broad frameworks integrating neuroscience to support the belief that all students can develop new skills exist. One example is the *Growth Mindset* framework. This approach encourages students and teachers to see skills as malleable, not fixed or innate (Dweck, 2019). However, while Growth Mindset references neuroplasticity, it does not use neuroplasticity as a lens to challenge ST. Nor does it examine *how* to use neuroscientific findings to combat stereotype threat in a mathematics classroom.

Culturally responsive pedagogy (CRP) is another neuroscience-related framework designed to improve engagement and learning outcomes for diverse learners (Hammond, 2015). CRP pursues equity for diverse learners by addressing five key concepts: identity and achievement, equity and excellence, developmental appropriateness, teaching the whole child, and fostering positive student-teacher relationships (Brown-Jeffy & Cooper, 2011). CRP addresses neuroscience, emphasizing the importance of building relationships to lower anxiety, a known element that facilitates and increases cognition. However, while this pedagogy underscores cultural competency to address race, it does not directly use scientific evidence to disconnect race or gender from academic ability. Nor does it use neuroscience findings to provide teacher training on how ST operates or how to counter its effects. Researchers have suggested that future frameworks will require students susceptible to ST and their teachers to reframe how disadvantaged learners perceive their academic potential regarding race (Boykin & Noguera, 2011).

Anti-Stereotype Threat Pedagogy

This dissertation proposes the development of ASTP, an experimental intervention that bridges gaps in the stereotype threat literature. The overall design of ASTP contains a structured, real-world application framework for K-16 educators to understand ST and how to disrupt its activation or effects using relevant neuroscience. To accomplish this, ASTP consists of two components. The first is professional development for teachers, consisting of six modules, while the second contains the praxis or application of strategies learned in the professional development with students in the classroom.

ASTP's modules cover topics designed to address the dearth of practical training on how ST operates in classroom settings and neuroscientific findings to counter ST activation and its impact. Introductory modules explain how ST operates, its neurological impact on learning, and neuroscientific evidence refuting the spurious correlation of race or gender with math ability. Subsequent modules outline the praxis and activation of ASTP in the classroom, including novel math lesson structures and strategies to counter the effects of ST. More information on ASTP's structure, methodology, and professional development is covered in Chapter 3.

This dissertation explores educators' ASTP implementation experience. It also investigates changes in learners' self-perception of math potential and engagement and teachers' beliefs around the teaching and learning of diverse students. The following research questions consequently guide this study.

Research Questions

1. What evidence (if any) exists of changes in student self-perception of math potential and engagement?
    a. According to students' self-reports in a survey;
    b. According to students in focus groups; and
    c. According to teacher observations and reports.
2. What are teachers' experiences and reflections regarding implementing ASTP?
3. How did the implementation influence teacher perceptions and beliefs around math teaching and learning for diverse learners?

Research Design

I used a mixed methods design involving qualitative and quantitative data (Creswell & Creswell, 2018). Mixed methods research design outlines three core elements: the integration of qualitative and quantitative research while simultaneously optimizing the strengths and minimizing the limitations of both individual approaches (Creswell & Creswell, 2018; Creswell & Plano Clark, 2011; Teddlie & Tashakkori, 2009). Procedurally mixed methods are helpful when comparing different perspectives from quantitative and qualitative data while explaining quantitative results with qualitative follow-up and data analysis. This methodology also optimizes the ability to evaluate the outcomes of a program or "experimental intervention" over other methods (Creswell & Creswell, 2018).

The methodological principles of mixed methods directly tie into this study's purpose and goals. First, a mixed methods experimental intervention model is appropriate, given that ASTP is an untested experimental intervention. Furthermore, the purpose of this study is twofold. The first is to measure changes in self-perception and engagement (dependent variables) that may be associated with the ASTP methodology (independent variable). The second is to uncover *how* changes occurred, gain insight into teachers' experiences throughout the implementation and how this experience influenced educators' beliefs around math teaching and learning for diverse students. To that end, I collected and analyzed quantitative data (student self-reports in a survey) and integrated these results with the qualitative data collected from student focus groups and teacher interviews.

Site and Population

Josiah High School (JHS) contains diverse populations (predominantly Latino) typical of many high schools in urban districts with a high percentage of low-SES students. This site selection is essential, as results may be generalizable to schools with similar populations. Moreover, this site contains historically and economically advantaged (White and Asian) and disadvantaged (Latino and Black) students, allowing for cooperative group context (one of the ASTP strategies). Like many schools nationwide, this site (and the district) needs help to meet mathematical proficiency on several state measures. One such measure is the SBAC, whereby the school's majority of students—60.74% score below standard in mathematics. Last, another vital element is the desire for school leaders to increase mathematical learning outcomes. Teachers and administrators have recognized the challenges students at JHS face with such outcomes. Teachers and administrators have also desired to innovate ways to increase these results.

Study Significance

This study contributes to our knowledge of how teachers and schools can overtly disrupt correlating race with math ability using relevant neuroscientific findings. This intervention (ASTP) also aims to investigate how neuroscientific evidence can impact students' self-perception, motivation, and engagement, critical components connected to achievement that may help alleviate differential learning outcomes in math. Additionally, this study seeks to understand teachers' implementation experience, including trends and observations, and how the implementation experience impacted instructors' beliefs about the learning and teaching of diverse students.

Closing differential learning outcomes for diverse learners remains a difficult challenge in math and other subjects (NAEP, 2023). ASTP holds promise for other subjects where gaps are found in achievement, as this intervention's structures are not exclusive to mathematics and are malleable enough to be adapted to other content areas. This is especially important as despite advances in research around engagement designed to motivate learners, DLOs in mathematics (and other subjects) remain frustratingly unbending. ASTP provides teachers and students with concrete methods, merging complex theoretical findings with real-world application strategies, and makes implementation approachable on the ground. ASTP may support teachers' and students' understanding of the human mind's perpetual learning potential and how such capacity is not correlated, nor a result of race or gender, based on neuroscientific findings.

CHAPTER TWO: LITERATURE REVIEW

In this literature review, I first examine the nature of differential learning outcomes and the historical attempts to address such disparities. Next, I review the literature on variables correlated with differential learning outcomes, leading to engagement as a significant contributor. Subsequently, I provide research indicating stereotype threat (ST) as a significant disruptor of engagement, followed by historical attempts to address ST. From here, I examine the gap many historical and pedagogical attempts (to alleviate ST) have yet to address—*the spurious correlation between race or gender and academic potential*. Addressing this gap in the literature, I connect neuroscientific evidence to disrupt this erroneous correlation and elucidate how ST impacts learners neurologically. Last, I close this chapter by reviewing the most closely related neuroscience-framed pedagogies and efforts designed to counter ST.

Differential Learning Outcomes (Historically Known as the Achievement Gap)

In recent years, national institutions have exchanged the term achievement gap for differential learning outcomes or *DLOs*. According to the National Council of Teachers of Mathematics (NCTM, 2014), the term achievement gap erroneously assumes that outcomes depend on students' ability regardless of learners' unequal access to learning resources and opportunities. To that end, the updated terminology *differential learning outcomes* account for such complex and unequal opportunities and treatment differences between subgroups that inform unequal achievement (NCTM, 2014). In other words, the term DLOs acknowledges opportunity gaps students of diverse backgrounds encounter. Such opportunity differences include grade-level or more advanced curriculum, teacher expectations for students and beliefs about their academic potential, exposure to culturally relevant instructional strategies, and instructional support (Flores, 2007). Research indicates that learning opportunities significantly predict student learning and achievement (NRC, 2002).

Examining Differential Learning Outcomes

National data captured and analyzed through the National Assessment of Educational Progress (NAEP) represents one of the most reliable metrics on DLOs. The NAEP, established in 1969, is the most comprehensive and ongoing nationally representative assessment of U.S. students' knowledge and skill sets in math, English, and other subjects (NAEP, 2021). The NAEP administers two assessments: the long-term trend (administered nationally to students at ages 9, 13, and 17 in reading and mathematics) and the main NAEP (assessing students nationally and statewide in grades 4, 8, and 12 in various subject areas and with varying periodicity). NAEP assessments, uniformly administered, use the same testing materials while remaining primarily unchanged (aside from minor changes) from year to year (NAEP, 2021).

Data collected and analyzed from the NAEP indicate three troubling trends regarding the nature of differential outcomes. The first is the persistence of DLOs between White and Asian and their Latino and Black peers in all subjects since NAEP's establishment. Second, advantaged (historically higher performing) groups continue to experience parallel and more significant gains over other groups, leaving DLOs largely stagnant or expanding. Third, research indicates differential outcomes intensify or compound as students progress through the K-16 pipeline.

Persistence of Differential Learning Outcomes

Analyzing NAEP math assessment data among fourth, eighth, and twelfth grades demonstrates the persistence of DLOs. Between 1978 and 2004, fourth-grade and eighth-grade data between White and Black students showed no significant closure of math achievement, with this gap remaining between 23 and 31 points. Extending the timeframe to 2017, fourth-grade

White-Black achievement gaps in mathematics achievement scores remain (albeit narrowing slightly in 1990) at 25 points, while the White-Hispanic gap in 2017 (19 points) was not measurably different from the gap in 1990. Any closures between groups throughout the years of assessment remain statistically insignificant. For example, although the math performance gap decreased by 4 points (a statistically insignificant margin) between 1996 and 2000, between these groups and ages, the average continuation of gaps between performance remains thereafter (NAEP, 2007).

Examining eighth-grade math results further demonstrates DLOs between groups. In 2008, 13-year-old African American and Latino students' performance in mathematics compared to White students was behind 74% and 66% of a standard deviation, respectively (Borman et al., 2016). Although the White-Latino gap narrowed from 26 points in 1992 to 19 points in 2017, the White-Black 2017 gap (25 points) was not measurably different from that in 1992 (NAEP, 2018). Similarly, gaps persist for 12th graders across the United States from 2005 onward (NAEP, 2023).

Parallel Gains and Expansions

Parallel and expanding gaps between White and Asian students compared to their Latino and Black counterparts further exacerbate DLOs. For instance, while the most significant math gains for 4th grade Black and Latino results occurred between 2000 and 2003, growing from 203 to 216 and 209 to 222, respectively, White and Asian scores also increased from 235 to 243 and from 229 to 246 respectively (NAEP, 2021). Parallel increases for 8th graders across the nation show similar trends. Although eighth-grade Black and Latino math scores increased from 244 to 263 and 253 to 272, respectively, from 2000 to 2013, White and Asian scores also increased from 284 to 293 and 291 and 306, respectively. Parallel gains continue in twelfth grade, as math results from 2005 to 2019 show similar directionality of scores between groups (NAEP, 2021). Although all student groups have made slow and steady improvements in math and science achievement in recent years (NAEP, 2006), the significant gap between White and Asian and their Latino and Black counterparts remains unaffected (Johnson, 2009; Kulm, 2007).

Progressively Widening Gaps Along the K-16 Pipeline

Data indicate DLOs widen between White and Asian and their Latino and Black peers throughout high school, culminating in significant differences in college acceptance through college graduation (Appel & Kronberger, 2012). Outcomes in mathematics are particularly problematic as DLOs develop in this content as early as age nine between White and non-White learners (Lyons et al., 2018). Comparing Asian to Black learning outcomes throughout the K-12 pipeline highlights this problematic expansion between groups. In 2003, the fourth-grade Black-Asian performance gap was measured at a 30-point difference, increasing in 2009 to a 40-point difference. Reviewing the performance in 2019 reveals one of the most significant gaps between recorded racial groups, with a 45-point difference between Asian and Black students (NAEP, 2021).

Attempts to Address Differential Learning Outcomes

National legislative efforts have intensified over the past 20 years to address DLOs. The No Child Left Behind Act (NCLB), a 2002 federal education policy, introduced guidelines for public schools to improve learning outcomes via heightened accountability, enhanced flexibility, local control of funds, and improved parental choice and research-based instructional methods (Eisenhart & Towne, 2003). NCLB required all states to assess students during grades 3 through 8 and once in high school in math and reading and use the results to set annual achievement goals. A primary goal of this legislation was to achieve 100% proficiency status by the 2013–

2014 school year. The adequate yearly progress (AYP) metric was introduced to help monitor and quantify this effort. Schools not meeting the AYP faced severe financial consequences via the removal of funding. Per AYP requirements, this expectancy of 100% proficiency extended to all learners, including any underperforming subgroups defined by economic, racial, and disability characteristics. In 2013, this goal of proficiency was not met.

Researchers Dee and Jacob (2010, 2011), studying the impact of NCLB, reported from initial analyses that NCLB led to a statistically significant increase in test scores in math for 4th-grade students and a positive, but not statistically significant, increase for eighth graders in math. However, other researchers found these findings problematic (Ladd, 2017). Upon closer examination, the change in the average score was due to data collected too early to be attributed to NCLB in 2003, as this was the first year of its implementation. Based on the scrutiny of the data, other researchers have reached similar conclusions. Research indicates that, given the new program had just been implemented, these outcomes were not indicative of NCLB, but rather cumulative efforts from previous years. Removing this year from the analysis, the claimed statistically significant effect in fourth-grade improvement eliminates (Ladd, 2017).

Common Core and Every Student Succeeds Act

In 2010, another legislation, Common Core State Standards (CCSS), sought to calibrate state standards and the instructional playing field to address persistent DLOs. The method CCSS implemented was twofold. One clarified student expected learning goals for each grade level. The second was implementing systems to monitor the acquisition of those standards. States were encouraged to adopt the Common Core Standards through race to the top grants. However commendable, NAEP results running concurrently since CCSS's implementation in 2010 demonstrate no significant closure of DLOs.

Every Student Succeeds Act (ESSA) represents the most recent legislation (2015) designed to address DLOs. Although ESSA maintains the annual standardized test requirements of NCLB, ESSA distinguishes itself from NCLB by decentralizing federal accountability provisions to states. Under this latest law, students continue participating in annual tests (per NCLB requirements) between the third and eighth grades. However, ESSA places responsibility on individual states for determining student standards. States must submit goals, standards covered, and accountability measures to the US Department of Education (DOE) for feedback and approval. In this manner, the DOE still holds states accountable by reviewing states' implementation plans, including standardized tests used to determine student capabilities in the classroom. The states are also left to determine the consequences of low-performing schools and determine support for such schools. Furthermore, ESSA prohibits any state mandates to adopt the CCSS and gives states explicit permission to withdraw from the CCSS.

Since the implementation of ESSA in 2015, NAEP reports problematic differential outcomes. For starters, fourth-grade Black and Latino gains in mathematics have come to a halt, as average math scores remained unchanged for Black students at 224 and 231. At the same time, Asian learning outcomes have continued to increase since ESSA's implementation (expanding gaps), while White learning outcomes continue to prevail in accordance with historical trends (NAEP, 2021). The compounding effects of problematic DLOs culminate in twelfth grade. At this grade Black and Latino scores move from stagnation to a downward trend of results between 2015–2019, while scores of White students prevail at 159, and those of Asian learners grew from 170 to 173.

Variables Correlated with Differential Learning Outcomes

Researchers recognize that identifying variables correlated with DLOs remains complex. Given the myriad of possible causes, attempts to uncover variables have left researchers grasping for explanations, ranging from genetics (a controversial claim) to more plausible societal factors (Barlow, 1999; Olszewski-Kubilius et al., 2004; Ramirez & Carpenter, 2005). However, recent analysis across several studies illuminates trends connected to this multivariate challenge. Based on analyses of educational data, a consistent pattern emerges - race, culture, ethnicity, language, and economic status continue to be consistent variables correlated with DLOs (Howard, 2002). Analyzing these trends, further research on DLOs indicates how such factors intersect variables at three specific levels, including (a) District, (b) Classroom, and (c) Student levels.

District Variables

Inequitable school funding, uneven distribution of highly qualified instructors, biased disciplinary policies, minimally articulated core curriculum, and lack of consistent instructional support correlate with DLOs (Fergus, 2016). Moreover, a 10-year root cause analysis of disproportionality finds that, in addition to these variables, the *quality and unevenness* of the *distribution* of “wellness of instruction and curriculum,” represented by the quality of instructional support teams, intervention services, assessments, and GATE programs, consistently emerge as conditions and practices that disproportionately affect diverse learners and their learning outcomes (Fergus, 2016).

Research indicates that district and school funding significantly contribute to differential outcomes. Although school funding increased dramatically per student, nationally quadrupling between 1960 and 2015, disparate funding between geographic locations continues to correlate with outcomes. Less money for technological supports, materials, and higher pay, which attract highly qualified teachers, disproportionately challenges less funded districts, contributing to DLOs.

Classroom-Level Variables

At the classroom level, implicit bias, limited beliefs about student ability, potential or readiness, racism, and teacher expectations correlate with student achievement. These variables historically permeate the literature. As early as 1968, Rosenthal and Jacobsen uncovered teacher expectations as self-fulfilling prophecies in “Pygmalion in the Classroom.” Researchers find instructors’ perceptions of their learners of particular significance; as Jon Saphier (2016) writes, “Students are profoundly influenced by the messages they get from the significant people in their lives about their ability.” In this way, teachers’ perspectives on their students’ abilities may be unknowingly communicated through body language, tone, word choice, and behavior. Such actions may thus require educators to vigilantly reflect to ensure high student expectations (Saphier, 2016).

Part of the challenge at the classroom level is the need for more professional development in culturally responsive teaching practices. In an increasingly segregated world, educators have limited opportunities to engage with people consistently and deeply from other ethnic, racial, language, and social-class groups (Banks, 2001). Although teacher preparation and professional development changes in recent decades underscore cultural competency, educators will likely require additional opportunities to gain the cultural skills to work effectively in diverse educational environments (Johnson et al., 2020). Consequently, professional development focusing on building teachers’ cultural competency and classroom applications of culturally responsive teaching practices becomes critical in building bridges of understanding and strong student-teacher relationships.

Additionally, highly effective teachers remain strongly correlated with outcomes and student learning (Johnson, 2009; Wenglinsky, 2002). Specifically, highly qualified teachers' *experience in teaching,* rather than their subject matter knowledge, remains significant when impacting outcomes. According to multiple studies (e.g., Muñoz & Chang, 2007; Zehr, 2009), researchers find that teaching experience and high expectations—more than teacher training programs or advanced subject matter knowledge—translate to higher achievement for diverse learners.

Student-Level Variables

Student-level opportunity gaps correlate with DLOs. Opportunity differences can include access to grade-level or more advanced curricula, instructors' expectations of students, beliefs about learners' academic potential, exposure to culturally responsive instructional strategies, and other instructional supports (Flores, 2007). Research indicates that learning opportunities significantly predict student learning and achievement (NRC, 2002). Moreover, diverse students and students of poverty may lack access to enrichment experiences and social capital compared to their advantaged counterparts. For instance, diverse students may not have access to resources such as field trips, vocabulary-rich environments, tutoring services, elective classes, advance coursework, and technology, typical of more advantaged areas. Researchers find that schools that provide students with opportunities to engage in extra- and co-curricular activities also support the knowledge, skills, and attitudes that increase academic achievement.

Historically marginalized students (Latino, Black, and poor learners) experiencing DLOs are more likely to be exposed to negative messages about their "ability," being perceived at a disadvantage, and internalizing such messages (Saphier, 2016). Consequently, work towards eliminating DLOs requires altering students' mindsets about their supposed low ability.

Researchers also indicate that this process of student-level thinking around potential requires reflection of teacher beliefs around students' potential, implicit biases, racially centered assumptions, or doubts about malleable ability.

More problematic, data show that DLOs can persist between races even within the same learning institutions. This presents a unique challenge, as differentials prevail despite controlling for common district and classroom variables, including opportunities to learn, access to teacher quality, socio-economic status, and geographic location. Data from some of the most diverse schools demonstrates this phenomenon. For example, students attending Inderkum High School in Sacramento, California, ranked one of the most ethnically diverse high schools in the nation (Latino 24.2%, White 13.5%, Black 24.1%, and Asian 15.9%) demonstrate differential outcomes mirroring national rates, as Asian and White students outperform their Latino and Black students on math measures (SARC, 2021). Reviewing such examples, requires an investigation of what proximal variables at the student level (despite controlling for district and classroom variables) significantly impact achievement differences between racial groups.

Student Engagement: A Significant Contributor to Differential Outcomes

Empirical evidence demonstrates student engagement as a significant variable correlated with achievement (Boykin & Noguera, 2011). Engagement remains especially important for historically marginalized students, including Latino and Black learners. According to Balfanz and Byrnes (2006), self-reported engagement through effort was a statistically significant predictor of whether Black and Latino students would make gains in achievement. Specifically, engagement that optimizes task performance in actively doing math and reading material at a non-superficial level provides the foundation for task completion and academic achievement (Greenwood et al., 1987). Multiple studies indicate engagement remains significant despite changes in other variables, such as funding, policy changes, and geographic location. For instance, a study by Borman and Overman (2004) investigated what variables differentiate academically successful and unsuccessful Black, Latino, and White students from low-income backgrounds. Their study concluded that engagement was a statistically significant contributor. Much research indicates that such engagement correlates with favorable learning outcomes especially for students identified as at risk for academic failure (Borman & Overman, 2004; Tucker et al., 2002; Wenglinsky, 2004).

As a construct, engagement has three distinct yet interrelated dimensions: affective, behavioral, and cognitive (Fredricks et al., 2004). Affective engagement refers to emotional reactions linked to task investment. The greater each student's interest level, positive attitude, positive affect, positive value held, curiosity, and task absorption (less anxiety, sadness, stress, or boredom), the greater the affective engagement. Behavioral engagement conveys the presence of general "on-task behavior." This dimension includes effort, perseverance, attention, asking pointed questions, and seeking help. Cognitive engagement includes the understanding of complex concepts to acquire difficult skills. It conveys deep (rather than surface-level) information processing, whereby students gain a critical or higher-order understanding of the subject matter and solve challenging problems.

The three dimensions of engagement remain consistently correlated with improved achievement for diverse or marginalized learners. Research specific to math learning and the performance of Black and Latino students strongly suggests that increased engagement leads to increased success for these populations. In a study by Borman and Overman (2004), researchers identified correlations with students perceived as high achievers. Students were divided into two groups. Those whose scores increased substantially were labeled resilient, and those students whose scores decreased by 6th grade were termed non-resilient. The percentile rank for both groups was 39 in the 3rd grade. In the 6th grade, the percentile ranks were 59 and 11, respectively, for the resilient and non-resilient groups. Engagement was shown to be a significant variable, differentiating successful from unsuccessful students. In addition, another factor that distinguished resilient from non-resilient children was having *a positive attitude* toward school—an element connecting to engagement's affective dimension.

Research also indicates *how* engagement operates. Engagement arises from the symbiotic relationship between teachers and students. Specifically, rather than a simple teacher-initiated student action, the concept is more complex. Sutherland and Oswald (2005) note that linear conceptual models, which examine teacher impact on the child or vice versa, need to be reconsidered, as engagement arises from the bidirectional influence that educators and learners have on one another. Furthermore, this dynamic becomes problematic when, for example, low-achieving students receive fewer (and lower-quality) interactions with their instructors—often because these interactions are fewer in quantity. Students more engaged in classroom activities receive more positive teacher attention in return, while unengaged students receive less positive attention and more "coercion" from teachers. Therefore, more classroom engagement ensues for already engaged students while less develops for disengaged students, creating progressively polarizing results.

Attempts to Address Disengagement

Disengagement, the converse of engagement, also known as task avoidance, is an even more significant indicator of performance outcomes than engagement for disadvantaged students. Historical attempts to improve engagement are well documented (Borman & Overman, 2004). Many K-16 learning organizations incorporate Bloom's taxonomy-driven focused learning targets (FLTs) to increase cognition and engagement. These are learning goals that teachers and students establish for a given class period, calibrating success criteria for the lesson. To deepen conceptual understanding and support learners in acquiring the target of a lesson, lessons designed with an objective also help students with metacognition or self-monitoring towards acquiring such learning goals. Pedagogically, K-12 learning institutions use a gradual release lesson cycle, where lessons begin with more teacher-directed instruction, gradually releasing tasks and activities towards more student-centered engagement. Learners engage the classroom with more student-centered activities towards the middle and end of a class period to increase participation and sustained interest or focus, an element connected to all three dimensions of engagement.

Educators seeking to improve engagement usually learn about strategies from professional development. Typically provided by the district/organization a teacher works with, efforts to increase engagement can range from classroom management and class participation equity strategies to differentiated instruction. Specific strategies common to K-12 engagement also include effective classroom management practices, such as setting high expectations, or equity-centered strategies, such as using cold calling cards to ensure equal participation of learners.

School districts desiring to bolster engagement have also increased technological integration. Studies indicate that technological support in learning environments improves interest in learning. Likewise, educators have expressed a greater interest in trying new strategies and approaches to enhance active learning and engagement (Findlay-Thompson & Mombourquette, 2014). Educators accessing multimedia resources via online services such as YouTube and Teachertube have observed increases in math students' engagement (Olakanmi, 2017). Digital tools, according to research, improve the teaching and learning process with online tools such as Delta Math (online math platform) and Desmos (online math learning platform) by increasing student interest in learning.

While these traditional and technologically driven strategies are noteworthy, national DLOs persist and expand. Some researchers have argued that such strategies focusing on teacher planning, reviewing student work, and changing instruction (including technology), do not directly address the psychological antecedents necessary for engagement (Boykin & Noguera, 2011). Furthermore, researchers have underscored the need to investigate which antecedents are linked to which types of engagement (Ladd & Dinella, 2009).

Drivers of Student Engagement

Based on cognitive neuroscience research, the How People Learn (HPL) framework provides significant findings on what drives engagement and learning. HPL results from a joint effort between the National Research Council (NRC) Commission on Behavioral Social Sciences in collaboration with the Committee on Learning Research and Educational Practice. It provides critical engagement antecedents based on research in the learning sciences. In its findings, the HPL framework identifies significant drivers of engagement. These include children's early proclivity or self-interest in learning about some topics and not others, metacognition or "thinking about their learning," and the influence of community on children (Turner, 2011). According to the HPL framework, environmental influences such as teacher-student relationships, neighborhood, and family influence the motivational and metacognitive drivers of motivation needed for engagement.

Researchers recognize society's influence on classroom learning over the last 30 years. Social belonging is shown to be significant in determining whether diverse students choose to engage in the learning environment. For instance, cognitive engagement depends on how students perceive their role in learning. HPL finds that students come to the classroom with *preconceptions* about how the world works, and unless teachers address these preconceptions, students may fail to grasp new learning. Another finding is that to develop content competence, students must have a foundation of factual knowledge, understand facts in a framework, and organize knowledge in ways that facilitate retrieval and application.

Research from the learning sciences and the HPL framework suggests recommended practices to enhance teachers' capacity to address the antecedents of engagement. Learning environments retrofitted according to the HPL frame are learner, knowledge, and assessment-centered, with community-centered principles. Such principles include progressive formalization, prior knowledge/metacognition, and instruction linking critical concepts of a curriculum that support the learning and transfer of instructional concepts (Lowery, 1998).

Together, these combined strategies and supports drive students' capacity to take the intellectual risks necessary for learning. HPL and findings from the learning sciences underscore that a student must first feel secure in their learning space before deciding to engage in the classroom. Moreover, students must be free from any perception of humiliation, teasing, punishment, or judgment if a learning mistake occurs. According to the HPL framework, this sense of *psychological safety* is essential to student engagement (Turner, 2011).

School teachers who seek to engage reluctant learners can plan instruction according to the HPL framework. Developing instructional methods accordingly can help students accomplish specific academic or behavioral goals and meet learning objectives, cornerstones of effective instruction (Darling-Hammond, 1998). With professional knowledge of HPL, teachers can choose more purposely among different instructional techniques to accomplish specific learning goals and objectives with psychological safety in mind (Bransford, 2000).

Consequently, the HPL framework and studies from the learning sciences underscore the need for learners to feel safe to engage in learning. Given the importance of psychological safety, it becomes necessary to examine significant disruptors of this construct.

Stereotype Threat: A Significant Disruptor of Psychological Safety & Engagement

Research indicates that stereotype threat (ST) significantly disrupts psychological safety and engagement and contributes to differential learning outcomes (Lyons et al., 2018). ST is a socially premised *psychological threat* arising when one is in a situation or engaged in a task for which a negative stereotype about one's group applies (Steele & Aronson, 1995). ST activates when three factors are present: (a) a heightened sense of one's racial identity; (b) a perceived negative correlation between race or gender and academic performance; and (c) a reduction in learning or performance compared to peers of similar cognitive capacity (Smith & Hung, 2008).

When experiencing stereotype threat, learners at risk cognitively disengage from learning environments, lowering their motivation, leading to restrained academic performance. Diverse and minoritized learners (Latinos and Blacks) are especially susceptible to ST, given the historically pervasive negative/racist/deficit attitudes towards these groups. Multiple regression analyses indicate a positive correlation between historically disadvantaged students' racial identity and their disengagement from learning environments (Leath et al., 2019). The consequences of ST on performance are widely documented, with well over 100 separate studies examining performance deficits (Davies et al., 2005). Societal stereotyping influences students during testing and everyday learning contexts (Larnell et al., 2014; Nasir et al., 2009; Nasir et al., 2012; Steele & Aronson, 1995). According to researchers, stereotype threat is a statistically significant disruptor of test performance as learners are preoccupied with the possibility of confirming a negative stereotype rather than the task. The longstanding sociological hypothesis responsible for this phenomenon is that cognitive resources are temporarily suppressed by intrusive thoughts and worries, leading individuals to underperform despite high content knowledge and ability (Schmader & Beilock, 2012). Extensive research in adults and growing work with children (e.g., McKown & Strambler, 2009; Neuburger et al., 2015; Wasserberg, 2014) documents that when a negative stereotype is primed prior to an examination, performance declines compared to when the primer is removed.

In Steele and Aronson's (1995) seminal study, ST was primed among African-American participants by describing the study as concerned with "various personal factors involved in performance" and as a diagnostic of participants' ability. In contrast, in the control condition, the test was described as simply aimed at *better understanding factors involved in problem-solving.* African-American participants who received the instructions with the ST primer underperformed compared to African American participants in the control group. White participants who received either prompt were not affected.

As shown in subsequent studies, the implication here is that ST as a situational context can be invoked. This extends the concept of this type of threat to situations that contain cues in the environment that one's social identity is not welcome or is linked negatively to the given task. The categorization of these cues overlaps with racially related assaults known as microaggressions, as referenced in sociology and social psychology (Solórzano et al., 2000). Microaggressions are subtle insults (verbal, nonverbal, or visual) directed toward people of color, often automatically or unconsciously. Following this logic, ST can also, therefore, arise from microaggressions.

Studies have shown that children become aware of negative racial stereotypes and microaggressions as early as six years old. Most children are aware of broadly held racial stereotypes by age 10 (McKown, 2004; McKown & Weinstein, 2003), and stereotype-aware children can be susceptible to prompts that invoke ST by increasing identity salience, resulting in restrained cognitive resources (McKown & Strambler, 2009; Wasserberg, 2014). This is highly problematic in disciplines such as mathematics, as curriculum tends to build sequentially. Therefore, if a student fails to understand one content area fully, the learner becomes disadvantaged in learning future content with compounding consequences. This element consequently results in a secondary effect of ST, whereby decreases in performance erode student interest in and identification with the stereotyped domain (Smith et al., 2007; Woodcock et al., 2012).

ST can also arise based on the perceived negative association between ability and gender. For example, Beilock, McConnell and Rydell (2007) tested women on a multi-step mathematics problem. They had two groups: one exposed to a negative stereotype primer and a control group without treatment. Both groups first did a set of mathematics problems, which measured their baseline mathematics ability. To prime ST, the treatment group was told the task was used to investigate why women do worse than men on mathematics *(assuming the stereotype*). In contrast, the control group was told that researchers were only studying problem-solving. Both groups then completed a post-test of mathematics ability. In the threatened group (i.e., those told the study investigated gender differences in mathematics), accuracy dropped 10% from baseline to post-test. In contrast, the control group saw an increase in accuracy.

Attempts to Address Stereotype Threat

As learners internalize the negative self-talk associated with ST, sociologists theorize that cognitive energy (necessary for learning) is instead galvanized to manage anxiety, resulting in restrained performance (Ryan & Ryan, 2005). Stereotype threat interventions, therefore, seek to improve self-perception and increase engagement or performance. Interventions addressing ST include four types: (a) providing external attribution for the difficulties (Ben-Zeev et al., 2005; Schmader & Beilock, 2012); (b) encouraging self-affirmation and micro affirmations (Bowen et al., 2013; Cohen et al., 2006; Solórzano et al., 2020; Spencer et al., 2016); (c) providing role models (Aronson & McGlone, 2011; Huguet & Regner, 2007); and (d) emphasizing an incremental perspective on intelligence (Goff et al., 2008).

External attributions for difficult situations to regulate anxiety and arousal can disarm stereotype threat. For instance, student anxiety invoked by ST can be redirected by acknowledging the possibility of not being taught the prerequisite material for a given math lesson or that it is normal to have anxiety when starting a new class at a new school. Studies consistently demonstrate this strategy's promise. Researchers studying its impact showed marked improvement for populations susceptible to ST.

Another anti-ST strategy is self-affirmation. This strategy protects learners from perceived threats and the consequences of failure by affirming self-worth. Members of a group susceptible to ST using self-affirmation or micro-affirmations can engage, for instance, in self-affirmation essays before an exam or listen to positive self-affirmations from others about their group (Borman et al., 2016). Another delivery method includes teachers reading the self-affirming essays written by students (Bowen et al., 2013). Prior to a high-stakes exam, such positive self-talk—verbally or in written essays—increases performance for many learners experiencing ST (Borman et al., 2016). Researchers studying this strategy's impact indicate encouraging results. These researchers found that self-affirmation has a statistically significant impact on reducing the impact of ST on women taking a mathematics test compared to men taking the same exam. Using this strategy, women outperform men compared to when the strategy is removed (Kuhl et al., 2006). Similar to self-affirmations is the practice of microaffirmations, a practice designed to counter microaggressions, an element that can also trigger ST.

Including role models representing the racial or gender background of learners during instruction has also been shown to reduce ST. Specifically, role models demonstrating proficiency in a domain can reduce or even eliminate stereotype threat effects (Blanton et al., 2000). When disadvantaged learners were provided role models from a learner's racial background, students re-engaged with their learning environment. For example, a study in 2015 found that women exposed to role models felt less threatened and inspired, thus alleviating the impact of ST (Blay, 2015).

Another intervention uses "cooperation context," where members of an ST at-risk group work collaboratively with a group not typically prone to ST towards a common goal. For example, a learning task meeting these criteria would group African American and Latino students working with Asian and White peers for a shared learning objective. To support this strategy, teachers create structures and classroom groups to help students become trusting partners for an objective, each with equal perceived value and task level (Wen et al., 2016). Data shows that using a cooperative group context reduced anxiety connected to ST and helped reshape learners' perception of their capacity.

Emphasizing an incremental view of intelligence has also shown promise towards disarming ST. Several studies suggest ST can be reduced or even eliminated if an incremental view of ability is emphasized. This strategy emphasizes the importance of effort and motivation in performance while de-emphasizing inherent “talent” or “genius.” Individuals encouraged to think incrementally will tend to react more effectively to challenges and are less likely to fear confirming negative stereotypes of their group. Researchers investigating the impact of incremental views of intelligence find that students become more receptive to reflecting on errors than when an innate ability perspective is taken.

While these strategies counter the effects of ST, such strategies do not confront the spurious correlation of race or gender with academic potential, a critical construct necessary for ST’s activation. Overtly exposing the false nature of such correlations serves two goals. The first is to dismantle the plausibility of this correlation, while the second is to provide an additional frame to counter ST. To this end, I turn to compelling evidence within the neuroscience and anthropology learning sciences to challenge the validity of correlating race or gender with academic potential.

Neuroscience to Elucidate and Counter Stereotype Threat

Neuroscience, the study of the nervous system and how the brain operates, holds several keys to unlocking how learning mechanisms—motivation, perception, and cognitive potential can disrupt this fundamental construct of ST. Of particular interest is the brain’s ability to grow new neural pathways via *neuroplasticity* and the brain’s capacity to generate new brain cells via *neurogenesis*. The brain’s ability to build neural pathways (connections between brain cells) facilitating the acquisition of new skills, abilities, and memories is a fundamental physiological capacity of the human mind (Tovar-Moll & Lent, 2016). Revealing the fluid nature of the mind, the brain, via neuroplasticity encodes learning experiences and creates dedicated neurons with stronger synaptic connections, facilitating the acquisition of skills, memories, and specialized talents at any age with sufficient motivation, *engagement*, and practice.

Neuroplasticity endures throughout one's lifetime. Knowland and Thomas (2014) highlight that while the greatest maturation of the brain occurs during early or mid-childhood, some brain systems show substantial change right up to the end of adolescence, with neuroplasticity occurring throughout life. The sequence of neuroplasticity occurs in three main stages. In the first stage, the number of synapses (connections between neurons) is established in early to mid-childhood. In the second stage, an initial over-proliferation is followed by a period of pruning, leaving those synapses regularly used and, therefore, functional. Finally, changes thereafter in plasticity are not strictly linked to chronological age but depend partly on experience.

The second neuroscience key in combating the problematic correlation of race and academic ability is that neuron connections facilitating learning regenerate. The brain's ability to create new brain cells, *neurogenesis*, starts in the embryonic phase and continues thereafter for life. Erroneously, scholars previously thought humans could not create new neurons in the brain after the first few years of life. However, researchers across several scientific studies showed that adult neurogenesis occurs (Deprez, 2015). The hippocampus is one of the regions in the brain most studied concerning neurogenesis and remains an area of the brain of particular interest in the process. In addition to the hippocampus, neurogenesis occurs in the subventricular zone, which involves memory, learning, emotions, and spatial orientation. Scientists have linked neurogenesis with increased cognitive function and better memory (Costa et al., 2015).

The ability for humans to engage these mechanisms is a biological and *anthropological* part of being human, intersecting all ethnic, cultural, and societal constructs of “race,” across species *homo sapiens*. All learners, therefore, have the physiological potential to access perpetual learning capacity via neuroplasticity and neurogenesis. These scientific findings consequently diametrically oppose the belief that academic potential is correlated with constructs of “race,” or “gender,” as perpetual learning capacity is embedded in *human* physiology.

Neurological Impact of Stereotype Threat

In addition to highlighting neurological mechanisms behind perpetual learning capacity, neuroscience holds several keys to unlocking the neurological impact of ST. Although numerous sociological and psychological studies have measured learning disengagement and lower achievement due to ST, technologies used in neuroscience research unveil *how* this occurs. Functional magnetic resonance imaging (fMRI) scans from lab experiments demonstrate how cognitive energy (measured by blood flow to the brain) changes when ST is induced (Wraga et al., 2007). In several studies neuroscientists found that when participants were primed with a negative stereotype (during a math task) about their group (e.g., females doing poorly in mathematics), blood flow (correlated with cognitive energy) becomes rerouted from the prefrontal cortex (math problem-solving areas of the brain) towards the limbic systems or the brain’s emotional control centers (Derks et al., 2008). The process of how this occurs has been documented across several studies. During one particular study, control group participants were asked to solve a math problem, while those in the treatment group were confronted with a negative stereotype and then asked to do the same math task. Those not confronted with the negative stereotype saw activation in the usual regions associated with math learning and performance, including the inferior prefrontal cortex and left inferior parietal cortex, and bilateral angular gyrus (Derks et al., 2008). Those participants primed with their group's supposed inferiority in mathematics did not experience this enhanced activation in the typical math-related brain regions. Instead, activation increased in the regions associated with emotional self-regulation, including the ventral anterior cingulate cortex. Similar studies demonstrate that when ST is primed, student working memory, retrieval, and activation of knowledge are hindered due to the anxiety triggered by ST.

These findings are not uncommon in the neuroscientific field. Such outcomes ratify and clarify decades of sociological observations whereby "disadvantaged learners" were unable to perform at the same level as their "advantaged peers." The implication here, albeit simple, is profound. As learners perceive their ability, neurological mechanisms calibrate accordingly, shifting neural activity towards either facilitating learning or managing anxiety associated with ST. Therefore, as researchers postulated, the achievement gap may be partly informed by a "treatment gap," or rather how populations are prompted, which then contributes to differential outcomes.

Neuroplasticity and neurogenesis have yet to be positioned toward disrupting the correlation of race or gender with academic capacity in ST literature. Furthermore, there is a dearth of research underscoring these capacities as human traits spanning all social constructs of "race." Nor has the discovery of the rerouting of neural activity for both "advantaged" and "disadvantaged" learners been included in mainstream professional development for K-16 teachers. Nor do mainstream teacher training programs illuminate how ST operates, with an urgency to inform interventions on the ground. Consequently, this lack of neuroscience application towards combating ST requires an investigation around what current neuroscience-based pedagogies most closely address these gaps.

Countering ST: Approaches and Structures Applying Neuroscience

No studies have developed neuroscience-based pedagogical frameworks to overtly disrupt the false correlation of race or gender with math ability. However, a few frameworks *integrate* neuroscience findings to facilitate *cognitive engagement,* a known construct impacted by ST.

Neuroscience knowledge undergirds the instructional technique: "chunk, chew, check and change," as a way to merge instructional pedagogy and neuroscientific knowledge to bolster engagement (Nickelsen & Dickson, 2019). Teachers apply this framework in four stages. In the "chunk," content is broken into meaningful, smaller, similar, and interrelated sections, helping the brain perceive each section as a coherent group of ideas, making content more comprehensible. For "chew," teachers give students time to practice or deeply explore the topic. Students can process through such activities as practice, reading, solving, or collaborative work, among other activities. This gives the brain time and opportunity to process. Next, teachers "check," their learner's understanding throughout the chew process or as the chew culminates. Students subsequently can modify their approaches based on errors or successes. As formative assessment, teachers offer actionable feedback about where the students are concerning the learning target. Students can also check their learning and self-assess/self-monitor. The cycle culminates with the teacher making a "change," to instruction, including student grouping, pacing, or assignment rigor based on student learning.

Countering ST: Pedagogies Applying Neuroscience

No pedagogies position neuroscientific findings (neuroplasticity and neurogenesis) as a frame to disrupt the false correlation of race or gender and math ability or combine/integrate separate anti-ST strategies through this lens. The most closely related subsequent frameworks integrate neuroscience findings by helping students view their skills as malleable or addressing the intersection of race and culture, two constructs relevant to ST.

Growth Mindset is a well-known theory grounded in the belief that intelligence and learning can be improved and developed. Created by psychologist Carol Dweck, this framework stems from studies observing student attitudes towards failure, finding that those who were more resilient and not so disheartened by academic setbacks found greater success. According to her research, student attitudes toward failure were statistically significant indicators of academic success. Dweck coined the terms “growth mindset” and “fixed mindset,” suggesting that learners with a growth mindset persevered through obstacles while those with a fixed mindset did not. This framework proposes that mindsets are malleable and that teachers should facilitate the development of habits that will sustain a growth mindset.

This paradigm applies evidence of neuroplasticity to establish a scientific basis for a growth mindset. However, while *Growth Mindset* references the capacity for learners to gain new skills via neuroplasticity, it does not position neuroplasticity or neurogenesis as a lens to challenge assumptions such as *correlating race or gender with academic potential* that undergird ST activation. Nor does it examine *how* to apply neuroscientific findings to combat ST in a mathematics classroom.

Neuroscience and Culturally Relevant Pedagogy

In the early 1990s, Dr. Gloria Ladson-Billings, outlined CRP as a framework driven to empower students to maintain cultural integrity while succeeding academically. CRP permeates the literature as a framework that is “culturally appropriate” (Au & Jordan, 1981), “culturally congruent” (Mohatt & Erickson, 1981), “culturally responsive” (Cazden & Leggett, 1981; Lee, 1998; Mohatt & Erickson, 1981; Raphael et al., 2009), and “culturally compatible” (Jordan, 1985; Vogt et al., 1987). CRP applies empirical and theoretical lenses helpful in reducing "opportunity gaps" to environments that are responsive to increasingly diverse student populations by applying cultural synchronization (Irvine, 1990; Monroe & Obidah, 2004), cultural congruence (Au & Kawakami, 1994; Day-Vines & Day-Hairston, 2005), "cultural solidarity" (Ladson-Billings, 2001, p. 81), cultural connectedness (Irizarry, 2007), and, most recently, culturally sustaining pedagogy (Paris, 2012; Paris & Alim, 2014, 2017). One of the goals of CRP is to assist educators in accessing cultural capital in classrooms (Ladson-Billings, 1994). In doing so, teachers can see culture as an asset rather than a hindrance to communicating learning to students.

Researchers have made connections between Culturally Responsive Pedagogy (CRP) and findings in the neuroscience field. Practices within CRP have been connected to processes that reduce anxiety, as shown in neuroscience. CRP researchers theorize the neurological implications CRP has on the brain's capacity to increase cognition, as stress and anxiety reduction are known precursors to increased cognition (Hammond, 2021). Researchers have made connections between CRP and the brain's physical structures, emphasizing how creating learning environments sensitive to culture helps comfort learners, thus preventing the mind from activating the reptilian brain known for its fight-or-flight response. In addition, emphasizing culture supports the acquisition of positive learning experiences, an element positively theorized to support learning through recording positive learning experiences in the limbic part of the brain, which assesses perceived threats to an environment (Zull, 2004).

To increase cognition, along with the retrieval and facts from the prefrontal cortex, researchers recommend that CRP practitioners become aware of the brain's various structures and connect how supporting culture helps the brain feel safe and secure before learning.

Culturally supportive environments may help alleviate the brain's danger defense mechanism (also known as "neuroception") or the unconscious safety-threat detection system (Hammond, 2021). CRP emphasizes cultural inclusion to promote psychological safety in the classroom, a theme central to the HPL framework.

An emerging framework called "Liberation Education," extends CRP's benefits using neuroscientific references (Hammond, 2021). Liberation Education encourages awareness of learning sciences when applying CRP to create learners that actively improve their cognition—practitioners of LE and CRP are encouraged to learn about how the brain operates. Examples include creating lessons that stimulate curiosity rather than simple compliance with a task, an element linked with increased activity of neurotransmitters—namely dopamine—to increase cognition and interest (Hammond, 2021).

Although LE's extension of CRP into the neuroscience field connects culture, race, and cognition (constructs *related* to ST), it does not use neuroscientific evidence to dismantle presuppositions correlating race or gender with perceived academic potential. Nor does it provide teacher training on how stereotype threat operates or how to counter its effects using neuroscientific findings. Last, these pedagogies do not position neuroscientific findings in a real-world application framework to combat ST in a mathematics classroom.

Growth Mindset, CRP, and LE extend the belief systems of educators to become aware of the intersectionality of race, culture, and the capacity for the mind to grow, as well as how the brain responds to cultural sensitivity using neuroscience. Race, culture, and beliefs are central constructs relevant to ST. Consequently, however, two gaps in the literature emerge: (a) pedagogical attempts do not overtly position neuroscientific findings (neuroplasticity and neurogenesis) to disconnect the correlation of race or gender with academic potential in math settings; (b) *mathematical instructional practices* are not aligned using neuroscience as a frame to disrupt this underlying construct of ST (correlating race or gender with math potential) to increase self-perception of math potential, engagement, and achievement.

CHAPTER THREE: METHODOLOGY

This research addresses the self-perceptions and engagement of math students susceptible to Stereotype Threat (ST) by convening a cadre of math educators to implement Anti-Stereotype Threat Pedagogy (ASTP), a novel intervention. Although historical attempts to address ST are well documented, this intervention is unique, as it applies a neuroscience-framed approach to counter the correlation of race or gender with math potential, a fundamental construct required for ST activation in math learning contexts. ST disrupts learning and performance by negatively affecting student self-perception in mathematics and classroom engagement. This study hypothesizes that disrupting ST's core construct (correlation of race or gender with math potential) may alleviate potentially strained self-perceptions of math potential for diverse learners and increase engagement and achievement. Consequently, three research questions guide this study.

Research Questions

This study sought to answer three research questions.

1. What evidence (if any) exists of changes in student self-perception of math potential and engagement?
    a. According to students' self-reports in a survey;
    b. According to students in focus groups and
    c. According to teacher observations and reports.
2. What are teachers' experiences and reflections regarding implementing ASTP?
3. How did the implementation influence teacher perceptions and beliefs around math teaching and learning for diverse learners?

Research Design and Rationale

I utilized a mixed methods design integrating quantitative and qualitative data to provide a more comprehensive understanding of the ASTP implementation experience and potential impacts of the intervention. According to Creswell and Plano Clark (2011), several features define a well-designed mixed methods study. These include (a) collecting and analyzing both quantitative (closed-ended) and qualitative (open-ended) data; (b) applying robust procedures in collecting and analyzing data according to each method, such as ensuring the appropriate sample size for quantitative and qualitative analysis; (c) integrating data during collection, analysis, or discussion; (d) applying qualitative and quantitative procedures simultaneously or sequentially, with the same sample or with different samples; and (e) framing the procedures within a theoretical model.

My design focuses on collecting preliminary evidence of the effectiveness or impact of a treatment, as well as exploring the participants' experience to deepen the analysis of factors accounting for changes in quantitative data (Creswell & Plano Clark, 2011). This methodology requires adding qualitative data on participants' personal experiences to complement the pre-and post-test quantitative comparison (Creswell & Plano Clark, 2011). In this way, the qualitative data helps uncover reasons for differences in quantitative pre-post-survey responses. This directly ties into the motive of the ASTP intervention, whereby changes in self-perception and engagement measured quantitatively are clarified by gaining the perspectives of those involved in the experiment—teachers and students qualitatively.

This design also allows for the collection of evidence and feedback to revise or refine the treatment (Creswell & Plano Clark, 2011). This is another point of intersection with the goals of this study. Qualitative data from teacher interviews exploring the implementation experience (research question two) may provide a basis for ASTP improvement in future iterations. Additionally, since research question one involves potential changes in student self-perception and engagement from multiple sources, collecting known measures of these constructs and assessing changes in these variables is helpful. To that end, students participated in pre- and post-intervention surveys measuring student self-perception of math potential and engagement in three dimensions (affective, behavioral, and cognitive). Complimentary to the survey, qualitative data on these changes from the instructor's perspective were collected during instructor interviews. Additionally, student focus groups explored *how* ASTP may have (if at all) altered learners' perceptions of math potential and engagement while teacher interviews explored how this experience impacted educators' beliefs about the math teaching and learning of diverse students.

Research Site

Several criteria must be met to ensure site appropriateness. For starters, ASTP requires populations susceptible to stereotype threat including Latino, Black and female populations. Additionally, this study requires students commonly not susceptible to ST in math contexts, including White, Asian and male populations, for the purposes of cooperative group context (one of the ASTP strategies). In other words, the site must have a diverse population containing historically advantaged and disadvantaged students. Moreover, the school must be typical of high schools in urban or rural districts that serve racially diverse and low socioeconomic status (SES) populations. Next, students must demonstrate a historical challenge to meeting mathematical benchmarks on standardized tests and schoolwide learning outcomes. Last, school administration and teachers must be open to exploring ways to increase mathematics outcomes for their students.

One site that meets this study's criteria is Josiah High School (JHS) in the Josiah Unified School District. JHS has an enrollment of about 1,671 students. It is a Title I designated school, with about 69.7% of students eligible for free or reduced lunch. The school's racial makeup is about 88.51% Latino, 0.42% Filipino, 0.6% Asian, 1.26% Black/African-American, 0.12% Native Hawaiian/Other Pacific Islander, 8.02% White, 0.42% two or more, 0.66% declined to state. The site meets study criteria: (a) the school is typical of many high schools in urban districts with the presence of diverse populations in addition to a high percentage of low-SES students; (b) the school's majority of students (an average of 60.74%) taking the Smarter Balanced Assessment Consortium (SBAC) score below standard in mathematics; and (c) site administration and teachers are interested in exploring ways to increase mathematics performance.

The ASTP Intervention

Participants

Participants included teachers and their students. The demographics and characteristics of teachers, student survey participants, and students in focus groups follow.

Teacher Demographics

The sample consisted of four female teachers, each having one participating class. All four teachers completed the post-study interview. Half of the sample consisted of White teachers (n = 2, 50%), while the other half comprised of Asian (n = 1, 25%) and Latina/Hispanic (n = 1, 25%) teachers. The range of teaching experience varied from less than one year to a maximum of 24.5 years. All teachers are credentialed in mathematics (n = 4, 100%). Frequencies and percentages for teacher demographic variables are presented in Table 3.1.

Table 3.1

Frequency Table for Teacher Demographics

Variable	*n*	%
Gender		
Female	4	100
Ethnicity		
White	2	50
Asian	1	25
Latino/Latina/Hispanic	1	25
Years of experience		
0–10	2	50
11–20	1	25
21–30	1	25
Mathematics course taught		
Integrated Math I	1	25
Integrated Math II	2	50
Integrated Math III	1	25
Credentialed in Mathematics	4	100

Student Survey Demographics

A pre-post-student survey captured demographics and changes around self-perception and engagement. The survey was administered on Qualtrics to 100 students. Seventy-five students from the four classes completed the pre-test and post-test questionnaires. What follows are descriptions of these students.

The sample consisted of 75 participants in total, 43 females (57.3%), 30 males (40.0%), one non-binary participant (1.3%), and one participant who indicated “other” gender (1.3%). A majority of the sample consisted of Latino/Latina/Hispanic (n = 66, 88.0%). The sample consisted of ninth graders (n = 17, 22.7%), tenth graders (n = 31, 41.3%), eleventh graders (n =

20, 26.7%), and twelfth graders (*n* = 7, 9.3%). Frequencies and percentages for the student demographic variables are presented in Table 3.2.

Table 3.2

Frequency Table for Student Survey Demographics

Variable	*n*	%
Gender		
Female	43	57.3
Male	30	40.0
Nonbinary	1	1.3
Other	1	1.3
Ethnicity		
Asian	1	1.3
Black	1	1.3
Latino/Latina/Hispanic	66	88.0
White	1	1.3
Multiracial/multiethnic	2	2.7
Other	1	1.3
Decline to state	1	1.3
Grade		
Grade 9	17	22.7
Grade 10	31	41.3
Grade 11	20	26.7
Grade 12	7	9.3
Class Student Counts		
Class 1	26	34.7
Class 2	13	17.3
Class 3	17	22.7
Class 4	19	25.3

Student Demographics: Focus Group A

The sample consisted of eight students. Students were randomly chosen from survey respondents, demonstrating increased self-perception and engagement. Each of the four classes was represented by two students (*n* = 2, 25%). Focus group A consisted of four females (50.0%)

and four males (50.0%). This group contained six Latino/Latina/Hispanic students (*n* = 6, 75.0%), one White student (*n* = 1, 12.5%), and one Black student (*n* = 1, 12.5%). The sample comprised of 9th graders (*n* = 3, 37.5%), 10th graders (*n* = 2, 25.0%), 11th graders (*n* = 1, 12.5%), and 12th graders (*n* = 2, 25.0%). Frequencies and percentages for the student demographic and characteristic variables are presented in Table 3.3.

Table 3.3

Frequency Table for Focus Group A Demographics and Characteristics

Variable	*n*	%
Gender		
Female	4	50
Male	4	50
Ethnicity		
Black	1	12.5
Latino/Latina/Hispanic	6	75
White	1	12.5
Grade		
Grade 9	3	37.5
Grade 10	2	25
Grade 11	1	12.5
Grade 12	2	25
Mathematics Class Enrollment		
Integrated Math I	3	37.5
Integrated Math II	3	37.7
Integrated Math III	2	25
Class		
Class 1	2	25
Class 2	2	25
Class 3	2	25
Class 4	2	25

Focus Group A: Student Pre-Post Self-Perceptions and Demographics

Below are the baseline and post-perceptions for students in focus group A. Learners' gender and race, according to the survey, are also included.

Table 3.4

Focus Group A: Self-Perceptions of Math Potential (Pre-Post) and Demographics

Pseudonym	Pre-Perception	Post-Perception	Gender	Race
Olivia	Limited	Unlimited	Female	Latina
Tiffany	Average	Unlimited	Female	Latina
Trinity	Average	Growth	Female	Latina
Samantha	Limited	Unlimited	Female	White
Fernando	Growth	Growth	Male	Latino
Stephen	Limited	Growth	Male	Black
Sean	Limited	Growth	Male	Latino
Edwin	Limited	Growth	Male	Latino

Student Demographics: Focus Group B

The sample consisted of eight students. In contrast to student focus Group A, Focus Group B students were randomly chosen from survey responses using an online random number selector. All four classes were each represented by two students (*n* = 2, 25%). Focus group B consisted of four females (50.0%) and four males (50.0%). This group contained seven Latino/Latina/Hispanic students (*n* = 6, 75.0%) and one multiracial/multiethnic student (*n* = 1, 12.5%). The sample comprised of 9th graders (*n* = 2, 37.5%), 10th graders (*n* = 4, 50%), and 11th graders (*n* = 2, 37.5%). Frequencies and percentages for the student demographic and characteristic variables are presented in Table 3.5.

Table 3.5

Frequency Table for Focus Group B Demographics and Characteristics

Variable	*n*	%
Gender		
Female	4	50
Male	4	50
Ethnicity		
Latino/Latina/Hispanic	7	87.5
Multiracial/multiethnic	1	12.5
Grade		
Grade 9	2	25
Grade 10	4	50
Grade 11	2	25
Grade 12	0	0
Mathematics subject		
Integrated Math I	2	25
Integrated Math II	4	50
Integrated Math III	2	25
Class		
Class 1	2	25
Class 2	2	25
Class 3	2	25
Class 4	2	25

Focus Group B: Student Pre-Post Self-Perceptions and Demographics

Below are the baseline and post perceptions for students in focus group B. Learners' self-identified gender and race, according to the survey, are also included.

Table 3.6

Focus Group B: Self-Perceptions of Math Potential (Pre-Post) and Demographics

Pseudonym	Pre-Perception	Post-Perception	Gender	Race
David	Average	Limited	Male	Latino
Anita	Average	Growth	Female	Latina
Thea	Average	Growth	Female	Latina
Phil	Unlimited	Unlimited	Male	Latino
Scarlet	Unlimited	Limited	Female	Latina
Sandra	Average	Growth	Female	Latina/White
Silverio	Limited	Growth	Male	Latino
Ernie	Unlimited	Unlimited	Male	Latino

Site Access

Administration and district leaders approved this research. Site administration and teachers within the math department supported the prospect of this research and were enthusiastic about their participation.

Anti-Stereotype Threat Pedagogy (ASTP) Intervention Content

Structure Overview

The following sections outline the structure and content of the ASTP intervention and its accompanying professional development. The ASTP intervention with learners contains three main components: (a) five-minute mini lessons referred to as *modules*, (b) lesson structures supporting cognitive engagement, and (c) a specific lesson cycle sequence. An overview of the interventions' modules follows, along with a detailing of the ASTP lesson cycle and structure. After that, I similarly explain the professional development schedule and content.

Student Modules

ASTP has six student modules corresponding to the six weeks of the study. Each module contains (a) 5-minute slide decks (presentations) with supplemental videos and (b) consumables (handouts) for students and a digital reflection. Modules sequentially build on the concepts shown in previous modules. The first module introduces the interventions neuroscience frame as neuroplasticity and neurogenesis serve as the cornerstone of evidence in subsequent modules around perpetual learning capacity. The second module introduces self-affirmations. In this module, teachers guide learners toward reflecting on the neuroscience-framed self-affirmations listed in this module. Instructors can do a call and response, choral read, or have students read the self-affirmation independently. Students document how many times they use a self-affirmation using supplemental materials.

The next module, *Role Models in Science Technology Engineering and Mathematics* (STEM), features pioneering NASA astronauts Dr. Mae Jemison and Jose Hernandez. This module contains video interviews with role models and provides students time to reflect on the accomplishments of these role models on either handouts or a digital Google form. The following module, *Shattering Math Myths*, applies previous neuroscience and references role models to distinguish evidence-based findings around math learning from false assertions common in math learning contexts. Such assertions that are addressed include the falsities around math as an inborn or innate skill, perceived limits in math learning, and others. In the *Error Reflect Redirect* module, students are exposed to fMRI and CT scans of the brain along with diagrams showing increases in electrical activity for learners with a growth mindset when reflecting on errors as opposed to learners with a deficit or limited mindset when committing such mistakes. This module includes handouts structuring guided practice with neuroscience-framed self-affirmations, whereby learners circle affirmations prior to an error analysis. Students must attempt the same type of problem twice to increase the opportunity for accuracy within this procedure. In the final module, students work collaboratively in pairs (think pair share) to discuss how the intervention (if at all) was helpful (or not) toward increasing their perception of math potential and engagement. The modules were presented to students three days per week (Mondays, Wednesdays, and Fridays).

The following summarizes each week's module and focus.

Week 1: *Neuroscience and Math Potential*

Week 2: *Self-Affirmation*

Week 3: *Role Models in Science Technology Engineering and Mathematics (STEM)*

Week 4: *Shattering Math Myths*

Week 5: *Error Reflect and Redirect*

Week 6: *Student-Centered Instruction*

Lesson Structures

ASTP includes neuroscience-framed and anti-ST, strategies designed to increase engagement. ASTP's core structures include group cooperative context (GCC), a uniquely parameterized Chunk, Chew, Check (CCC) methodology, as well as modified focused learning targets (FLTs). Cooperative group context intentionally optimizes racial or gender diversity in a group as a means for learners to appreciate and build upon each other's strengths as they solve. In this case, in the think pair share, teachers ensured pairs were gender and racially diverse as much as possible. Figure 3.1 outlines these elements. On the left is the given focus, corresponding to each week shown at the top. The three structures are permanent and run concurrently with each week's foci shown in the three boxes below each week.

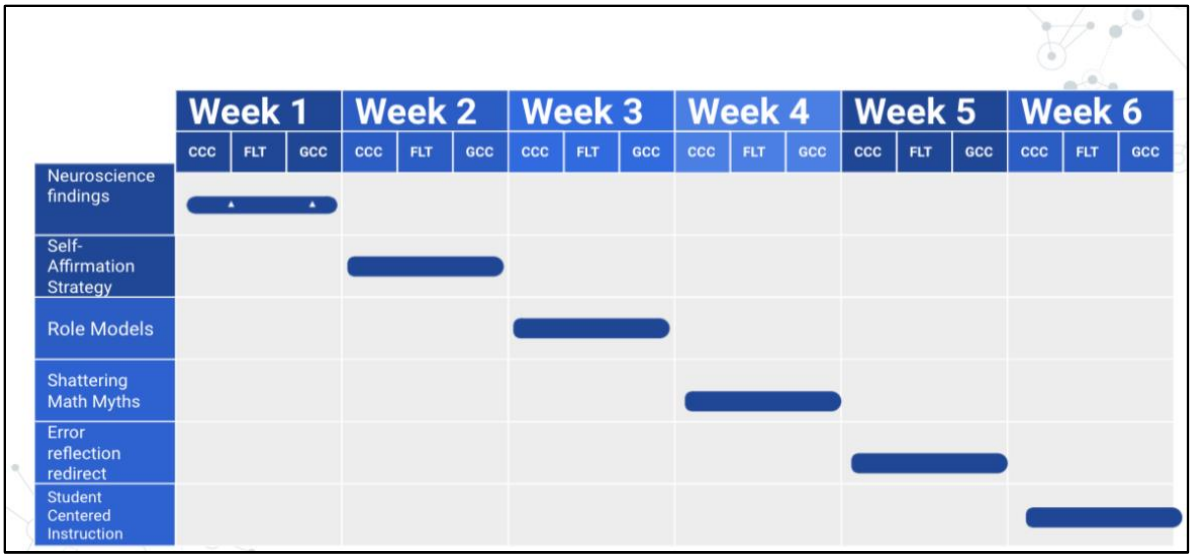

Figure 3.1. Structure and Sequence of ASTP Intervention.

ASTP Lesson Cycle

Modules and FLTs

ASTP lesson cycles adhere to a specific sequence. Three of five weekly lessons begin with the ASTP module and activity (Monday, Wednesday, and Friday). Each module is designed to take five minutes. Teachers then open their lessons and content using the ASTP-modified focused learning target (FLT) or learning objective. The FLT has three sections commonly used by schools: (a) level of cognition (per Bloom's Taxonomy); (b) content (math chunk to be covered with students); (c) proving behavior (specific math steps or concept); and, unique here is part (d) ASTP-specific concept/strategy/focus for the week. This transparency of connecting anti-ST modules to lessons is a novel modification to FLTs introduced here. In other words, while FLTs are a common practice, the overt communication of the anti-ST strategy, focus or module is a distinguishing feature unique to ASTP methodology.

Direct Interactive Instruction--Modified Methodology

After a brief warm-up not exceeding five minutes of reviewing a previous lesson's content or introducing an ASTP module, teachers lead students in direct interactive instruction using the "chunk, chew check," (CCC) method. Although CCC is not novel and comes from research, its adaptation is. ASTP parameterizes or confines the chunk or amount of content covered per lesson; in particular, learning objectives must contain between four to seven procedural steps in conjunction with no more than two mathematical concepts and must be contained within a lecture not to exceed 15 minutes. These parameters optimize cognition based on the researchers' experience and expertise as a math teacher. ASTP instructors provide the mathematical steps or procedures, concepts, and math examples for the lessons "chunk," accordingly. Students process or "chew," information during the lecture by listening, asking questions, taking notes, and answering questions from the instructor to "check," their understanding.

Guided Practice—Modified Methodology

Teachers then release students to a timed (three to five-minute) guided practice with at least two problems. This is where students must engage in practice problems identical to the "chunk," shown in direct instruction, with only minor changes to establish a new problem. Students process or solve, thereby "chewing," the chunk provided in direct instruction. The instructor must resist assisting or doing the work for students or interrupting this cognitive exercise. The instructor must also use a visual timer so students and instructors can self-monitor lesson cycle activity completion. At the end of the five minutes, using equity cards (or a similarly effective strategy ensuring randomization), instructors call on and "check" students' mathematical reasoning and learning. There are two rounds of guided practice before students work on the same “chunk,” of material during collaborative or think pair share work. Students complete a reflection at the end of each round during guided practice and self-score their work as they reflect. On a four-point scale, students learn to grade their work, reflect on how to improve their accuracy and review errors in procedural or conceptual understanding.

Think Pair Share—Modified Methodology

In the student collaborative element, students are partnered using the group cooperative context (GCC). In this collaboration, students solve and then take turns sharing their mathematical reasoning and establish if (a) they agreed and came to the same conclusion with the same reasoning or (b) they disagreed, in which case they must conduct an error analysis. Instructors then close this section with a randomized “check” for understanding. Students use metacognition to evaluate their understanding as well as that of their peers by agreeing or disagreeing with their partner’s claim using evidence from the mathematical solving as shown during the direct instruction portion of the lesson.

Exit Slips with Reflection

A common practice in K-12 education is to close a lesson with a formative assessment called an Exit Slip. This is where the unaided student demonstrates their proof of learning by solving one to two math problems aligned with the lesson’s objective. What is novel here, however, is the timing of the activity and reflection, as students must complete this activity within four to six minutes and reflect on how the ASTP strategies impacted their learning (if at all). Simultaneously, teachers reflect on their learners’ progress via exit slip data and then use this information to inform their next FLT. Below is a graphic outlining the sequence of procedures.

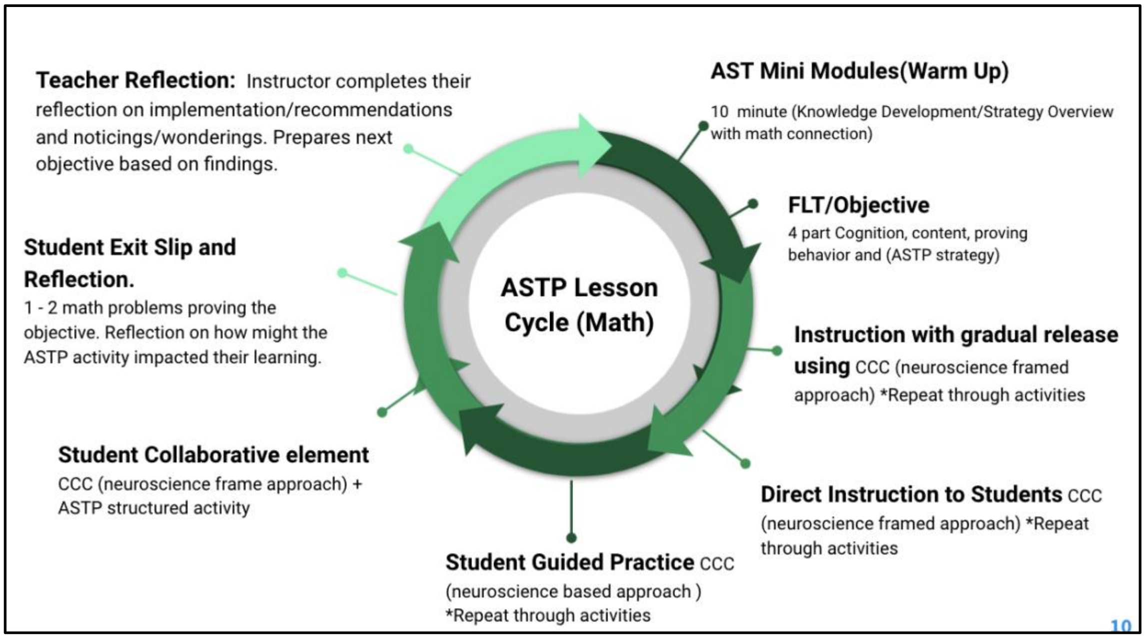

Figure 3.2. ASTP Lesson Cycle (Math).

ASTP Professional Development

Overview

The ASTP teacher training is an interactive process consisting of six training modules (not to be confused with the student modules). I led the interactive teacher training over two days, each day covering three of the six modules, with weekly follow-up support to help teachers troubleshoot challenges or issues. During professional development modules (PDM), teachers rotated among the activities: reflection, periodic turn and talk, sharing responses with the whole group, questions to check for understanding, and watching informative videos on stereotype threat and neuroscience research. For example, module one began with a 10-minute presentation on ST and how it operates based on research. Next, teachers discussed what prevailing stereotypes around gender or race they or their students may have experienced using a Jamboard reflection. Teachers then presented their findings and discussed the implications of these stereotypes on students and their learning.

Teachers continued in such a cycle of training with exposure/presentation, reflection, turn and talk, and sharing aloud on the topics presented. In module two, teachers explored neuroscience-related topics relevant to countering ST's effects. Teachers watched a brief video on neuroplasticity, followed by a Peardeck activity where teachers shared thoughts on how these findings challenge the central constructs of ST. Closing this activity, a presentation on Google Slides outlined empirical evidence supporting perpetual learning capacity through neuroplasticity, neurogenesis, and the importance of engagement in such neurological mechanisms.

In module three, teachers watched and analyzed a video summarizing the neurological impact of ST. I supplemented this video with diagrams showing how cognitive energy is rerouted during ST activation. Teachers then used a Padlet to reflect on these neurological changes and their implications on math students, followed by a group discussion around their findings and reflections. In modules four and five, teachers participated in a Peardeck activity asking for short-answer responses to check their understanding of ASTP structures and strategies, most notably "chunk chew check," and the modified lesson cycle. Teachers reviewed an exemplar lesson plan and planned one lesson cycle by filling out an online template. Teachers then discussed and critiqued their colleagues' lesson plans in pairs and shared their results with the whole group. In the final module, module six, teachers worked independently to complete their first three weeks of modified FLTs while focusing on merging the ASTP activity schedule with their curriculum map or pacing plan. Teachers then shared their plans with the entire group.

Ongoing Support

Teachers were provided a physical handbook and online access (Google Classroom) to teacher training modules and materials shared during professional development. Provided in the handbook were copies of teacher training modules with activity handouts for students to complete.

Data Collection Methods

Pre-Post Student Survey

Self-Perception

A pre-post student survey explored patterns of change in self-perception and engagement. This survey was developed uniquely for this study and contains two sections. In the first part, students rate their self-perception of math potential on a five-point Likert scale from five options (5-unlimited potential, 4-growth potential, 3-average potential, 2-limited potential, 1-no potential). The survey was field-tested with over 90 students prior to administration. Students predominantly found the survey to be clear and intuitively navigated the rating system.

Engagement

In the second part of the survey, students self-assessed their engagement using a five-point Likert scale. Because the nature of each engagement subscale differs, the Likert scale, in summary, ranges from 1-non engagement to 5-full engagement. The five-minute class survey was administered to all students in each of the four classes online via Qualtrics one day before the intervention and again on the final day of the intervention. Rather than collect names, to support anonymity, students listed their student ID and email instead of their names. These data were later referenced for student selection into the focus groups. For the pre-post student survey and Likert scales, see Appendix A.

Teacher Post-Intervention Interview Protocol

Four separate teacher interviews were conducted post-intervention. I conducted the interviews using a protocol of 19 questions, separated into subsections according to the data required for each research question. Specifically, the first section probed teachers' implementation experience. I then asked questions regarding observations around student self-perception and engagement in the second section. The final section of the interview protocol asked teachers to share how this experience impacted their beliefs about teaching and learning for diverse students. For the teacher post-intervention interview protocol, see Appendix B.

Focus Groups and Teacher Interview Logistics

Two focus groups of students were created, Focus Group A and Focus Group B. Upon reviewing survey data, students demonstrating the most changes in self-perception and engagement from all four classes were pooled for randomized selection into Focus Group A. An online random number generator was used to select numbers assigned to students on a spreadsheet. Focus Group B was randomly selected without regard to their self-perception or engagement change. Similarly, they were randomly selected from the entire pool of students from all four classes using an online number generator. The reason for this process is two-fold: (a) *Focus Group A* included students who can explain what attributed to their change in each category, ensuring data is connected to the research questions; (b) *Focus Group B* served as a randomized cross section of students, providing a general overview of experiences, including perception and engagement, stagnation and or decrease. In doing so comparisons can be made between the average experience from random students and the group that contained the most changes. For the focus group interview protocol, see Appendix C.

Each focus group comprised eight students (two from each of the four participating classes). I asked students how ASTP impacted their self-perception of math potential and their engagement (affective, behavioral, and cognitive). The focus group protocol was divided into subsections corresponding to the research questions.

Two digital recording devices were used to capture all audio input from the in-person focus group. One was the voice memos application on the iPhone, and the second was recorded via Zoom. The focus groups were in person; Zoom recorded and transcribed the data. A second transcription service, Otter Ai, was used as a second source (redundancy). Focus groups were held in a private study hall room in one corner of the school's library, which was reserved to keep the focus groups confidential and not accessible to the rest of the library.

All four teachers participated in four separate teacher interviews. Each interview lasted approximately one hour and 30 minutes. The teacher interviews were exclusively on Zoom, and the transcription service Otter Ai transcribed the interviews.

Data Analysis

Quantitative Analysis

Pre- and post-survey intervention results were analyzed using descriptive statistics and statistical tests. Descriptive statistics included measures of frequency (count, percent, and frequency), measures of central tendency (mean, median, and mode), and dispersion of variation (range, variation, and standard deviation). The analyses explored patterns within student responses associated with implementing ASTP (independent variable). These were assessed across the two time points (pre- and post-exposure to ASTP) concerning measures of self-perception of math potential and engagement (dependent variables). Measures of frequency of responses were of particular interest to measure changes in the dependent variables.

Paired *t*-tests were used to determine the statistical significance of self-perception, affective, behavioral, and cognitive engagement changes. I also conducted an Exploratory Factor Analysis (EFA) to explore the underlying constructs of the latent variables of self-perception, affective, behavioral, and cognitive engagement. Last, Cohen's *d* or standardized mean difference was calculated to obtain the effect size of the shifts.

Qualitative Analysis

Teacher interviews and student focus group transcripts were analyzed using thematic analysis. Thematic analysis is a method for analyzing qualitative data by identifying, interpreting, and reporting repeated patterns (Braun & Clarke, 2006). This method is recommended when extracting understanding from a set of experiences, thoughts, or behaviors across a data set and not those of a single individual (Braun & Clarke, 2012). Engaging in thematic analysis requires several steps. These include (a) data familiarization, (b) generating initial codes, (c) searching for themes, (d) reviewing themes, (e) defining and naming themes, and (f) connecting narrative description (findings) to the research questions. In the familiarization phase, researchers repeatedly and actively read through the data, which may include focus groups or interviews (Braun & Clarke, 2006). Generating initial codes is the first analytical step. At this stage, researchers begin to take notes on items of interest or questions, make connections between data items, and annotate preliminary ideas. In coding development, (stage two) researchers ensure that codes are the most essential segment or element of raw data that can be assessed meaningfully. Codes can be generated inductively or deductively, guided by specific theories or theoretical frameworks.

The third stage entails an examination of the codes and collected data extracts to create themes. The researcher constructs themes via analysis, combining, comparing, and visually mapping how codes relate. At this stage, deductive analysis using predefined theories can inform the theme's development in aspects of data for specific questions of interest. Stage four requires two steps in reviewing themes. The first is to ensure the appropriateness of codes within a theme, while the second is to ensure that themes connect meaningfully within a given data set when reviewing the thematic map. In steps five and six, researchers create a definition of the narrative description, connect them to the study (research question), and then describe the findings respectively.

Several aspects of thematic analysis connect to the goals of this study. For instance, large data sets were collected from the four teacher interviews and two student focus groups. This study aimed not to look for individual perspectives but to gain insight into the overall experiences of students and teachers relating to student self-perception and engagement. To that end, the intersecting frameworks of HPL and stereotype threat informed how codes were created and summarized significant trends associated with the data. Anticipating these trends, four larger categories emerged, with one category that was further distilled and analyzed for trends contained therein. These included (a) increased change in self-perception and engagement associated with ASTP; (b) neutral or no change in such variables; (c) lower engagement or reduced self-perception of capacity associated with ASTP; and (d) other results (to be further analyzed for trends). These codes, among many others, were applied to teacher interviews and focus groups, increasing the viability of comparing findings (Creswell & Plano Clark, 2011). A deductive-inductive approach was applied toward focus group data, while an inductive-deductive approach was used with teacher interview data.

Triangulation

Triangulation refers to using multiple methods or data sources in research to develop a comprehensive understanding of phenomena (Patton, 1999). Furthermore, triangulation assesses the validity of findings by converging information from different data sources (Creswell & Plano Clark, 2011). Following the collection and analysis of the (a) pre-post survey, (b) teacher interviews, and (c) focus groups, these data findings were then triangulated. In this particular study, datasets were compared for complementarity, convergence, and divergence.

Specifically, in interpreting findings, I assessed data in the following ways. Findings indicative of convergence would demonstrate substantial overlap and accuracy between the data sets collected (Nightingale, 2020). Additionally, data was assessed for complementarity findings, which would be those findings that create a richer picture of the research results, allowing the results from different methods to inform each other. Next, findings were assessed for divergence. These would be data that show discordance or "conflicting evidence between the qualitative findings and the quantitative results" (Patton, 2002; Pluye et al., 2009). Divergence can indicate that the methods or the results are flawed or be treated as new data and analyzed for new insights. Therefore, I also coded data categorically according to complementary, convergent, or divergent elements. Additionally, the guiding frameworks used to explore results were the HPL and ST frameworks. The HPL and ST frames were applied throughout the analysis. I did this by reviewing responses for elements related, intersecting, or oppositional to "preconceptions of self-perception and learning in math," as well as "psychological safety," among other elements.

Role Management

I underscored my role at Josiah High School as a graduate student/researcher with UCLA. Moreover, students understood that they had the right not to participate or opt out of the process at any time, given that I was not grading or evaluating them. Furthermore, I contacted parents/guardians per IRB and explained this element to them.

I am not in a supervisory role with the research participants (teachers or students). I communicated that as a UCLA graduate student, I ensured all ethical standards were followed. I also asked parents, teachers, students, and administrators to share any final comments, questions, or concerns regarding the purpose and structure of the study. Teachers were informed that I would not communicate with administrators or other teachers regarding anything the teachers say or do during our sessions. I explained to students their responses were also confidential.

Ethical Issues

Similar studies on the impact of ST have been conducted at the Middle and High School levels; therefore, ethical issues remained limited. The study followed all Institutional Review Board (IRB) policies and guidelines and was IRB-approved. The study content did not address race directly with students, only directly with teachers, and such discussions remained confidential so as not to interfere with teachers' careers. The data was anonymous, and I destroyed it after completing the study. Pseudonyms for all participants and the school were applied.

Reliability and Validity/Credibility and Trustworthiness

To reduce researcher bias, I included direct quotes that did not conform to or contradict the presuppositions of this study's hypothesis. To that end, I extensively reviewed all data transcripts. I did not omit any findings indicating that ASTP did not help change student engagement or perceptions or resulted in decreased perception or engagement.

Study Limitations

Results from the student sample sizes and number of participating teachers may not be necessarily generalizable to larger populations. Also, studying a complex phenomenon such as ST would be better served with a more extended timeframe (beyond six weeks), allowing me to compare changes occurring over more extensive periods. Additionally, this study's design precludes evidence of causality and is designed only to provide descriptive patterns associated with the intervention for further research and exploration. Therefore, findings serve as a foundation for further investigation.

Summary

This study used a mixed-methods exploratory design. Students participated in pre- and post-intervention surveys measuring differences in student self-perception and engagement in three dimensions (affective, behavioral, and cognitive). During teacher interviews, I collected qualitative data on such changes from the instructor's perspective, data on the educator's implementation experience, and how this experience impacted their beliefs about the teaching and learning of diverse math students. Finally, student focus groups examined perspectives on the nuances behind *how* ASTP may have altered perceptions of math potential and levels of engagement.

CHAPTER FOUR: QUANTITATIVE FINDINGS

This mixed methods study examined students' self-perceptions and learning engagement from implementing Anti-Stereotype Threat Pedagogy (ASTP). Designed to disrupt the correlation of race or gender with academic potential, this pedagogy used neuroscientific evidence to shape ASTP instructional methods, modules, and learning activities. Four math teachers were recruited and trained, who then implemented ASTP in their classrooms over six weeks. This chapter presents the findings from quantitative data analysis from student participants' pre and post-test survey responses. The quantitative analyses sought to answer the first research question in this study, related to changes in student self-perception of math potential and engagement.

I conducted an Exploratory Factor Analysis (EFA) to investigate the underlying factor structures and paired sample t-tests to assess the statistical significance of changes. For more information on methodology, see Chapter 3.

Dimensionality and Internal Consistency of Construct Measures (Scales)

Sample Adequacy

A Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity were applied to measure the sampling adequacy at the pre-test and post-test. For the pre-test data, the variables' KMO value was 0.850, indicating that underlying factors may cause 85% of the variance of the survey items. Bartlett's test of sphericity was statistically significant ($p < .001$), indicating that the correlation matrix was significantly different from the identity matrix, *confirming an EFA as an appropriate analysis of the pre-test data*. For the post-test data, the variables' KMO value was 0.812, indicating that underlying factors may cause 81.2% of the variance of the survey items. Again, Bartlett's test of sphericity was statistically significant ($p < .001$), indicating that the correlation matrix is different from the identity matrix and that the *EFA is an appropriate* *analysis of the post-test data.* An eigenvalue represents the variance a factor can reproduce out of all the variance present within and between the items in the matrix of associations (Henson & Roberts, 2006). A conventional process involves retaining factors with eigenvalues greater than 1. Examining the eigenvalues suggests four to six factors in the survey questionnaire. Table 4.1 summarizes these findings of the initial eigenvalues and the percent of variance explained by the factors at the pre-test and post-test.

Table 4.1

Number of Eigenvalues and Total Percentage of Variance (Pre-test and Post-test)

	Pre-test Eigenvalues			Post-test Eigenvalues		
Factor	Total	% of Variance	Cumulative %	Total	% of variance	Cumulative %
1	10.44	37.30	37.30	10.06	35.92	35.92
2	2.52	9.01	46.31	3.40	12.15	48.07
3	2.49	8.89	55.20	2.56	9.15	57.22
4	1.55	5.53	60.73	1.54	5.50	62.72
5	1.45	5.19	65.92	1.40	5.01	67.73
6	1.07	3.82	69.74	1.25	4.45	72.18

Note. Extraction method: Principal component analysis.

A scree plot was utilized to examine the eigenvalues visually (see Figures 4.1 and 4.2) for the pre-test and post-test. Both scree plots showed a leveling off around four to five factors.

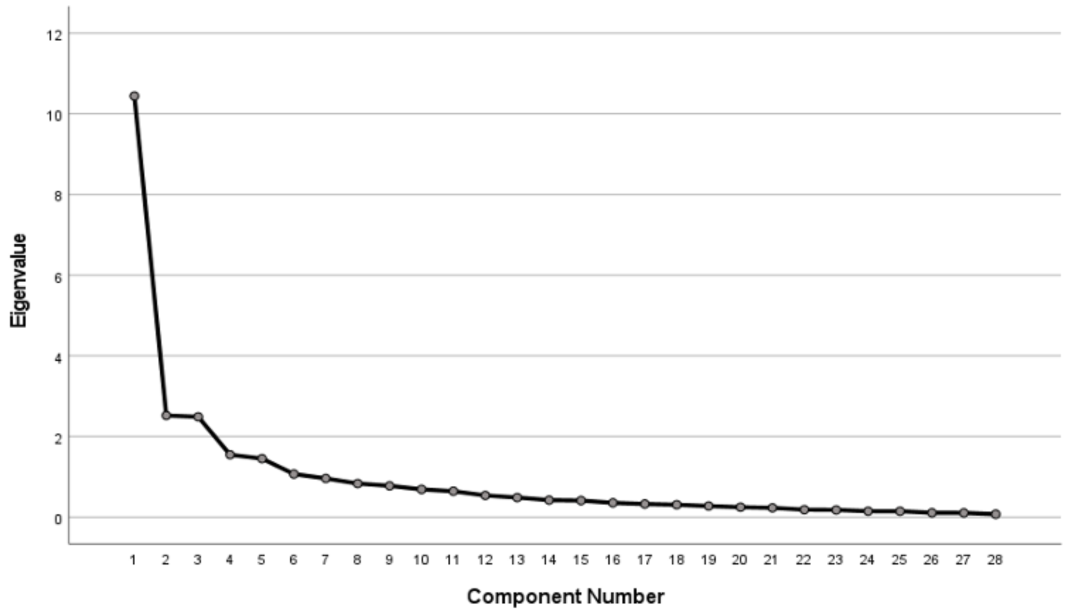

Figure 4.1. Scree Plot for Pre-test Examination.

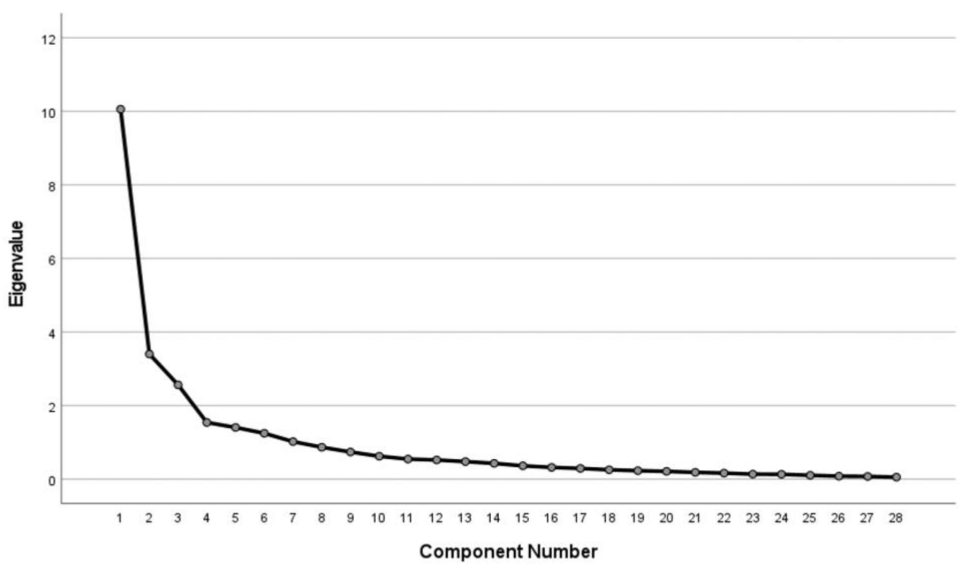

Figure 4.2. Scree Plot for Post-test Examination.

Exploratory Factor Analysis

The EFA examined the latent traits or constructs underlying the measured variables in this study. The four hypothesized latent variables were self-perception, affective engagement, behavioral engagement, and cognitive engagement. Global engagement refers to the three subscales of engagement in aggregate and is not defined by the EFA. To better understand how constructs possibly mapped unto factors, initially, all eigenvalues were retained, demonstrating six possible factors. However, this initial EFA was not conclusive in determining how constructs mapped unto factors and exhibited a large number of cross-loadings.

A second EFA was conducted with constraints to four-factor solution confinement aligned to the four hypothesized factors in this study. Using this approach, factor loadings within each construct were shown to map largely toward three of the four constructs: self-perception, behavioral engagement, and cognitive engagement.

Affective and Cognitive Subdivisions

According to the EFA results, the *affective* and *cognitive* subscales contained two subdivisions. The first two questions in the cognitive scale (related to student perception of performance) cluster closer together, distinct from the other questions in this construct. The remaining questions of the cognitive scale measured metacognitive practices such as deeper math understanding, connecting math content to other areas, and self-monitoring of learning, among others. Consequently, two cognitive subdivisions emerged: (a) perception of math performance and (b) metacognition. According to the literature, and as shown in the EFA in this study, while these two elements are categorically cognitive, they were shown to be distinct enough to warrant partition.

Factor loadings for the affective construct divided between affective and self-perception subconstructs with high interrelatedness between these two constructs. In particular, the first three affective survey items, mapped unto the affective construct, were questions measuring fear of failure (*anxiety*). The remaining questions (mapped unto the self-perception) construct revolved around the *enjoyment* of learning math.

The factor loadings in the post-test survey questionnaire indicated this same correlative pattern with three of the four constructs and sub-divisions, as shown in Table 4.2 (pre-test) and Table 4.3 (post-test).

Table 4.2

Pre-test EFA – 4 Factors (Extraction Method: Principal Component Analysis, Rotation Method: Promax with Kaiser Normalization)

Variable	Factor 1: Self-Perception	Factor 2: Behavioral	Factor 3: Cognitive	Factor 4: Affective
Rate your belief in your math potential	.668	.214	-.102	.262
I am capable of doing well in math	.815	-.073	-.160	.339
I am capable of solving challenging math problems	.743	.054	-.030	.256
My math skills can improve with practice	.733	.002	-.082	.132
Even with effort my math skills will remain the same	.775	-.009	-.249	-.203
Even with practice I will not do well in math	.807	-.020	-.025	-.179
There is no limit to my ability to solve math problems	.294	-.319	.276	.343
Rate your current level of effort in this math class.	.225	.516	.116	.183
How often do you participate in class by asking your math teacher questions?	-.455	.660	.360	.104

Table 4.2 Continued

Variable	Factor 1: Self-Perception	Factor 2: Behavioral	Factor 3: Cognitive	Factor 4: Affective
How often do you participate in math class by sharing your answers with other students?	-.082	.858	-.096	-.003
I work through a math problem until I understand it	.381	.426	.163	-.042
I am prepared to answer when called on by my math teacher in class	.103	.709	.012	.096
I remain focused on the lesson throughout math class	-.065	.434	.457	.008
I help my peers with their math questions	.128	.782	-.149	.020
I show all my work when I'm solving a math problem	.280	.626	-.110	-.336
I feel anxious when learning math	.182	.017	.175	.368
I feel nervous when sharing my mathematical reasoning with other students	-.071	.608	-.059	.506
I fear getting the wrong answer in math	-.120	.097	-.101	.827
I enjoy learning math	.616	.013	.290	.044
I expect that my math skills will improve	.608	.215	.174	-.178
I am interested in learning math	.569	-.075	.418	-.014
I enjoy learning new skills in math	.507	-.134	.438	-.206
My understanding of math concepts has been improving in this class	.405	.439	.090	-.012
My academic performance has been improving in this math class.	.369	.544	.048	-.086
I set goals for my mathematical learning	.178	-.244	.865	.124
I monitor my progress towards my learning goals in math.	-.082	.108	.841	-.026

Table 4.2 Continued

Variable	Factor 1: Self-Perception	Factor 2: Behavioral	Factor 3: Cognitive	Factor 4: Affective
I can connect concepts from my math class to other classes	-.244	.267	.741	-.060
I can connect the math curriculum to my experiences	-.108	-.057	.924	.020

Table 4.3

Post-test EFA – 4 Factors (Extraction Method: Principal Component Analysis, Rotation Method: Promax with Kaiser Normalization)

Variable	Factor 1: Self-Perception	Factor 2: Behavioral	Factor 3: Cognitive	Factor 4: Affective
Rate your belief in your math potential	.893	.064	-.155	.095
I am capable of doing well in math	.991	-.049	-.206	.146
I am capable of solving challenging math problems	.886	-.127	.075	.136
My math skills can improve with practice	.856	-.009	-.189	-.089
Even with effort my math skills will remain the same	.344	.147	.190	.046
Even with practice I will not do well in math	.450	-.044	.254	.236
There is no limit to my ability to solve math problems	.799	-.111	-.067	.100
Rate your current level of effort in this math class.	.061	.681	.067	-.076
How often do you participate in class by asking your math teacher questions?	-.212	.851	-.015	.072
How often do you participate in math class by sharing your answers with other students?	-.156	.919	-.240	.009
I work through a math problem until I understand it	.322	.460	.173	.081
I am prepared to answer when called on by my math teacher in class	.126	.717	-.136	.285

Table 4.3 Continued				
Variable	Factor 1: Self-Perception	Factor 2: Behavioral	Factor 3: Cognitive	Factor 4: Affective
I remain focused on the lesson throughout math class	-.163	.638	.311	-.179
I help my peers with their math questions	-.045	.868	-.159	.154
I show all my work when I'm solving a math problem	.095	.622	.079	-.026
I feel anxious when learning math	.115	.032	.056	.836
I feel nervous when sharing my mathematical reasoning with other students	-.091	.158	.024	.813
I fear getting the wrong answer in math	.044	.036	.083	.849
I enjoy learning math	.583	.246	.003	-.269
I expect that my math skills will improve	.881	-.215	.075	-.043
I am interested in learning math	.526	.283	-.002	-.327
I enjoy learning new skills in math	.648	-.059	.253	-.272
My understanding of math concepts has been improving in this class	.158	.379	.414	.074
My academic performance has been improving in this math class.	.154	.475	.279	-.016
I set goals for my mathematical learning	-.044	-.168	.854	.022
I monitor my progress toward my learning goals in math.	-.054	-.177	.943	.212
I can connect concepts from my math class to other classes	-.003	.148	.711	-.002
I can connect the math curriculum to my experiences	-.154	.008	.875	-.077

Cronbach's Alpha

Finally, the *internal consistency* of the pre-test and post-test scales deemed unidimensional was examined using Cronbach's alpha. The resulting alpha coefficients measured the degree to which groups of items on the pre-test and post-test surveys were related to a common underlying trait (for a unidimensional set, this also reflects the scale reliability).

Alpha coefficients were interpreted using guidelines from George and Mallery (2021), where α >.9 Excellent, α >.8 Good, α >.7 Acceptable, α >.6 Questionable, α >.5 Poor, and α <.5 Unacceptable.

The alpha coefficient for *self-perceptions* at the pre-test (α =.84) and post-test (α =.86) was good; *global engagement* at the pre-test (α =.91) and post-test (α =.90) was excellent; *affective engagement* (anxiety) at the pre-test (α = .63) and post-test (α = .85) ranged from questionable to good; affective (enjoyment) at pre-test (α = .89) and post-test (α = .89) was good, *behavioral engagement* at pre-test (α =.85) and post-test (α =.86) was good; cognitive engagement (performance) at the pre-test (α = .86) and post-test (α = .88) was good; cognitive engagement (metacognition) at the pre-test (α = .87) and post-test (α = .83) was good. Self-perception, global engagement, and behavioral and cognitive engagement demonstrated high reliability except for the affective (anxiety) subscale at the pre-test.

Statistical Significance

Participants' pre-post survey responses were analyzed for changes in self-perception and global engagement (including affective, behavioral, and cognitive engagement subscales) using descriptive statistics followed by paired sample t-tests.

Descriptive statistics in Table 4.4 indicate that most participants reported increases across the aforementioned study variables and subscales. In particular, 74.7% of student participants reported increased self-perception, and roughly 50 to 60 percent reported increases in global, metacognitive, and behavioral engagement. A smaller but significant percentage of student participants reported decreased engagement (affective (enjoyment) 29.3%; cognitive (metacognition) 22.7%; behavioral 28.0%, and global 37.3%), while very few students reported decreasing self-perceptions..

Table 4.4

Frequency Table for Self-Perceptions, Global Engagement, Affective, Behavioral and Cognitive Change

Variable	n	%
Self-perceptions		
Increased	56	74.7
No change	13	17.3
Decreased	6	8.0
Global engagement		
Increased	46	61.3
No change	1	1.3
Decreased	28	37.3
Affective engagement (reduced anxiety)		
Increased	31	41.3
No change	20	26.7
Decreased	24	32.0
Affective engagement (enjoyment in learning math)		
Increased	35	46.7
No change	18	24.0
Decreased	22	29.3
Behavioral engagement		
Increased	38	50.7
No change	16	21.3
Decreased	21	28.0
Cognitive engagement (perception of performance)		
Increased	26	34.7
No change	27	36.0
Decreased	22	29.3

Table 4.4 Continued

Variable	n	%
Cognitive engagement (metacognition)		
Increased	40	53.3
No change	18	24.0
Decreased	17	22.7

Paired t-tests assessed the statistical significance of changes between the pre-test and post-test for all scales.

Seven of fourteen Kolmogorov-Smirnov tests (pre and post) were significant indicating deviation from a normal distribution. However, Howell (2013) indicates that violations of normality are not problematic when the sample size exceeds 50 cases. Since the sample size in this study was $n = 75$, *t*-tests were conducted as initially proposed. The results for each scale are presented below and summarized in Table 4.5.

Self-Perception

Self-perception mean scores increased by approximately 0.40 units between the pre-test ($M = 3.52$) and post-test ($M = 3.92$). A paired sample *t*-test for this difference was statistically significant ($t(74) = -7.21$, $p < .001$), indicating that this increase in self-perception was unlikely due to random and sampling error. The difference is equivalent to Cohen's *d* of 0.83 standard deviation units, indicating a *large* effect size.

Global Engagement

Global engagement mean scores increased by approximately 0.19 units between the pre-test ($M = 3.16$) and post-test ($M = 3.35$), which was statistically significant ($t(74) = -4.06$, $p < .001$), with a Cohen's *d* of 0.47 indicating a *moderate to medium* effect size.

Affective Engagement – Reduced Anxiety

On the affective scale measuring anxiety (increases indicate reduced anxiety), scores increased by 0.06 units between the pre-test (*M* = 2.91) and post-test (*M* = 2.97), which was not statistically significant (*t*(74) = -0.84, *p* = .402).

Affective Engagement – Enjoyment

On the affective scale measuring enjoyment, mean scores increased by 0.11 units between the pre-test (*M* = 3.28) and post-test (*M* = 3.39); this difference was not statistically significant (*t*(74) = -1.56, p =.124).

Behavioral Engagement

Behavioral mean scores increased by 0.20 units between the pre-test (*M* = 3.12) and post-test (*M* = 3.32). A paired sample *t*-test for this difference was statistically significant (*t*(74) = -3.10, p =.003), with a Cohen's *d* of 0.36 indicating a *small* to *medium* effect size.

Cognitive Engagement (Perception of Performance)

On the cognitive scale measuring perception of performance, mean scores increased by 0.07 units between the pre-test (*M* = 3.63) and post-test (*M* = 3.70), and this difference was not statistically significant (*t*(74) = -0.82, p = .415).

Cognitive Engagement (Metacognition)

On the cognitive scale measuring metacognition, mean scores increased by 0.35 units between the pre-test (*M* = 2.96) and post-test (*M* = 3.31); this difference was statistically significant (*t*(74) = -4.39, p <.001), with a Cohen's *d* of 0.51 indicating a *medium* effect size.

Table 4.5

Paired Sample t-tests Results Between Pre-test and Post-test (n = 75)

Variable	Pre-test		Post-test					
	M	SD	M	SD	Pooled SD	t(74)	p	Cohen's d
Self-perception	3.52	0.68	3.92	0.69	0.68	-7.21	<.001	.83
Global engagement	3.16	0.61	3.35	0.58	0.60	-4.06	<.001	.47
Affective - anxiety	2.91	0.86	2.97	1.01	0.93	-0.84	.402	.06
Affective - enjoyment	3.28	0.86	3.39	0.89	0.85	-1.56	.124	.18
Behavioral engagement	3.12	0.76	3.32	0.76	0.76	-3.10	.003	.36
Cognitive - performance	3.63	0.80	3.70	0.79	0.80	-0.82	.415	0.10
Cognitive - metacognition	2.96	0.81	3.31	0.81	0.82	-4.39	<.001	0.51

Figure 4.3 visualizes shifts in self-perception and engagement, including subscales and subdivisions between pre-test and post-test means. While all variables and subscales demonstrated an increase, steeper increases in self-perception and metacognition are notable, followed by moderate increases in global, behavioral, and perception of performance and modest increases in affective subdivisions.

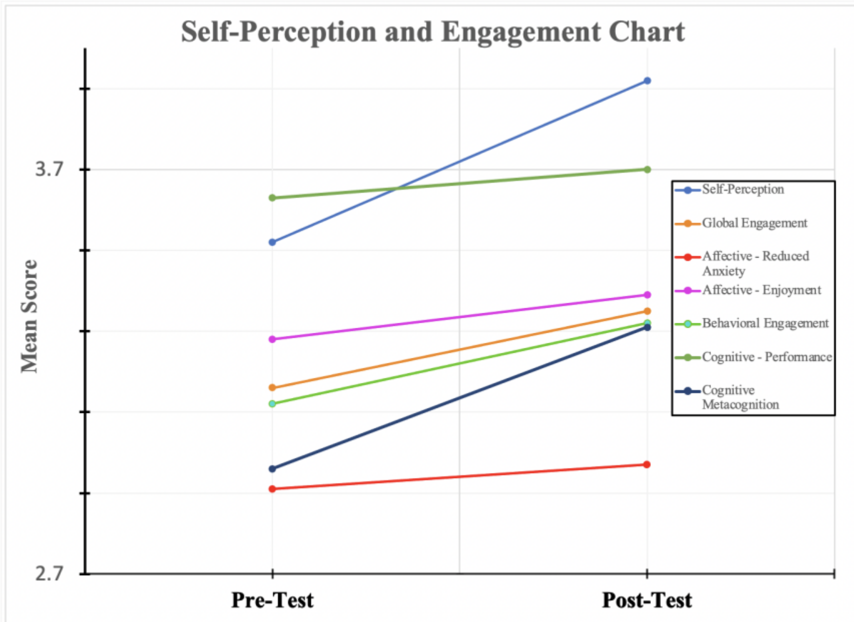

Figure 4.3. Mean Score Pre-test and Post-test (n = 75).

Conclusion

This chapter sought to answer this study's first research question, probing changes in self-perception and engagement during the six weeks of Anti-Stereotype Threat Pedagogy (ASTP). Significantly, this study sought to contribute to our understanding of neuroscience-framed teaching and classroom practices as drivers of changes in self-perception and engagement for math students prone to stereotype threat. This was important because scholars have shown that learners' deficit beliefs around learning (perception), impacted by stereotype threat, hinder students' sense of psychological safety, a known precursor to engagement and achievement (Turner, 2011).

Trends and Patterns

Participants in this sample (n = 75) predominantly reported increases in self-perception (74.7%), global engagement (61.3%), metacognitive engagement (53.3%), and behavioral engagement (50.7%). In addition, considerable proportions (46.7%) reported increased enjoyment in learning math, (41.3%) reduced anxiety around math learning, and (34.7%) increased perception of performance.

Adding context to perceptual shifts, students' change in self-perception means (pre-test to post-test) indicates participants (on average) shifted toward a growth mindset in math. Contextualizing engagement shifts, students reported predominant gains in metacognition, or learners' "thinking about learning and deeper understanding," and behavioral engagement, such as participation and effort. Such shifts in engagement were consistent with findings in the literature on stereotype threat and education psychology, as improvements in learners' beliefs around their learning can correlate with increased metacognition (deeper understanding) and on-task behavior. Although perceptual shifts accompanied less anxiety and elevated enjoyment of learning math, these changes were comparatively more modest. After six weeks of ASTP, self-perception, cognition, and behavior showed significant change, while learners' enjoyment in learning math and reduced anxiety around learning math remained comparatively less impacted.

While it is essential to distinguish which shifts were unlikely due to random and sampling error, statistically significant results do not necessarily imply practical significance. For example, shifts in self-perception, global engagement, and metacognitive engagement were statistically significant at ($p<0.01$), while behavioral engagement was statistically significant at ($p<0.05$). For practical significance, the effect size (Cohen's *d*) for self-perception was large, followed by moderate effect sizes for metacognitive, global, and behavioral engagement. At the same time, affective shifts such as increased enjoyment and reduced anxiety and cognitive shifts around the perception of performance resulted in modest or small effect sizes. In other words, the most considerable shifts were increases in self-perception of math potential followed by increased engagement and metacognition.

In sum, the data suggests ASTP implementation correlated with a considerable impact on self-perception, followed by noteworthy shifts in global engagement, particularly students' metacognitive engagement and frequency of observable on-task actions or behavioral engagement. However, the data also suggest learners were more divided around shifts in their perception of performance gains, their enjoyment in mathematics, and their anxiety reduction.

Implications, Issues and Concerns, and Limitations

The quantitative findings have implications for studies investigating the relationship between interventions designed to disrupt the impact of stereotype threat and their impact on learners' self-perception of math potential and engagement. While engagement and self-perception are distinct constructs, their concurrent shifting supports *possible* interrelatedness between these variables, as the EFA shows. Additionally, the questions used to elicit student feelings toward math learning (affective scale) mapped according to the EFA analysis, with students' self-perception of math potential. However, more significant self-perception shifts coincided with only modest gains in the affective measure. This suggests that while students' self-perception around their potential may increase, enjoyment around learning math can remain less likely to shift within six weeks. Likewise, more substantial concurrent increases in behavioral and metacognitive engagement were observed, indicating possible interrelatedness between learners' on-task behavior and deeper content processing.

The data also adds to the literature on the degree of interrelatedness and complexity of multidimensional constructs such as engagement. For example, while engagement is well known to contain affective, behavioral, and cognitive constructs, this study's EFA found subdivisions distinct enough to warrant separation in the affective and cognitive domains. This suggests that future researchers may want to explore such subdivisions to understand how engagement further divides into subcategories. Challenging the literature, the quantitative results of this study also indicate that the three engagement subscales–affective, behavior, and cognitive may not be as dependently interrelated as some studies may suggest (Luo et al., 2019), as metacognitive and behavioral shifts far exceeded affective changes. In other words, while cognitive and behavioral increases were notable, they were not commensurate with affective shifts as changes in students' emotional engagement remained less malleable.

Concerning the overlay of affective and self-perception mapping shown in the EFA, questions arise as to how to distinguish such closely intertwined constructs to assess each of these measures more distinctly. One way could be to focus on the different emotions within the affective domain and measure accordingly. For instance, the first three statements of this study's proposed affective scale, measuring anxiety or fear of failure–strong emotions that can arise during math learning–can be used as a starting point to subdivide "feelings" students have toward math. In other words, while measuring anxiety, another scale could measure insecurity, apathy, curiosity, or other feelings that may arise, intersecting with the student's affective engagement.

Several limitations emerge through the quantitative data analysis. First, it is essential to distinguish that this exclusively exploratory and descriptive study cannot quantitatively determine the causal relationship between variables. Second, while this study hypothesizes that changes in self-perception may drive changes in engagement, the exact ways perception may have driven such shifts in engagement remain undeterminable using the metrics in this chapter. Third, while quantitative data here show a correlative pattern of increases across self-perception and primarily cognitive and behavioral engagement, how these variables impacted each other is unknown as the directionality of influence is also undeterminable. For instance, while self-perception and some engagement shifts were notable, it remains unknown to what extent (if at all) students' reduced fear of failure and increased enjoyment, albeit very modest drove changes in on-task behaviors such as problem-solving. Finally, another limitation is that such quantitative data, however valuable, does not illuminate student and teachers' perspectives on such shifts in self-perception and engagement, nor how the intervention (if at all) elicited shifts in the study's variables. In other words, this quantitative chapter only measured the extent to which these changes occurred and is, by its design, unable to link specific elements within the intervention to these shifts.

To address these limitations and further explore the impact such shifts had on participants, I turn to participant reports (qualitative data) as proposed in Chapter 3. Such data explored participants' experiences around such shifts in perception and engagement, the teachers' implementation experience, and how the experience influenced teachers' beliefs about the teaching and learning of diverse students.

CHAPTER FIVE: QUALITATIVE FINDINGS

This chapter presents findings from two student focus groups and four teacher interviews exploring participant experiences throughout the six weeks of Anti-Stereotype Threat Pedagogy (ASTP). I first present an overview of each principal finding, then detail how each surfaces in participants' responses. Principal findings arise from the perceptual and engagement shifts experienced by students and observed by teachers, from the instructors' implementation experience, and shifts around educators' beliefs around the teaching and learning of diverse students.

Students Shift Their Perception of Math Potential and How They Engage

Data shows teachers and students perceived fundamental shifts during ASTP. They identified that low math performance, lack of content mastery, and exposure to deficit stereotypes contributed to their limited perceptions of math potential. These participants then explained how ASTP's inspiration via role models, motivation through self-affirmation, and neuroscientific evidence of perpetual learning capacity helped challenge them and reverse deficit perceptions.

Limited Baseline Perceptions

Twelve of sixteen students in focus groups began the ASTP intervention believing their math potential was limited or, at best, average. Olivia stated, "I believed I had *limited* math potential," a sentiment mirrored by Angelica, who said, "I put [on the survey] that I had *average* math potential." Unsurprisingly, twelve students indicated that school and state math performance tests critically contributed to such perceptions. As Tiffany explained:

> I had average math potential . . . I started believing that in, I'd say, elementary school. Because I remember when we started doing state testing, and there was math, I'd always get so nervous, and then I'd get home, and then there were the results. I would always have like a two; I'd never got past a three on the state testing. And I just always thought it was because I wasn't good at math.

Thea echoed this revelation of continued disappointment in scores by adding, “I believed I was average because all my test results would be, like, in the middle,”—consequently labeling herself as “average.”

Such performances commonly evoked feelings of mathematical defeatism. Twelve students underscored that experience with such results in elementary and middle school led to perpetual self-doubt, as performance feedback was interpreted as absolute. Consequently, twelve students identified school as a source of dejection—upon review of their limited performance. Twelve of these sixteen students also expressed doubt in their math skill capacity and hopelessness around improvement. Olivia’s comments were representative of this sentiment, as she shared:

> I’ve never been good at math throughout my whole life. I’ve always felt like I had limited math potential because of my grades. School led me to that belief because I’m not good at math. So I thought I was limited in what I could learn.

Revealing the fixed nature of this mindset, Olivia further emphasized, “I thought I was limited in what I *could learn*,” insisting that the ability to acquire new math skills was precluded based on past performance. In this way, eleven learners like Olivia exposed an essential byproduct of low performance–self-branding as deficient math learners.

However, while most participants felt as Olivia did, four entered the study with self-described “growth,” and “unlimited,” mindsets around their capacities. These four students viewed their math potential as continuously growing without limitation. Phil, speaking for this subset, attributed the origins of his growth perspective:

> I believe I had unlimited math potential, like my freshman year [of high school], first semester, because I started to put in more effort, so I would understand the equations, and that made me want to try more. So then in my second semester in math, I got an A better than my first semester when I had a B, so that’s when I started believing I had unlimited math potential.

Phil's growth perspective was rooted in his ability to manifest performance increases commensurate with his effort. Connecting his exertion's impact on improving performance, Phil's incremental success perpetuated more effort, leading to a realization that his potential could be expanded. Nevertheless, Phil and a few others were the exceptions.

Low Math Performance and Content Mastery

Compounding low scores, learners indicated another root cause of limited perception—a lack of content mastery in algebra. Seven learners described how worsening confusion around algebraic topics exacerbated deficit perceptions around potential as they moved along the K-12 pipeline. Stephen shared:

> I feel like math was easier in elementary. And then as school progressed, they [teachers] started adding letters and stuff. Then I got confused. In eighth grade, the problems just got bigger and harder, I just lost focus in the subject.

Steven indicated how the introduction of algebraic reasoning with variables or "letters," led to uncertainty about navigating such problems. As Steven underscored, cognitive disengaging, or opting out of learning activities by "losing focus," remained a common experience among seven students' introduction to algebra. Sean, mirroring this experience shared:

> I believe I had limited math potential. It all started in eighth grade when I barely got into middle school. It happened when, all of a sudden, the problems had y = mx +b [slope intercept equation of a straight line] or something like that.

Rather than demonstrate a resolve to persevere with an effort to meet the demands of such problems (an indicator of a growth mindset), learners with limited perception cognitively withdrew as mathematical abstraction increased. Expressing a feeling of being "left behind," students self-blamed for this learning shock, emphasizing, "*I* got *confused,*" and "It happened when . . . problems had $y=mx+b$ . . ." Thus, learners with limited perception interpreted their confusion around abstract or complex mathematics as an intellectual limit, rather than a challenge that could be overcome through effort.

Three of the four teachers in the sample also described a lack of content mastery as contributing to students' baseline deficit perspectives around math potential. Ms. Amelia's perspective was representative of this description, as she noted,

> I would say most students started with a limited belief of their math potential, or even no potential. I think they're thinking that they're never going to get the material [math content] and they're going to struggle to get a D or a C in math their whole life as they always have been. They're always going to think it's a struggle. I would say that's what most of them believed, with only maybe a few thinking they had growth or unlimited potential.

Ms. Amelia connects students' deficit mindset around potential to their continued struggle with mathematical content. Furthermore, she asserts that students remain in that struggling state because of the deficit perception, serving only to perpetuate low performance, exacerbating deficit perspectives.

Stereotype Threat Susceptibility and Perceptions

Not just test scores and increasing algebraic complexity but also race or gender stereotypes undermined students' perceptions of their math potential. Ten learners reported how racial, or gender stereotypes influenced math potential perceptions. Furthermore, students shared how difficulties navigating such stereotypes and personal attempts to mitigate stereotype threat strained their self-perceptions.

Race and Self-Perception

Seven students defined how stereotypes correlated race with math potential, casting doubt on the mathematical potential of minorities [Latino and Black learners]. As Phil stated:

> There are stereotypes against minorities [Blacks and Latinos] doing well [in mathematics]. Minorities are discouraged and feel like they don't have as much potential as maybe someone whose race is stereotyped to do better…

Phil explained how stereotypes linking mathematical deficiency to minorities' racial identity demoralize them and undermine their self-perceptions. Phil unearthed how societal stereotypes penetrated the classroom, underscoring the challenge diverse learners face as they consider their capacity to achieve mathematically. He emphasized how ". . . minorities [Black and Latinos] *are discouraged and feel like they don't have as much potential* . . ." Examining the nature of these stereotypes further, four of these seven students explained a racial hierarchy ranking minorities [Blacks and Latinos] math potential inferior to other racial groups, particularly Asian learners. As Scarlet mentioned:

> I personally think students might believe there's a connection between race and math ability. Because some people think stereotypically about certain races being good at certain things. So I think it has a connection. Some people may believe Asians are supposed to be good at math. Like all Asians are. It's a stereotypical way to think. And then some people think the opposite, like a certain race or group, can be at a disadvantage.

In line with the literature on stereotype threat, Scarlet, as did three other learners, examined the capacity of stereotypes to assert claims about students' potential, not only comparatively between racial groups but also as a function of racial identity. Scarlet articulated, "Asians are *supposed* to be good at math." In describing such racialized assertions, Scarlet described how this stereotype attributes mathematical competence to race. Learners emphasized the capacity of such beliefs to assert a racially biased shorthand assessment of mathematical potential, with expectations favoring Asian learners. Tiffany elaborated, "I heard Asians are good at math. Yeah, I don't know why . . . it's all over the internet, basically," stressing uncertainty about the origin of the stereotype while expressing the commonplace nature of such correlations in the media.

Gender and Self-Perception

In addition to racial stereotypes, students unveiled stereotypes around gender. Four female students revealed stereotypes associating gender with math potential, positioning their math ability inferior to males. Females shared how gender salience arose in their families, with consequences on school efforts to buffer against the fear of confirming deficit stereotypes, as Scarlet shared:

> My brother, he's really smart. Since he's a male and I'm a female, I feel like it's different for me because he could have more advantages than me. So I put in more effort. I believe my parents think he was better [in math] just naturally. I think, because my parents like have an expectation that since I'm a woman, I should be involved with different things than my brother . . . not really school-wise [related]. People expect him to do better than me [in mathematics] because he's male, because they expect them to like know everything in a way, to be more superior.

Scarlett assessed her math capacities through her parents' lens of gendered expectations. Precisely, she weighed her math ability against her brother's "natural" ability, a purported function of his gender. Scarlett struggled to unravel the veracity of such stereotypes, giving rise to their plausibility. In mentioning that ". . . it's different for me, because he *could* have more advantages than me," Scarlett insisted she had to prove she was not inferior. Her coping mechanism—increased effort—although designed to buffer against the fear of possibly confirming the stereotype, affirmed reactivity to the stereotype–a defining characteristic of stereotype threat.

Such pervasiveness of stereotypes found in families is considerable, as stereotypes can be implicitly "passed down," generationally. Another unique element that Scarlet's story illuminates is her solitude in attempts to counter such stereotypes, as she does not mention examples, concepts, or other social contexts in which she could counter such perceptions.

Although such racial and gender stereotypes are commonly referenced in the literature, these quotes emphasize the pervasive and persistent intransigence of such tired stereotypes to permeate learners' beliefs despite teachers' and districts' efforts to foster a growth mindset for learners. Further, learners revealed how the compounding impact of a lack of content mastery, confusion around increased abstraction in math (algebra), and deficit racial and gender stereotypes strained their self-perception of math potential.

Aside from a minority of students who came into the study believing in growth or unlimited potential, for most learners, the idea that math potential could be grown or unlimited was out of reach. In this next section, students and teachers explore how learners shifted their self-perception.

Students Shift Self-Perception of Math Potential

Ten of the sixteen focus group student participants and all four teachers reported how learners increased their perception of math potential through the ASTP mini lessons or *modules.* They noted how role models inspired them, how self-affirmations motivated them, and how neuroscientific evidence informed them of continuous learning capacity. More profoundly, students expressed a new framing around their mathematical capabilities, one unshackled from low scores, content confusion, and tired stereotypes. While other aspects of ASTP are later referenced in changing engagement, student and teacher evidence of perceptual shifts drawing from three particular modules follows.

Role Models and Self-Perception Shifts

Nine students identified ASTP's module*, Role Models in Science, Technology, Engineering, and Mathematics (STEM)*, as a contributing factor in shifting self-perception. Featuring pioneering Black and Latino NASA astronauts Dr. Mae Jemison and Jose Hernandez, learners remarked how role models' perseverance through failures and setbacks inspired perceptual shifts. Students cited the *tenacity* of role models as a central catalyst in the reevaluation of perceptions, as Teresa mentioned:

> How did my belief change? My belief went from average to growth potential [on the survey] because of the role models. Knowing how many times they [Dr. Mae Jemison and Jose Hernandez] failed and still tried, and they were able to do it [become astronauts]. So I think that made me want to push myself more so I could achieve, too.

Teresa was influenced by how role models faced challenges. Expressing surprise that such failure would not result in resignation, Teresa was stunned at how often role models failed and "still tried," noting their endurance through challenges as central to shifting her perception.

Five students expressed how the underprivileged beginnings of role models further accentuated their success and perseverance. As Trinity highlighted, "The role models showed me that even coming from farming, like Jose Hernandez did, basically from being poor to going to NASA, he [Jose Hernandez] showed me that just by putting effort, *you actually can* grow." Trinity identified Jose Hernandez's *effort* as a pivotal factor in overcoming the challenges of limited resources or "*being poor*." In this way, Trinity emphasized how disadvantages, such as poverty, were unexpectedly not the final determinant of achievement. This view contrasted with learners' baseline perceptions, in which students interpreted setbacks or profound challenges as an *absolute* preclusion to high achievement.

Six female learners identified how role models challenged gender stereotypes of math potential; as Olivia stated:

> After, I put [on the survey], I have unlimited math potential. My belief changed because of what we learned about Dr. Mae Jemison and how people in her life would tell her she couldn't become an astronaut or learn this or that, but she believed otherwise. And she would try her hardest, and then she proved them wrong. I guess since many people believe only men could become an astronaut, and women can't. So it was, it was different seeing a woman actually overcome that.

Olivia attributed her shift in perception to the determination of Dr. Jemison to prevail against gendered stereotypes about her capacity. Recognizing the defiant optimism of Dr. Jemison's stance of "believing otherwise," Olivia articulated her novel exposure to such female role models as central to shifting her perspective. This example of female success in the face of deficit stereotypes and an objectively demanding goal (becoming an astronaut) challenged and relieved six females' baseline trepidation around their math potential.

Three teachers also noted the novelty of such role models in math education, and their impact on students' perception, as particularly important for diverse learners. Ms. Amelia mentioned:

> I grew up in elementary learning about role models. So when I saw the modules, I was like, oh yeah, role models, of course. I feel like these students, however, may not have learned much about role models or talked about it. So when I introduced the module, there's a scene, especially geared towards math and science, and NASA. They [students] were like, "Oh, wow," at seeing how Jose Hernandez grew up as a farm worker and eventually made it to NASA. They were like, "Wow, Jose Hernandez did that, and his dad encouraged him to do all that?" I think it just clicked with them [students], like, wow, if they [role models] can do it, then I [student] can do it.

Ms. Amelia reflected on the contrast between her experience with role models and those of her diverse learners. While noting role models were common in her experience, she presumed her *diverse* students lacked exposure to such examples, as she emphasized, "I feel like *these* students, however, may not have learned much about role models . . ." She cites her students' marveling and intrigue around role models' accomplishments as evidence of their lack of exposure. She emphasized her students' wonderment, "Wow, Jose Hernandez *did all that* and his father encouraged him *to do all that*?" In such a way, Ms. Amelia sheds light on the rarity and the highly responsive effects of role models for diverse learners.

Ms. Eve added depth to the discussion around how role models' racial representation sparked inspiration for diverse learners, adding:

> The influence of the role models in my opinion was due in part because they [role models] were non-White and representative of many of our students. They [role models] were able to achieve things that were beyond what anybody would possibly think that they could due to the color of their skin. The main thing that may have helped is that we countered any negative stereotypes connected to like the role models race. We didn't have to mention their race it was there for everyone to see. We're just talking about the human brain in general. How we all share abilities in our brain, and how we're all one.

Ms. Eve assessed role models' influence on diverse students through a racial lens. In particular, she underscored how role models' diverse racial backgrounds held promise in countering any potential deficit racialized presuppositions, as they exemplified evidence to the contrary. Interestingly, Ms. Eve unearthed her exposure to deficit correlations between limited math capacity and race and presupposed these correlations were embedded in her learners' perspective as she emphasized, "They [role models] were able to achieve things that were *beyond* what *anybody would possibly think* that they could do to the *color of their skin* . . ." The aforementioned student's comments confirming knowledge and challenges around stereotypes demonstrate her presupposition.

Self-Affirmations and Increased Self-Perception

Nine students and three instructors identified the ASTP module, "*Self-Affirmations*" as increasing students' perception of math potential. As Tiffany elaborated:

> I think a part of this program that led me to a change in my belief [in math potential] from average potential to unlimited potential was the self-affirmations. Especially the self-affirmation, "I can do this, I have unlimited math potential." I just noticed that I started participating more in class. It went from like doing it [participating] once a week to everyday participating in class and answering questions. I think the self-affirmations gave me the confidence to try.

Tiffany linked positivism around self-affirmations to increased perception accompanied by unexpected boosts in confidence. Tiffany interpreted her increased participation as confirmation of her improved outlook, emphasizing, "I just *noticed* that I started participating more in class." Learners' newfound enthusiasm brought upon by such self-affirmations sharply contrasted with baseline hopelessness around math skill development.

Six students connected self-affirmations to the neuroscience frame of the intervention by linking neurogenesis (brain cell growth) to self-affirmations, reporting a deepened belief in affirmations, as Edwin shared:

> The self-affirmations helped, it's motivational. I guess you really can do it, I mean can do anything, and the science behind my growing brain cells [neurogenesis] shows that. So that motivated me to do better. Because the teacher in front of the class would repeat it

> and make us circle the self-affirmation, and you could choose to say it to yourself. Like I said, it motivated me more . . .

Edwin contextualized self-affirmations in neuroscience. He connected the self-affirmation, "*I can do it*," with neurogenesis and explained how this combination of strategy and knowledge led to an increased perception of math potential. Edwin drew from emerging neuroscientific knowledge to deepen his *trust* in self-affirmation, underscoring, "as the *science behind growing brain cells shows*." In this way, such neuroscience knowledge magnified the capacity for self-affirmations to increase confidence and improve self-perceptions for learners. This connection is noteworthy, as there is no current literature on how counter-stereotype threat measures (typically implemented separately) intensify each other's effectiveness in dissolving deficit perspectives, particularly through a neuroscience lens.

Students also linked self-affirmations to role models' success, reflecting on how role models used affirmations to boost confidence toward becoming astronauts. Students reasoned they could similarly use self-affirmations to increase their optimism toward developing math skills. As Teresa observed, "I would see the self-affirmations *used by the role models*, and I feel like that's what helped me the most. It showed how if I put in more effort and engagement, *like they did*, I could actually do math and get better at it too." In this way, learners reported connecting self-affirmations to the success of role models, as they synthesized these two modules (*self-affirmations and role models*). Students hybridized self-affirmations and role model modules in much the same way they grounded the productivity of affirmations in neuroscience, underscoring their creative synthesis of such strategies and knowledge.

Neuroscience and Increased Self-Perception of Math Potential

Seven learners explained how neuroscientific topics induced perceptual shifts of math potential exclusive from other modules. In particular, these students identified the ASTP module:

"*Neuroscience and Math Potential*," as central to reconceptualizing math potential. As Sandra shared:

> Before, I believed I had average potential, after [the intervention], I believed I had growth potential because of the [neuroscience] module, where it shows the brain does grow over time. You just need to keep practicing to get there. So that was also motivating. I was amazed because it never occurred to me . . . I really don't think about how my brain, and my math skills, connect. So I thought I just need to practice more, instead of just giving up or asking my friend for the answers, like if I actually do try then I can get better.

As did six other participants, Sandra emphasized how unknown knowledge around brain capacities [neurogenesis and neuroplasticity] held promise towards increasing her math skill development. Sandra reassessed her baseline belief, describing how such neuroscience findings opposed her doubts about her ability to grow her math skills, emphasizing, "I believed I had *growth potential* because of the [neuroscience] module, where it shows the brain *does grow over time*." Sandra reconsidered the benefits of re-engaging as she recontextualized the promise her effort would bring given the neuroscience, demonstrating a newly empowered growth mindset, emphasizing, "You just *need to keep practicing to get there*." Sandra's reflection underscores the rarity of neuroscience knowledge in her education. She marveled at such an unknown understanding, emphasizing, "I was *amazed* because it never occurred to me . . . how my brain and my math skills *connect*."

Like Sandra, Samantha identified how neuroscience evoked perceptual shifts. Samantha extended the discussion by adding how neuroscience countered her preconception of math ability as a *genetically innate*, fixed capacity immutable even with effort (the stereotype of a *math person*). As Samantha shared:

> Before I believed my math potential was limited, now I believe it's unlimited. Learning about neurogenesis and neuroplasticity . . . helped me realize that your brain can learn new things and you are capable of doing great things. This really helped me get out of my limited potential belief, because it shattered what I used to believe. I used to believe that regardless of race or gender, people were just born good at math.

Samantha unearthed how neurogenesis and neuroplasticity dispelled her assumptions that math achievement is exclusive to those "just *born* good at math." Instead, Samantha and others each implied how math ability could be *developed through effort* given such neuroscientific evidence.

All four instructors underscored how the intervention's transparency of neuroscientific concepts and evidence shifted learners' perceptions of learning potential. Ms. Eve mentioned:

> One of the main parts of this program that helped increase perception the most was learning about the brain [neuroscience modules]. In the error reflect redirect module, where it had the CT scan and the fMRI scans of the brain where you showed that if you find a mistake, and then you believe you can learn from your mistake, then your brain has more activity, you can create more brain cell connections over the new skills. So I think seeing that image or that video helped them [learners] to see like, oh, this is legit. Like it's actually happening in our brains.

Foremost in teachers' voices was the productivity of showcasing neurological scans to lift the veil on increased brain activity for growth-minded learners. Teachers underscored the profundity of such evidence on their learners as Ms. Eve emphasized, ". . . where it had the CT and fMRI scans . . ." Teachers highlighted how neurological changes detailed via fMRI and CT scans overruled student doubts around claims of perpetual learning capability and the influence of perception *on* learning, emphasizing, "Oh, it's *actually* happening in our brain, *it is legit*." In this way, teachers underscored how such detailing deepened learners' assuredness of mistakes as opportunities. In other words, these scans became compelling "proof," to substantiate claims of continuous learning capacity.

In this way, six learners and all four instructors revealed two byproducts of exposure to such neuroscience findings—*certitude* in perpetual learning capacity and the influence of self-perception *on* learning. In contrast to the literature, what is new or unique here is that while the education system purports a growth mindset, students and teachers expressed the necessity to have irrefutable data, as such information was productive in dissolving even the most intransigent of mindsets.

This impact was more complex for the four learners entering the study with growth and unlimited mindsets. While these learners reported no change in self-perception, having already held the most robust perspective, they experienced a deepening of their beliefs; as Phil mentioned, “My belief didn’t change, it [neuroscience modules] just gave me *more reason* to believe in my abilities, I found it interesting.” Thus, while neuroscience increased perceptions for most learners, it also acted as a sealant, locking in baseline beliefs for learners with pre-existing growth mindsets. This adds to the literature, as little is known about how such neuroscience evidence impacts learners with high self-perception of math potential.

Increased Self-Perception and Engagement Shifts

According to students and teachers, learners’ increased perception of mathematical potential catalyzed engagement shifts. First, students shifted from disinterest and pessimism around learning math toward a renewed optimism toward content learning (*affective re-engagement*), evidenced through learners’ self-initiated affirmations around potential. Second, students reported less fear of failure or anxiety around math learning, while baseline lack of enjoyment around learning math remained largely unbending. Third, students shifted their *behavior* by increasing participation and perseverance of effort rather than disengaging during complex or particularly demanding mathematical tasks. Finally, students shifted their *cognition*, revealing enriched understanding and increased mastery of the content, as evidenced by elevated assessment performance.

Learners' Baseline Disengagement

Affective Disengagement

Disinterested and Pessimistic Attitude Toward Learning Math

All four teachers and ten students tied learners' limited baseline self-perceptions of math potential with a pessimistic or deficient attitude toward math activities. Teachers reported a collectively resistant attitude toward engagement in their classes. Ms. Eve's comments summarized teachers' observations:

> Initially, they [students] would often say, "well, this is hard, I don't know if I can do this," or, "I'm not a math person." Currently we are in a unit in math where there is a lot of graphing. From the start, they were like, "Ms. Eve, we do not like graphing, we hate tables, we hate graphing." "Well, I'm not a math person. I can't do this. This is too hard." "I'm never going to understand this."

Ms. Eve interpreted her students' comments as evidence of a disinterested and despairing attitude toward math learning. Expressing frustration around her students' complaints, Ms. Eve noted her learner's inclination toward dismissing math tasks and relegating problems as exceedingly difficult or categorically unsolvable. Furthermore, all four teachers insisted that students' aversion and retreat from mathematical learning was *absolute*, with commonly reported phrasing such as "I can't do this. This is too hard. I'm never going to understand this." Unraveling the deeper reasons for such hesitancy, learners unearthed how a fundamental and longstanding fear of failure—an extension of their limited self-perceptions, contributed to such aversion.

Fear of Failure and Anxiety Around Learning Math

Ten students revealed how low self-perception led to an insecure and anxious disposition, further fueling pessimism toward math learning. Students explained how their lack of confidence precluded their willingness to problem-solve, despite possessing a degree of content knowledge. As Teresa shared:

> For me my limited belief impacted my effort in class. Because, well, although I would understand what she [teacher] was saying, I would never participate in class. So I felt like that impacted me because I felt like I wasn't trying enough. I was not participating. My belief made me think I wasn't good at math, because I was so scared that I would get the answer wrong.

An intense fear of failure predominated Teresa's attitude towards math, severing her willingness to participate in class activities such as problem-solving. Teresa traced her task aversion to intense anxiety about committing mistakes. Consequently, as did seven other learners, Teresa revealed a cascading effect of limited perception in mathematics—a rise in anxiety or fear of failure (*psychological unsafety*), leading to participatory aversion, stifling opportunities for a deeper understanding of the content. In addition to anxiety, students unearthed how their lack of enjoyment around mathematics contributed to such attitudes toward math learning.

Lack of Enjoyment Around Learning Math

Nine students and all four instructors reported learners' baseline lack of enjoyment in learning math–an indicator of affective disengagement. Scarlett's comments summarized this sentiment as she revealed:

> Well about my level of enjoyment in math, I never liked math because I was never good at it. Really always struggled. Like since I started learning math, in kindergarten-first grade. I was never really good at it. I think I might like it better if I was better at it. Because I do enjoy things that I'm good at, such as writing or English.

Scarlett correlated her persistent dislike toward learning math with her mathematical struggle rooted in early childhood. Scarlet asserted her enjoyment would increase commensurate with any performance gains–illuminating a possible change in her enduring discontent. Like eight other students, Scarlett confirms the research around engagement as, according to the HPL framework, students "make up their minds" early in childhood about their proclivities towards learning some subjects and not others (Bransford, 2000; Bransford & Schwartz, 1999).

Behavioral and Cognitive Disengagement

Task or Participation Avoidance

All four teachers and nine students linked limited perception of math potential with opting out of learning tasks or activities such as class discussion or problem-solving, as Ms. Rhonda shared:

> For me one of the indicators that they [students] had a limited perception would be that when I would ask them [students] to volunteer or when I asked a question to them, they often would just answer well, "I don't know how to do this." "I don't get it it's too hard." Things like that, and just give up.

Ms. Rhonda, as did three other teachers, reported that opting out of tasks or "giving up," was commonplace in their classes–evidence of students' lack of confidence to solve. Importantly, all four teachers indicated student expressions, such as "I don't know how to do this," preceded complete shutdown or withdrawal from beginning or continuing with learning activities for most learners. Aligning with the literature on engagement, such antecedents of learning (self-perception and beliefs around learning) can drive or stifle engagement as learners assess their sense of psychological safety. Teachers' tones mirrored a degree of resignation as they accepted their learner's reluctance. The literature around engagement addresses this deeply bidirectional phenomenon between instructors and pupils (Boykin & Noguera, 2011).

Limited Perseverance of Effort

Nine students expressed how limited self-perceptions stifled confidence to sustain effort during complex learning activities or tasks requiring such perseverance. Steven shared:

> Well, my limited belief in my math potential did affect me with certain problems. Like if I understood it [math problem] easily I was all right, but like if I didn't get it past a certain point, then I'm reminded of my limited math potential. I would just stop trying to keep going with the problem.

Stephen's perceived limited potential undermined his determination to solve complex mathematical problems, stifling his cognitive engagement. Such retreats for students were common and spoke to the interrelated nature of behavioral and cognitive engagement - as decreased effort (behavior) undermined understanding (cognition). Interestingly, like eight others, Stephen expressed how his focus rerouted from problem-solving to managing feelings of mathematical defeatism.

Significantly, this phenomenon of rerouting focus is found in neuroscience and sociological literature, as cognitive energy (required to solve math problems) moves towards brain regions that manage anxiety and away from areas governing problem-solving, usually due to stereotype threat (Zuo & Wen, 2018). For example, Stephens' doubts about his capacity to solve complex math problems rerouted his focus away from solving and toward processing such anxiety. Importantly, this underscores how such anxiety-inducing disengagement is not necessarily the result of stereotype threat but can also result from the belief of oneself as a deficient math learner during cognitively demanding tasks. In this next section, learners and teachers reveal how an increased perception of math potential, along with ASTP, modules, and lesson structures, galvanized engagement shifts.

Students Shift Engagement

Affective Engagement Shifts

Four teachers and eleven learners reported that while students improved optimism around learning and reduced anxiety and stress, their baseline lack of enjoyment and disinterest remained largely intransigent. Students attributed increased optimism, reduced anxiety, and stress to the interventions, neuroscience-framed modules, and self-affirmations.

Improved Optimism Toward Learning Math

Four instructors and six students explained how learners' increase in self-perception manifested elevated optimism toward problem-solving and other learning tasks such as class discussions. According to teachers, learners shifted from voicing self-defeatism around math learning to initiating affirmations around their ability to understand the material. Instructors explained that as students shifted their attitude, their classes became enlivened with renewed confidence. As Ms. Hannah shared:

> I say this shift towards growth mindset is the case because they are saying on their own, "I can do this." So what better way for me to evaluate than students' reactions, in what they are saying and that they are working now [solving problems]? Some kids keep saying even though we are done with the study, "I can do this," repeatedly, and "As I practice my brain is growing," I see by their actions and responses, how their beliefs have changed.

Ms. Hannah interpreted learners' affirmations as evidence of a shifted, more reassured attitude toward learning tasks. Such resolve sharply contrasted with students' baseline resigned and pessimistic attitudes toward math tasks. Significantly, learners synthesized self-affirmations with neuroscience and connected participation to neurological development, a unique amalgamation not mentioned in stereotype threat or engagement literature.

Continued Lack of Enjoyment and Disinterest in Math Content

While participants reported increased optimism toward learning math, eleven learners and four teachers reported that learners' baseline lack of enjoyment during math tasks remained. Both self-reported high-achieving students and those with a history of difficulty cited such intransigence. Phil mentioned:

> I found it [the intervention] interesting, as a new approach. I thought math will now, not be as difficult. But math itself is still boring but it's gotta get done. So I gotta just suck it up and keep going. Honestly, I completely despise math. I feel like math is really unnecessary. Even though I recently started getting better grades, I still found myself not liking math. There is nothing that will change that.

Phil, a self-reported high-achiever with an unlimited perception of math potential, profoundly detested math. Albeit piquing his intrigue, Phil found the intervention unable to generate enjoyment or interest in math. Phil underscored the fixed nature of his disdain as he emphasized,

“. . . I completely *despise* math . . . *nothing* will change that,” a sentiment mirrored by Teresa, who added, “No, my enjoyment did not change. It [the intervention] just basically like impacted my grades and my understanding, but *the lack of enjoyment sticks* and I *don’t* think anything is going to change that.” While learners’ optimism toward understanding content increased, their disinterest or lack of enjoyment in learning math remained. Significantly, this data strongly aligns with quantitative findings as self-perception and cognitive increases exceeded increases in affective engagement (for more information, see Chapter 4).

Changes in Enjoyment Levels

A fixed enjoyment level or disinterest in math was not the case for some learners. Three learners reported increased enjoyment commensurate with their understanding, while two reported an increased displeasure in learning math, Olivia’s comments summarize learners’ rationale for their increased enjoyment as she shared:

> I’ve never really liked math. At the beginning of this, my teacher asked, oh, do you guys like math? And I said, “no.” And she was like, “I hope that could change.” And it did change. And I actually do enjoy learning math now. The whole program [ASTP] helped me. Just like having more understanding of math, helped me change my ability to like math more.

Olivia, as did two others, remarked that as their understanding (cognitive engagement) of the content increased, so did their enjoyment of math. These two learners tied their increased capacity to comprehend and navigate the material to their emotional satisfaction. In contrast, two other learners mentioned how personal life events and strained relationships with their teachers diminished their level of enjoyment in mathematics.

Reduced Fear of Failure

Three teachers and eleven learners explained that students experienced less fear of failure as they increased their optimism. Tiffany’s comments summarized learners’ change in reduced apprehension, adding:

> Now I'm less anxious. Before, sometimes if I can see that I feel that I'm not gonna understand a problem, I would get so nervous. Like I really want to get this right. Because I don't want to fail. I've always had that [fear of failure] mindset. It's never changed. Until now. I think it was the self-affirmations again, because it was just giving me the confidence to try. It [self-affirmations] just gave me more confidence in answering the questions, and more than likely I was right. Once I got the confidence.

Like ten others, Tiffany explained how her anxiety lessened as she grew in confidence–a change she attributed to the intervention's self-affirmation strategy. As a secondary effect, she found that as her anxiety subsided, she could focus more readily on class discussions and problem-solving. Tiffany emphasized the efficacy of self-affirmations in ameliorating prolonged fears around learning math, as she emphasized the longstanding nature of such anxieties, underscoring, "I've always had that [fear of failure] mindset. It's never changed. *Until now*." Additionally, students and teachers unearthed a shift in how learners reframed their mistakes, giving rise to a new outlook on setbacks–one unshackled from fear and anxiety.

Interpreting Errors as Areas of Opportunity

Three instructors and ten learners identified ASTP's Neuroscience Module, *Error Reflect Redirect*, as pivotal in reshaping students' *attitudes* around mistakes and setbacks as growth areas rather than evidence of limited ability. This module showcased fMRI and CT scans that demonstrated higher electrical brain activity for learners with a growth mindset, in contrast to lower activity for learners with a deficit mindset when committing mistakes. This module structured assignments, accordingly, requiring students to reflect on errors while circling prewritten neuroscientific affirmations on assignments before attempting subsequent problems (for more information, see Chapter 3).

Teachers reported how such neuroscientific data and structured learning resulted in learners accepting mistakes as growth opportunities instead of evidence of restricted math potential. Ms. Amelia shared:

> The error analysis . . . [error reflect redirect] module is really a great thing, and I feel like more students are noticing it [mistakes as an opportunity], as I would point it [errors] out. Like if I took a student's work sample to compare answers, maybe on the think pair shares, I would at times notice a small mistake. We would then do an error analysis, and I would ask them, is it okay to make a mistake? And they [students] would respond yes, we can learn from that mistake. And so I saw that it [module] changed their beliefs around their mistakes.

As did three other instructors, Ms. Amelia observed a reduced fear of failure among her students as they began to interpret their mistakes as areas of opportunity. Such positivity and confidence contrasted with baseline deficit voicings as Ms. Amelia reported an example of learners' refreshed perspective on errors: ". . . yes, *we can learn* from that mistake." This reported perspective on errors is significant, as learners previously feared such setbacks as indicators of a deficiency in their *ability* to learn the content.

Students Shift Behavioral and Cognitive Engagement

Concerning behavioral shifts, four teachers and eleven students reported increased participation during problem-solving rather than task aversion and perseverance of effort rather than resignation during complex math challenges. Finally, concerning cognitive shifts, three instructors and thirteen learners reported how task immersion and perseverance enriched student understanding and content mastery, evidenced by increased summative and formative performance.

Increased Participation

All four instructors and eleven learners reported increased participation rather than task avoidance or hesitation when prompted to solve or engage in learning activities. Ms. Hannah shared:

> They're changing because before [prior to the intervention] almost all didn't try [participate] at all, they would just sit there. And only those students who got it [understood the content] were the only one's working [solving]. Now, even those kids except maybe one or two kids, now everybody else tries [solves]. They look at the notes and they try to imitate it [solving procedure]. And then instead of asking another person,

> can I just copy the paper [solution], they are actually doing the work on their own. That was a big change.

Ms. Hannah contrasted her students' baseline disengagement of "just sitting there" with renewed class-wide task immersion, emphasizing, "Now, *even those kids* except one or two kids, *now everybody else tries* [attempts to solve]." Ms. Hannah marveled at how historically disengaged students were re-engaging. Such shifts in participation was observed among all teachers. Furthermore, Ms. Hannah underscored how learners' behavioral engagement or "trying" set the stage for increased cognitive engagement (understanding). She observed low-level cognitive engagement, such as copying their neighbor's paper (solution), move toward higher-level cognitive engagement, such as independent problem-solving.

Nine learners unearthed how neuroscientific evidence of perpetual learning capacity galvanized participation. Olivia shared:

> I feel like when I put more effort into my work, I have more, math skills, and that's when the unlimited math skills come in that I could learn more and learn anything. I think it changed because the program made me push myself to learn and focus, knowing I could grow new brain cells and expand my math skills.

Like eight others, Olivia reflected on how neuroscientific evidence, particularly neurogenesis, supporting perpetual learning capacity increased her *value* of engagement, ". . . the program *made me push myself* to learn and focus *knowing* I could grow new brain cells and expand my math skills." Olivia connected her effort with math skill development by referencing neurology via "growing new brain cells" (neurogenesis). Students renewed hopes that such participation would yield increased math skills and understanding, concluding that putting forth effort was worthwhile, given the neuroscientific evidence connecting effort to skill improvement.

Increased Perseverance of Effort

Ten students and three instructors reported how learners sustained this newly resolved effort, Fernando shared:

> I participated more in class even when it [math problems] did get a little bit hard. I think using the self-affirmations helped me push through, and also the module on errors where the teacher was showing that mistakes could actually make you grow new skills [error reflect redirect]. . . . I feel like that helped me to push through the harder problems and focus.

Fernando sustained his effort despite mathematical hurdles. Interestingly, nine other students similarly expressed newfound determination as they no longer withdrew their efforts when faced with mathematical difficulties–but persisted through them. Importantly, Fernando revealed how such a combination of neuroscience and self-affirmation (knowledge and strategy) reduced his previous fear of failure, rendering such anxiety inert, as he recontextualized mistakes as productive toward skill development. This finding is consistent with the sociological and neuroscience literature on engagement, as anxiety reduction correlates with increased focus and concentration (Borman et al., 2016).

Adding depth on how self-affirmation and neuroscience combined to catalyze perseverance, Sandra found self-affirmations such as "*I can do this,*" unproductive without sufficient evidence to substantiate such claims. Sandra added:

> I think the neuroplasticity module and self-affirmations helped improve my effort, because whenever, like I would say "I can do this," before, I don't think I would ever like really believe it [self-affirmation]. I was just saying it, but, the neuroplasticity and the self-affirmation modules connected and I started thinking like, oh I actually can get better at this and try again. Then when I did say "I can do this," I would actually think, yeah, I can, take some breaths, and then push forward. That helped my understanding of the material and increased my scores.

Sandra attributed her newfound perseverance to a deepened trust in the veracity of self-affirmations by referencing neuroscience. Sandra found self-affirmations, absent of neuroscience evidence, insufficient for inducing perseverance, interpreting such affirmative claims as empty unsubstantiated assertions. Upon contextualizing self-affirmations in neuroscience, Sandra reported a shifted assuredness in such practices. Precisely, Sandra connected how neuroplasticity validated self-affirmations, increasing her participation and trust in such practices. In this way, like five others, Sandra unveiled how neuroscience provided sufficient data to help unlock the capacity of self-affirmations to drive perseverance.

Instructors confirmed student reports around perseverance, as all four teachers observed a class-wide shifted determination, especially during guided practice. Ms. Eve shared:

> In the last two weeks of the study we work independently on problems for the guided practice. They [students] actually tried longer and so I would set the timer for about four minutes to work out a problem, and I'm like, "Alright, your four minutes are almost up. How many of you guys need a little bit more time?" And normally students that I wouldn't see working, we're still attempting the problems.

Ms. Eve observed students' endurance as they independently solved practice problems during guided practice. Significantly, Ms. Eve expressed a stunned tone around such shifts in her learning environment as learners were not only trying problems but were requesting more time to ensure task completion and thoroughness.

Most profoundly, ten learners and four teachers reported that this perseverance increased content understanding, an indicator of cognitive engagement. As Sandra summarized, "When I did say I can do this, I would actually think like, yeah, I *actually can* and . . . try it again and . . . ended up *understanding* the math problem . . . and *increasing* my math scores" In this way, students connected how such shifts in their determination set the stage for gains in content mastery.

Students Shift Mathematical Understanding and Performance

Concerning cognitive engagement, three teachers and eleven learners cited increased formative (exit slips, quizzes) and summative assessment performance (unit examinations, grades) as evidence of students' enhanced content understanding.

Students Improve Formative Assessment Performance

Three teachers and ten students reported gains in formative assessment results through exit slips and quizzes. Notably, participants reported learners increased *accuracy* on such assessments. Ms. Amelia shared:

> They're believing in themselves more. I am seeing changes in their exit slips. They are scoring better on quizzes and tests. I would say student performance has increased significantly with the majority of students. It's the chunk chew check [CCC] that really helps with their accuracy in general. I was really shocked as I was grading my exit slips. I was like, oh, another perfect one, another perfect one. Like they've just got it down. It shows that they understand the concept.

Ms. Amelia's surprise around increased mathematical accuracy on formative assessments was notable as she recorded consistently perfect scores. Further, she interpreted such results as a formative indication of increased content mastery, emphasizing, "It shows that they *understand* the concept." Two instructors also connected these performance increases back to learners' increase in self-perception, Ms. Amelia elaborated, "They [students] are *believing in themselves* more." A notable contrast as Ms. Amelia, like three other instructors and twelve learners, originally tied students' baseline limited self-perception to restrained baseline academic outcomes.

Ms. Eve detailed improved metrics, sharing, "I have a lot of fours now [maximum score on a scale from one to four], and perhaps a few 3.5s, for about 85% of the class. Pretty high performance during the study. I think the chunk chew check really helped." She and two other teachers attributed performance increases to the ASTP-adapted Chunk Chew Check (CCC) methodology.

These three instructors additionally emphasized the unique combination of the *CCC structure*, *increased task participation*, and *decreased fear of failure* as drivers of increased formative performance. Ms. Rhonda added:

> I saw an increase in scores in the exit slips. My exit tickets in the past were usually a lot of blanks because they [students] just didn't try. And now every single student in my classroom would at least now try, which is a big thing. So that was the turning point where I saw change. Really the chunk chew check that really helped. That and also they would actually try now and they weren't afraid to make a mistake.

Ms. Rhonda attributed increased formative assessment results to students' increased *task participation* rather than opting out of such tasks and decreased fear of committing errors. In this way, Ms. Rhonda, as did two other instructors, linked learners' change in attitude (affective engagement –reduced anxiety) and participatory re-engagement (task participation) with increased cognitive understanding evidenced by formative increases in performance (exit slips).

Eleven learners added depth to their instructors' reports of increased formative understanding, clarifying how formative exit slip performance led to higher summative performance and metrics (examinations and grades). Tiffany's comments summarized this group's sentiment as she shared:

> My math performance has improved, with my exit slips. I've been getting all fours [scale from one to four]. I can see them [exit slips] on a wall in the back of the room. My test scores have gone up too, from like 85 to a hundred, consistently. And my grade is like an A now. What helped me was the self-affirmations our teacher, would always say them before the test and while we're taking the test. So that helped a lot.

Tiffany reflected on her increase in content understanding noting how her gains on formative assessments corresponded to improvements in summative performance, thereby connecting her rise in exit slip performance to increased examination results and grade shifts. In this next section, participants unveil how such formative increases informed increases in summative performance.

Summative Assessment Performance Shifts

Three instructors and ten learners reported increased summative assessment performance during the ASTP intervention. As instructors reviewed their summative data, they evidenced shifts by comparing results to corresponding data, including previous semester summative performance, assessment performance in years prior, and corresponding results to course-alike colleagues'(not part of the study) outcomes at the same site.

Ms. Amelia summarizes the semester-to-semester comparative analyses of shifts in summative assessment results, adding:

> One of the tests that I gave during the study, was the unit 7A exam. I did have more As on that test than I had in other tests, especially in first semester. There was more [student] effort on that test and perseverance, and it was a hard test. A lot of students who hadn't had As on a test before did now, especially since they've tried harder and maybe practiced a little extra. I've had students say, "I did better and I worked through faster." I feel like the pieces are coming together for most students, where they're thinking okay I'm learning every day with less mistakes. And, you know, learning is becoming faster and easier and its showing on their results.

Compared with the first semester, Ms. Amelia noted her learners' summative performance increases were above trend to such an extent that learners who had never had an A on any exam did so during the intervention. Significantly, Ms. Amelia attributed the increased performance to shifts in learners' perseverance, confidence, and accuracy.

While Ms. Eve's learners similarly increased in summative performance, she detailed more precisely such shifts through an analysis of grade distributions adding:

> So there was an increase, most definitely, I recorded how test scores increased a lot. So there was a big shift from mainly Cs, Ds, and Fs to As and Bs as a majority. 20 students took our test. 16 got an A, 2 got a B, and then one got a D, and one got an F. There's a lot of As on this test. And prior to the intervention, and last semester, the majority of the grades, were not As and Bs. There would only be I'd say maybe three or four As or Bs. The majority would be Cs, Ds, and Fs.

Ms. Eve identified a sharply shifted grade distribution from previous exam performances predominated by Fs or, at best, Cs to 90% achieving As or Bs followed by 10% earning a D or F. Such changes link to quantitative findings, as learners reported statistically significant increased results in the metacognitive (content-understanding) measures.

Ms. Rhonda compared her student increases on her unit 3B exam to results in years before and her colleagues' students (not part of the study), adding:

> My test [Unit 3B] grade average shifted to almost 80%. In years prior I would have a low C–D average. We [teachers] graded the Unit 3B assessment together. My scores were mostly As and Bs, [while] other teachers had several blank exams. I had very few Fs, like the lowest. They asked me what I was doing. I just said, I'm following this new framework in this study, and it works.

Ms. Rhonda found her current learners outperformed previous students taking the same test and her colleagues' current learners, "Out of the huge majority of us, I had very few Fs, like the *lowest*." Uniquely, Ms. Rhonda's data analysis indicated considerable shifts compared to two data sources (*previous* and *contemporary classes*), further accentuating the extent of her learner's mastery. Results sparked her colleagues' curiosity as they inquired about what contributed to this shift in learning outcomes. Ms. Rhonda identified the intervention as a central driver of increased learning outcomes.

As mentioned, not all instructors experienced gains in such performance. One teacher, Ms. Hannah, added, "To be honest, grades are about the same because they were doing well before. Except some kids who were absent a lot…they were failing."

Ten students added depth to teachers' observations of increased summative outcomes. Stephen, like six others, emphasized a sense of increased pride and confidence as he noted how self-affirmations and reduced fear of failure contributed to his increased content mastery as he added,

> This experience, made me more, interested in math, and I noticed my exit slips scores got better. They [exit slips] even got put up in a wall in our classroom. My tests and grades have improved a lot too since this experience because I used to have really low grades like Ds and Fs, and all of a sudden I have an A in the class. The self-affirmations and the error reflect redirect modules helped me get there knowing that you learn from errors.

Learners reported how their grade improvements sharply contrasted with baseline reports of limited mathematical content mastery and a history of difficulty, linking such changes to their newfound knowledge and strategies from the intervention. Stephen credited his performance shifts to a *combination* of self-affirmation strategies, neuroscience evidence of perpetual learning capacity and reframing of mistakes as productive toward learning. Interestingly, most students identified not one single part of the intervention toward increasing their performance but rather combinations of such strategies and knowledge.

Anita, like nine others who described shifts, particularly reported a sharp shift in her summative performance as her grade increase spanned the spectrum. She attributed this change primarily to the role models components of the intervention sharing:

> The last test I took I didn't pass, so I had an F before we did this [study]. Now I'm at an A. My grade went up quickly. I think because before I wasn't really turning in my work but then when I started to pay more attention and focus, then I actually passed my test with a hundred percent. What helped me I think was the role model section, because they were putting effort and before I wasn't really, like, I wasn't really paying attention. I was talking to my partners, you know, but this semester, I'm paying attention and focusing now.

Anita reported significantly shifted grades resulting from increased task immersion and "turning in her work." More importantly, however, she described increased focus and effort inspired by role models' perseverance and example.

In this way, eleven learners yielded a common byproduct of increased engagement due to changes in self-perception–increased content understanding evidenced by elevated formative and summative performance. In this next section, teachers reflect on the implementation experience and how the aforementioned perceptual, engagement, and performance shifts deepened their professional satisfaction.

Teachers Adapt Instruction and Increase Professional Satisfaction

Teachers reflected on their experiences around perceptual and engagement shifts. Educators described how they adapted instruction, citing practical training and ease of module (mini-lesson) integration. Teachers reported that adapting ASTP lesson structures required them to restrict lectures and re-prioritize time toward cognitive processing during guided practice with increased checks for understanding. Teachers expressed ease around adopting ASTP lesson activities, including a warm-up, truncated direct instruction, guided practice, and exit slip activities, more quickly than the group activities (think–pair–share), describing a gradual implementation of this activity on a continuum.

All four teachers remarked on how their students acclimatized to the intervention. They explained how learners grew from their initial confusion and hesitation around the ASTP module (concepts and activities) toward increased understanding and participation in such tasks. Consequently, teachers remarked on their professional satisfaction around such perceptual, engagement, and performance shifts, resulting in their desire to adopt the intervention post-study. While mirroring research-based practices, these changes took new meaning in the context of student mindset and stereotype threat.

Practical Training

All four teachers reported sufficient preparedness for implementation. Moreover, while teachers characterized ASTP as content-dense, they explained how the ASTP professional development and ongoing support resources helped grow their understanding and ease their implementation. Ms. Eve shared:

> The training was practical and easy to understand. Very straightforward presentation, even though it was a lot of information. What was also helpful was the handbook matching the online guide so we knew what to do and when. If I had questions in the moment, I had multiple resources. I like how the folder contained everything online but printed out. That was very helpful, like as a resource that also covers everything that was in the training and the research supporting it. When I needed support, I had multiple resources.

Ms. Eve found the professional development productive in clarifying her understanding of ASTP pedagogical activities, structures, and modules. Such clarity helped her overcome concerns about the program’s complexity. Three other teachers, like Ms. Eve, voiced appreciation for the online and printed resources, alleviating their apprehension around anticipating or troubleshooting implementation challenges over the six weeks. A common trend, three teachers found increasing comfort and confidence around the end of the second week of the implementation.

Ease of Module Integration

All four teachers noted the ease of integrating ASTP mini lessons or *modules*. Ms. Eve's comments were representative of this sentiment:

> The modules were the easiest part to implement because they were well designed and truly because I didn't have to add anything, I just had to make time for them I didn't have to add or create them myself. We would do our warm up and then right after we would go into the modules. So that was pretty easy. I just had to make sure to go over it beforehand, just to make sure I knew what I was talking about.

Ms. Eve found the modules' self-contained nature relieved her concerns about undue burden or excessive effort on her part. In addition, educators commonly expressed their appreciation as modules could be "attached" to existing lessons.

Likewise, Ms. Amelia reported ease of module implementation; however, she attributed such efficiency to the modules' capacity to *enhance* pre-existing learning activities such as error analysis:

> I found the error analysis [error reflect redirect module] easy to implement because it fit well with what we had been doing, like looking for mistakes. But it was great to add the neuroscience aspect so we could finally prove we can learn from our mistakes; that stuff like I said was fairly easy. And the students truly understood what I'm saying.

Ms. Amelia explained how the error reflect redirect module raised the productivity of her pre-existing activities, particularly error analysis, as she emphasized, ". . . it was great to add the neuroscience aspect so we could *finally prove* we can learn from our mistakes." In this way, teachers leveraged neuroscientific evidence to persuade learners about the *neurological* benefits of maintaining a positive outlook and how such perception optimizes learning. In such a manner, Ms. Amelia found her error analysis enhanced by the *clarity* of the neuroscientific modules making such technical content approachable for learners underscoring, "And the students truly *understood* what I'm saying." Ms. Amelia's assertions about student understanding of such concepts around mistakes as areas of opportunity were validated earlier in this chapter through student data.

Integration of Lesson Cycle Activities on a Continuum

While all four instructors reported ease of integrating most lesson cycle activities - (*warm-up, direct instruction*, *guided practice*, *think pair share* (collaborative learning), and *exit slips*, two teachers reported implementing the think pair share activity progressively on a continuum, citing challenges in time management; as Ms. Eve shared:

> So I would do the warm-up and then the module. From there I would do a couple of examples. Then they had their guided practice. And then I was looking at the time and I'm like, I really wanted them to do a think pair share, but there just wasn't enough time because I wanted to make sure that we could kind of cover a little bit more [curriculum]. But when I did have a chance, I had them share with their partner but it wasn't structured like the think pair share that you trained us in, it was just like a quick, okay, explain this to your partner. That was a little more challenging, because I didn't do it so often.

While Ms. Eve endeavored to include all activities within the lesson cycle, she expressed that time management challenges hindered her ability to conduct a think pair share. However, her reflection revealed a deeper reason for her lack of activity implementation beyond time management, as she *weighed the value* of either allocating additional cognitive processing time (think pair share) or reviewing more content. While she chose the latter, this deliberation sheds light on a gap in the literature as little is known about how or why educators acquiesce to the temptation of covering more math content (a traditional approach) rather than prioritizing additional cognitive processing opportunities (a more modern approach). While ASTP emphasizes the latter, interestingly, both the newest and most experienced teacher in the study found it difficult to detach from such traditional philosophies of "more is better," despite evidence presented to the contrary during the training, where cognitive processing is optimized by using less content per lesson, not more. In other words, as the education system moves towards increased time for cognitive processing, it may be worthwhile to uncover why teachers sometimes default to more traditional modes of delivering content. Furthermore, while all teachers purported to have understood the training, such data showed that completing the lesson cycle to fidelity remained an area of growth for two teachers.

Teachers Adapt to ASTP Structures

Unsurprisingly, all four teachers reflected on the necessity to reformat content and timing to conform to the parameters of re-chunking (reducing) math content covered per period. Further, teachers observed the productivity of reducing content (restricting lecture), reallocating time toward cognitive processing or "chewing," and increasing "checks," for understanding. Ms. Rhonda's reflection was representative of this sentiment as she added:

> The chunk chew check procedure increased students' confidence in solving problems, because I gave them structured time to do it [solve math problems]. In the past I would say you've got three minutes to do this, but I wouldn't put a timer or hold them accountable. So I started to grant them more structured time. The chunking, and chewing of the material along with the check was easier to implement by the fifth and sixth week. I found I had to do smaller chunks, I think the way I was chunking it before was too much information and it was going over their heads. And continuing last week, I'm still implementing it. I got the hang of it. The students got the hang of it.

Interestingly, all four teachers remarked on reducing their lecture (smaller chunking), reflecting how their previous content coverage per lesson appeared to overwhelm learners as Ms. Rhonda reflected, "I think the way I was chunking it before was *too much information*, and it was going over their heads." In this way, teachers described how excessively large default chunking of material contributed to student disengagement, as educators reflected how they were covering too much content per lesson. Additionally, Ms. Rhonda underscored the productivity around the "chewing," portion of the CCC methodology, highlighting the importance of granting students structured time to process the material. Using such methods, Ms. Rhonda grew in her awareness and appreciation of reducing content and structuring processing time for cognition.

In the following section, teachers reflect on not only their adaptation experiences to the intervention but those of their students. All four teachers expressed how students adapted to the program, growing from initial confusion and hesitancy around neuroscience topics toward gradual confidence and familiarity around such information. Teachers also shared how the productivity of the intervention—by way of increased perception, engagement, and achievement—resulted in their desire for post-study adoption of the intervention and its strategies.

Students Acclimatize to the Intervention

Students' Initial Confusion

At the onset of the intervention, all four instructors described learners' confusion and reluctance around neuroscience concepts. Ms. Rhonda shared:

> I think the first week throwing the words neuroplasticity and neurogenesis at them was very interesting to watch them read that, it seemed to go over their head at first. So at first that [student confusion] was challenging eventually they did understand what that language meant. But at first I felt like they just heard it and were all deer in the headlights like what is this? So that was probably the most challenging to try to get them to wrap their head around those concepts, as you know I've never taught that before.

Ms. Rhonda interpreted students' surprise, or "deer in the headlights," during the onset of neuroscience topics as an indicator of learners' unfamiliarity. Interestingly, Ms. Rhonda was determined to ensure students grew in understanding, highlighting her resilience through initial learner hesitance. She underscored, ". . . at first that was *challenging* [student confusion] eventually they did understand what the language meant." Significantly, Ms. Rhonda insisted that although her students were initially confused, she did not avoid administering the intervention to fidelity. This is valuable as Ms. Rhonda's reflection adds to the literature on the productivity of instructors' grit and resolve when guiding students through such unusual topics.

Students Acclimatize to the Program

Over time, students grew in their understanding and comfort around activities and terminologies. Three teachers explained how it was not until the self-affirmations (week 2) that students began to show a degree of assuredness around the process. Ms. Rhonda shared:

> It was in the self-affirmation week [week 2] where I saw a big difference with students feeling more confident to answer questions and try problems. I think it came about because they felt more confident in their abilities rather than constantly doubting themselves. It [the intervention] definitely increased their [learners] confidence in solving problems, because it gave them motivation and time to do it and a structure as to how much time they had to solve and demonstrate that confidence and new learning.

Ms. Rhonda observed that learners reduced confusion during the second week of the intervention as learners grew in their familiarity and confidence around ASTP structures. From weeks three to five, teachers found students understanding and embracing of more complex topics, particularly neuroscience, increased. Ms. Amelia shared:

> Seeing a review of the previous topics each week, especially things they've never heard about, like neuroplasticity or neurogenesis, repeatedly helped students. They needed to hear those terms again and again. And I'm glad we started week one with that [neuroscience] because they could hear it more and it explains the reason why everything else [subsequent modules] is true. They maybe didn't quite believe it in the first week. But by the shattering math myths module ,[week 4], they [students] were like okay, I feel like that's when it started to click like this [limited potential] is a math myth because we have neuroplasticity and neurogenesis.

For Ms. Amelia, the program's clarity for students came from the repetition of neuroscience topics covered in first weeks' module. While learners found neuroscience initially confusing, teachers and students reported how reinforced exposure to these concepts throughout the modules facilitated clarity and familiarity with such topics.

Teachers commonly outlined a final phase of the program where students became *ASTP-adapted*, a phase characterized by increasing acclimatization to the program. Such student adapting took the form of becoming comfortable with the adopted lesson cycle, structures, while demonstrating task immersion throughout the lesson cycle.

Teachers Increase Professional Satisfaction

All four teachers reported increased professional satisfaction. Instructors related how changes in their learners' perception, engagement, and performance reignited their professional pride and left a notable emotional impact. Ms. Amelia shared:

> It's a nice feeling when you see your students using what you teach them, even if it's not math. Like the positive affirmations, students would do those [self-affirmations] and I was like, wow, they're doing those strategies because I taught them. That's always a good feeling. Or when I see less distractions and less time on their phone. The students who would ask almost every day for a restroom break wanted to stay in class. That's good because I'm thinking, oh, they're engaged now. They see how important it is to be in class. They want to be here. It made me feel better about wanting to be there and not wanting to miss out, you know, wanting to make sure that I was there with them.

Ms. Amelia experienced a newfound appreciation for her capacity to influence her students' optimism toward learning mathematics. In addition, she expressed enjoyment around her students' re-engagement. Ms. Amelia gained a new perspective on the profundity of her role as an educator as she linked her learners' shifts to her actions. Such evidence suggests that as learners deepened their engagement, so did their instructors. Significantly such bidirectionality in emotional changes affirms findings from the engagement literature as engagement is described as a profoundly symbiotic and complex inter-relational experience between teacher and pupil (Boykin & Noguera, 2011).

Post-Study Adoption

As part of their satisfaction with the implementation experience, all four teachers indicated their desire to continue implementing the ASTP framework. Ms. Hannah's remarks summarize teachers' endeavors for post-study adoption as she shared:

> I'm gonna keep doing this, everything together. I'm not gonna change anything. Like you know how you're going through the neuroscience part of it, yeah, it's good. It's just that the neuroscience part is needed so that they [students] can see the whole picture of it. So they [students] can see they can do whatever kind of problem being asked of them.

Teachers desired to maintain the proposed components of the intervention. Emphasizing the productivity of the adapted lesson cycle, new chunking of material and the neuroscience modules. Three of the four teachers emphasized the CCC methodology, noting the promise of such a structure on cognition. Ms. Eve emphasized:

> I would continue using the chunking. As part of like my lesson, the chunks of the lesson cycle, all of it. Because I think it works. I mean, the study kind of showed it because as I connected the final results to the way I started chunking the material I think it helped my students learn and understand [math content] better.

Ms. Eve spoke for all teachers when she underscored a deep willingness to continue implementing the strategies and techniques within the ASTP intervention. Ms. Eve cited both the productivity of the chunking, particularly CCC, as an integral part of supporting students in their content mastery.

While teachers remarked on the productivity of the intervention and perceptual, engagement, and performance shifts, they reflected on their beliefs about learning and teaching diverse students. In this final section, teachers internally examine changes in their perspectives toward the instruction of diverse students, particularly regarding stereotype threat and growth mindset.

Teachers Reveal Expanding Commitment to a Growth Mindset

The ASTP experience deepened instructors' commitment to a growth mindset. While all instructors purported a growth mindset, along the way, some teachers unearthed presumptions about the learning potential of diverse students, eliciting shifts in such perspectives. All four teachers grew in believing that persistently disengaged diverse students *can* re-engage *and rise* to rigorously high mathematical expectations, eliminating considerations or contemplations to the contrary. Precisely, instructors unearthed and eliminated doubts around their diverse learners' capacity to excel in activities demanding rigorous mathematical solving, perseverance, and discourse. Such reflection led to teachers' resolve to expand rigorous learning opportunities and raise expectations for diverse learners.

Teachers Baseline Growth Mindset for Their Students

All four teachers purported initial growth mindsets underscoring how all students, regardless of ethnic background or gender, could succeed in math. As Ms. Hannah shared, "I've always believed *all students* have the ability to learn, like regardless of their ethnicity . . . if they put in enough effort and engagement during class time that they can learn." A sentiment mirrored by Ms. Rhonda, who shared, "I've always believed that everybody is capable . . . all students are capable." Instructors shared how their philosophy toward diverse learners' capacity was unlimited regardless of ethnicity or gender.

Challenges to Growth Mindset

Two teachers described how school leadership conveyed deficient messaging about their diverse learners, strained their growth mindsets. Two teachers found such assertions in the professional milieu necessitated a defensive stance to maintain their growth mindsets. Ms. Rhonda shared:

> It came from leadership. They definitely conveyed that students are at a disadvantage. And that we as teachers need to basically feel sorry for them while we teach. That was a struggle for me, I've never been big on feeling sorry for anybody. I've always had the mindset that everybody's capable, no matter where you come from, what you do, and so that was always really hard for me. I had to reaffirm my mindset that students are capable, which went against what we were being told from the top down. They [leadership] would say," Don't require them to do a test. If they [students] don't feel like it don't require them to do any work if they had a bad day." I believe that's not okay.

Ms. Rhonda interpreted leadership's approval of allowing students to opt out of classroom learning or assessments as a lowering of academic expectations for diverse learners. Ms. Rhonda felt such messaging devalued learners' capacity to rise to high expectations, as her administration readily reported abandoning engagement or assessment requirements contingent if students "had a bad day." Interestingly, such messaging unearthed a resigned posture around engagement and assessment as teachers described some administrators as capitulating on learning accountability. In response, Ms. Rhonda described how such messaging strained her growth mindset, "So I had to *reaffirm my mindset* that students are capable, which went against what we were being told from the top down." In such a way, two instructors unveiled how holding on to their growth mindset required them to oppose their leadership's value system and outlook for diverse learners. Significantly, such tension between instructors' and administrators' mindsets revealed how systemic systems of bias (leadership policies and philosophies) strained teachers' growth mindsets.

Teachers Reveal Inconsistencies in Their Growth Mindset

While instructors purported a growth mindset, they unearthed and reflected on implicit or unintentional perspectives and actions to the contrary. Nevertheless, teachers were steadfast upon recognizing such patterns of thinking or instructional decisions and resolved quickly to expand on such limitations.

Two instructors reported doubts about diverse students' capacity for robust peer-to-peer, problem-solving sharing, and error analysis. Ms. Eve's comments summarized teachers' perspectives:

> The way this study challenged my beliefs around my teaching is like giving the students time to talk among themselves about math. I think I wouldn't encourage it and ended up not doing it because my fear is that if I give them time to talk about math, they're just going to go off topic and talk about their weekend or what their plans are. So that was one of the challenges about my beliefs around teaching diverse students.

Although Ms. Eve reportedly held a growth mindset, she contrastingly revealed *disbelief* in her learners' willingness to share their mathematical solving and reasoning during think pair share, a cognitively demanding task requiring error analysis and reflection. In other words, Ms. Eve assumed diverse learners would not rise to the expectations of the task, presupposing they would more likely "go off topic and talk about their weekend." Notably, Ms. Eve presupposed such *off-task* behavior before even attempting the activity. In doing so, Ms. Eve revealed, as did one other instructor, a byproduct of such preconceptions–barred access to cognitively engaging activities due to instructor bias.

In this way, two teachers reported limiting intellectual opportunities to engage with the content based solely on presuppositions doubting diverse learners' capacity to engage and rise to the expectations of the activity. Significantly such teacher receding of opportunities aligns with the literature on engagement, as reduced opportunities for robust learning are more likely to occur where diverse populations are present (Boykin & Noguera, 2011). Such correlating between students' diverse backgrounds with an inability to engage in rigorous learning demonstrated inconsistencies in teachers' purported growth mindsets.

Remediating Implicit Expectations and Deepened Commitment to Growth Mindset

Deficient presuppositions unearthed during the six-week study prompted shifts around such perspectives, resulting in a deepened commitment to a growth mindset. In particular, three instructors reported an invigorated growth mindset as they found increased learner performance eliminated even the most modest reservations about diverse learners' capacities. Ms. Rhonda shared:

> Now, I don't need to worry as much about kids. I don't feel like I'm doing the wrong thing by pushing them to be successful anymore. In the past I felt like pushing them [diverse learners] was me being a mean person or, you know, wrong based on my [site] leadership. Knowing that this student might have had a bad day. But they're so capable they can do it [increase achievement] and watching them actually do that during this study confirmed that. It's very rewarding for me.

Ms. Rhonda, pressured by her administration to view her learners through a remorseful and low-expectant lens, struggled to unravel the appropriateness of such messaging as she felt "guilty" for pushing her diverse learners to excel. Ms. Rhonda's growth mindset in this way showed some strain and perhaps even some vulnerability by such influences. She said, ". . . I felt like pushing them [diverse learners] was me being a mean person . . . or wrong based on site leadership." However, as Ms. Rhonda observed learners excelling, she reported a more resolved, less assailable growth mindset, ". . . they're so capable they can do it [increase achievement] and watching them actually do that during this study confirmed that." In this way, two other teachers reported how diverse learners' academic achievement reduced and to some degree relieved guilt about pushing diverse learners to excel. These teachers used observable data of increased achievement as confirmatory evidence to strengthen their growth mindset.

Ms. Eve added depth to the discussion around such deeper commitments to a growth mindset as she experienced a rise in her expectations for her diverse learners, adding:

> Being part of the study, I feel like I'm being watched a bit more so I'm like I need to up my game. Now, they [diverse learners] are being more specific with their responses. And I think it's also on my part. I'm expecting that from students. When we go over problems and their answers I'm like this is how you need to write it [exact units]. I need to be at that level of expectation. I should have always been at like at that higher level. So now, my students they're more specific, they're more accurate to what they need to produce and I think it's because the level of expectation changed on my part because of the study.

Ms. Eve, as did two other instructors, noted a shift in their expectations for learners' performance. Ms. Eve shifted expectations by demanding increased accuracy as she scrutinized learners' placement of units requiring exactitude. Ms. Eve, related how her learners rose to such expectations as she emphasized, "Now they're being more specific . . ." She attributed such changes to the accountability of her participation in this study, highlighting, "I'm being watched a bit more . . . I need to up my game." Additionally, Ms. Eve remarked how such increases in expectations left her with an increased self-accountability unveiling, "*I need* to be at that level of expectation. *I should have always been* at like at that higher level." As Ms. Eve completed her reflection, a more satisfied tone emerged around the productivity of such increased expectations.

Additionally, two teachers remarked how they put away doubts around the re-engagement of diverse learners with a history of prolonged disengagement. Ms. Hannah's comments summarize teachers' sentiments:

> My belief around engagement changed. Because some of the boys always had a hard time, like they just give up so easily. But I think this helped them to see that they should always still try and never give up. So it [the intervention] helped me to see that they can change even more. You always have some boys that are fooling around . . . I saw that even those boys who fool around can learn and change their mind.

Ms. Hannah shifted her assumptions around disengaged male learners with traces of stereotyping as she insisted, ". . . you know *you always have some boys* that are fooling around." In such a manner, Ms. Hannah correlated an expectancy around her learners' disengagement with maleness. Importantly, teacher's experiences were shown to unravel stereotyping and *remediate* those expectations as Ms. Hannah unveiled, ". . . I saw that *even those boys who fool around can learn and change their mind*." In this way, one other teacher, like Ms. Hannah, expressed how such presuppositions were alleviated, increasing opportunity for a more robust growth mindset.

Conclusion

ASTP implementation was linked with increases in students' self-perception, catalyzing behavioral and cognitive engagement, with mixed shifts in affective engagement. Affectively students reported increased optimism but largely no change in their enjoyment of math. Interestingly, students were not the only ones to shift their perception and engagement. As learners' perceptions and engagement changed, teachers changed. They revealed how systemic deficit-mindedness had challenged their growth mindset by pressuring them to lower expectations around learning and assessment. Some teachers also reflected on how their implicit bias restrained the implementation of some of the more cognitively demanding activities within ASTP. Conversely, teachers shared how learners' increased perceptions, engagement, and learning outcomes reinvigorated their growth mindsets, leading to instructors' increased expectations with greater student access to cognitively rigorous activities. Consequently, the ASTP implementation revealed a common byproduct for all participants—a shifted perception around the mathematical learning potential of diverse students.

CHAPTER SIX: DISCUSSION

This mixed methods study implemented Anti-Stereotype Threat Pedagogy (ASTP), a neuroscience-framed intervention that seeks to disrupt students' perceptions of math potential linked to race or gender. ASTP referenced neuroscientific evidence of perpetual learning capacity (PLC) via *neuroplasticity* and *neurogenesis* when shaping instructional methods, modules, and student learning activities. ASTP emphasizes how PLC is a biological and anthropological part of being human, intersecting all ethnic, cultural, societal, or biological constructs of "race" or "gender" across species homo sapiens. This research hypothesized that exposing learners to such evidence and methods would increase students' psychological safety—a driver of engagement, which could help close differential learning outcomes (DLOs) in high school mathematics. Consequently, I examined teachers' implementation experience and how learners' self-perception of math potential (SPMP), affective, behavioral, and cognitive engagement, and instructors' beliefs around the teaching and learning of diverse students *changed* when introducing such a methodology.

In this final chapter, I summarize key findings from qualitative and quantitative analyses, relating them to the literature on cognitive neuroscience, stereotype threat, and education psychology. Next, I review this study's limitations. I then close with recommendations for stakeholders and researchers.

Key Findings

Students reported a statistically and practically significant increase in their self-perception toward a "growth potential" mindset. Teachers' and students' reports highlight the potential value of role models, self-affirmation, and neuroscientific evidence of perpetual learning capacity (PLC) to improve learners' self-perceptions of their math potential (SPMP) and counter negative perceptions rooted in low math performance, lack of content mastery, and deficit racial or gender stereotypes.

Teachers and students linked increased SPMP to elevated behavioral and cognitive engagement but not affective engagement. Learners reported no significant changes in important affective constructs like enjoyment toward learning math, or reduced fear of failure (anxiety). Learners, however, reported statistically significant behavioral and cognitive engagement increases.

Concerning affective shifts, learners' and teachers' qualitative reports suggest that change in the enjoyment of math may be more difficult owing to long-standing low achievement and the comparative difficulty of math to other subjects. Simultaneously, teacher and student reports indicate learners increased *optimism* toward math learning.

Concerning behavioral shifts, teachers and students noted how increased participation and perseverance contrasted with learners' baseline aversion to tasks and challenges. Teachers and students attributed these behavioral shifts to learners' increased confidence galvanized by mini lessons on PLC via neuroplasticity and neurogenesis, verbalized or written self-affirmations, video interviews of diverse role models, and reviewing fMRI or CT scans showing increased brain activity when reflecting on mistakes through a growth mindset perspective versus a deficit one.

Concerning cognitive shifts, teachers and students pointed to learners' increased performance on formative (exit slip) and summative assessments (examinations) as evidence of increased understanding (cognition). Students and teachers linked such increased achievement to behavioral and affective shifts such as participating in tasks, persevering through challenges, and experiencing less fear of failure. Teachers also connected students' increased understanding to reducing content covered per lesson ("chunking"), allowing more cognitive processing time.

Teachers also reflected on how adapting instruction to the ASTP intervention impacted them and their learners. They cited practical training, ease of module (mini-lesson) integration, restricting lectures (reduced chunking of material), and prioritizing cognitive processing (chew-time) with increased "checks" for understanding. Instructors emphasized how such changes helped learners master smaller chunks of math content and reflected how previous coverage, by contrast, overwhelmed students. All teachers adopted lesson cycle activities–warm-up, truncated direct instruction, timed guided practice, and exit slips, while two instructors gradually implemented think pair shares. Teachers reported students' change from initial confusion and hesitation around ASTP neuroscience modules and using self-affirmations toward increased understanding and use of such concepts and strategies. Teachers grew in professional satisfaction, reflecting on their capacity to drive or influence learners' increased perception, engagement, and achievement.

While teachers purported a growth mindset during their implementation experience, some struggled to implement robust learning activities such as think pair shares fearing diverse learners would not be willing to participate. Others shared how deficit messaging from school leadership and implicit bias further strained their growth mindset, feeling guilt over pushing their diverse learners to achieve. As teachers saw their learners' perception, engagement, and achievement shift, they felt encouraged to push them to meet higher expectations. Instructors stretched their mindset, affirming that students with a record of persistent disengagement could re-engage and rise to rigorously high mathematical expectations.

Findings and the Literature

The How People Learn (HPL) framework calls for teachers to understand how students learn using knowledge from cognitive neuroscience and other learning sciences, address students' preconceptions around learning, and promote psychological safety to drive engagement (Bransford, 2000; Bransford & Schwartz, 1999). This study's findings suggest that modifying professional development in these areas holds promise in addressing students' psychological safety. Teachers and students reported how learners increased their SPMP through exposure to neurological scans showing increased brain activity for learners with a growth mindset when committing errors. Learners also reported how such information increased their optimism toward learning and reduced their fear of making mistakes. Such changes in perception, optimism, and reduced anxiety are associated with psychological safety (Bransford, 2000; Bransford & Schwartz, 1999).

Learners revealed indicators of ST consistent with the literature, including awareness of racialized or gendered deficit stereotypes, fears of confirming stereotypes, strained self-perception, and withdrawn engagement (Mendoza et al., 2002). Learners' lack of confidence, task hesitation, self-uncertainty about abilities, and challenge avoidance were consistent with ST effects (Aronson & Inzlicht, 2004; Walton & Cohen, 2007).

Findings suggest the promise of counter-ST strategies. Learners explained how Latino and Black astronauts Jose Hernandez and Dr. Mae Jemison (role-models) helped provide counter-evidence to gendered or racial doubts about their potential, spurring increased participation. At the same time, self-affirmations countered learners' negative self-talk and increased tenacity during complex problem-solving. Learners reported how reading, stating, or listening to self-affirmations helped ease their anxieties during demanding problems or examinations. Such anxiety-reducing and inoculating effects are consistent with findings concerning counter-ST strategies throughout the literature around self-affirmation and micro-affirmations (Bowen et al., 2013; Cohen et al., 2006; Solórzano et al., 2020; Spencer et al., 2016) and role models (Aronson & McGlone, 2011; Huguet & Regner, 2007).

This study adds to the literature by testing the combined productivity of counter-ST strategies *through* a neuroscience lens to shift SPMP. Learners created connections between counter-ST measures while referencing evidence of PLC. For instance, students expressing skepticism around self-affirmations such as, “I can do this, I have unlimited potential,” grew in their belief of such affirmations citing that neuroscientific evidence verified that the brain does change and grow through engagement. Students subsequently connected their increased participation driven by self-affirmation to their neurological development. Teachers overheard student-authored neuroscience affirmations such as, “As I practice my brain is growing,” an amalgamation of self-affirmation strategy and neuroscience knowledge not mentioned in ST or engagement literature.

Students made other connections. Learners noticed role models’ use of self-affirmations. Students reasoned that if self-affirmations could spur confidence and achievement for role models, they could similarly do so for themselves. The literature does not mention such learner hybridization of self-affirmation and role model strategies. Most importantly, learners reported how such connections helped alleviate anxiety around fear of affirming stereotypes, fear of failure, or limited SPMP leading to increased engagement in learning activities.

According to Dweck (2015), a growth mindset asserts that abilities develop through dedication, noting how brains and talent are just starting points, emphasizing how resilience is fundamental for accomplishment. Findings suggest resilience and perseverance–indicators of a growth mindset spurred engagement and achievement.

As students shifted toward a growth mindset, teachers' perceptions changed. While teachers purported a growth mindset, some simultaneously unveiled contradictory biases and doubts about their diverse learners' ability or willingness to engage. Compounding this tension, teachers described how school leaders encouraged instructors to hold lax expectations for engagement or opt out of administering assessments for learners. Such bias and influences were not without effect. Teachers reported feeling strain or *guilt* for pushing their diverse learners to reach high expectations. Most problematic, some teachers explained how such doubts restrained their implementation of cognitively demanding activities such as error analysis via think pair shares. Such internal contemplations, instructional decisions, and assumptions highlight how even self-purported growth-minded teachers can still hold implicit bias and refrain from providing opportunities for engagement. Notably, such restrictions may deprive learners of robust and cognitively demanding opportunities and create a differential between other math learners exposed to higher expectations and expanded learning opportunities.

Such handling of diverse learners supports how DLOs, historically known as the "achievement gap," may be informed by differences in treatment based on implicit bias or a "treatment gap" (Osborne, 1995; Steele & Aronson, 1995). Interestingly, learners' engagement and achievement gains in this study shifted as teachers changed their "treatment" through increased expectations and improved beliefs about their learner's potential. Teachers reported increasing their expectations and reaffirmed that students could rise to high expectations as learners increased engagement and achievement. Lastly, findings support teacher and pupil engagement is bidirectional (Boykin & Noguera, 2011). Teachers' enjoyment around teaching and instructional expectations increased as learners engaged.

Significance of Findings

Differential learning outcomes (DLOs) remain the focus of intense national and international interest from policymakers, practitioners, and the public. This interest reflects deeply held concerns about student math performance in national and international assessments (Williams, 2011), along with evidence of increasing gaps (NAEP, 2023) and inequities faced by diverse students, who, as a group, are more likely to be taught by teachers with lowered expectations and reduced opportunities for rigor (Boykin & Noguera, 2011). Although there is widespread consensus that DLOs remain a multivariate challenge, discussions center on the importance of psychological factors–mindsets, perceptions, or antecedents of learning–to improve engagement and achievement (Turner, 2011).

Exploring shifts in learners' SPMP and engagement when disrupting *constructs* undergirding ST using neuroscientific and anthropological data is a promising horizon in research. No formal studies have explored student SPMP changes and engagement using the proposed neuroscience-framed methodology.

Therefore, findings demonstrating increased SPMP, behavioral and cognitive engagement are significant for three primary reasons. First, these changes occurred within six weeks. This suggests the malleability and room for improvement of important constructs like SPMP and behavioral and cognitive engagement, that were linked to achievement. Second, learners and teachers described how increased SPMP preceded behavioral and cognitive engagement and achievement increases. SPMP, therefore, holds value as a possible driver of behavioral and cognitive engagement and achievement. Third, such achievement increases were among diverse learners. Such increases for these populations are fundamental when pursuing the closure of DLOs between racial or gender groups.

Findings unveiling inconsistencies in teachers' purported growth mindsets also hold significance. Teachers purported that all learners, regardless of race or gender, could achieve. Along the way, however, some teachers reflected on beliefs and actions contradicting this assertion. They unveiled how unintended bias caused them to doubt their diverse learner's willingness or capacity to re-engage or rise to high expectations. Some expressed how this bias stopped them from implementing robust learning activities such as cooperative error analysis through think pair shares. This is important, as teachers purporting growth-mindedness can still harbor unintended deficit perspectives and strained expectations toward diverse learners. These beliefs are problematic as they limit learners' access to vigorous learning opportunities. Evidence of PLC helped to remediate teachers' beliefs. Such reflection reveals how a growth mindset may be insufficient to inoculate against or remediate "nose-blind" bias and lowered expectations for diverse learners. This study demonstrates the productivity of providing compelling data on PLC to *recalibrate* learners' and their teachers' perceptions.

Limitations of the Study

This study's exploratory design precludes evidence of causality. While some of the participants' interview reports could point to shifts in perception, engagement, and cognition, the quantitative evidence only inconsistently pointed to such shifts in students, and to the degree some variables did change, remained confined to only descriptive patterns, whether the intervention was responsible for these shifts cannot be ascertained with the methodology used in this study, which was aimed at producing generative, descriptive evidence for further exploration. Stronger causal evidence in future research would require experimental or quasiexperimental designs that compare multiple treatment and control groups while controlling for extraneous variables.

Some variables that may have influenced the findings include different grading practices across classes, pre-existing teacher variability in growth mindsets, and comparative difficulty in content material from the first semester to the second semester (when the study occurred) and between different levels of mathematics. Teachers with different grading practices recording achievement metrics may also skew the representation of growth in learners' achievement. Additionally, teachers' willingness and baseline desire toward a growth mindset may have made the intervention theoretically more productive than a sample that contained instructors with firmly held deficit beliefs. Sample adequacy in future research can also be enhanced as populations in this study, while diverse, could be expanded, enriching the spectrum of viewpoints.

Conclusion

Findings support this study's hypothesis that exposing learners to neuroscientific evidence of PLC, anti-ST measures, and increased cognition opportunities could increase SPMP, student engagement, and achievement. Such findings hold important implications and recommendations for research, practice, and policy.

Considering the limitations of this study, future research may consider investigating and testing the hypothesized model and methodology with a more robust design to ascertain whether and how the intervention leads to changes in diverse learners' SPMP, engagement, and achievement.

Researchers may also find it beneficial to investigate ways to mitigate ST effects by disrupting its constructs and assumptions. For instance, in this study, the adverse effects of spuriously correlating race or gender with math potential were addressed by exposing learners to evidence of PLC via neuroplasticity and neurogenesis. Additional research can build on this approach. Studies may consider investigating how other compelling evidence from the learning sciences may help further expose and counter the correlation of intellectual capacity with race, gender, and other student characteristics, potentially disrupting ST and its deleterious effects on perception, engagement, and achievement.

The proposed methodology is not limited to mathematics and could help close DLOs in other subjects or situations where ST may inhibit perception, engagement, and achievement. Interestingly, learners' capacity to build connections between neuroscientific evidence of PLC and counter-ST strategies reportedly magnified the impact. Future research, therefore, may investigate how combining counter-ST methods may yield other unique and productive connections, possibly leading to changes in engagement or achievement in other subjects.

Additional implications for research arise from teacher reflections noting increased cognition and focus for learners as they adapted lesson structures. The strategy of "chunk," "chew," and "check" was uniquely parameterized in ASTP methodology. Future research may consider how these parameterized structural changes, independent of other components of the proposed intervention, impact engagement and achievement.

Importantly, even in this study, there is evidence that teacher growth mindsets were strained by doubts about learners' capacity to achieve in math. Such evidence implies that research further examines how and why implicit bias persists despite the education systems' purporting of a growth mindset and how evidence of PLC may remediate such implicit bias.

Last, the results of factorial analyses demonstrate some overlap in constructs like affective engagement and self-perception. Researchers may consider investigating ways to delineate the distinguishing features between the two constructs.

Concerning practice, additional implications arise from findings. Historically, policies and initiatives designed to improve math achievement have focused on restructuring math content and introducing math standards and mathematical practices. While such policies are undoubtedly important, this study's findings imply that psychological factors such as SPMP and psychological safety also hold value and weight toward increasing engagement and achievement. These psychological factors, therefore, complement the goals of content standards that aim to increase academic achievement. Educational institutions may, therefore, consider additional focus and resources on addressing and bolstering psychological drivers of engagement to increase achievement.

The study demonstrated that educators' growth mindsets may still be susceptible to deficit messaging and systemic influences without compelling evidence of PLC from the learning sciences (neuroscience and anthropology). Practitioners or educational leaders may consider redesigning *professional development* to unearth and remediate hidden or subtle doubts about diverse learners' capacity and do so even where a growth mindset is purported. Investigating ways to expose students, teachers, parents, and other stakeholders to evidence of PLC in practical or actionable ways on the ground using concrete strategies may be productive toward this endeavor.

Other recommendations arise for policymakers. No teachers or learners in this study knew about ST, neuroplasticity, or neurogenesis and how this relates to evidence of PLC. Nor did educators have any previous training on countering ST or the possible implications of SPMP upon engagement and achievement. These gaps around learners' and teachers' knowledge suggest growth areas for stakeholders vested in learning outcomes, such as students, teachers, parents, administrators, and other educational leaders. Therefore, policy around increasing math achievement may consider educating stakeholders on ST and its impact on learning and ways to counter its activation and impact. Promising avenues include understanding the neurological impact of ST and referencing neurological evidence of PLC to counter ST. Such concrete modifications for incoming educators in teacher prep programs or district initiatives for instructors already in the field may yield additional tools to counter ST activation or impact and improve engagement and achievement.

How students and teachers perceive a learner's potential can influence engagement and achievement. Evidence suggests that increasing students' perceptions about their potential can drive engagement and academic performance changes. Such changes in learners and their learning outcomes can also impact their teachers. As teachers deepen their growth mindsets, educators may become encouraged to provide more robust learning opportunities and raise expectations. This research suggests that educating learners and teachers on the perpetual learning capacity of the human mind using neuroscience holds promise toward increasing the perceptions, engagement, and achievement of diverse students—critical factors inextricably linked to the closure of DLOs.

APPENDIX A: PRE-POST STUDENT SURVEY

You are invited to participate in a study conducted by Gilbert M. Ramirez, a doctoral candidate at the University of California, Los Angeles (UCLA). The purpose of the study is to deepen our understanding of students perceptions and levels of engagement in math. The survey asks about your beliefs around your current math potential and your level of engagement in your math class. Your responses may help us learn how to better teach students in math, as well as help your school and district enhance teacher training. If you choose to participate, you will complete this survey, which should take approximately 5-10 minutes to complete. Your participation in this survey is completely voluntary. For data collection purposes please complete all sections of this survey. Again your participation with any and all questions is completely voluntary. This survey is strictly confidential. The survey results will be reported at the aggregate level and your individual responses will not be released. If you have any questions or concerns feel free to contact researcher Gilbert Ramirez at gmram@ucla.edu Thank you for your time and consideration. Sincerely, Gilbert M. Ramirez

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Participation I voluntarily agree to participate in the study.

- ◯ I agree (1)
- ◯ I do not agree (2)

Skip To: End of Survey If Participation = 2

End of Block: Introduction and Consent

Start of Block: Instructions

Instructions*:*
The following questions relate to you as a math student.
Be completely honest.
Your answers are confidential, will not be shared with your teacher and have no impact on your grade.
Should you have any questions raise your hand and someone will assist you. You may also contact the researcher Gilbert Ramirez.

End of Block: Instructions

Start of Block: Self-Perception of Math Potential (Calibration)

1 (Calibrate SP Math) **Rate your belief in your math potential**

	1 I have no math potential (1)	2 I have limited math potential (2)	3 I have average math potential (3)	4 I have growth potential in math (4)	5 I have unlimited math potential (5)	Decline to state (0)
Rate your belief in your math potential. (1)	o	o	o	o	o	o

End of Block: Self-Perception of Math Potential (Calibration)

Start of Block: Self-Perception of Math Potential

2 Self Perceptions **Select to what extent you disagree or agree with the following statements.**

	1 Strongly Disagree (1)	2 Disagree (2)	3 Neutral (3)	4 Agree (4)	5 Strongly Agree (5)	Decline to state (0)
A. I am capable of doing well in math (34)	○	○	○	○	○	○
B. I am capable of solving challenging math problems (33)	○	○	○	○	○	○
C. My math skills can improve with practice (28)	○	○	○	○	○	○
D. Even with effort my math skills will remain the same (27)	○	○	○	○	○	○
E. Even with practice I will not do well in math (1)	○	○	○	○	○	○
F. There is no limit to my ability to solve math problems (32)	○	○	○	○	○	○

End of Block: Self-Perception of Math Potential

Start of Block: Engagement Calibration

3 (Calibrate Engage) **Rate your current level of effort in this math class.**

	1 No Effort (1)	2 Some Effort (2)	3 Average Effort (3)	4 Good Effort (4)	5 Strong Effort (5)	Decline to state (0)
What is your current level of effort in this math class? (1)	○	○	○	○	○	○

End of Block: Engagement Calibration

Start of Block: Engagement - Behavioral - Frequency

4 Engagement Freq-B **Please indicate your level of engagement in math class.**

	1 Never (1)	2 Rarely (2)	3 Sometimes (3)	4 Very Often (4)	5 Always (5)	Decline to state (0)
A. How often do you participate in class by asking your math teacher questions? (1)	○	○	○	○	○	○
B. How often do you participate in math class by sharing your answers with other students? (2)	○	○	○	○	○	○

End of Block: Engagement - Behavioral - Frequency

Start of Block: Engagement Behavioral

X→

5 Engage Behavioral Select the extent you disagree or agree with these statements.

	1 Strongly Disagree (1)	2 Disagree (2)	3 Neutral (3)	4 Agree (4)	5 Strongly Agree (5)	Decline to state (0)
A. I work through a math problem until I understand it (4)	○	○	○	○	○	○
B. I am prepared to answer when called on by my math teacher in class (5)	○	○	○	○	○	○
C. I remain focused on the lesson throughout math class (6)	○	○	○	○	○	○
D. I help my peers with their math questions (2)	○	○	○	○	○	○
E. I show all my work when I'm solving a math problem (1)	○	○	○	○	○	○

End of Block: Engagement Behavioral

Start of Block: Engagement - Emotional

6 Engage - Emotional **Select the extent you disagree or agree with these statements.**

	1 Strongly Disagree (1)	2 Disagree (2)	3 Neutral (3)	4 Agree (4)	5 Strongly Agree (5)	Decline to state (0)
A. I feel anxious when learning math (1)	○	○	○	○	○	○
B. I feel nervous when sharing my mathematical reasoning with other students (27)	○	○	○	○	○	○
C. I fear getting the wrong answer in math (28)	○	○	○	○	○	○
D. I enjoy learning math (29)	○	○	○	○	○	○
E. I expect that my math skills will improve (32)	○	○	○	○	○	○
F. I am interested in learning math (34)	○	○	○	○	○	○
G. I enjoy learning new skills in math (33)	○	○	○	○	○	○

End of Block: Engagement - Emotional

Start of Block: Engagement - Cognitive

7 Engage Cognitive **Select the extent you disagree or agree with these statements.**

	1 Strongly Disagree (1)	2 Disagree (2)	3 Neutral (3)	4 Agree (4)	5 Strongly Agree (5)	Decline to State (0)
A. My understanding of math concepts has been improving in this class (11)						
B. My academic performance has been improving in this math class. (4)						
C. I set goals for my mathematical learning. (1)						
D. I monitor my progress towards my learning goals in math. (2)						
E. I can connect concepts from my math class to other classes (6)						
F. I can connect the math curriculum to my experiences (10)						

End of Block: Engagement - Cognitive

Start of Block: Background

8 - Grade **What grade are you in?**

- 9th (1)
- 10th (2)
- 11th (3)
- 12th (4)

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9 Ethnicity **Select the racial/ethnic category you most identify with.**

- Asian/Asian American (4)
- Black/African American (2)
- Hawaiian/Pacific Islander (5)
- Latino/Latina/Hispanic (1)
- Multi-Racial/Multi-Ethnic (6)
- Native American/Indigenous (7)
- White (3)
- Other (8) ____
- Decline to state (9)

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10 ID **What is your student ID number?**

____

11 School Email What is your school email address?

____

12 - Gender **Select your gender identity.**

- ○ Female (1)
- ○ Male (2)
- ○ Non-Binary (3)
- ○ Decline to state (5)
- ○ Other (4) ____

End of Block: Background

APPENDIX B: TEACHER POST-INTERVENTION INTERVIEW PROTOCOL

Interview Protocol Questions

Thank you for the time and energy to participate in this interview. The interview is designed to last about 90 minutes. The data coming from this interview will help me gain a deeper understanding of how the implementation process went for you regarding ASTP over the last 6 weeks.

With your permission, I'd like to use a voice recorder so I can be more in the moment with you rather than focused on trying to document every word. Your name and names of anyone you mention will be replaced with pseudonyms as the goal of the interview is to collect data in aggregate. If at any time you wish for me to turn off the recorder please let me know. What questions might you have about the interview? Great, let's get started.

Warm Up:

1. What inspired you to become a teacher?

Implementation Reflection

2. A. When we began our teacher training for the intervention what were your initial impressions of the program?

   B. What were your initial expectations?

3. How did the implementation compare or differ from your initial expectations?

4. A. What aspects of the intervention did you find to be easy to implement?

   B. Which was more challenging?

Self-Perception of Math Potential (SPMP)

5. Prior to starting the program how would you describe this class' overall belief in their math potential? (No potential/limited/average/growth/unlimited) What were indicators to leading you to this description?
6. A. What indicated to you that students' beliefs in their own math potential were changing (if at all) as you progressed through the past 6 weeks? What do you believe caused these changes?

   B. If changes were not observed, why do you think this was so?
7. A. Which part(s) of the ASTP framework (structure, modules, or other sections) (if any) do you believe were helpful in changing student beliefs around their own math capacity?

   B. If so, how? Why do you believe this was the case?
8. What else about students' responses or actions (if any) demonstrated a transition of beliefs around math potential?
9. How would you describe this classes' current overall belief in their own math potential? (No potential/limited/average/growth/unlimited)? Why so?

Student Engagement

10. As you progressed through the program what observations (if any) did you make:
    A. About student effort in the classroom?
    B. About students during testing?
    C. About volunteering in the classroom? (e.g, raising their hand, asking questions)
    D. About their confidence in sharing responses?
    E. About student quality of responses?

F. About student-to-student interaction? (e.g, the quality of responsiveness, thoroughness, amount of time invested)

G. About student enjoyment around learning math?

H. About student performance in this class?

I. About the way students monitored their progress/grade?

J. About the way students reflected on their own learning?

11. If you were to implement the process again what would you change and why?

A. What would you keep and why?

The next series of questions relate to your beliefs around learning for diverse students?

15. In what ways did the implementation process:

A. Confirm (if at all) your beliefs around how diverse students learn?
B. Change (if at all) your beliefs around how diverse students learn?
C. Challenge (if at all) your beliefs around how diverse students learn?

The next series of questions relate to your beliefs around teaching math for diverse learners?

17. How did the implementation process influence your beliefs around **teaching** math for diverse students?
18. How did this process challenge any preconceptions around **teaching** diverse students?
19. What other comments, or closing thoughts do you have about the ASTP framework would you like to mention?

Thank you for your feedback and participation.

APPENDIX C: FOCUS GROUP PROTOCOL

Focus Group Questions

Hello. Thank you for participating in this focus group. The focus group is designed to last about 90 minutes. The data coming from this focus group will help me gain a deeper understanding of your experience over the last 6 weeks.

With your permission, I'd like to use a voice recorder so I can be more in the moment with you rather than focused on trying to document every word. Your name and names of anyone you mention will be replaced with pseudonyms as the goal of the interview is to collect data in aggregate (in general). If at any time you wish for me to turn off the recorder please let me know.

To keep this confidential each of you has a pseudonym (assigned name) you'll be using. Each time you answer you'll say this same then share your responses. We will endeavor to go about this round robin (going clockwise) so each of you has a chance to share your responses as your voices are important to this research, but we can go out of order if you need to. There are no right or wrong answers, simply share your honest view. What questions might you have about the focus group? Great, let's get started.

Self-Perception: (PRE-ASTP)

1. What was your math potential belief before we began our study? (Refer to the survey handout) Keep this rating in mind as you answer the next questions. As you answer, be specific and use examples.
    A. What influences led you to that belief? (For example school, family, society etc…)?

B. When did you begin to believe this was true about yourself?

C. Why did you believe this to be true about yourself?

D. How did this belief impact your effort in your math class last semester?

E. Consider what you stated on the survey as your race, and gender identity. In what ways did these identities impact this rating (if at all)?

Self-Perception (POST-ASTP)

2. What was your math potential belief after the study? (Keep this rating in mind as you answer the following questions).

A. What about this program led (or did not lead) to this change in belief?

B. How did those parts (if at all))lead to this change in belief?

C. Which of the modules (if any) contributed to this change in your beliefs in your math potential? How did it do so?

D. How did any change in your belief in your math potential impact your level of effort (if at all)?

E. How long do you think this change in your belief will last?

Engagement

3. What rating of engagement (effort) did you select prior to the study? What was it after the study?

4. How did this program lead to this change in effort? OR Why do you think your effort remained the same or lowered during this program? Please be specific and use examples.

5. How did your experience over the last 6 weeks impact (or not impact)

A. How often you asked questions in class?

B. Your math performance? Your ability to reflect on your mistakes and correct them?

C. Your ability to work through difficult problems?

D. How you viewed mistakes?

E. Your ability to reflect on your mistakes and correct them?

F. (Emotional) Your level of enjoyment of math? Your confidence in your math skills?

G. Your ability to feel safe to make mistakes in the classroom?

Reflection

6. How would you describe your experience overall now that you've completed this program?
7. If you were to go through the program what would you change and why?
8. Which parts were easy to understand (if any)?
9. Which parts were more difficult to understand (if any)?
10. What would you keep and why?
11. What other comments, questions or concerns do you have?

Thank you for your participation!

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