Praxis Preparation for Preservice Teachers:

Using Online Tools to Engage in Productive Struggle

by

Nathaniel Lloyd Sams

Bachelor of Arts, West Virginia University, 1995

Master of Science, West Virginia University, 1998

Submitted to the Graduate Faculty of

School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Education

University of Pittsburgh

2021

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

This dissertation was presented

by

Nathaniel Lloyd Sams

It was defended on

August 17, 2021

and approved by

Dr. Cassie Quigley, Associate Professor of Science Education, Department of Teaching, Learning, and Leading

Dr. Keith Trahan, Visiting Assistant Professor, Collaborative for Evaluation and Assessment Capacity

Thesis Advisor/Dissertation Director: Dr. Kari Kokka, Assistant Professor of Mathematics Education, Department of Teaching, Learning, and Leading

Praxis Preparation for Preservice Teachers:

Using Online Tools to Engage in Productive Struggle

Nathaniel Lloyd Sams, EdD

University of Pittsburgh, 2021

This paper presents findings on research-based interventions that were employed as part of a semester-long PDSA (Plan-Do-Study-Act) cycle at Davis & Elkins College (D&E) aimed at decreasing math anxiety while increasing student achievement on high-stakes standardized assessments with a focus on growth mindset and productive struggle. Based on data from 2015-2018, the success rate of preservice elementary teachers (K-6) on the mathematics portion of the Praxis Core Academic Skills for Educators exam was approximately 30% on first attempt at D&E. Drivers of this problem of practice include the attitudes, beliefs, and mindsets of test takers. Often, students who have a history of negative experiences in mathematics suffer from a cycle of math anxiety involving a lack of confidence and avoidance of mathematics. Due to the COVID-19 pandemic, students were enrolled in online courses and the interventions included two free online courses: Stanford University's *How to Learn Math: For Students* and Khan Academy's *Praxis Core Math*. The interventions aimed to enable students to experience a more positive, productive cycle of math achievement. Results indicate that these methods were more helpful for some groups of students than for others. The characteristics of each group are noteworthy for future study.

Table of Contents

List of Tables

List of Figures

1.0 Naming and Framing the Problem of Practice

1.1 Problem Statement

My problem of practice aimed to improve proficiency in mathematics in preservice elementary teachers (PSETs) at Davis & Elkins College (D&E). Results from standardized assessments indicated that my students were in danger of failing to complete the requirements for teacher licensure. Most of my students were from West Virginia, and according to data from the West Virginia General Summative Assessment, just 37% of the state's K-12 students were considered proficient in mathematics ("State Assessment," 2018). Additionally, the average ACT/SAT scores of incoming freshmen at my place of practice were below the 50th percentile ("College Navigator," 2018; "Guide to the 2018 ACT/SAT," 2018; "SAT Understanding Scores," 2018). Further, based on figures from 2015-2018, only 30% of candidates at D&E passed the mathematics portion of the Praxis Core Academic Skills for Educators exam on their first attempt.

I noted through conversations with students in my classes that many of my students were experiencing a *cycle of math anxiety* (Sloan, 2010; "Teacher's Professional Resource," n.d.) (see Figure 1), in which their lack of confidence and avoidance of mathematics contributed to lower achievement and negative experiences that perpetuated the problem. Each year, students in my classrooms nodded in agreement as others asserted that this cycle perfectly described their circumstances, made them unwilling to engage in mathematical problem-solving, and caused them to procrastinate in their preparation for the mathematics portion of the Praxis Core Academic Skills for Educators exam.

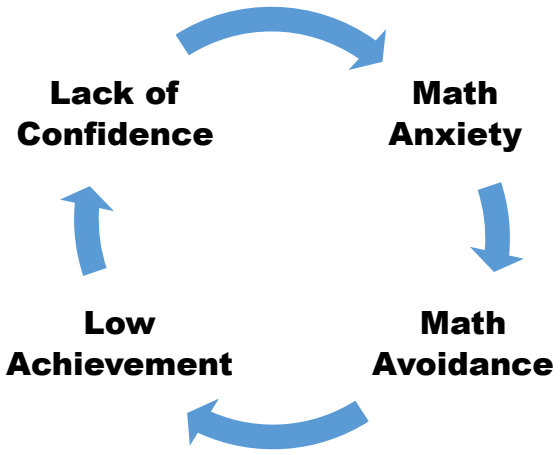


Figure 1 Cycle of Math Anxiety

Note. This figure illustrates the experiences for many PSETs at Davis & Elkins College.

Research indicates lack of confidence and math anxiety indeed affect PSETs' mathematical achievement (Harper & Daane, 1998; Sloan, 2010), but progress can be made by fostering more productive and positive interactions with mathematics (Gresham, 2007; Cardetti & Truxaw, 2014; Finlayson, 2014). Research suggests student beliefs and attitudes can be changed by working together to solve real-world problems in learning contexts where productive struggle and a growth mindset were integral components used to increase confidence, participation, and achievement while lessening anxiety (Felton & Koestler, 2015). This project sought to transform the attitudes, beliefs, and mindsets of preservice teachers who were experiencing the cycle of math anxiety so that they may instead experience a cycle of math achievement in which a growth mindset and engagement in mathematical problem-solving via productive struggle would lead to success in mathematics and a more positive identity. Congruent with such research, in my study, a more positive *cycle of math achievement* began to emerge (see Figure 2) with the interventions I implemented.

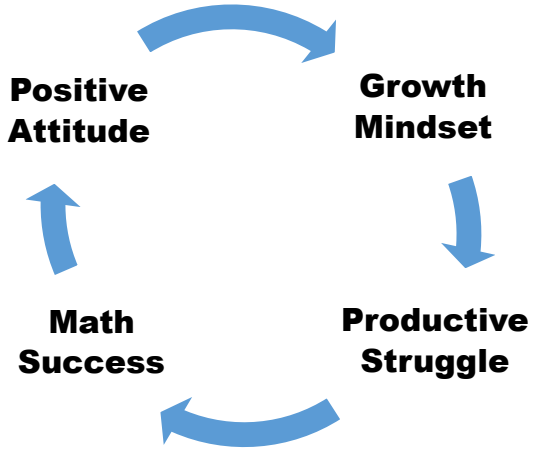


Figure 2 Theory of Change: Cycle of Math Achievement

Note. This figure illustrates possible changes in attitudes, beliefs, mindsets, and experiences for PSETs.

Researchers have also argued high-stakes tests like Praxis are biased against underrepresented groups and should not be used as gatekeepers for the teaching profession (Blue, O'Grady, Toro, & Newell, 2002; Wakefield, 2003; Bennet, McWhorter, & Kuykendall, 2006; Graham, 2013). Nearly 90% of elementary teachers in the United States are women ("Primary Education," 2019), and the potential of stereotype threat exists for women on highs-stakes tests (Steele, 1997). Moreover, data from Educational Testing Service (ETS) shows that women score worse on computer-based Praxis exams (Gallagher, Bridgeman, & Cahalan, 2000), yet we remain entrenched in a system in which these computer-based standardized assessments are mandated by policymakers.

While ETS claims its Praxis tests are valid and reliable via studies by its own researchers and psychometricians, safeguarding of the exams prevent comprehensive independent studies by other researchers (Watras, 2006). Still, many scholars have studied their local contexts and argued for social justice and equity goals in teacher preparation and licensure (Wakefield, 2003; Graham, 2013). Central to their concerns is the *consequential validity* (Glaser, 1990; Shepard, 1993) of

Praxis exams. Consequential validity of assessments considers the resulting educational opportunities and social consequences for individuals and minoritized groups when high-stakes exams such as Praxis are used to screen potential teacher candidates. Darling-Hammond (1994) stresses how these types of assessments limit educational access and opportunity to learn for women and people of color for several decades by sorting and tracking students inequitably. Still, based on my experience and research, I believed we could overcome these obstacles.

Although other factors such as socioeconomic status (Berliner, 2013), K-12 mathematical preparation ("State Assessment," 2018), and additional causes existed (see Fishbone Diagram in Appendix A), the cycle of math anxiety was the potential cause of this problem of mathematical proficiency that I, as their instructor at D&E, could influence the most. Therefore, I built on research that suggested improving growth mindset and related teaching practices could decrease math anxiety, build confidence, improve achievement, and develop agency of PSETs (Anderson, Boaler, & Dieckmann, 2018; Sun, 2018). As Heifetz, Grashow, and Linsky (2009) stated, "Adaptive challenges can only be addressed through changes in people's priorities, beliefs, habits, and loyalties" (Heifetz et al., 2009, p. 19). This quote was a continued source of inspiration in my work on this project as I addressed my own "priorities, beliefs, habits, and loyalties" along with those of my students and colleagues in order to improve mathematical proficiency and move students from a cycle of math anxiety toward one of achievement in mathematics.

1.2 Organizational System

The work to interrupt the cycle of math anxiety and to improve mathematical proficiency is particularly important in my region of the country. In Appalachia, students of low

socioeconomic status from rural areas often lack access to high quality educational opportunities (Koricich, Chen, & Hughes, 2018). I am an assistant professor of mathematics at Davis and Elkins College - a small, private, rural, liberal arts college in West Virginia. My colleagues and I designed two standards-aligned, prerequisite courses which are required for PSETs before their math methods course (EDUC 316) based on the recommendations of researchers to focus on National Council of Teachers of Mathematics (NCTM) standards and strategies such as a constructivist framework focusing on student-centered, active-learning and the use of manipulatives (Gresham, 2007; Tooke & Lindstrom, 1998). I teach Math for Elementary Education Teachers (MATH 109), which focuses on number and quantity, statistics, and probability, Geometry Concepts (MATH 110), which focuses on geometry, and Teaching Mathematics to Children (EDUC 316), which focuses on implementing state content standards in lesson plans in K-6 classrooms. College Algebra (MATH 193), which focuses on algebra and functions, is also required for PSETs, and is usually taught by other math faculty (Davis & Elkins, 2018).

The content of these required courses consists not only of mathematical material covered on the Praxis exams for PSETs, but also includes real-world applications, the use of technology to solve problems, and an introduction to writing and presenting lesson plans. Knowledge is often constructed via group work in positive learning environments in my classes, based on research demonstrating greater learning gains with such approaches (Felton & Koestler, 2015). The math methods course (EDUC 316) also follows recommendations from the literature in stressing the use of manipulatives, differences in learning styles, and problem-solving techniques (Vinson, 2001). Fieldwork is required in all education classes, and cooperative teaching and reflection on field experiences in local elementary classrooms is another important component of EDUC 316 at D&E (Davis & Elkins, 2018).

Despite our intentional design of the curriculum, PSETs at D&E continued to struggle on the mathematics portion of the Praxis Core Academic Skills for Educators exam. Success on the Praxis exam is required for state licensure, as well as for acceptance into the teacher education program at D&E, but in the past many students in the 300-level math methods course had not obtained passing scores and thus risked making adequate progress as education majors. Although my concerns were not limited to results on high-stakes standardized assessments, improvement of the success rate on Praxis Core was a major goal in the interruption of the cycle of math anxiety and in the creation of positive experiences to increase confidence, achievement, and agency in PSETs.

The West Virginia Department of Education recognized this problem of practice, and a new state policy required institutions of higher education to implement a remediation plan for any student who failed a Praxis exam twice ("Approval of Educator," 2019). Our remediation plan at D&E involved tiered intervention with a goal of preventing the problems we have seen with previous cohorts of PSETs. To identify struggling students and to increase self-awareness, we required all students to complete an official Praxis practice test provided by ETS prior to the end of their sophomore year, and to utilize a free preparation course offered online by Khan Academy ("Praxis Core Math," 2019). To expose students to even more opportunities for practice and productive struggle, I designed timed, computer-based modules in MATH 109 and MATH 110 to mimic the conditions of the Praxis exam using Pearson MyLab from the publishing company of the textbooks used in my courses. Like on the Praxis exam, students had approximately a minute and a half to complete each question. However, their grades for my class were not lowered by the shorter practice quizzes. They received immediate online feedback on these standards-aligned

modules, we discussed the concepts and problem-solving techniques in class, and they practiced similar problems as many times as needed for success.

If candidates did not pass the Praxis due to these curriculum changes, then the remediation plan called for summer workshops and additional remedial, non-credit courses for students who did not earn passing scores on the Praxis exam. However, a similar approach was not successful in the past. Few students took advantage of free tutoring, which indicated math avoidance and fixed mindsets were perpetuating the cycle of math anxiety. Again, I believed a holistic approach with a growth mindset focus was the missing piece in our remediation plan for struggling PSETs at D&E.

In an effort to begin to change PSETs' attitudes toward and beliefs about mathematics, I incorporated a free course from Stanford University, *How To Learn Math: For Students*, into my 100-level math courses to introduce students to growth mindset and productive struggle in mathematics ("How To Learn Math," 2014). Conversations with my students provided informal evidence that mathematical mindset messages from the course contributed to positive experiences for those who were open to change. I saw early signs of success as several PSETs improved their performance in mathematics after adopting more of a growth mindset and the associated practices, beliefs, and work ethic. Results from a large study of students who took the online course from Stanford showed increases in student engagement, in proficiency on a standardized assessment, in perseverance in problem solving, and in growth mindset. Treatment participants also showed a decrease in their fear of mathematics (Boaler, Dieckmann, Perez-Nunez, Sun, & Williams, 2018).

1.3 Stakeholder Description

As stated above, based on data from 2015-2018, 70% of PSETs at Davis & Elkins College were risking future employment by failing the mathematics portion of the Praxis Core Academic Skills for Educators exam on their first attempt. Stakeholders in this adaptive challenge include (but are not limited to) the current and prospective students who take the exam, the higher education faculty who educate the students, the communities of families and local school boards who depend on high-quality teachers, and the state and national policymakers who determine licensure requirements and administer standardized assessments.

Educational Testing Service (ETS) authors and administers Praxis exams that have often functioned as gatekeepers for teacher licensure for minoritized groups throughout the United States. In an undated letter provided as an open note on ETS's website, president and CEO, Walt MacDonald, wrote:

> In light of recent events, it is important that ETS reiterate — indeed, underscore — its commitment to diversity, inclusion and opportunity through education for learners worldwide. These are core principles that guide all that we do. Every product that we design and deliver, every service that we offer, every employment policy and practice that we implement is informed and animated by these principles. (MacDonald, n.d.)

According to Ahmed (2012), MacDonald's statement is a non-performative which "speaks to a gap between the past and future tense" (p. 126). Furthermore, evidence and data show that the letter "is a commitment that points to the future it brings about . . . but, the past that accumulates overrides this futurity" (p. 127). ETS claims their "mission is to help advance quality and equity in education by providing fair and valid assessments" (The ETS mission, n.d.). However, as authors and administrators of the Praxis test series, the company plays one of the largest roles in maintaining the status quo in education today by helping to perpetuate the system of social inequities. In actuality, the diversity of our nation's population has not been reflected in our

professional teaching workforce, and a large body of evidence exists to show that Praxis tests are discriminatory (Lawrence & Crehan, 2001). While grossing more than one billion dollars annually, ETS is classified as a non-profit, and the company's CEO has been paid a salary of over one million dollars per year. Meanwhile, students of low socioeconomic status struggle to afford to take (and re-take) multiple Praxis exams which cost hundreds of dollars each (ETS, 2020).

Although ETS is considered a nonprofit in the United States, the company operates subsidiaries for profit throughout the world and benefited considerably from the increase in accountability and standardized testing. In an analysis of high-stakes testing in K-12 education, Nichols, Glass, and Berliner (2012) considered the effects of such exams on student achievement in 25 states where political pressure from policymakers tied standardized assessments to educator accountability. The authors rated West Virginia in the middle of the pack on their scale measuring this accountability pressure. Notably, they also found the following:

> For example, our data suggest that test related pressure is significantly and positively correlated with state poverty index (percent poverty in state). That is, states with greater number of individuals living in poverty also tended to employ test-related practices that exerted greater amounts of pressure. The nation's poorest children, and the teachers who teach them, tend to feel more pressure when it comes to high-stakes tests than their more privileged contemporaries (Nichols et al. 2012, p. 24).

Nichols et al. (2012) argue high-stakes testing not only fails to narrow racial, ethnic, and income-based achievement gaps, but also, "In spite of a growing literature indicating that high-stakes testing has had deleterious effects on teaching practices and student motivation, policymakers continue to argue for its effectiveness in increasing student learning" (p. 4). Moreover, based on NAEP data they claim"students were progressing in math at a much faster rate before the national high-stakes testing movement" (p. 23). The authors suggest "policy researchers to continue work that sheds light on the ways in which test-based instructional

practices affected by accountability pressures impact students' motivation, development, and achievement" (p. 27).

West Virginia policymakers, like those in many other states, worked with ETS to establish minimum scores for admission to educator preparation programs in public and private institutions of higher education ("Approval of Educator," 2019). Under the guise of higher standards, legislators have continued to require prospective teachers to succeed on redundant high-stakes standardized assessments without proof that those who have succeeded performed better in the classroom than those who struggled on the timed, computer-based tests (Wakefield, 2003). Further, as low salaries were the status quo nationally, leaders did little to incentivize individuals to enter the teaching profession (Darling-Hammond, 2010).

To better understand the experiences and feelings of preservice teachers in my local context, I engaged with students during empathy interviews to discuss their histories with math anxiety and math achievement. The empathy interviews were meant to be relaxed, open conversations from which I could learn more about how to provide supportive instruction for PSETs. During these empathy interviews with students who had taken several math education classes at D&E, PSETs cited tracking in K-12 math classes, unsupportive instruction during their K-12 education, and fixed mindsets of district leaders as barriers to their success. These students felt years of negative experiences in mathematics classes contributed to their cycle of math anxiety (see Figure 1) in which a lack of confidence and avoidance of mathematics made high achievement seem unattainable. However, other PSETs at D&E who were able to succeed on Praxis exams after initially failing commented that a growth mindset, perseverance, self-belief, and productive struggle were key factors in overcoming the cycle of math anxiety.

As an assistant professor of mathematics at D&E, I sought to work within my sphere of influence to implement a holistic approach to interrupt the cycle of math anxiety and to foster a positive and productive cycle of math achievement for PSETs. Further, nearly all PSETs in my classes were women, and math anxiety of female teachers often affected achievement of their female students (Beilock, Gunderson, Ramirez, Levine, & Smith, 2010). It was my hope that rather than a lack of confidence, poor performance, and math avoidance, this positive, constructive cycle of math achievement (see fig. 2) would create beneficial experiences in mathematics, thereby increasing achievement, confidence, participation, and agency for PSETs. Ultimately, these new teachers could pass on their improved abilities and positive experiences, they could raise expectations, and they could increase mathematical proficiency in their own local contexts.

With an emphasis on teaching practices such as focusing on conceptual understanding, multiple representations, high cognitive demand, and productive struggle which are common between growth mindset strategies, NCTM recommendations, and other research findings (Dweck, 2008; NCTM, 2014), I believed the firsthand experience and personal success of mathematical achievement via productive struggle with a growth mindset would be empowering for PSETs as well as for their future students. The most important stakeholders were our students, and they deserved the opportunities provided by increased power, access, identity, and achievement via high-quality mathematics instruction, learning, and application (Gutiérrez, 2009).

1.4 Statement of the Problem of Practice

My problem of practice involved improving proficiency in mathematics in preservice elementary teachers (PSETs) at Davis & Elkins College (D&E). The success rate of PSETs (K-6)

on the mathematics portion of the Praxis Core Academic Skills for Educators exam was approximately 30% on first attempt at D&E from 2015-2018.

1.5 Positionality Statement

I am a white, middle-class, cisgender, straight, non-disabled, married man. I have a daughter and a son, and we live in Appalachia. I was born in West Virginia and raised in a single-parent, low-income household with my mother and my younger sister. I am a first-generation college student who has loved math for as long as I can remember. I began tutoring other students in mathematics during high school over thirty years ago. I have been teaching in higher education for over twenty years, but my degrees are in chemistry and mathematics (not education).

I was raised not only by my hardworking mother, but also by several other strong women: my aunts and my grandmothers. Nearly all my best teachers have been women, and I strongly believe in the methods outlined in this paper to empower all learners as future teachers. While I have a mostly positive history with mathematics, I do have memories of instruction that was not supportive, especially in geometry class in junior high school, and I experienced failure on exams in graduate school. While it is difficult to admit, I have suffered from depression, and I am currently experiencing a high level of anxiety during the COVID-19 pandemic and the ongoing struggle for social justice for people of Color.

I see myself as a lifelong learner. Perhaps the most important concept that the EdD program at Pitt taught me in the user-centered approach of improvement science was to listen to my students. Via conversation and listening to our amazing students, we became determined to work together to overcome their cycle of math anxiety.

1.6 Review of Supporting Knowledge

1.6.1 Purpose of Review

In order to employ approaches informed by research to interrupt the cycle of math anxiety in my classrooms, I reviewed the literature on preservice teachers' math anxiety, growth mindset, agency, and attitudes toward mathematics. I decided to focus my review on articles about preservice teachers from approximately the last 30 years since the beginning of the reform movement in mathematics education when the National Council of Teachers of Mathematics (NCTM) published *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). I aimed to determine how I could holistically support my students to become more confident in their mathematical abilities, to increase their proficiency and achievement, while also empowering them to become impassioned and effective teachers. Below, I present two questions which guided my literature review along with themes from the literature that responded to these questions, as well as a synthesis and summary of the potential applicability of these ideas in my local context.

What are some key factors that affect preservice elementary teachers' success in mathematics?

Researchers have found PSETs' success in mathematics is affected by several factors that influence their attitudes toward and beliefs about mathematics. Research has shown a lack of confidence in mathematics is often prevalent in students with high levels of math anxiety (Bursal & Paznokas, 2006; Harper & Daane, 1998; Novak & Tassell, 2017). Math anxiety also affects problem-solving abilities (Novak & Tassell, 2017), while group work, critical reflection, and real-world projects with sociopolitical examples using multiple problem-solving strategies have been found to foster agency and improve students' beliefs about mathematics (Felton & Koestler, 2015).

Several instruments have been used in measuring math anxiety (FSMAS, MARS, R-MANX), and researchers suggested that careful attention to student responses on these surveys and other qualitative data from interviews reveal more specific factors that contribute to PSETs' achievement in mathematics (Bursal & Paznokas, 2006; Cardetti & Truxaw, 2014). Finlayson (2014) studied strategies which her preservice teachers employed to deal with their anxiety and lack of confidence. She discovered that they improved mathematically by making connections to prior skills, building on small accomplishments, asking for help from others, and having a positive attitude about their potential abilities. Finlayson's students also described more traditional study skills such as good organization, reviewing notes, completing homework, and avoiding procrastination as helpful aspects of their productive growth in mathematics.

To become more mathematically proficient, researchers found students must persevere when facing difficulties with anxiety and confidence (Bass & Ball, 2015). Middleton, Tallman, Hatfield, and Davis (2015) define perseverance as "the continuance of effort, carried out in a thorough and diligent manner, towards some perceived goal while overcoming difficulties, obstacles, or discouragement along the way by amending one's plan of attack" (2015, p. 4-5). Star (2015) emphasizes the importance of metacognition to understand the need to employ various strategies when persevering in solving problems. Like other researchers, Star connects the motivation to persevere to student identity, interest, engagement, and goals (Bennett, McWhorter, & Kuykendall, 2006; Berry & Thunder, 2015; Star, 2015). Star (2015) also cites the need for students to understand the concept of struggle as a learning opportunity, and to possess a *growth mindset*. Dweck (2006) defines "growth mindset" as the belief that intelligence and ability can change with effort, as opposed to a "fixed mindset" belief that intelligence and ability cannot be improved or developed.

In summary, the research shows PSETs' success is indeed affected by their lack of confidence and math anxiety, but progress has been made by fostering more productive and positive interactions with mathematics.

What are some instructional methods to best support PSETS' success in mathematics?

Research indicates that the use of manipulatives supports PSETs' success in mathematics (Gresham, 2007; Sloan, 2010; Vinson, 2001). Studies also found that following an active-learning, constructivist framework in math methods courses led to a significant reduction in math anxiety (Gresham, 2007; Vinson, 2001). Additionally, researchers suggest the methods courses should focus on NCTM strategies and standards (Gresham, 2007; Tooke & Lindstrom, 1998), and the prerequisite courses leading to math methods should be designed specifically for PSETs (Cardetti & Truxaw, 2014). It is necessary to challenge student beliefs about mathematics learning and teaching (Wood, 1988; Felton & Koestler, 2015), and the math methods course may be the last opportunity to influence attitudes, build confidence, reduce anxiety, and focus on effective teaching and learning (Harper & Daane, 1998). Wood (1988) proposed that effective teaching techniques are the keys to increasing confidence and decreasing anxiety, but he did not detail specific practices. More recently, Finlayson (2014) reiterated the need for a constructivist approach with a focus on the process of learning mathematics via diverse teaching styles. She stressed using a variety of assessment methods beyond exams, and engaging students with reflective journals to increase confidence and lower anxiety.

While recent NCTM recommendations from *Principles to Actions* (2014) did not target PSETs specifically, they did consist of research-based practices recommended for all mathematics classrooms. The teaching practices included focusing on reasoning, conceptual understanding, problem solving, discourse, and multiple mathematical representations. Further, the use of student

thinking, including the value of making mistakes and learning via productive struggle, was stressed. Additionally, NCTM asserted that safe learning environments must foster confidence as students and teachers engage with each other in challenging tasks with high expectations. Finally, NCTM also called for leaders to sustain a growth mindset (NCTM, 2014).

Dweck (2008) outlined interventions to alter mindsets and increase achievement in math and science. She encouraged educators to teach students that their brains can make new connections and intelligence can grow as effort is made to learn from mistakes while struggling through challenging material. In addition, Dweck recommended educators continually praise the process of perseverance rather than intelligence or results. She noted that training future teachers to have a growth mindset is particularly important, and past results, especially on high-stakes assessments, do not indicate what a student may be capable of with a growth mindset and support from positive learning environments. Further, Dweck endorsed the notion that the material on standardized tests can be mastered with proper preparation.

More recently, Sun (2018) continued the work of Dweck and others as she summarized a framework of teaching practices which conveyed mindset messages in order "to further our understanding of how psychology and mathematics education might speak to each other" (p. 331). Sun (2018) argues that to foster a growth mindset, teachers should have high expectations of all students in relation to mastery goals and cognitive demand, verbalize the importance of learning from mistakes, value student struggle, encourage risk taking, provide ample written feedback, and offer opportunities for extra help outside of class. Anderson, Boaler, and Dieckmann (2018) provided professional development with a focus on growth mindset and effective teaching practices to in-service teachers. In-person coaching and an online course were used to change mindsets and to emphasize teaching practices that valued student mistakes, encouraged high-level

learning for all students, provided open-ended mathematics problems, and maximized interactions between students. The researchers found improvements in student beliefs as well as in standardized test scores, and that their blended approach especially benefited minoritized students and others of low socioeconomic status (Anderson et al., 2018).

1.6.2 Synthesis

While Sun's (2018) framework was promising, and many earlier studies by Boaler (1999, 2002, & 2006) demonstrate improvements in K-12 settings, I hope my study can contribute to the literature in terms of applying productive struggle and a growth mindset to interrupt the cycle of math anxiety and improve the confidence, achievement, and agency of PSETs. I found it encouraging that the NCTM endorsed these practices, but I was surprised researchers had not used established metrics to investigate the extent to which math anxiety decreased as growth mindset and math achievement increased in PSETs. The methods of Anderson et al. (2018) which changed teaching practices and mindsets of in-service teachers seemed particularly applicable to PSETs as well.

Table 1 below summarizes findings from the literature review that revealed key factors that influenced student success as well as instructional strategies that had been shown to support students. This review also led to the inquiry questions, potential interventions, measures, and methods discussed later.

Table 1 Student Success: Contributing Factors and Supportive Methods

Contributing Factors	Supportive Methods
Math Anxiety*	Active, Learner-Centered
Confidence*	Social Constructivist
Attitudes*	Project-Based Learning
Beliefs*	Manipulatives
Motivation	Productive Struggle*
Goals	Reflective Journals*
Traditional Study Skills	Group Discourse

Note. Factors and methods marked with * were explored in this project.

2.0 Theory of Improvement and Implementation Plan

2.1 Aim Statement

I aimed to improve the passing rate of PSETs at Davis & Elkins College on their first attempt on the mathematics portion of the Praxis Core Academic Skills for Educators exam from approximately 30% to greater than 50% by September 1, 2021. Further, I aimed to improve students' mindsets and attitudes toward mathematics in order to support their confidence in their mathematical abilities, while also empowering them to become impassioned and effective teachers.

2.2 Theory of Improvement

In order to succeed on a high-stakes standardized assessment like the mathematics portion of the Praxis Core Academic Skills for Educators exam, many students must overcome several obstacles. Dweck found that one of those obstacles was often a fixed mindset about their mathematical ability (2008). Figure 3 represents the theory of improvement from a cycle of math anxiety to a cycle of math achievement. My theory, based on research findings from the literature review (e.g. Bass & Ball, 2015; Gresham, 2007; Vinson, 2001) and on my professional experience, is that students who develop a growth mindset and engage in productive struggle to make progress in mathematical problem-solving achieve greater success. I believe this success leads to more positive attitudes toward mathematics and a positive, constructive cycle of math achievement to

replace the negative feelings and lack of confidence that often accompany a history of poor results and math anxiety.

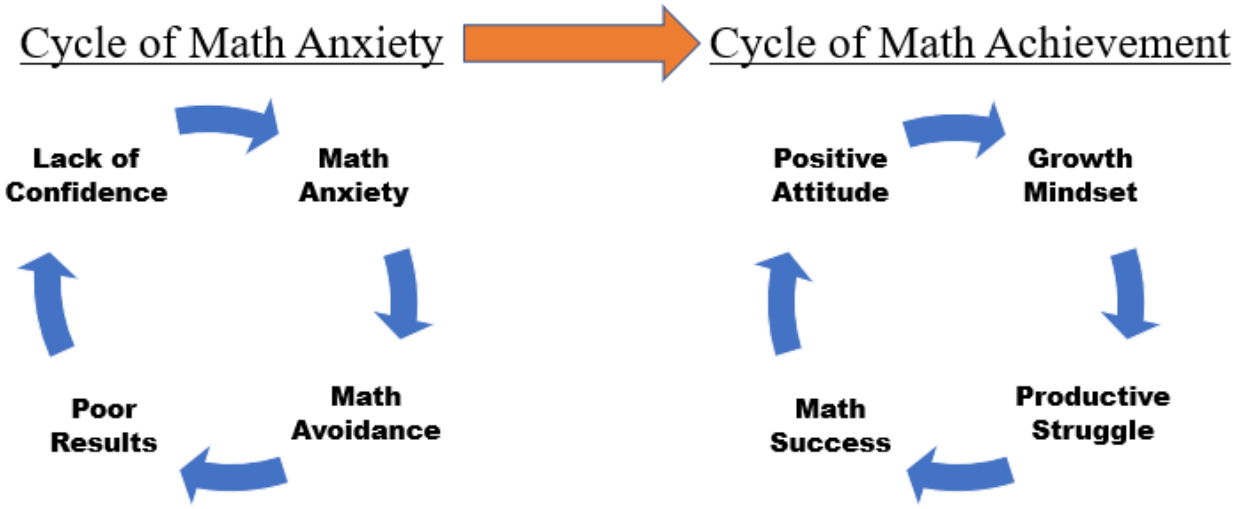


Figure 3 Theory of Improvement

Note. This figure illustrates the theory of improvement.

In order to move a student from feelings of anxiety about mathematics toward a cycle of mathematics achievement, students engaged in a variety of activities. The free online course from Stanford University on applying a growth mindset to learning mathematics aimed to improve students' attitudes toward mathematics. A key concept from the course was that everyone makes mistakes and that our mistakes are opportunities to learn, persevere, and productively struggle through challenging concepts ("How To Learn Math," 2014).

Another important concept from the literature review which may be new to students is that we learn mathematics socially by sharing our work and problem-solving strategies. Boaler (2008) found that students who shared in these classroom experiences not only increased their mathematical achievement, but they also learned to respect, communicate, support, and care about the learning of others. Yackel and Cobb (1996) underscored the importance of the teacher in establishing sociomathematical norms in our classrooms. Instruction in my courses included less

lecture and more active involvement by students in an approach where mathematical knowledge was socially constructed by the students rather than given by the instructor. Learning in this context was meant to be empathetic and supportive. It required an open mind and a belief that progress was possible despite past experiences which may have involved poor performance and math anxiety for many students.

Research indicates good study skills, test preparation, and mathematical content knowledge are also keys to success on high-stakes standardized tests (Finlayson, 2014; "Praxis Core Academic Skills," 2020). Timed, computer-based practice modules using Pearson MyLab, as well as the free course provided by Khan Academy in partnership with ETS, provided opportunities for students to engage in productive struggle with problems aligned to the mathematics portion of the Praxis Core Academic Skills for Educators exam. Weekly entries in reflective journals served as a useful tool as students considered their feelings, confidence, beliefs, approaches, and attitudes regarding growth mindset, productive struggle, and online learning tools as part of the supportive, social constructivist methods employed in my classes.

The driver diagram presented in Figure 4 operationalizes the theory of improvement, summarizes the aim of my semester-long PDSA (Plan-Do-Study-Act) cycle, the drivers that I addressed, and the change concepts and ideas that I implemented in this study. The change concepts were meant to address the aim of moving students from a cycle of math anxiety to a cycle of math achievement as shown in Figure 3 above. As stated above, based on research (e.g. Bass & Ball, 2015; Gresham, 2007; Vinson, 2001), professional experience, and listening to my students, I believed that developing a growth mindset (starting with the Stanford course) would help to alleviate math anxiety. Online assignments from Pearson and Khan Academy would address math avoidance and would require students to engage in productive struggle with problems aligned to

the Praxis Core exam. Success on these components, along with reflective journals and group discourse that shared not only problem-solving strategies but also feelings about mathematics, was included to build confidence, belief, and more positive attitudes. I also hoped this first iteration of the PDSA cycle would serve to improve my teaching strategies, curricular materials, and help to determine which activities and change concepts were beneficial to students so that future cohorts of PSETs would have a greater chance to succeed on their first attempt on the math portion of the Praxis Core exam.

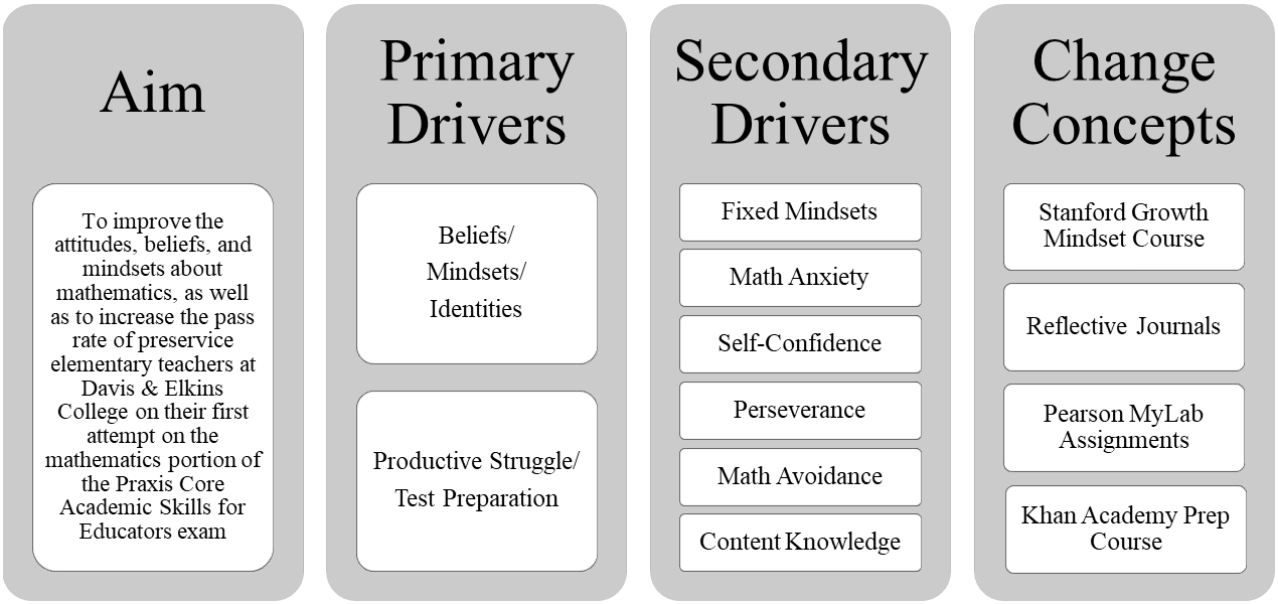


Figure 4 Driver Diagram

2.3 Interventions, Measures, and Methods

As previously discussed, one potential intervention to address my problem of practice was aimed at improving the mindsets that students had regarding their mathematical abilities. I aimed to foster a growth mindset rather than a fixed mindset. I believed this would help to improve

PSETs' confidence, attitudes, and beliefs about their mathematical abilities. One change idea central to this intervention that was required for all students was the free online course that focused on growth mindset in mathematics offered by Stanford University ("How To Learn Math," 2014). Participants' mindsets were measured pre/post using Dweck's three-item growth mindset scale (Dweck, 1999, 2006). Based on research (Finlayson, 2014; NCTM, 2014), I believed reflective journals aimed at fostering positive beliefs about and attitudes toward mathematics would also play a role in improving student mindset. Survey items were used to gain insight from participants regarding these learner-centered, social constructivist approaches.

In order to succeed on high-stakes mathematics exams like the Praxis Core Academic Skills Educators, students also needed to improve their study skills and test preparation ("Practice Core Academic Skills," 2020). Thus, another intervention I implemented involved engaging in productive struggle using the online course from Khan Academy which was aligned with the mathematical content covered on the exam ("Praxis Core Math," 2019). See Appendices B and C for survey items, journal prompts, and interview questions aimed at assessing the usefulness of these interventions.

Pearson MyLab homework assignments also focused on improvement on mathematical content knowledge and problem-solving strategies via productive struggle. Unlimited opportunities to practice timed, computer-based Pearson MyLab quizzes designed to mimic Praxis conditions were used in an effort to increase engagement in productive struggle while also increasing confidence in students' mathematical abilities. Again, participant responses to survey items (see Appendix B), journal prompts, and interview questions (see Appendix C) shed light on student perception of the benefits of these curricular materials.

While I believed an increase in growth mindset and better test preparation would improve Praxis exam scores, these interventions were also aimed at decreasing math anxiety and increasing participants' confidence in their mathematical abilities. The Abbreviated Math Anxiety Rating Scale (A-MARS) (Alexander & Martray, 1989) were also administered as a pre/post measure of the effectiveness of this PDSA cycle. These interventions were practical in that they were easily woven into my daily practice in the teaching of my courses. Anecdotally, some students had already shown improvement based on curricular changes and had commented in empathy interviews that similar interventions were helpful. I chose these change concepts based on a review of the literature as well as on more than two decades of professional experience in higher education.

2.4 Inquiry Questions, Data Sources, and Data Analysis

1. How do students respond to instruction focused on growth mindset and productive struggle to decrease math anxiety in preparation for the mathematics portion of the Praxis Core Academic Skills for Educators exam during the COVID-19 pandemic?

Both qualitative and quantitative data sources were analyzed to investigate student responses to the interventions of this PDSA cycle. Individual results from participants' responses to Dweck's mindset scale (see Appendix D) (Dweck, 1999, 2006) as well as the Abbreviated Math Anxiety Rating Scale (A-MARS, see Appendix E) (Alexander & Martray, 1989) were used to examine changes in mindsets and attitudes toward mathematics. These results along with participant surveys, journals, interviews, and my teacher journal were employed to identify commonalities among student-participants in this study.

2. How does the Stanford online course increase growth mindset in preservice teachers?

I administered Dweck's mindset scale (pre/post) as a quantitative measure to gauge whether this free course increased growth mindset in my students. With a small sample size, analysis of changes in individual student scores proved to be more valuable than comparing averages of all participants on this mindset scale. Surveys (see Appendix B) were administered at the end of the semester to gather more quantitative data. In this case, average responses of participants were calculated to investigate the helpfulness of this intervention. Qualitative data gathered from students' weekly journal entries and interviews conducted at the end of the semester (see Appendix C) was evaluated using deductive coding (Saldaña, 2009) with codes related to students' attitudes, beliefs, and mindsets before and after the Stanford course.

3. How does developing a growth mindset influence PSETs' attitudes about math and willingness to engage in productive struggle?

Journal entries and interviews also revealed information regarding students' self-efficacy based on past experiences. As students progressed through the semester, they engaged in productive struggle via the Khan Academy course and Pearson MyLab assignments. I was interested to learn qualitatively via their journal entries and interviews how their experiences after learning about growth mindset in this course were different than the experiences they had with mathematics in the past. My own teaching journal yielded valuable qualitative information related to this inquiry question as well. These qualitative data were analyzed using deductive coding and analytic memos (Saldaña, 2009) with codes related to students' attitudes, beliefs, and mindsets as well as their experiences persevering and engaging in productive struggle throughout this study as they prepared for the Praxis exam.

Again, Dweck's mindset scale (pre/post) assigned quantitative values for participants' mindsets from the beginning to the end of the semester. The Abbreviated Math Anxiety Rating Scale (A-MARS, see Appendix E) (Alexander & Martray, 1989) was also administered as a quantitative pre/post measure of participants' attitudes toward mathematics with a focus on changes for individual participants in this relatively small study. The end of semester survey items were designed to gather more quantitative data as well regarding participants' opinions on growth mindset and on their willingness to engage in productive struggle. I analyzed the average of students' responses to these survey items to help to determine the effectiveness of a growth mindset on attitudes about mathematics and willingness to engage in productive struggle.

4. How does engaging in productive struggle reduce math anxiety?

Participants' math anxiety was measured pre/post using the Abbreviated Math Anxiety Rating Scale (A-MARS, see Appendix E) (Alexander & Martray, 1989). Individual scores on this scale were compared to determine if anxiety levels decreased from the beginning to the end of the semester. Rather than avoiding mathematics, students engaged with a variety of problem-solving methods in the Khan Academy course and Pearson MyLab assignments. Averages of participant responses to survey items at the end of the semester elicited more quantitative data on the relationship between productive struggle and math anxiety. In addition, student and teacher journal entries, interviews, and analytic memos were coded deductively (Saldaña, 2009) to assess participants' feelings, attitudes, and beliefs about themselves, their anxiety, productive struggle, and the interventions.

5. How do students feel the Khan Academy course influenced their understanding of material on the Praxis exam?

This component of the semester-long PDSA cycle was especially crucial during the COVID-19 pandemic while my courses were online. End of semester survey items were the quantitative measure which addressed this question, and I calculated averages of participants' responses to measure the effectiveness of the Khan Academy course. I also gathered rich qualitative data from journal entries and interviews to gauge the effectiveness of this intervention in preparing students for the high-stakes standardized assessment. These qualitative data were analyzed using deductive coding (Saldaña, 2009) with codes related to students' feelings about and experiences with the material they encountered on Khan Academy as they prepared for the Praxis exam.

Table 2 Inquiry Questions and Data Sources

	Data Sources (Type of Measure)			
Inquiry Questions	Participant Surveys, Journals, and Interviews (Driver and Leading Outcomes)	Teacher Researcher Journal	Dweck's Growth Mindset Scale (Leading Outcome)	Abbreviated Math Anxiety Rating Scale (Driver)
Frequency and timing	Journals: weekly (~12x) Interviews and Surveys: after course ends	Reflective notes will be taken each day after teaching each class with weekly analytic memos.	Participants (~12) will take this at the beginning and end of the course.	Participants (~12) will take this at the beginning and end of the course.
1. How did students respond to instruction focused on growth mindset and productive struggle to decrease math anxiety in preparation for the mathematics portion of the Praxis Core Academic Skills for Educators exam during the COVID-19 pandemic?	X	X	X	X
2. How does the Stanford online course increase growth mindset in preservice teachers?	X		X	

Table 2 (continued)

3. How does developing a growth mindset influence PSETs' attitudes about math and willingness to engage in productive struggle?	X	X	X
4. How does engaging in productive struggle reduce math anxiety?	X	X	
5. How do students feel the Khan Academy course influenced their understanding of material on the Praxis exam?	X		

3.0 Summary of Data Analysis

Table 2 above summarizes my inquiry questions and data sources to utilize triangulation in this PDSA cycle. As stated above, the interventions I implemented are available free online. This was particularly important as I taught all courses online during the COVID-19 pandemic. What may have been lost is the personal interaction which I have in face-to-face classes with my students, but via journal entries and interviews I hoped to gauge the effectiveness of online modes of communication such as blogs, forums, and virtual meetings. In my recent experience, video chat sessions have been invaluable in maintaining positive learning environments with high cognitive demand in online classes since we have transitioned to distance education.

Qualitative data from journal entries and interviews were analyzed as I especially looked for evidence of increased confidence, improved attitudes about and feelings toward mathematics, as well as experiences involving growth mindset and productive struggle. Quantitative data were collected and analyzed from pre/post results on both the growth mindset scale and on the math anxiety scale. With an anticipated small number of participants, I was more interested in individual comparison of pre/post results rather than averages. Survey items were administered at the end of the semester only and whole group averages for each question of these quantitative data were analyzed to help determine the effectiveness of the Stanford course, the Khan Academy course, Pearson MyLab assignments, and the reflective journals.

4.0 Research Context

4.1 Introduction

During the fall semester of 2020, ten students volunteered to participate in my PDSA cycle (see Tables 3 and 4 below). Nine of these students had previously taken at least one class with me. The one who had not was a senior specializing in physical education. Seven of the remaining nine participants were PSETs, and two of those students were also specializing in teaching math in middle school. The remaining two students were seeking licensure to teach secondary mathematics. Two participants were taking both the 100-level math course and the 300-level math methods course. Five of the participants had previously completed several math courses and were enrolled in the 300-level math methods course, while three were enrolled in the 100-level math course only. None of the students were in their first year of college, and the participants included eight women and two men, all of whom identified as white. Also, note that all names have been changed to pseudonyms chosen by the participants.

Table 3 Participant Demographics (N = 10)

Education Specialization	Fall 2020 Course Enrollment(s)	Year in School	Gender
Elementary: 5 Elementary with Middle School Math: 2 Secondary Math: 2 Physical Education: 1	MATH 109 only: 3 EDUC 316/317 only: 5 Both EDUC 316 and MATH 109: 2	Sophomores: 2 Juniors: 7 Senior: 1	8 Women 2 Men

Table 4 Participant Demographics Continued

Participant Pseudonym	Education Specialization(s)	Fall 2020 PDSA Cycle Course Enrollment(s)	Year in School	Gender
Bridgette	Elementary	EDUC 316	Junior	F
Brinley	Elementary	MATH 109	Sophomore	F
Charley	Elementary	EDUC 316 MATH 109	Junior	F
Gayle	Secondary Mathematics	MATH 109	Sophomore	F
Margaret	Elementary	EDUC 316	Junior	F
Mia	Elementary; Middle School Mathematics	EDUC 316	Junior	F
Mike	Elementary; Middle School Mathematics	EDUC 316 MATH 109	Junior	M
Nico	Physical Education	MATH 109	Senior	M
Sara	Secondary Mathematics	EDUC 317	Junior	F
Tylr	Elementary	EDUC 316	Junior	F

While our global society battled the COVID-19 pandemic, D&E offered students the opportunity to live on campus and to attend classes wearing masks in person during the fall semester of 2020. Professors were tasked with being flexible in offering hybrid courses to accommodate students who were physically present as well as those who were attending class

virtually due to quarantining, social distancing, or other factors such as medical conditions or being international students. In my case, due to a history of asthma, I am in a high-risk category and received a recommendation from my physician to teach remotely. I taught all classes online using Microsoft Teams for video calls with my students and the SAKAI platform for course management such as posting class notes and other documents, forum discussions, and a calendar of assignments and other activities.

As the semester began, a small number of D&E students tested positive for the new coronavirus. Thus, about 3% of the college's approximately 500 residential students were in quarantine for two weeks at the beginning of the semester. Some participants made me aware of a new phrase when they said they were "living life online." Others noted economic responsibilities such as car repairs and getting a new job at a bar in town where pandemic protocols were not being followed and dozens of students were gathering without masks or social distancing. Notes in my teacher journal indicate students were often attending class from work, or even answering my calls and participating in class while driving. I tried to be understanding and flexible as I dealt with my own unreliable internet. Frequently, I had to teach from various off-campus locations such as city parks or friends' and relatives' porches where there was better internet connectivity.

During the first month of this semester-long PDSA cycle, I became concerned about students who were not fully participating in my courses. I reached out to a colleague who was teaching on-campus in the education department. We talked via video call on Microsoft Teams, and she related her experiences with in-person classes at that point during the pandemic. She noted that her students were "clammed up" in class as well. She said while students were attending class in masks, they were less active, less social, and she was not able to have students work in groups as she was accustomed to doing in the past. We discussed ways to continue to be supportive and

student-centered, especially regarding Praxis preparation. This colleague is another doctoral student who has taken on the responsibility of helping students succeed on the reading and writing portions of the Praxis Core exam and is also encouraging the use of Khan Academy preparation courses for the high-stakes exams.

After our conversation, I pivoted to using Khan Academy materials more specifically during my class meetings online. While I continued to use materials from Pearson MyLab for examples and online homework, it seemed imperative to emphasize Khan Academy as the course was designed specifically for Praxis preparation in a partnership with ETS. I hoped that by modeling this behavior in class, students would see its value and spend significant time on their own on Khan Academy to prepare for Praxis.

4.2 Finishing the Semester Online

Notes in my teacher journal from the final month of the semester also showed that the COVID-19 infection rate on campus continued to increase. While most students had been patient and followed guidelines throughout the semester, some decided to break protocol and visit local bars for Halloween. Soon, we had 22 positive cases on campus. This resulted in nearly 25% of our residential students being placed in quarantine. Within just a few days there were more than 30 positive cases and approximately 40% of on-campus students were quarantined. Thus, when only two weeks plus final exams remained to complete the semester, D&E was forced to move all classes online for at least a week, and most students left campus to live back home for the remainder of the semester.

I noted that when I saw their faces on our next Teams video call, students looked much happier and relaxed at home. They were less worried and less depressed, but ready for the end of the semester and a chance to decompress. I also indicated in my journal that I was exhausted and quarantined with the hope of sharing a socially-distanced Thanksgiving meal with family outdoors. By the last day of classes I noted that the students who had gone home were settled into their routines, working new jobs, and enjoying time with their families.

5.0 Results

In the following sections, I present the results of this PDSA cycle by revisiting my inquiry questions. I aimed to place student voices in the foreground by focusing on responses to prompts from their student journals entries. I also relied heavily on the teacher journal which I kept throughout the semester to chronicle the interventions, events, activities, and experiences of the students who chose to participate in this study during the COVID-19 pandemic. I used student journal entries, my teacher journal, focus group interviews and quantitative results from the growth mindset and math anxiety scales to introduce the reader to these amazing student-participants. I let student voices drive the discussion as I believe their first-person quotations are the most powerful evidence I have found to relate their experiences to my theory of improvement. I focused on the factors of confidence, attitudes, and beliefs which the literature review revealed as keys to student success, along with the supportive methods of reflective journals, productive struggle, and growth mindset in mathematics education, especially as these methods pertained to preparing for the high-stakes mathematics portion of the Praxis Academic Skills for Educators exam for students at Davis & Elkins College. I intended to have the participants' voices tell their stories of our collaborative efforts to move many of them from a cycle of math anxiety to a cycle of math achievement.

The main takeaway from this study is that different types of students responded differently to the interventions. I found the participants could be grouped into four classifications based on common characteristics and experiences. I categorized these preservice teachers as *persevering student-athletes*, *anxious achievers*, *exempt enjoyers*, and *frustrated resisters*. The persevering student-athletes were student-athletes who worked hard, pushed through challenges, and developed growth mindsets in order to improve their attitudes and mathematical abilities. The

anxious achievers were close friends who exhibited some math anxiety but were highly-motivated and helped each other succeed academically, both in terms of grades as well as standardized test scores. The exempt enjoyers shared positive prior math experiences during their K-12 years, enjoyed mathematical problem-solving, and were exempt from the mathematics portion of the Praxis Core Academic Skills for Educators exam. The frustrated resisters had more negative experiences in their previous math classes, did not identify as having math anxiety, needed more support than what was available online, and did not succeed on the Praxis Core exam during this PDSA cycle. Each of these group classifications (or typologies) and their individual members are described below.

The persevering student-athletes and anxious achievers benefited the most from my theory of improvement. Both of these groups experienced math anxiety and worked hard to employ the change concepts of this PDSA cycle to improve their attitudes, beliefs, and mindsets in order to achieve mathematically. Meanwhile, the exempt enjoyers and frustrated resisters did not benefit as much from the interventions, but for different reasons. Neither the exempt enjoyers nor the frustrated resisters reported experiencing as much math anxiety, but while the exempt enjoyers were confident and had the advantage of supportive instruction and positive mathematical experiences in the past, the frustrated resisters lacked confidence, were more fixed in their mindsets, avoided math, and did not experience the cycle of math achievement.

I also found one participant's experience as a commuter student was distinct and fell outside the realm of the other classifications. Her journey is also presented below. After addressing the inquiry questions and educational experiences of the participants, I discuss some additional themes which emerged via analysis of the qualitative and quantitative data generated from this

PDSA cycle. Finally, I address conclusions, limitations of this study, and my plans for future PDSA cycles and other research.

5.1 Inquiry Questions Revisited

5.1.1 How did students respond to instruction focused on growth mindset and productive struggle to decrease math anxiety in preparation for the mathematics portion of the Praxis Core Academic Skills for Educators exam during the COVID-19 pandemic?

Like Bennett et al. (2006), as noted above, I found preservice teachers could be classified together in small groups. The participants in this study fell into the following clusters: persevering student-athletes, anxious achievers, exempt enjoyers, and frustrated resisters. The students in each typology are listed in Table 5.

Table 5 Group Classifications

Group Classification	Participants in Each Classification
Persevering Student-Athletes	Charley and Mia
Anxious Achievers	Bridgette, Sara, and Margaret
Exempt Enjoyers	Gayle and Brinley
Frustrated Resisters	Nico and Mike

5.1.1.1 Persevering Student-Athletes

The two "persevering student-athletes" in this study, Charley and Mia, exhibited several common experiences in their mathematical backgrounds and in their Praxis preparation toward teacher licensure. These students initially shared a fair amount of math anxiety and lower confidence in their mathematical abilities but improved their self-belief by employing more of a growth mindset. In addition, each of these participants devoted significant time to engaging in productive struggle, especially with the Khan Academy course, to prepare for the high-stakes exam despite the extra responsibilities they shared as Division II athletes.

Their experiences as student-athletes who exhibited strong work ethics, learned to manage their time well, and persevered athletically helped enable them to succeed academically, too. As students who were accustomed to forming good habits in a culture where coaches and teammates have high expectations for all team members to have a drive to succeed, to do their best, to listen to their coaches' instructions, to follow directions, to be detail-oriented, and to diligently prepare in practice in order to succeed in competition, these preservice teachers bought into an analogous culture in our math classes. I think of myself as a coach and cheerleader for all students. During classes, I often referenced the similarities between my theory of improvement and experiencing a growth mindset and productive struggle in sports. I encouraged all students to have an open mind to the possibilities for self-improvement in mathematics as well, and the persevering student-athletes related well to the supportive instruction of this approach.

According to my teacher journal, the supportive pivot that I made to focus on the use of Khan Academy study materials early in the semester had an immediate positive impact on the persevering student-athletes. Charley, a student-athlete and PSET in her junior year, was enrolled in both the 100-level and the 300-level course during this PDSA cycle. She scheduled a Praxis test

date earlier than I anticipated and had only ten days to prepare for the exam. Although she had also taken two other classes from me in previous semesters, including a developmental algebra class during her first year of college, Charley was not confident in her mathematical ability. In an effort to increase her confidence and to encourage her to engage in productive struggle, I reminded Charley that she had done very well in the developmental class and that she just needed to practice the concepts presented in the Khan Academy course.

As we worked through examples on Khan Academy and she solved problems correctly, her confidence grew. Her facial expressions and voice changed on our video calls. She was smiling, and I could literally hear the positivity as she spoke! Charley's journal entries indicated a lack of preparation for standardized tests in the past, but increased motivation during her time at D&E. Charley wrote, "I never prepared for the SAT when I took it, but I studied many hours for my Praxis math test. I wasn't motivated to study for the SAT, but I was very motivated to study for the Praxis." Charley's hard work paid off quickly as she passed the mathematics portion of the Praxis Core on her first attempt during the first month of the semester. I found this result to be extremely gratifying as well and took it as an early indicator of the potential success of the interventions, especially Khan Academy, during this PDSA cycle.

During our focus group interview at the end of the semester, Charley provided more details about her past educational experiences and about her motivation during the fall semester of 2020.

> So, I think my lack of motivation when taking the SAT was I was homeschooled until my second semester of junior year and I came into high school not knowing that you needed it for college, so I just I didn't study for it. I didn't really care for it. But the Praxis, knowing that I needed to pass in order to get my teaching certification, that helped me with studying more and making sure that I passed.

For Charley, her unique experience of being homeschooled nearly throughout her K-12 years led to her lack of knowledge regarding high-stakes standardized tests in general. However,

as a PSET at D&E, she came to understand the importance of succeeding on the Praxis Core exam in order to pursue her career in education. As she gained more experience, confidence, and knowledge in college, she also gained the motivation and willingness to engage in productive struggle, especially via the free online practice provided by the Khan Academy course.

According to the quantitative measure of math anxiety which I used in this study (A-MARS; see Appendix E), Charley experienced between "a fair amount" of and "very much" anxiety when studying for and when taking math exams. Her comments during our interview provided some qualitative evidence that the online Khan Academy curriculum did indeed help her to reduce her math anxiety while engaging in productive struggle. Charley said, "Khan Academy helped me a lot with my math anxiety because if I did get a problem wrong it would explain why and what the right answer was so that helped my brain process what I need to do."

Charley developed a more positive attitude, growth mindset, and willingness to engage in productive struggle prior to her successful effort on the Praxis exam. She scored 14 of a possible 18 on Dweck's mindset scale (she did not complete the post-assessments), which indicated her belief that intelligence is malleable. For her fourth journal entry, Charley wrote:

> Growth mindset was introduced to me by Professor Sams and it has helped dramatically. It came to my attention my freshman year of college in my fundamentals class. I use the growth mindset in all of my classes now and I have definitely noticed a difference.

While Charley was preparing for her first attempt on the Praxis Core exam, another student in the 300-level math methods course was studying to take the exam for the second time. Mia, another student-athlete and PSET in her junior year, was also pursuing a specialization in middle school mathematics. She had signed up to use the new "at home" option for testing which ETS created during the COVID-19 pandemic. My colleagues in the education department at D&E set up a space in an empty office to follow the guidelines outlined by ETS so that our students did not

have to travel to other testing centers. After I received an excited email with the subject line "I passed!!!!!" from Mia, I asked her to share helpful hints with her peers on Microsoft Teams. Mia told us based on her past performance she knew that she needed to focus on statistics and geometry in order to succeed. She said that she was able to stay "on track" with her preparation using the Khan Academy course, and the timed practice tests at the end of the course were particularly helpful. She also mentioned that she benefited from becoming more comfortable with the on-screen four function calculator which ETS allowed during the exam. When asked about the Khan Academy course during our focus group interview, Mia said, "I liked how it was almost identical to the Praxis. It was super helpful in preparation for the test. It gave me an idea of what I was getting into on the day of the test."

Mia's positivity and confidence in mathematics grew tremendously during her time at D&E. Her first journal entry revealed a history of frustration with algebra and geometry classes in high school, but also a willingness to engage in productive struggle, and an awareness regarding her own learning and teaching. When asked about her past experiences with mathematics, Mia wrote in her journal:

> They are just teaching straight from the book and I discovered that is not how I learn. Once I got to college, I kind of fell in love with math. It made sense, I enjoyed putting in the work. Now I am here pursuing a Math specialization. I am not sure if these are considered positive or negative examples, just that there needs to be a change in the way schools are teaching math.

Interestingly, Mia had the highest math anxiety score of all study participants at the beginning of this PDSA cycle, and it did not significantly reduce by the end of the semester. In her second journal entry, Mia addressed her math anxiety, but again showed an awareness of her own responsibility to engage with the material in order to learn from her mistakes. Rather than

continuing to avoid math and exacerbate her difficulties, Mia has learned to be positive, to learn from her mistakes, and to engage in productive struggle.

> I definitely can relate to the cycle of math anxiety. This usually occurs when I am a little bit behind in a class. After maybe not doing so well on a homework assignment or a quiz, I kind of have a self-check and am able to bounce back on the next quiz or test.

Mia's third journal entry showed her willingness to engage in productive struggle in preparation for a standardized test did not just begin in college. Mia wrote:

> In high school I took a SAT prep class. Taking this class was super helpful, I received two books, and lots of tips and tricks for taking the SAT. My goal for the first time I took the test was to just break 1000. I ended up getting a 1020. I took it one more time and got a 1040. I was relieved that I at least broke a 1000.

Although her method for preparing for a standardized test in high school was more traditional than the online materials used in this study, Mia was motivated to put in extra work to achieve a particular score. When I asked her to elaborate on her journal entry during our focus group interview, Mia stated:

> I was motivated to break 1000 on my SAT when I was in high school because I did not have super great grades, so I just needed a little extra push and that definitely transitioned into college when I decided to add a math specialization. That continued on and motivated me to keep pushing with my math studies.

Despite Mia's first journal entry which indicated some frustration with her high school math classes, she stated in her fourth journal entry that she was already familiar with the growth mindset concepts presented in the free course from Stanford. Mia indicated that having a growth mindset has improved her confidence and willingness to engage in productive struggle rather than avoiding math. Her scores on the growth mindset scale were consistently high from beginning to end of this PDSA cycle (she scored 15 of 18 on both assessments). Again, I believe Mia's experiences in high school, along with her positive attitude, self-belief, and hard work laid the groundwork for her success in college and contributed to moving her toward a cycle of math

achievement. When prompted to discuss her experiences with applying a growth mindset to her education, Mia wrote:

> The information was not new to me. Growth mindset was pretty big at my high school. I never really "believed" in it until I got to college. It has been super helpful in not feeling defeated in my classes. You just have to work that much harder to get to where you want to be. You are not always going to get the results you want and that is okay!

Along with her belief in a growth mindset, Mia has embraced the process of productive struggle, learning from her mistakes, and is committed to perseverance in her pursuit of a math specialization. She and Charley both served as excellent examples and early indicators that my theory of improvement involving improved confidence, attitudes, and beliefs together with a growth mindset and engagement with the mathematical content via productive struggle can lead to mathematical achievement and success on high-stakes standardized Praxis exams for preservice teachers.

After Charley and Mia passed their Praxis exams by the end of September and we moved toward the mid-term of the semester, I began to hear similar success stories of other students who had taken classes from me in the past but were not directly participants in this study. Two sophomore student-athletes who were in the two 100-level math courses for elementary education majors with me last year drove together on a Saturday morning to a local testing center which is more than an hour from our campus. Both of these PSETs passed their Praxis exams on their first attempts. From previous interactions with these students in class, I know that one is confident in her mathematical abilities and used Khan Academy to prepare for the exam, while the other began with less confidence, but also embraced productive struggle as she told me on email that she studied every night for two weeks in advance of her test date. Both students were also encouraged to complete the Stanford growth mindset course during the previous semester, but I do not know to what extent the intervention was helpful. These students were on track to take the 300-level

math methods course from me the following year. At a small school like D&E, where all education majors know each other, it is important to celebrate the successes of all students since word spreads quickly and students openly share their methods of achievement. I reported their results here to show more evidence of an overall improvement in the system or culture at D&E, and hope preservice teachers will continue to share their experiences with peers and future cohorts to help others progress toward teacher licensure.

By the middle of October, two more student-athletes in the math methods class also succeeded on their first Praxis attempts. These PSETs chose not to participate in this study, but they did complete the 100-level classes with me previously and used Khan Academy to prepare for the exam. I do not believe these students have experienced much math anxiety, and that may have played a role in their choices not to participate in my PDSA cycle. I also believe the demands on their time as student-athletes, especially during the COVID-19 pandemic, may have made them wary of taking on what may have seemed like extra work when I asked for volunteers at the beginning of the semester. Still, I am proud of their hard work and successes. I also feel their achievements are examples showing that the supportive methods which my colleagues and I have put in place throughout the teacher education curriculum are serving many students well. This was certainly true for the preservice teachers in the next group classification.

5.1.1.2 Anxious Achievers: A Supportive Relationship

A group of three friends (Bridgette, Sara, and Margaret) also participated in this study although they had already passed the mathematics portion of the Praxis Core Academic Skills for Educators exam prior to the fall semester of 2020. They were all local students who were enrolled in the 300-level math methods class and had taken at least two math courses from me in the past. While they may have already succeeded on Praxis Core, they still needed to succeed on other high-

stakes standardized Praxis exams before student teaching. These participants indicated they used the interventions in this study to prepare not only for the Praxis Core exam, but also for their additional Praxis exams. Based on similar group portraits described by Bennett et al. (2006), I decided to interview these three "anxious achievers" together as a focus group to gather more qualitative data at the end of this PDSA cycle.

I classified these three participants as anxious achievers based not only on their relatively higher scores on the math anxiety ratings scale, but also on their qualitative responses to survey prompts, journal entries, and interview questions. These three study participants were achievers with high grades who passed the mathematics portion of the Praxis Core Academic Skills for Educators exam earlier than most other preservice teachers at D&E. Interestingly, while they were motivated to achieve in their pursuit of high grades and successful exam scores, they also experienced math anxiety and discussed the stress they shared related to their desire to achieve mathematically. Furthermore, these anxious participants were all disciplined in their approaches to overcoming their anxiety and achieving mathematical success by diligently employing the methods and materials of this study in their preparation for high-stakes standardized exams. This group not only believed in the potential of the change concepts in this PDSA cycle, but also in their own abilities to continue to improve and to thrive in the cycle of math achievement despite their math anxiety.

Bridgette, a junior PSET and anxious achiever, showed the highest level of math anxiety during this study according to her A-MARS score of 3.48 (on a scale of 1 to 5) at the end of the semester. This overall score placed Bridgette at a level between "a fair amount" of and "much" math anxiety on the rating scale (see Appendix E). It is interesting to note that this was a significant decrease from the end of her first year in college when I began to consider using the questionnaire

for my PDSA cycle. In that course, Bridgette took one look at the 25-question survey and said, "I'm just going to mark down all fives." Such a rating at that time would have given Bridgette the maximum math anxiety score indicating she experienced "very much" math anxiety.

However, over the last two years, Bridgette showed tremendous progress in her confidence, attitude, ability, and willingness to engage in productive struggle. Bridgette was successful on her second attempt on the Praxis Core exam. Shortly thereafter, Bridgette achieved a passing score on her first attempt at taking the mathematics subtest of the multi-subject Praxis exam which is required for PSETs prior to student teaching ("West Virginia Test Requirements," 2021). She was also one of two participants with the highest possible scores on Dweck's growth mindset scale. Bridgette was one participant who related strongly to my theory of improvement and worked hard to manifest mathematical achievement in her life. In her second journal entry, Bridgette wrote:

> When I first came to college I followed the cycle of math anxiety wholeheartedly. Now, three years in I have found myself slowly moving toward the cycle of math achievement. The cycle of math anxiety is something that follows me and sometimes I still get caught up in it. Math anxiety is something that develops over time. Unhelpful math teachers, bad test grades, no hope, and stress have taken over for so long but my math teacher in college has greatly helped me overcome such past. The cycle of math achievement has shown that progress and success is possible even when you can't see it.

Bridgette spent a good deal of time reflecting on her improvement over the last two years. When asked about her feelings regarding math anxiety versus math achievement during our focus group interview, Bridgette stated:

> For me the cycle of math anxiety and the cycle of math achievement kind of interlock sometimes, but I find myself following in a cycle of math anxiety more often because of the lack of confidence from my previous experiences. So that does make me avoid math a little bit, but once I figure something out with my poor results I kind of do that productive struggle and that tends to having a better attitude towards math and I feel like when I'm more open then I have more math success, so I kind of start with the math anxiety cycle and then I get to the better end of it.

Bridgette went on to discuss her progress and feelings about productive struggle later in the interview, noting the Stanford course laid the groundwork for her positive attitude. She said:

> So, I've never heard of productive struggle until after their growth mindset videos and talking about it in class, but I do feel like productive struggle is one of those things that's really, really important for everyone to know because everyone struggles and they're not sure how to take it because they feel like they're failing. But for me productive struggle is exciting because you know you're not the only one. You know that everybody struggles, and you know that you're not crazy for trying to push through your struggles. So, whenever you are productive and you're trying your best even though you're struggling you're really learning through all the mistakes that you're making throughout the way.

When asked about Pearson MyLab and Khan Academy as online tools for Praxis preparation, Bridgette said:

> So, I really, really enjoyed Khan Academy, but on the other hand Pearson was not my favorite because it had to be an exact answer or it would count it incorrect which for me just kept pushing me down. But Khan Academy really helped with the Praxis because it had exact questions just like what was on the actual test and I think I even had a few questions that were on my Praxis test. Khan Academy is also free which is nice, and it relieved my math anxiety by giving us like points for watching videos or getting answers correct and it would give really, really good explanations along with videos explaining why the answer was correct. I feel like that's super helpful when you're trying to study and take notes and actually try to pass a test that you would need to have.

Sara, another anxious achiever and one of Bridgette's most supportive allies throughout her journey, added:

> I just want to say that I can see the Khan Academy works. I've known Bridgette since we were very little, and she's never liked math. I have seen her struggle with math and then this Khan Academy course; I watched her gain so much confidence, like as a friend, that it just proved to me that this Khan Academy helps so much!

Sara was in her third year in college as a preservice secondary mathematics teacher. Her mindset score improved from 15 to 17 during this study, while her math anxiety score decreased from 2.24 to 1.72. This was the largest change of all participants and indicated a decrease in math anxiety from a level between "a little" and "a fair amount" to between "not at all" to "a little." As expected for someone who is majoring in mathematics and seeking a specialization in teaching

secondary mathematics, Sara had mostly positive past experiences in mathematics and enjoyed the subject. For her first journal entry, Sara noted different levels of support from her teachers in the past:

> Overall, I have had good experiences in my math classes. Math comes relatively easy to me, so I have been able to excel in most of my classes. One negative experience would be when the teacher is going very fast through a topic and gives a quiz/test no matter where the students are. A positive experience is any time a teacher spent time specifically with me when they could see I was struggling.

During our focus group interview, despite her previous successes, Sara did note some recent math anxiety:

> So, my math anxiety was more in college. I didn't really experience it much in high school. When I did start to experience it though, I had seen that graphic of the cycle of math anxiety, and I was able to kind of notice that I was and could tell myself, "Hey, you're getting anxious about it, don't let yourself, because you'll get in that cycle, so try and get out of it now before it's way worse than it is." So, I think "just no way math anxiety is affecting me, get help" because then you don't feel crazy about not wanting to do math because a lot of people feel that way.

Sara explained in our interview how she applied a growth mindset and engaging in productive struggle to her own teaching and tutoring of younger students:

> So what I wanted to add is I had never heard of the term productive struggle until college, but I definitely heard of like learning from your mistakes, and I like to say that whenever I'm talking to students in the classrooms I observe in because they can relate to that more because you know you learn from your mistakes when you're learning a sport when you're little or when you're just learning a new hobby when you're little. I feel like it makes it less, it's not as overwhelming whenever it's learning from your mistakes, because that's something you've been taught since you were little, so I like to connect those two terms.

Sara passed the mathematics portion of the Praxis Core Academic Skills for Educators Exam on her first attempt, then began to study for the mathematics content exam which is required before student teaching as part of the licensure process for future secondary mathematics teachers ("West Virginia Test Requirements," 2021). Rather than procrastinating or avoiding math, Sara was motivated to engage with the material and passed her second Praxis exam on her first attempt

approximately a year and a half before the deadline. In Sara's third journal entry, she noted a combination of traditional study skills along with using online resources helped her succeed. She outlined a successful blueprint which I have encouraged other preservice secondary teachers to follow:

> For my ACT I did minimal studying just to get a baseline score and I was able to get the score I needed on the first try. For my Praxis, I was definitely motivated to reach a certain score, and this was good motivation for studying. I spent about a month studying for my Praxis. I made a large binder of everything I needed to know with their corresponding notes, and I watched many Khan Academy videos.

In her seventh and eighth journal entries, Sara elaborated on her traditional and online methods for studying. The preparation of the binder of material that she needed to know for the math content exam, review material that I provided to support her using Pearson MyLab, and familiarity with the Khan Academy course provided her with flexibility while studying for the exam. Sara wrote:

> I used Pearson assignments and Khan Academy videos for various topics when studying for Praxis 5161 (5-Adult Math). It was nice to have another way to study besides using old class notes and my own research. It made a very large test seem manageable and gave me a place to start when I began studying.
>
> There is not a specific course for Praxis 5161, however I still used Khan Academy very often in my studying for that Praxis. They had videos on basically every topic I needed to study so it was a very convenient resource. The videos were helpful and easy to understand.

Margaret, the third friend in this supportive trio of anxious achievers, was a junior PSET who passed the mathematics portion of the Praxis Core Academic Skills for Educators exam on her first attempt. Like her friend Bridgette, Margaret also achieved a passing score on the mathematics subtest of the multi-subject exam for PSETs on her first attempt despite what she described as mostly negative experiences in the past. In her first journal entry, Margaret wrote simply, "I wasn't taught any math in the classes I had in high school." During our focus group interview, Margaret elaborated on this and how it made her feel:

> I feel like I relate to the cycle of math anxiety because of my previous math experience in a K-12 setting. I definitely have a lot of lack of confidence when it comes to math which then enhances my math anxiety. I definitely avoid math because I'm so anxious about it and then it just leads to this big cycle of poor results and more math anxiety.

Margaret's third journal entry revealed how these negative experiences led to a lack of motivation and preparation for high-stakes standardized tests in the past. Further, she noted a lack of support and encouragement from her teachers in high school. Although students of low socioeconomic status may receive a fee waiver for their first time taking the ACT or SAT (like I did), Margaret mentioned the added financial stress so many students from Appalachia face. Margaret shared the following:

> I studied for about an hour for the ACT and SAT immediately before taking the test. I was not motivated at all to achieve a high score because all of my teachers told me to just get a score that will get me into college and not worry about any higher because I will have to take the test multiple times to get a high score. I also didn't have the money to take the test multiple times.

Despite the financial hardships and lack of support in her educational experiences prior to college, I found Margaret to be a hard-working, high-achiever who was extremely capable of success in mathematics in her college courses at D&E. Surprisingly, her mindset score actually decreased by two points from the beginning to the end of this PDSA cycle. Still, Margaret demonstrated tremendous growth, confidence, and a positive attitude while engaging in productive struggle to prepare for Praxis exams using the online interventions of this study. Margaret's scores on the math anxiety scale placed her in the top three most anxious participants in this study. Analysis of her responses to individual scale items indicated she is most anxious when taking math assessments, whether they are pop quizzes, scheduled tests, or high-stakes exams. Margaret indicated she felt "very much" anxiety in those situations. However, during our focus group interview Margaret elaborated about how the online interventions focused on productive struggle eased those feelings. Margaret said:

> So, when I was working with the Khan Academy course and Pearson, especially when studying for my Praxis, I think it helped a lot and it really helped to reduce that math anxiety because it showed growth and it also helped with the productive struggle because even though I would get a question wrong it would tell me what I did wrong. So, then I could see that and fix my mistakes quickly. It also just showed you a path and like a plan towards the goal which was to pass the test. So, I really liked the Khan Academy course.

For Margaret and her close friends, Bridgette and Sara, developing a growth mindset and willingness to engage in productive struggle via the supportive online tools in this PDSA cycle enabled them to be more confident, to manage their math anxiety, and to experience the more positive cycle of math achievement. For the preservice teachers in the next group classification, confidence in problem-solving from an early age allowed them to be less anxious, to have better results, to enjoy math, and to become familiar with the cycle of math achievement prior to college.

5.1.1.3 Exempt Enjoyers: Positive Past Experiences

Brinley and Gayle, two sophomore preservice teachers who were both student-athletes from out-of-state, enjoyed much more supportive, positive experiences than many other students during their K-12 years. I have classified these two study participants who experienced success and the cycle of math achievement as "exempt enjoyers" based on the qualitative and quantitative data from this study. Both students reported in journal entries and survey responses that they enjoyed math. They also had the lowest levels of math anxiety based on their A-MARS scores during this PDSA cycle. Consequently, perhaps, they were both also exempt from taking the mathematics portion of the Praxis Core Academic Skills for Educators exam based on their scores on college entrance exams. Due to their positive past experiences with mathematics and lower levels of math anxiety, these exempt enjoyers did not experience the cycle of math anxiety. Rather than avoiding math, Gayle and Brinley were confident, enjoyed engaging in productive struggle, and thrived mathematically. Since my theory of improvement was aimed at preservice teachers

who experienced the cycle of math anxiety with poor results, low confidence, and math avoidance, these two exempt enjoyers benefited less from the interventions in this study.

Gayle, a secondary mathematics major, scored the maximum on Dweck's mindset scale, and rated the lowest of all study participants on the math anxiety scale. While the supportive instruction Gayle experienced in high school helped shape her confidence and ability, she noted some differences thus far in college. In her first journal entry, Gayle wrote:

> I have generally had good experiences. My favorites were all in high school, I had good teachers that were always willing to help. Most of my negative ones are in college with one professor. She was very hard and did not really know how to help.

In her second journal entry, Gayle identified with the cycle of math achievement. Again, she credited supportive instruction in high school and a teacher who stressed productive struggle as a key to success when facing challenging material in mathematics in her college courses.

> Being someone who has always been good at math I do not relate to the math anxiety cycle, but I do relate to the math achievement. I found that I learned to kind of relate to it more in my senior year of high school when my AP calc teacher taught us about productive struggle and would put us through a lot of productive struggle during our classes. I found this to really help me while in most of my college math courses as well.

Gayle's positive attitude and growth mindset continued to serve her well as she progressed through higher level math courses and prepared to teach high school herself. She planned to take the Praxis mathematics content exam for secondary teachers a year early. Based on the following from her fourth journal entry, I have no doubt that the growth mindset she noted will be passed on to her future students.

> Being someone who has suffered through a lot of mental health challenges, I have really dove into growth mindset before because I believe that it does not just apply to school but also applies to everyday life. I think that everyone has the ability to change their mindset and grow. I do use growth mindset in my education as I know that through education you learn and grow more, and that everyone has this ability. It may take more work for some but through asking for help and finding extra practice is a way that the mind can grow.

Brinley, a PSET whose low math anxiety scores were nearly identical to Gayle's, also related to the cycle of math achievement and credited supportive teachers for her past positive experiences. In her first two journal entries, Brinley stated:

> I have generally had a positive experience in mathematics courses. A positive experience I have had in a mathematics course is when my teacher gave many examples and thoroughly explained how to solve the problem.
>
> I relate to the cycle of math achievement. I have a positive attitude towards math. I like to have a productive struggle with challenging problems. I have always had success in my math courses.

Although Brinley's self-assessment on Dweck's quantitative mindset scale was not as high as might be expected (she scored 12 of a possible 18), she gave some of the most detailed qualitative responses in her fifth and sixth journal entries when prompted about productive struggle and growth mindset. Brinley wrote:

> No, productive struggle is not new to me. It means that you have struggled through a math problem or concept, but you have learned from the difficulties and struggles. I have engaged in productive struggle in past mathematics classes when I have taken advanced placement statistics as it was a more challenging course. More challenging problems or multiple step problems are examples where productive struggle might be applied.
>
> I have not really experienced math anxiety in the past. Although, a growth mindset helps to solve problems in this class. It is important when problems are more challenging to have a positive and growth mindset. This betters not only the learning but also the understanding of the concept. It is okay to make mistakes and employing a growth mindset will allow growth and improvement.

I have noted Brinley's ability, hard work, and positive attitude many times in class and have encouraged her to pursue a math specialization. She spoke with her advisor about this and chose to focus on elementary education for now with an eye toward further study in graduate school. Like Gayle, Brinley will certainly pass her confidence, self-belief, and willingness to engage in productive struggle on to her future students. However, the preservice teachers in the next group classification were less confident and continued to avoid mathematics by being less

willing to engage in productive struggle via the online tools in this PDSA cycle. They were more fixed in their attitudes, beliefs, and mindsets, and in danger of passing these negative characteristics on to their future students.

5.1.1.4 Frustrated Resisters

According to my teacher journal, although several students had success on the math portion of the Praxis Core exam during this PDSA cycle, I was still trying to find the keys to help two other participants during the last month of the semester. Borrowing another label from Bennett et al. (2006), I categorized the two male study participants in this PDSA cycle as "frustrated resisters." Both of these preservice teachers lacked confidence in their mathematical abilities but did not relate as well as others to my theory of improvement regarding moving students from a cycle of math anxiety to one of math achievement. They were both frustrated by the online delivery of our course content during the pandemic. These frustrated resisters exhibited more fixed mindsets than other participants, were more reluctant to engage in productive struggle, and seemed to be resistant to the online interventions aimed at improving their attitudes and beliefs about mathematics as well as those aimed at helping them to achieve passing scores on high-stakes Praxis exams.

Nico, a senior physical education major who was unsuccessful on his first attempt at passing the mathematics portion of the Praxis Core Academic Skills for Educators exam early in the semester, had difficulty scheduling time with a tutor in D&E's learning center. The online delivery of our course had a detrimental impact on my ability to connect with Nico and to provide the resources he needed for success. We connected in conversations about sports, and he was from a rural county where my dad lived when I was younger, but I was unable to help him one-on-one in my office. When asked about online learning during the pandemic in journal ten, Nico wrote, "I

feel like I was maybe less motivated to get my schoolwork done and learn. I would have much rather been in person, just my personal preference!" I think Nico's emphasis here showed some of his frustration with the online nature of the 100-level course. Nico expressed his need for more in-person instruction in his eighth journal entry when asked about the Khan Academy course. Nico wrote, "In all of the Khan Academy courses I've taken, I feel they haven't really helped me because I need more help actually working out the problem."

Nico scored 13 of 18 on Dweck's growth mindset scale before the interventions of this PDSA cycle. This score indicated that he believed intelligence is malleable. However, he did not complete the post-assessments. He was rated in the lower half of participants on the math anxiety scale at the beginning of the semester. Despite his fairly low self-assessment of math anxiety, Nico's responses to some of the individual questions were revealing about his attitude toward mathematics. Nico's responses included evidence that he is most anxious regarding final exams and final grades in math courses. The math portion of the Praxis Core Academic Skills for Educators exam could be viewed as a similar type of comprehensive exam or summative assessment comparable to a cumulative final exam or overall course grade. Perhaps some of Nico's frustration with the interventions in this PDSA cycle stemmed from not relating to the math anxiety portion of my theory of improvement. In his second journal entry, Nico stated, "I'm not really sure if I have math anxiety, I just know I'm not good at it." Nico's lack of confidence and somewhat fixed mindset (despite his score on Dweck's scale) could be heard in his brief statement, and his next journal entry echoed a resignation to his fate on past standardized tests. In his third journal entry, Nico wrote, "I didn't really prepare much for the ACT, just with the class I was having at that time. I wasn't really motivated to get a certain score, I was okay with what I was going to get."

Since this was the first course Nico took from me, I struggled to help him overcome his lack of confidence and poor results from the past in a few short months. Students who were successful on Praxis often benefited from several years of supportive instruction that encouraged a growth mindset in high school and college. When asked about the Stanford course and productive struggle in journals four and five, Nico wrote:

> If I were to use any of the ideas it would be the encouragement of the students even if the answer is wrong.
>
> I feel like this is what I have done with most of my math experience. Most problems I have faced in the past, I didn't really know how to solve them but that has helped me to keep trying and go with the process.

Although Nico found the Khan Academy course to be less helpful, he was familiar with Pearson MyLab from courses with other professors and felt the online tools provided there helped him make progress. When asked about the relationship between math anxiety and learning via Pearson MyLab in his seventh and ninth journal entries, Nico preferred to use different terminology. Again, Nico showed he did not relate to the cycle of math anxiety, but had made some progress when he wrote:

> I would call it more math stress because a lot of times I'm not exactly sure how to work it out, but the help tab comes in very handy on Pearson.
>
> I feel like I am better off now than I was before coming into the semester, especially with probability.

Unfortunately, I lost contact with Nico. I tried to reach out to him several times on email but did not receive a response. I heard from the chair of the education department that Nico was no longer seeking licensure, and I felt partly responsible for his decision. Nico's parents were educators, and in our previous conversations he seemed intent on becoming a physical education teacher. His choice to abandon this path seemed to be due to the Praxis exams.

Similarly, the other frustrated resister in this study also exhibited his lack of confidence toward the Praxis Core throughout our semester together. Mike, a junior PSET with a specialization in middle school mathematics, was the only other student who I had trouble helping during this PDSA cycle. He was the only participant who did not even attempt to take the Praxis Core Academic Skills for Educators exam. Mike's self-assessment on the math anxiety scale placed him at a level nearly identical to Nico's and his average responses before and after this study's interventions classified him as having only "a little" math anxiety. Remarkably, although the results were not a statistical outlier, Mike's scores on Dweck's mindset scale stood out among all study participants. Mike scored seven of a possible eighteen before the interventions and six after the interventions. These self-assessment scores placed him solidly on the fixed mindset end of the spectrum with a belief that intelligence is not malleable.

Another commonality between Mike and Nico as frustrated resisters was that their journal responses were generally briefer than those of other participants. When asked about math anxiety versus math achievement in the second journal entry, Mike wrote, "I do because if a student believes they will fail then they will fail." While his statement was a bit unclear, he seemed to refer to the cycle of math anxiety and a lack of confidence, although, like Nico, he did not say that he had experienced the feelings himself. In his third journal entry, Mike indicated motivation played a role when he prepared for college entrance exams. Mike stated, "I did, and I was motivated because I wanted to work hard to get into college."

In a conversation with Mike, I learned he did not have the confidence to manage his own classroom and would like to be an aide first to gain some more experience. I wondered if this lack of confidence affected his motivation to prepare for Praxis exams. Further, despite the fact that he took a practice exam on Khan Academy and achieved a passing score, I learned Mike planned to

take the ACT exam again in an effort to achieve a score on the mathematics portion which would make him exempt rather than taking Praxis. I discussed this with Mike's advisor in the learning center and with the chair of the education department. In my opinion, Mike should have taken the Praxis exam for several reasons. The ACT is still a high-stakes standardized test. The Khan Academy course prepared many other students for Praxis, and to obtain licensure Mike must succeed on other Praxis exams. He should become accustomed to the format of these tests. Finally, I encouraged his advisor to continue to try to foster a growth mindset in Mike and to instill a willingness to engage in productive struggle. While Mike did not relate to the cycle of math anxiety, there still seemed to be some math avoidance in play. Like my feelings regarding Nico, I regretted that I was unable to reach this student during the PDSA cycle.

Again, similar to Nico, Mike indicated in his final journal entry that the online nature of my courses and interventions during this PDSA cycle were a detrimental factor for him. When asked about online learning during the pandemic, Mike wrote, "It was a bit difficult to have a handle on at first but then it got easier to get used to. The hardest thing is the human interaction with people not being in person." I knew Mike received one-on-one attention in the learning center, but I believed he also needed in-person support from me and I was unable to provide it during the COVID-19 pandemic. Mike was from out-of-state and expressed that he missed the support of his family. As I report below, this feeling was common for many students during our semester together, but these concerns may have been different for students living on campus as compared to those who were commuting locally.

5.1.1.5 Commuter Student Persevered Through the Pandemic

As the fall semester progressed through October, the pandemic began to worsen locally. By the middle of the month, four students on campus tested positive for the coronavirus, and

approximately 15% of our residential students were in quarantine due to possible exposure. At least two study participants from outside West Virginia went home to quarantine at this time when their athletic teammates tested positive. In the 300-level course, the students took a day to just vent while I listened to their concerns. During one of our video calls, the students verified that I accurately noted their feelings in the following entry from my teacher journal:

> Students are really concerned about rising numbers. They are tired, angry, frustrated, scared, lonely, and anxious. They are afraid that they aren't being told the truth, are just on campus for their room and board fees, and may have to go fully online for all courses again.

Students who were not able to go home said they missed their family, while other local students were concerned about family members with compromised immune systems, asthma, and other lung problems. While most of the participants in this PDSA cycle lived on campus in residence halls, I found the experience of living and working as a commuter student during the COVID-19 pandemic was different for at least one preservice teacher in this study when compared to the other preservice teachers. Commuter students often face challenges balancing work, home, and school responsibilities while also not having a peer group for studying. One commuter student in this study did not quite fit in any other group classification, but still persevered to achieve success mathematically despite her unique issues during the pandemic.

Tylr, a junior PSET and local commuter student who lived at home with her family, worked at a local bar which was forced to close due to positive COVID tests from the owner, his friends and family, and at least one other employee. The bar continued not to follow health department guidelines and re-opened in less than ten days. While they were closed, Tylr persevered in her Praxis preparation. She was actually scheduled to take the Praxis Core exam when the pandemic began during the semester before this PDSA cycle, but her parents advised her not to travel to the testing site as schools across the country had just closed due to COVID-19. She struggled to

communicate with representatives from ETS for more than six months as she tried to be reimbursed for the exam for which she had already paid. After rescheduling the exam several times and finally using ETS's at home option to take the test, Tylr passed on her first attempt before the end of October.

Tylr's journal entries reveal both positive and negative experiences with mathematics in the past, but a good attitude and open mind toward the subject. In her first journal, Tylr wrote:

> I remember my 5th grade teacher who taught us memorable things about math and that's when my math career took off and I really enjoyed it. In middle school, I think seventh grade, the teacher did not teach us at all, we learned from an Odyssey Software.

Tylr's score on the growth mindset scale improved by three points from the beginning of the PDSA cycle to the end. This was the largest increase among all study participants. Remarkably, her math anxiety score also increased and was the largest change among the participants as well. When asked about math anxiety and growth mindset for her sixth journal entry, Tylr stated:

> The only math course I can remember having a harder time in, was statistics in high school. The teacher was great, he liked to explain everything to us and help us out, but my brain just couldn't process stats, so it was a harder time for me. Thinking about growth mindset, I feel that I have improved from that level.

Tylr also had prior experience with productive struggle when preparing for a high-stakes, standardized test. Like other participants in this study, Tylr was motivated to achieve higher scores for financial reasons. The College Foundation of West Virginia offers PROMISE scholarships of nearly $20,000 for students from West Virginia who meet GPA, ACT or SAT score, and high school course requirements as long as they also maintain good grades and make adequate academic progress in college ("Promise Scholarship," 2021). Tylr recalled the ACT prep course she took from another D&E professor who helps high school students prepare for the ACT during extra class sessions on weekends.

> Yes, I studied with Professor Moudry for the Math and it really helped me higher my score for the ACT. I mean, I wasn't really wanting to take the ACT but in order to strive for PROMISE I needed to study and work hard for that composite score.

Tylr's journal also contained entries where she succinctly summed up her approach and beliefs about mathematics. I believe her previous success in mathematics, growth mindset, and willingness to engage in productive struggle continued to serve her well as she pursued teacher certification. In her second journal, Tylr wrote:

> I relate to the cycle of math achievement. If you're positive and don't let your mindset become negative for the subject, you will have better outcomes than when you're negative about the subject.

Tylr's eighth journal entry could serve as a simple testimonial on Khan Academy's website. She stated, "Khan Academy prepared me for the praxis core and the format was similar; it was a very useful tool when studying." Again, I hope Tylr and others will speak to future cohorts, especially local students from Appalachia, and we can enable more students to persevere and experience the cycle of math achievement.

5.1.2 How does the Stanford online course increase growth mindset in preservice teachers?

As Table 6 below shows, only small changes occurred in the quantitative measure of participants' mindsets across all group classifications of students during this PDSA cycle. Note that higher scores indicate more of a growth mindset while lower scores indicate more of a fixed mindset, and that the response rate on the post-assessment was 80%. Still, nearly all participants possessed a growth mindset both before and after the interventions according to this scale. Coding of student journal entries revealed more details regarding mindsets. As shown in Table 7, eight of ten students reported in their fourth journal entry that they were already familiar with the concept of a growth mindset prior to this PDSA cycle. Of those eight participants, two stated they were

encouraged to develop a growth mindset in high school. Six of these participants responded they learned about growth mindset in previous mathematics or education courses in college. All eight of these students either passed the mathematics portion of the Praxis Core Academic Skills for Educators exam or were exempt from taking the test based on their college entrance exam scores.

Table 6 Results from Dweck's Growth Mindset Scale

Participants	Pre-assessment		Post-assessment	
	Total	Mean	Total	Mean
Persevering Student-Athletes				
Charley	14	4.7		
Mia	15	5	15	5
Anxious Achievers				
Bridgette	18	6	18	6
Margaret	16	5.3	14	4.7
Sara	15	5	17	5.7
Exempt Enjoyers				
Gayle	18	6	18	6
Brinley	12	4	12	4
Frustrated Resisters				
Mike	7	2.3	6	2
Nico	13	4.3		
Persevering Commuter				
Tylr	12	4	15	5

Note. Total scores range from 3 to 18 (mean 1 to 6) with higher scores indicating more of a growth mindset.

Table 7 Responses from Journal Four on Growth Mindset

Responses	Number of Participants
Familiar with Growth Mindset Prior to PDSA Cycle	8
Learned of Growth Mindset in High School	2
Learned of Growth Mindset in College	6

Surveys administered at the end of the semester indicated that the online course from Stanford University, *How to Learn Math: For Students*, helped most students gain confidence in their mathematical abilities and helped them to develop a willingness to engage in productive struggle. Results from the first three survey items (see Table 8) showed evidence that the study participants felt the Stanford course contributed to their belief that they can learn from their mistakes and can change their ability and intelligence through effort. Seven of eight respondents strongly agreed "The Stanford Growth Mindset Course helped me to believe in my ability to solve math problems." Further, zero participants disagreed with the statements regarding the helpfulness of the Stanford Growth Mindset Course. These results strongly indicated that study participants found this intervention helpful.

Table 8 End of Semester Survey Responses

	Number of Responses (Value)						
Survey Item Number	Strongly Agree (1)	Agree (2)	Mostly Agree (3)	Mostly Disagree (4)	Disagree (5)	Strongly Disagree (6)	Average Response
1	5	2	1	0	0	0	1.5
2	5	3	0	0	0	0	1.375
3	7	1	0	0	0	0	1.125
4	5	2	1	0	0	0	1.5
5	5	3	0	0	0	0	1.375
6	6	2	0	0	0	0	1.25
7	7	1	0	0	0	0	1.125
8	6	1	1	0	0	0	1.375
9	5	3	0	0	0	0	1.375
10	3	1	4	0	0	0	2.125
11	4	2	2	0	0	0	1.75
12	5	1	2	0	0	0	1.625

Note. Response rate was 80%.

5.1.2.1 Stanford Course Especially Helpful for Anxious Achievers

Student responses to journal prompts included several powerful testimonials about the importance of growth mindset for preservice teachers. The anxious achievers especially noted the helpfulness of the online modules on growth mindset. For Margaret, an anxious achiever who was not well-supported in her K-12 education prior to college, the concept of growth mindset was new, but after she completed the free Stanford course, Margaret's growth mindset helped her both inside and outside the classroom. Margaret wrote the following in her fourth journal entry:

> The growth mindset was new to me freshman year in the first class I had that you taught. Having a growth mindset is the only way I have gotten through the difficult trials of college, classes, and testing so far.

Sara, another anxious achiever and one of Margaret's supportive friends, connected confidence to growth mindset and benefited from naming the growth mindset concept. She applied

the methods from the Stanford course to overcome difficulties when she faced more challenging mathematics in her preparation as a preservice secondary math teacher. In her fourth journal entry, Sara stated:

> The concept of growth mindset was not new to me however I did not know it had a name. It was able to teach me more about why a growth mindset is important. I knew confidence was important, but it helped me understand that confidence can break down anxiety. The Stanford course made me more aware of my negative thoughts when doing math and how to not let negative and anxious thoughts take over.

As noted above, other than the frustrated resisters, most other participants also benefited from the free course on growth mindset. For Gayle, an exempt enjoyer whose scores on the mindset scale placed her at the top end of the growth mindset spectrum, the free Stanford course was still helpful. Since Gayle was already familiar with growth mindset from high school and had experienced the benefits firsthand, she continued to learn and apply her growth mindset in a productive cycle. For her sixth journal entry, Gayle wrote:

> I think that the course did help with adding new information to my bank of knowledge on growth mindset. I was not only able to use it in this course, but I will be able to use it in other courses.

5.1.3 How does developing a growth mindset influence PSETs' attitudes about math and willingness to engage in productive struggle?

Table 8 above (survey items 1 and 2) shows five of eight respondents strongly agreed the Stanford course on growth mindset "helped me to gain confidence doing mathematics" and "helped me to develop a willingness to engage in productive struggle in mathematics." All respondents across all group classifications at least mostly agreed with these statements. Gaining confidence and developing a willingness to engage in productive struggle were both keys to my theory of improvement aimed at moving students from a cycle of math anxiety to a cycle of math

achievement. Although there was not a significant increase in growth mindset as measured by Dweck's (1999, 2006) scale (see Appendix D), the quantitative results from the end of semester surveys indicated the free Stanford course and developing a growth mindset played notable roles as successful change concepts in addressing drivers of my problem of practice and my aim to improve students' mindsets and attitudes toward mathematics in order to support their confidence in their mathematical abilities.

Like the idea of growth mindset, the concept of productive struggle was not new to most of the participants in this PDSA cycle. Analysis of participant responses to the fifth journal question revealed seven of nine respondents across all group classifications said they had engaged in productive struggle in previous math classes, although three of the seven indicated while they realized they had experienced productive struggle, the terminology was new. For example, in her fifth journal response, Charley, a persevering student-athlete, wrote:

> Productive struggle has always been something I have worked on, but I never knew the actual word. There are some subjects that I need to do in my own way in order to understand a concept. Using it in mathematics has helped because there are so many things you can do for each standard. I will continue to use this in my future.

For Margaret, one of the anxious achievers, a stark contrast existed between her experiences with mathematics in high school versus college. Margaret reported the idea of productive struggle was new to her, but she defined it well and was motivated to continue to apply what she had learned. Margaret wrote:

> Yes, to me it means working through the struggles and learning from my mistakes. It means not giving up when I don't get a subject correct the first time. I feel like before college, I never engaged in productive struggle because I wasn't forced to have to learn the math skill. However, in college I have in math because I have to keep working at a skill to learn it and be able to continue in my education.

Sara, another anxious achiever, also found that while the terminology for productive struggle was new for her, she had indeed engaged in this practice before. In her fifth journal entry, Sara wrote:

> Productive struggle is something I had done in my math career without realizing I was doing it. My definition of productive struggle relates to determination and that when you work on a problem you may get it wrong, but you can learn from that mistake. Productive struggle is continuing to work on something that is hard because you know you can figure it out. Productive struggle can also be challenging yourself to do a math problem you may think you can't do only to find you can with the right tools and focus.

Bridgette, the third member of the supportive trio of anxious achievers, summarized her learning and application of growth mindset and productive struggle along with her improved attitude toward mathematics in her fourth journal entry:

> I have learned that mistakes are the most helpful. Learning from your mistakes will help you achieve more as a person and grow to love the subject you struggle with. I have now let my mistakes help me rather than tear me down.

Based on the results presented above, developing a growth mindset seemed to be most beneficial for the students characterized as persevering student-athletes and anxious achievers. For these two groups who were motivated to achieve their goals with better attitudes and boosted confidence, the improved mindsets and associated positive attitudes toward mathematics were indications of a more productive cycle of math achievement which involved engaging in productive struggle to experience success on the high-stakes exams. The anxious achievers and persevering student-athletes were genuinely excited to apply the concepts from the free Stanford course to their studies. These preservice teachers realized greater results as they persevered through challenging material.

The pair of exempt enjoyers needed less support than the anxious achievers and persevering student-athletes since they were already more successful mathematically and familiar with employing a growth mindset and engaging in productive struggle. On the other hand, the frustrated

resisters needed more support, but were reluctant to commit to the change concepts and theory of improvement. For the frustrated resisters who remained fixed in their mindsets, their attitudes toward mathematics did not change, they remained less confident, were not as willing to engage in productive struggle, and did not experience success on the Praxis exam during this PDSA cycle.

5.1.4 How does engaging in productive struggle reduce math anxiety?

This was a complicated question which appeared to be intertwined with mindsets, attitudes, beliefs, confidence, and motivation. In terms of quantitative data, Table 9 below shows the results from administration of the Abbreviated Math Anxiety Rating Scale (A-MARS, see Appendix E). Overall, numerical scores did not decrease during this PDSA cycle. The lack of a pattern of reduced math anxiety scores may be attributed to the relatively short time period for this PDSA cycle, the nature of the self-assessment questions on this chosen instrument, or perhaps the interventions truly did not change levels of math anxiety for these participants.

Table 9 Results from Math Anxiety Scale

Participants	Pre-assessment	Post-assessment
Persevering Student-Athletes		
Charley	2.64	
Mia	3.16	3.12
Anxious Achievers		
Bridgette	3.08	3.48
Margaret	2.72	2.64
Sara	2.24	1.72
Exempt Enjoyers		
Brinley	1.52	1.40
Gayle	1.44	1.36
Frustrated Resisters		
Mike	1.92	1.88
Nico	1.88	
Persevering Commuter		
Tylr	1.96	3.20

Note. Response rate on the post-assessment was 80%.

5.1.4.1 More Benefits for Anxious Achievers and Persevering Student-Athletes

A wealth of qualitative data from student journal entries indicated students with or without math anxiety experienced success via productive struggle. Supportive learning environments that increased confidence by improving mindsets and attitudes contributed to students' success. Participants also found resources such as the free Stanford course, Pearson MyLab exercises, and the Khan Academy Praxis preparation course to be helpful. Again, this was especially true for the students classified as persevering student-athletes, perhaps due to the organized structure of these activities which are akin to the practice and preparation that student-athletes are accustomed to experiencing with their teammates and coaches in their respective sports. When asked whether the

Stanford course and employing a growth mindset helped to reduce her feelings of math anxiety, Charley, one of the student-athletes who persevered in her journey to achieve success on Praxis Core, offered the following in her sixth journal entry:

> This course has helped me ease my math anxiety and it has given me more confidence even when I don't feel that confident. This course has made me realize that I can't learn everything in a day and be confident which is okay and it's normal.

Mia, the other persevering student-athlete who was determined to succeed, engaged in productive struggle after feeling math anxiety. Mia touched on her changes in approach to her education after developing a growth mindset in her sixth journal entry. Mia offered:

> I have experienced math anxiety in the past. I feel like growth mindset has definitely helped reduce those feelings. Changing my mindset has pushed me to being a better student and changing the way I do things like studying more and just applying myself more.

Unlike Charley and Mia, Sara did not face math anxiety in her past. As an anxious achiever in college, she was a hard-working future secondary math teacher with a growth mindset who engaged in productive struggle in order to earn her undergraduate degree in mathematics. Again, Sara's example served as a roadmap for others to follow in her footsteps. Sara offered the following reflection in her sixth journal entry:

> I watched the Stanford course pretty early in my college career when I had yet to experience much math anxiety. As my college courses got harder I was more aware of when I was falling into the loop of math anxiety and failure. This course also helped me know what steps to take when I started feeling math anxiety to overcome it.

Regarding the productive struggle that students engaged in via Khan Academy, not only were most of them able to gain confidence solving challenging math problems like those that would appear on the Praxis Core exam, but the process also helped them feel less anxious. In their reflective journals, five of eight respondents reported they found Khan Academy helpful in reducing those feelings. In her seventh journal entry, Margaret, another anxious achiever, wrote, "Yes, Khan Academy has helped a great deal with the Praxis tests. I feel more comfortable taking

math tests and feel more prepared from the course." Charley, a persevering student-athlete, agreed, "Khan Academy helped me with a lot of my math anxiety especially when preparing for the Praxis math test."

Study participants found Pearson MyLab to be a somewhat less beneficial intervention during this PDSA cycle. Average responses to the questions about Pearson MyLab on the surveys at the end of the semester (see Table 8) were higher than the averages on all other questions. On these survey items, lower averages indicated students found the interventions more helpful. Three of eight participants strongly agreed with the statement "Pearson MyLab assignments helped me to learn new mathematical content." Four of eight respondents strongly agreed "Pearson MyLab assignments helped me to use a variety of problem-solving techniques." Five of eight students strongly agreed "Pearson MyLab assignments helped me to engage in productive struggle in mathematics." Again, while none of the participants disagreed with any of these statements, the average responses indicated students found this intervention less helpful than the other interventions.

5.1.5 How do students feel the Khan Academy course influenced their understanding of material on the Praxis exam?

I wrote three questions on the end of semester survey (see Table 8 and Appendix B) to gather quantitative data to attempt to answer this inquiry question regarding Khan Academy's free online *Praxis Core Math* course. Participants across all group classifications overwhelmingly agreed the Khan Academy course was helpful in their preparation for Praxis exams. Seven of eight respondents strongly agreed with the statement that the course "helped me to learn new mathematical content." Six of eight respondents strongly agreed the course "helped me to use a

variety of problem-solving techniques." All eight respondents either agreed or strongly agreed the course "helped me to engage in productive struggle in mathematics." None of the respondents disagreed with any of these statements.

Entries in the students' journals explained more details about the mathematical content, problem-solving strategies, and productive struggle they engaged in by working through the Khan Academy course. Eight of ten participants responded positively about the Khan Academy course when asked about it specifically for their eighth journal prompt. Again, the anxious achievers and persevering student-athletes reported benefiting the most from the Khan Academy course. Bridgette, an anxious achiever, found the sequencing of the material particularly helpful while she also noted the course taught her one of the most important mathematical connections that I tried to stress to PSETs:

> Khan Academy breaks all math down, it teaches you that one skill must be mastered before mastering another. I never noticed how percentages, fractions and decimals were all so alike until Khan Academy.

As advertised, the partnership between Khan Academy and ETS built the skills students needed to succeed on the mathematics portion of the Praxis Core Academic Skills for Educators exam. Margaret, another anxious achiever, found the individualized study plan most beneficial. In her eighth journal entry, Margaret wrote:

> I loved the step by step plan Khan Academy gives to studying for the Praxis. I learned how to best find the answer even if I am unfamiliar with the content. Khan academy helped extremely with math Praxis.

Even though Brinley always enjoyed math and was exempt from the Praxis Core exam, she still found the course useful. Brinley learned new problem-solving techniques to help her with challenging mathematical content. As she looked ahead to other Praxis exams, Brinley wrote the following in her eighth journal entry:

> I liked that the Khan Academy course will help me to better be prepared for the math portion of my praxis. A lot of it was a review for me. Although, I had learned different problem-solving strategies that were easier than I had previously learned such as for probability. It is easiest to use multiplication and multiply fractions.

Khan Academy's website stressed that they offered "authentic practice questions" and "timed practice tests" ("Praxis Core Math," 2019). These were the final pieces of the puzzle for students of various mathematical abilities and backgrounds to succeed. Mia, a persevering student-athlete, who passed the mathematics portion of the Praxis Core Academic Skills for Educators exam on her second attempt, wrote in her seventh journal entry:

> Khan Academy was super helpful in preparing me for my PRAXIS. After taking it the first time and continuing with the practice problems on Khan academy that was super helpful to me. I also was a big fan of the practice test and getting that feel of taking the PRAXIS.

Along with building skills, Khan Academy claimed their course instilled "confidence to succeed on test day and beyond" ("Praxis Core Math," 2019). A lack of confidence was a key component in the cycle of math anxiety. Charley's eighth journal entry summed up her feelings succinctly and was representative of the experiences for most participants in this study. Charley, another persevering student-athlete, wrote, "I don't think I disliked anything about the Khan Academy course. I really liked how confident I felt when I did the course."

5.2 Additional Results Beyond Inquiry Questions

While the following observations were not intended to be part of this study, and were not asked in the inquiry questions, several themes which I note below emerged and are worthy of discussion. First, I present results about motivation, which was a contributing factor to student success according to the literature review and surfaced many times in the qualitative data. Then, I

note findings regarding metacognition from the end of semester survey prompts about the helpfulness of the reflective journals that students kept throughout this PDSA cycle. Next, I report important results pertaining to supportive relationships and learning during the pandemic. Finally, in preparation for the mathematics portion of the Praxis Core Academic Skills for Educators exam, participants engaged in productive struggle via two online resources – Pearson MyLab and Khan Academy. These are two of the most popular online resources for students and educators. I compare the usefulness of these online tools below.

5.2.1 Motivation

Coding of the qualitative data revealed motivation (or lack thereof in the cycle of math anxiety) was a missing component in my theory of improvement, especially in the cycle of math achievement. Financial concerns in our capitalist society motivated several participants to prepare for standardized tests in the past. Sara and Tylr, local students from West Virginia, were motivated to receive the PROMISE scholarship, while Margaret, an anxious achiever, lamented that she did not have the money to take the ACT or SAT multiple times and only received a waiver for one attempt for each test. Brinley and Gayle, the exempt enjoyers who were student-athletes from out-of-state, both noted striving to earn academic scholarships motivated them to study harder for their college entrance exams.

During our focus group interview, Margaret said:

> I think money is a big issue because I pay for my college. I pay for all of my practice tests and everything myself, so I'm investing all of this money into my education. I only want to take it once because they're very expensive.

One journal response from another anxious achiever which directly mentioned motivation was Bridgette's third journal entry. When asked about her past preparation for standardized tests, Bridgette wrote:

> For the ACT I got the ACT workbook, which wasn't very motivating. For the PRAXIS on the other hand, I worked with Khan Academy and scored beyond my goal score. Khan Academy was engaging and helped a ton with staying engaged.

When I asked Bridgette about this during our focus group interview, she connected her motivation to the more engaging, interactive, personalized, online resources which Khan Academy provided for studying as compared to the more traditional paper study materials for the ACT. This led us to discuss where motivation might fall in the cycle of math achievement. Bridgette said:

> So, I believe motivation is one of those things that you find when you're trying to do something that you know you're going to struggle with but you're also going to push yourself to succeed. I feel like motivation would fit in the cycle between growth mindset and productive struggling because to have growth mindset you're telling yourself that even though it's going to be difficult you're going to get through it and that's going to be your motivation to be productive during your struggles and during your mistakes. I feel like that's super important because if you would have it after the productive struggle it could still be there, but I feel like it's more defined before the productive struggle.

Bridgette's profile as a motivated anxious achiever was evident when she added the following during our focus group interview:

> So I think that the extrinsic motivation for most people is the peers or the friends that they have around them, because for me I have a math major friend so I know that if I'm struggling she's going to be able to sit down and actually go step by step through it with me, which is really important because if I can see it on a piece of paper or on a whiteboard, and have someone explain it to me, then I can do better whenever I'm on my own. I also think the extrinsic is the grade that you're going to get. I feel like that is huge motivation for some of us because we're perfectionists. We want that 4.0. We want to see our names on the president's list. So, to know that if I can get through this, then I'm going to get a 4.0 is a lot of motivation for some, and also it's a lot of stress on one person.

Bridgette's reflective quote above contained a wealth of interesting data from the end of this PDSA cycle. She demonstrated incredible growth and maturity during her time at D&E. Despite her success learning online, Bridgette showed her flexibility in mentioning the value of

more traditional instruction from her supportive peer. She then spoke of the productive struggle she engaged in on her own and discussed the pressure that she put on herself to succeed as an anxious achiever. Finally, she noted the need for support from faculty members. Bridgette's reflection further demonstrated the importance of the next theme, metacognition, in her learning.

5.2.2 Metacognition

According to the quantitative data gathered from the end of semester surveys, students found the metacognitive exercise of reflective journaling to be a helpful intervention. As students became more aware of themselves and reflected on their own learning and understanding, five of eight respondents strongly agreed with the statements that their reflective journal entries "helped me to gain confidence doing mathematics" and "helped me to develop a willingness to engage in productive struggle in mathematics." Six of eight respondents strongly agreed "My reflective journal entries helped me to believe in my ability to solve math problems." None of the respondents across all group classifications disagreed with any of the statements regarding the helpfulness of reflective journals.

5.2.3 Supportive Relationships During the Pandemic

Supportive relationships were another theme which emerged during this PDSA cycle. Mathematical success during the COVID-19 pandemic depended not only on supportive instruction from me, but also support from other professors, peers, family, friends, and significant others. For Mike and Nico, the two frustrated resisters who did not achieve passing scores on the mathematics portion of the Praxis Core Academic Skills for Educators exam during this PDSA

cycle, online support was not enough, and they sought in-person connections as they persevered through the semester. Mike utilized his learning support specialist on campus, and Nico was hopeful when his girlfriend was working on math problems with him after we failed to connect him with a tutor. While I was somewhat hesitant to say these frustrated students actively "resisted" (Bennett et. al, 2006) the interventions which helped others succeed on their Praxis exams, there did seem to be less buy-in from Mike and Nico.

As noted earlier, Bridgette and Sara have been friends for many years, and they are fortunate to have formed such close bonds in their supportive group of anxious achievers with Margaret. During our focus group interview, I asked these women to elaborate on how their learning and support changed during the pandemic. Margaret and Bridgette shared amazing details about how these anxious achievers helped each other persevere. Margaret began:

> Online learning and learning during the pandemic is extremely hard and was extremely difficult for me because not only did the pandemic just switch us to online classes but it also hurt a lot of people in other ways, just not in education. It was extremely, extremely difficult to balance normal and just outside of school life with my education as well. It was very difficult with internet and just technology in general is not perfect, so that really was difficult, and then trying to balance everything.

Bridgette continued:

> For me the pandemic is something that I would have never imagined us dealing with in life let alone be in college while it's happening, but I found myself struggling because I'm used to being in class, having my professor and my peers face-to-face, working together as a group in-person, and the pandemic completely changed it. We had to work through Zoom calls and Teams, and for me, I'm more of a hands-on learner. I like to write my notes down and ask questions after class and ask questions during class. Along with that, life outside of school was completely different. I went from working part-time to working full-time in just a matter of a week. Of course, that helped financially, but mentally it was a struggle all the time because I had to be somewhere all the time.

Margaret added:

> I think something that was really difficult switching from in-person to online learning was the fact that we weren't able to meet one-on-one or in-person in office hours. They kind of weren't a thing, which made it extremely difficult because I'm the type of person to always

> be in my professors' office hours to get one-on-one attention and to just be able to study more and get more help.

I asked Margaret how her friends helped her through those times when everything changed and her professors were less available in person. Margaret responded:

> So, with the pandemic I really had to rely on my friends and my peers to get more support and to work together. I did that by spending hours and hours a day at Bridgette's house working together. Just having a support group made it very easy to finish our work and to also just get things done and to hold each other accountable which really helps. I couldn't get through this semester without Bridgette.

Bridgette added:

> If we go back to last semester, our support group consisted of close friends, supportive professors, and even people that we've never met before. This semester completely changed, and we mainly had our friends and a professor when we were in class, but having that outside help wasn't really available for us. I think that's where we had a difficult time because we're used to asking questions on the fly, running up to a professor's office real quick to ask a question, whether it was about that class, life, or another class, and we didn't have that opportunity, so we had to find support within each other more than ever.

The stress, isolation, loneliness, and disorienting chaos of the pandemic became too much for many students shortly after mid-term. Since I was working from home due to being high risk for COVID-19, I was not allowed on campus, but I had another idea to connect with students, so I invited all of my classes to an extracurricular activity. On a beautiful sunny day, seven students met me at the local driving range to relieve some stress by hitting golf balls. Notes in my teacher journal indicated Bridgette, Margaret, and Sara from the supportive trio were there, along with four men who have had other classes with me, but who were not participants in this study. Everyone who came possessed a growth mindset and a good work ethic. Many had never swung a golf club in their lives but were excited to try something new. Some students wore masks, and everyone at least had a mask. We were outdoors, socially-distanced, and followed guidelines. It was fantastic. There were smiles all around! This is an example of the supportive relationships students need both inside and outside the classroom.

5.2.4 Learning During the Pandemic

Other study participants echoed many of the feelings students above had regarding the difficulties of learning online during the semester. In her final journal entry, Charley agreed with Bridgette that in-person, supportive instruction is especially important for hands-on learners. Charley wrote:

> Online learning has been sort of a struggle. I am a very hands-on learner, so being in class helps dramatically. I liked how Professor Sams stayed in contact with us and gave us reassurance that he is always there if we need anything. Using Microsoft Teams has definitely been better than nothing because I still get that face-to-face interaction.

Charley remained positive during our focus group interview when she elaborated on another aspect of her education which she missed during the pandemic. Charley said:

> I think learning as a college student during a pandemic has definitely been different, but I think everyone found ways to work with it even though it was really tough. Being an education major has been hard because we haven't been able to do our observation hours to get that hands-on learning.

During the same interview, Mia's perseverance, flexibility, and growth mindset showed again when she added:

> College during a pandemic is super stressful and I basically had to rediscover how I learn as a student. Having to learn through video calls and online lectures is completely different than being in-person, but it's out of our hands, so having to adjust was a necessity. Being a student athlete was also very hard doing things that I wasn't comfortable with and making decisions that I felt was necessary to keeping me healthy as well as my family.

One study participant found, surprisingly, that she benefited more from online learning as opposed to traditional face-to-face instruction. Tylr, the persevering commuter student who lives at home, reflected:

> I think I have learned a lot more this semester being online, than most. It does suck not meeting in person, but having online classes, you're able to prioritize what assignment you feel should be finished first, last, or what needs done ASAP. Being online has me more engaged because I'm in a comfortable setting (my home) and working on my own time to finish the tasks that need finished.

5.2.5 Pearson MyLab Versus Khan Academy

Several reasons existed to explain why students preferred Khan Academy over Pearson MyLab. ETS partnered with Khan Academy to design their free Praxis prep course and it is aligned closely with the test. Students paid approximately $100 per semester for Pearson MyLab and I use it to cover content in the curriculum which is not necessarily on the Praxis Core exam. Bridgette's seventh journal entry also shed some light on another important difference in these online interventions. Bridgette noted:

> Khan Academy helps break down problems and helps make understanding easier. Pearson Lab is very picky about how answers are given which still stresses me out. Khan Academy is bookmarked on my computer because it is beyond helpful.

Still, I believe there was value in the Pearson online textbooks which allowed me to design assignments that gave students an unlimited opportunity to achieve a perfect score and to engage in productive struggle with immediate feedback and helpful instruction. Further, researchers have warned educators against "teaching to the test" and allowing high-stakes standardized tests to drive the curriculum (Abrams, Pedulla, & Madaus, 2003; Nichols et al., 2003). From the perspective of a preservice secondary math teacher with a growth mindset, Gayle explained what she found valuable about Pearson MyLab in her seventh journal entry:

> Pearson has been something that I have used in all of my math classes and even in one of my education classes and biology class. I love Pearson because I feel as though it helps me understand what I am doing. My favorite part is using the view an example button because this function allows me to see step by step what I need to do to better understand it. And sometimes it will explain it in a new way so that I have multiple ways of solving one problem.

Based on the quantitative and qualitative data collected during this PDSA cycle and presented above, I have continued to use both the Khan Academy course and Pearson MyLab

assignments as tools to help students engage in productive struggle while solving problems with challenging mathematical content. I found that Khan Academy's free online *Praxis Core Math* course was an extremely successful change concept which addressed my problem of practice. The course was a well-designed intervention to alleviate issues among the secondary drivers of self-confidence, perseverance, math avoidance, and content knowledge, as well as the primary driver of test preparation. After developing a growth mindset, engaging in productive struggle, and gaining confidence in their abilities, students were able to experience the cycle of mathematical achievement. The Khan Academy course helped to increase the confidence of many students. This change contributed to more positive attitudes, which I believe is integral to the cycle of math achievement in my theory of improvement.

6.0 Discussion

Following recommendations from the literature review (e.g. Harper & Daane, 1998; Tooke & Lindstrom, 1998; Vinson, 2001; Gresham, 2007; Cardetti & Truxaw, 2014; Finlayson, 2014; NCTM, 2014; Felton & Koestler, 2015; Anderson, Boaler, & Dieckmann, 2018; Sun, 2018), a new culture of success among PSETs was created at Davis & Elkins College, and I intend to sustain this positive momentum. A holistic framework which included reflective journals, encouraging growth mindset, engaging in productive struggle, and supportive learning environments fostered opportunities for improvement in terms of students' confidence, attitudes, and abilities. As Ball (1990) noted, when she intervened to address preservice teachers' knowledge, assumptions, and feelings about math:

> The reason they feel anxious about and incompetent with mathematics is not due to some shortcoming on their part. That they feel the way they do, that they lack the understandings they do, may instead be the product of the math classrooms in which they were students (p. 14).

In my analysis, I saw the same trend as Ball thirty years later among preservice teachers at D&E. Through my doctoral work at the University of Pittsburgh, I aimed to create math classrooms which reduced the anxiety and incompetence Ball reported. In Table 1 I outlined some supportive methods which could help achieve this goal. As noted in the results pertaining to my first inquiry question, the interventions related to more supportive instruction were particularly beneficial for preservice teachers classified as persevering student-athletes and anxious achievers. Yet, the frustrated resisters did not respond as well to the online components of this study. Perhaps I was limited by COVID-19 restrictions and missed an opportunity by not pairing the frustrated resisters with the exempt enjoyers who could have served as tutors and role models. When revisiting Table

1, it is not surprising that some students needed more personal connections as the literature suggested many other supportive methods such as using an active approach, manipulatives, project-based learning, and group discourse that are prevalent in positive learning environments in in-person courses (Tooke & Lindstrom, 1998; Gresham, 2007; NCTM, 2014; Felton & Koestler, 2015). While these methods were not a focus of this study, I found it difficult to include such techniques in my courses while teaching online during the COVID-19 pandemic and my methods failed to reach all participants.

In addition, I expected the quantitative data to reveal increased growth mindset scores and decreased math anxiety ratings when pre/post scores were compared after the interventions of this PDSA cycle. As reported above in the results for my second and fourth inquiry questions, there was not a pattern of increased growth mindset scores, and math anxiety levels also did not decrease from the beginning to the end of this study. Growth mindset messages were not new for most of the participants. Many reported familiarity with the concepts from previous courses and this may partly explain the absence of much change in their scores. As for those preservice teachers who experienced anxiety, while many reported their feelings and attitudes improved qualitatively, this improvement was generally not reflected quantitatively. I believe overcoming years of anxiety toward mathematics may take years of positive experiences. Still, the persevering student-athletes and anxious achievers were able to succeed without truly lessening their anxious feelings. This may be another important takeaway and lesson which can be passed on to future cohorts of preservice teachers. Further, Wang et al. (2018) asserted "the need to move beyond linear relations among global constructs to address the complexity in the emotion-motivation-cognition interplay in mathematics learning, and highlight the importance of customized intervention for these heterogeneous groups" (p. 1). Wang et al.'s assertion (2018) will play a key role in the design of

future iterations of PDSA cycles for preservice teachers as I found not all groups of students benefited from the methods in this first iteration.

Future cohorts must also take advantage of the Khan Academy Praxis preparation course. As noted earlier, social justice and equity issues for minoritized groups are prevalent with regard to high-stakes standardized testing administered by ETS. When I began studying my problem of practice involving a lack of proficiency on the mathematics portion of the Praxis Core Academic Skills for Educators exam, the Khan Academy course did not exist. Frankly, as I began to design this PDSA cycle, I was shocked to discover the partnership between Khan Academy and ETS. As noted above in response to my fifth inquiry question, engaging in productive struggle via the free Khan Academy course was often the final, missing piece which preservice teachers needed to make progress toward licensure. Still, due to the history of biased standardized testing, I am hesitant to believe ETS will continue to be as supportive with their partnership and online study materials.

6.1 Recommendations for Educator Preparation Programs

Based on the results of this PDSA cycle, prior to employing Khan Academy's *Praxis Core Math* course for Praxis preparation, I believe all educator preparation programs should require the free online course from Stanford University, *How to Learn Math: For Students*, for all preservice teachers during their first year of college. Participants in this study found the material presented in the videos useful for success in math classes as well as in courses in other disciplines. Further, many noted a growth mindset helped them to overcome challenges in their daily lives outside of school. It is also imperative that these future teachers encourage their own students to employ a growth mindset. Again, I believe this is an integral component to increasing confidence, improving

attitudes, and increasing success in a productive cycle of achievement. Improvement from past standardized exams to current Praxis scores for students in this study mirrored Dweck's (2008) claims that the material can be mastered, and past performances, especially on standardized tests, are not indicative of what students are capable of if they possess a growth mindset and are supported in their learning.

Many student journal entries exhibited evidence of the improved mindsets, better attitudes toward math, and willingness to engage in productive struggle for preservice teachers in this study. This qualitative evidence addressed the drivers of perseverance and math avoidance in my problem of practice. Again, I believe these data showed that my theory of improvement was effective in moving preservice teachers from a cycle of math anxiety involving a lack of confidence and poor results toward a productive cycle of math achievement. As Dweck (2008) and Sun (2018) argued, a more positive attitude, growth mindset, and engaging in productive struggle are necessary components to success in mathematics, including success on high-stakes standardized tests like the Praxis exams.

Part of my theory of improvement, based on my professional experience and on research in the literature review (e.g. Bass & Ball, 2015; Gresham, 2007; Vinson, 2001), was that students who developed a growth mindset and engaged in productive struggle would make progress in mathematical problem-solving and achieve success on the math portion of the Praxis Core exam. Table 10 below shows the progress we made at D&E after I recognized the problem of practice in which PSETs were not succeeding on their first attempt on the Praxis exam. As shown in Table 10, during the three years prior to my enrollment in the doctoral program at the University of Pittsburgh, the success rate was just slightly better than 30%. Over the next two years while I explored drivers of this problem of practice, interventions to address these drivers, and more

supportive instruction to foster student success, the success rate improved to 50%. Finally, after a commitment to address math anxiety, math avoidance, and lack of confidence via growth mindset and productive struggle to change attitudes toward and beliefs about mathematics, 100% of PSETs enrolled at D&E who took the mathematics portion of the Praxis Core Academic Skills for Educators exam for the first time during the fall semester of 2020 were successful.

Table 10 PSETs' Success Rates on Praxis Core Math (First Attempt)

Dates	Number of Successful Test Takers	Number of Test Takers	Success Rate
September 1, 2015 – August 31, 2018	14	44	32%
September 1, 2018 – August 31, 2020	13	26	50%
September 1, 2020 – November 25, 2020	8	8	100%

6.2 Additional Considerations on the Theory of Improvement

6.2.1 Motivation

Based on Bridgette's suggestion during our focus group interview, I updated the cycle of math achievement to reflect a complete bidirectional network with five vertices as shown in Figure 5 below.

Figure 5 Updated Network of Math Achievement

Sun (2018) agreed with Bridgette's assessment to include motivation as well, especially with regard to maintaining high expectations for all students as they experience productive struggle. Perry (2010) stressed "mathematics content courses for preservice elementary teachers should be taught in a classroom climate that supports and encourages mastery goals" (p. 8) in order to improve confidence and motivation. My results indicate many students need extra motivational support to gain the confidence needed to succeed on challenging material with high cognitive demand. While the persevering student-athletes and anxious achievers experienced anxiety but were, the frustrated resisters did not report feeling anxious but were less motivated to engage in productive struggle. As Wang et al. (2015) noted, "A combination of moderate math anxiety and high intrinsic motivation may help drive students to work harder in math learning" (p. 1874). When encountering frustrated resisters in the future, I and other researchers must focus on their sources of motivation (or lack thereof) to provide additional support to these preservice teachers. Wang et al. (2018) stressed "for the least motivated students, building the internal drive for mathematics may be a priority" (p. 14).

6.2.2 Metacognition

In addition to the metacognitive benefits of the reflective journals presented in the results above, the important theme of metacognition was also present in the literature review, qualitative data, and other interventions of this study. Star (2015) stressed metacognition for students who engaged in productive struggle, and the Khan Academy course utilized diagnostics to create individualized study plans so that each student was aware of the material they needed to focus on to succeed on the Praxis Core exam. As Khan Academy's website advertised, "We'll identify your strengths and weaknesses, and create a customized practice plan that works with your schedule" ("Praxis Core Math," 2019).

Several students noted these additional metacognitive resources provided by Khan Academy helped enable them to achieve a passing score on the high-stakes standardized test. A preservice secondary mathematics teacher and anxious achiever like Sara, who benefited from positive experiences during her K-12 years, was able to organize study materials on her own, but still supplemented her traditional study materials with videos and examples from Khan Academy. Sara's combination of traditional and modern online methods built upon Finlayson's (2014) findings regarding her students' successful approaches to productive struggle. Meanwhile, the metacognitive practice plan from Khan Academy proved to be invaluable for the other anxious achievers and persevering student-athletes (Bridgette, Margaret, Charley, and Mia). These PSETs experienced poor results in mathematics in the past and were often overwhelmed by the volume of material on Praxis exams. Again, they found metacognition to be a difference maker in their journeys toward mathematical achievement. As noted below, motivation and metacognition warrant further study.

7.0 Limitations

Limitations of this study include a small sample size. In a larger study, the quantitative evidence may prove more valuable as a comparison of pre/post mean scores may be used to show a statistically significant difference in average anxiety levels from the beginning of the study to the end. Another important limitation is the lack of diversity among study participants. All participants were white. Comparisons between my results and those of other researchers with more racially diverse cohorts are needed. Additionally, these study participants may have exhibited different levels of math anxiety when compared to other cohorts. Different cohorts also may have been exposed to various levels of instruction involving growth mindset in their past. A larger study could also shed light on whether men are less likely to admit anxiety and less likely to benefit from reflective journals. Further, ETS and other policymakers make frequent changes to Praxis exams, passing scores, and other licensure requirements. One key unknown is whether the Khan Academy course will continue to exist online to help prepare preservice teachers for the high-stakes exam. Finally, this study represents only one iteration of a PDSA cycle. While much planning went into the study, the results represent just one iteration of the "do" portion of the cycle. There is still much work to be done in terms of studying the results and determining appropriate future actions in subsequent iterations.

8.0 Future Research

Future research may include focusing on connections between preservice teachers' motivation, goals, metacognition, anxiety, achievement, and standardized test preparation. A longitudinal study with the participants from this PDSA cycle could also explore how moving from a cycle of math anxiety to one of math achievement fosters identity and agency in teachers and in their K-12 students. Collaboration with educators throughout West Virginia and across the nation is necessary to examine whether this theory of improvement is successful in other contexts. The Association of Mathematics Teacher Educators (AMTE) recommends "Programs preparing beginning teachers of mathematics and Pre-K–12 schools and districts must develop close, respectful, bidirectional relationships that support the preparation of the next generation of teachers of mathematics" ("Standards for Preparing," 2017). In that regard, over the next three years I plan to be a consultant with the local county school system to utilize improvement science, including monthly PDSA cycles, to improve student learning in mathematics. The county has budgeted over a million dollars for this initiative. I have already presented professional development to approximately 50 county school teachers, and the high school teachers remarked that their ninth-grade students often suffer from a lack of confidence and perhaps many are stuck in the cycle of math anxiety. These teachers are particularly interested in using the free Stanford growth mindset course for all students during the first week of classes each semester. We will also use reflective journals to support, listen to, and learn from the students in the local system. Further, preservice teachers will work closely with K-12 students and in-service teachers in field placements during this initiative.

9.0 Conclusion

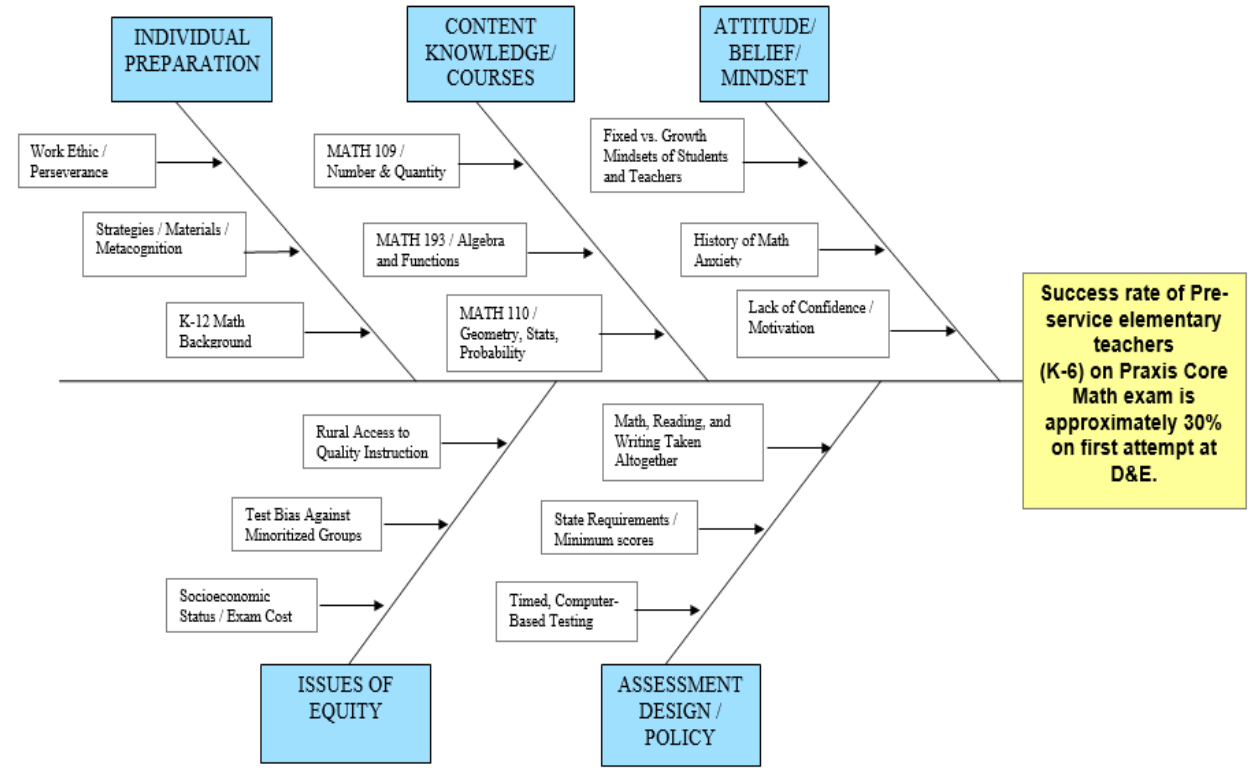
In addressing my problem of practice which was presented as a lack of proficiency in mathematics as measured by the high-stakes standardized Praxis Core Academic Skills for Educators exam, I discovered that rather than an achievement gap, preservice teachers at Davis & Elkins College experienced an opportunity gap. The following quote from NCTM's *Principles to Actions* (2014) guided my curricular improvements aimed at closing this gap for students from Appalachia who are often of low socioeconomic status:

> An excellent mathematics program requires that all students have access to a high-quality mathematics curriculum, effective teaching and learning, high expectations, and the support and resources needed to maximize their learning potential (p.4).

Throughout the last three years I endeavored to raise the quality and expectations for all preservice teachers at D&E while also improving my own teaching and learning. Growth mindset and productive struggle played vital roles in this process, as did key components such as seeing the system, being disciplined in my inquiry, understanding variation, and utilizing the power of networks in the user-centered approach of improvement science. Still, my methods and theory of improvement are works in progress as the resources I provided were supportive and effective for the persevering student-athletes and anxious achievers, but less so for the exempt enjoyers and frustrated resisters. However, as Dweck (2006) encouraged, I must value this shortcoming as an opportunity for growth. I am fortunate to work at a small college where the customization of interventions for different types of learners which Wang et al. (2018) alluded to is possible. As we embark on the beginning of our third year of teaching and learning during the COVID-19 pandemic, and I prepare to meet a new cohort of preservice teachers, I must recommit to listening to them to understand the problems we are trying to solve, the change concepts we might introduce

to solve them, and the quantitative and qualitative data to collect to measure improvement in future PDSA cycles.

Appendix A Fishbone Diagram



Appendix B Survey Items

6-point Likert scale

1 = strongly agree; 2 = agree; 3 = mostly agree; 4 = mostly disagree; 5 = disagree; 6 = strongly disagree.

1. The Stanford Growth Mindset Course helped me to gain confidence doing mathematics.

2. The Stanford Growth Mindset Course helped me to develop a willingness to engage in productive struggle in mathematics.

3. The Stanford Growth Mindset Course helped me to believe in my ability to solve math problems.

4. My reflective journal entries helped me to gain confidence doing mathematics.

5. My reflective journal entries helped me to develop a willingness to engage in productive struggle in mathematics.

6. My reflective journal entries helped me to believe in my ability to solve math problems.

7. The Khan Academy Praxis Course helped me to learn new mathematical content.

8. The Khan Academy Praxis Course helped me to use a variety of problem-solving techniques.

9. The Khan Academy Praxis Course helped me to engage in productive struggle in mathematics.

10. Pearson MyLab assignments helped me to learn new mathematical content.

11. Pearson MyLab assignments helped me to use a variety of problem-solving techniques.

12. Pearson MyLab assignments helped me to engage in productive struggle in mathematics.

Appendix C Journal Prompts and Interview Questions

1. Describe your previous experiences in mathematics courses. Give at least one positive example and one negative one, if possible.

2. Do you relate to the cycle of math anxiety? If so, describe your experiences and how you felt. If not, do you relate to the cycle of math achievement? Please explain.

3. How have you prepared for standardized tests such as the ACT or SAT in the past? Were you motivated to achieve a certain score on these types of exams? If so, why? If not, why not?

4. Was the information in the Stanford course on growth mindset new to you? If so, what did you learn and how might you apply this to your own education? If not, when and where did you learn about growth mindset? Do you use any of the growth mindset ideas in your education?

5. Is the idea of "productive struggle" new to you? What does it mean to you? Do you feel that you have engaged in productive struggle in the past in mathematics or in learning some other skill or concept? If so, please explain. If not, can you think of an example where you might apply productive struggle in the future? How have you engaged in productive struggle in this class?

6. If you experienced math anxiety in the past, did the Stanford course and employing a growth mindset help to reduce those feelings at all? Please explain. If you have not experienced math anxiety, did the Stanford course and employing a growth mindset help you to solve problems in this class?

7. If you experienced math anxiety in the past, did working on the problems in the Khan Academy course and/or Pearson MyLab help to reduce those feelings at all? Please explain. If you have not experienced math anxiety, please describe your feelings about the Khan Academy course and the Pearson MyLab assignments.

8. Discuss what you liked and disliked about the Khan Academy course. What new mathematical content or problem-solving strategies did you learn?

9.Discuss what you liked and disliked about the Pearson MyLab assignments. What new mathematical content or problem-solving strategies did you learn?

10.How has online learning this semester been different for you than in-person classes? Please discuss the pros and cons of ways we have communicated such as video calls and tools on SAKAI such as dropbox and forums.

Appendix D Dweck's Growth Mindset Scale

6-point Likert scale

1 = strongly agree; 2 = agree; 3 = mostly agree; 4 = mostly disagree; 5 = disagree; 6 = strongly disagree.

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

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

3. You can learn new things, but you can't really change your basic intelligence.

Appendix E Math Anxiety Scale

ABBREVIATED MATHEMATICS ANXIETY RATING SCALE (A-MARS) QUESTIONNAIRE

Please indicate the level of your anxiety in the following situations. Please choose ONE box on each line.

		Not at all	A little	A fair amount	Much	Very much
1.	Studying for a math test.	☐	☐	☐	☐	☐
2.	Taking math section of the college entrance exam.	☐	☐	☐	☐	☐
3.	Taking an exam (quiz) in a math course.	☐	☐	☐	☐	☐
4.	Taking an exam (final) in a math course.	☐	☐	☐	☐	☐
5.	Picking up math textbook to begin working on a homework assignment.	☐	☐	☐	☐	☐
6.	Being given homework assignments of many difficult problems that are due the next class meeting.	☐	☐	☐	☐	☐
7.	Thinking about an upcoming math test 1 week before.	☐	☐	☐	☐	☐
8.	Thinking about an upcoming math test 1 day before.	☐	☐	☐	☐	☐
9.	Thinking about an upcoming math test 1 hour before.	☐	☐	☐	☐	☐
10.	Realizing you have to take a certain number of math classes to fulfill requirements.	☐	☐	☐	☐	☐
11.	Picking up math textbook to begin a difficult reading assignment.	☐	☐	☐	☐	☐
12.	Receiving your final math grade in the mail.	☐	☐	☐	☐	☐
13.	Opening a math or stat book and seeing a page full of problems.	☐	☐	☐	☐	☐
14.	Getting ready to study for a math test.	☐	☐	☐	☐	☐
15.	Being given a "pop" quiz in a math class.	☐	☐	☐	☐	☐
16.	Reading a cash register receipt after your purchase.	☐	☐	☐	☐	☐
17.	Being given a set of numerical problems involving addition to solve on paper.	☐	☐	☐	☐	☐
18.	Being given a set of subtraction problems to solve.	☐	☐	☐	☐	☐
19.	Being given a set of multiplication problems to solve.	☐	☐	☐	☐	☐
20.	Being given a set of division problems to solve.	☐	☐	☐	☐	☐
21.	Buying a math textbook.	☐	☐	☐	☐	☐
22.	Watching a teacher work on an algebraic equation on the blackboard.	☐	☐	☐	☐	☐
23.	Signing up for a math course.	☐	☐	☐	☐	☐
24.	Listening to another student explain a math formula.	☐	☐	☐	☐	☐
25.	Walking into a math class.	☐	☐	☐	☐	☐

Bibliography

Abrams, L. M., Pedulla, J. J., & Madaus, G. F. (2003). Views from the classroom: teachers' opinions of statewide testing programs. *Theory Into Practice, 42*(1), 18-29.

Ahmed, S. (2012). *On being included: Racism and diversity in institutional life.* Durham, NC: Duke University Press.

Alexander, L. & Martray, C. (1989). The Development of an Abbreviated Version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation In Counseling and Development, 22*(3), 143-50.

Anderson, R. K., Boaler, J., & Dieckmann, J. A. (2018). Achieving elusive teacher change through challenging myths about learning: a blended approach. *Education Sciences, 8,* 98.

Approval of Educator Preparation Programs. (2019). Retrieved from https://wvde.state.wv.us/policies/.

Ball, D.L. Breaking with experience in learning to teach mathematics: the role of a preservice methods course. *For the Learning of Mathematics, 10*(2), 10-16.

Bass, H. & Ball, D. L. (2015). Beyond "You can do it!" developing mathematical perseverance in elementary school. Retrieved from: https://www.spencer.org/collected-papers-april-2015

Beaver, J. K. & Weinbaum, E. H. (2012). Measuring School Capacity, Maximizing School Improvement. Policy Brief. RB-53. Consortium for Policy Research in Education.

Beilock, S. L., Gunderson E. R., Ramirez, G., Levine, S. C., & Smith, E. E. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences of the United States of America, 107*(5), 1860-1863.

Bennett, C. I., McWhorter, L. M., & Kuykendall, J. A. (2006). Will I ever teach? Latino and African American students' perspectives on PRAXIS I. *American Education Research Journal, 43*(3), 531-575.

Berliner, D. C. (2013). Effects of inequality and poverty vs. teachers and schooling on America's youth. *Teachers College Record, 115*, 1-26.

Blue, T. W., O'Grady, R. J., Toro, J. A., & Newell, E. A. (2002). How do we find the best teachers? A study of the relationships among SAT, GPA, praxis series test scores, and

teacher ratings. *Paper presented at the annual conference of the Association of Teacher Educators*. Feb. 4, 2002. Denver, CO.

Boaler, J. (2008) Promoting 'relational equity' and ighh mathematics achievement through an innovative mixed-ability approach. *British Educational Research Journal, 34* (2), 167-194.

Boaler, J., Dieckmann, J., Pérez-Núñez, G., Sun, K. L., & Williams, C. (2018). Changing student minds and achievement in mathematics: the impact of a free online student course. *Frontiers in Education, 3*(26).

Cardetti, F. & Truxaw, M. P. (2014). Toward improving the mathematics preparation of elementary preservice teachers. *School Science and Mathematics, 114*(1), 1-9.

College Navigator. (2018). Retrieved from: https://nces.ed.gov/collegenavigator/?q=davis+elkins&s=all&id=237358#enrolmt

Darling-Hammond, L. (1994). Performance-based assessment and educational equity. *Harvard Educational Review, 64*(1), 5-30.

Darling-Hammond, L. (2010). Teacher education and the American future. *Journal of Teacher Education, 61*(1-2), 35-47.

Davis & Elkins College. (2018, July 1). The College Catalog 2018-2019.

Dweck, C. S. (1999). Self-theories: Their role in motivation, personality, and development. Philadelphia: Psychology Press.

Dweck, C.S. (2006). *Mindset: the new psychology of success*. New York: Ballantine Books.

Dweck, C.S. (2008). *Mindsets and Math/Science Achievement.* Carnegie Corporation of New York-Institute for Advanced Study. Retrieved from: https://www.growthmindsetmaths.com/uploads/2/3/7/7/23776169/mindset_and_math_science_achievement_-_nov_2013.pdf

ETS. (2020). Test and Service Fees. https://www.ets.org/praxis/about/fees

Felton, M.D. & Koestler, C. (2015). "Math is all around us and … we can use it to help us": teacher agency in mathematics education through critical reflection. *The New Educator, 11(*4*),* 260-276.

Finlayson, M. (2014). Addressing math anxiety in the classroom. *Improving Schools 17(*1), 99-115.

Gallagher, A., Bridgeman, B., & Cahalan, C. (2000). *The effect of computer-based tests on racial/ethnic, gender, and language groups*. Princeton, NJ: Educational Testing Service.

Glaser, R. (1990). *Testing and assessment: O tempora! O mores!* Pittsburgh, PA: University of Pittsburgh, Learning Research and Development Center.

Graham, A. (2013). Black teacher education candidates' performance on PRAXIS I: what test results do not tell us. *The Negro Educational Review, 64*(1-4), 9-35.

Gresham, G. (2007). A study of mathematics anxiety in pre-service teachers. *Early Childhood Education Journal, 35(*2*),* 181-188.

Guide to the 2018 ACT/SAT Concordance 2018. (2018). Retrieved from: https://collegereadiness.collegeboard.org/pdf/guide-2018-act-sat-concordance.pdf

Gutierrez, R. (2009). Framing equity: helping students "Play the Game" and "Change the Game." *Teaching for equity and excellence in mathematics, 1*(1), 4-8.

Harper, N.W. & Daane, C. J. (1998). Causes and reduction of math anxiety in preservice elementary teachers. *Action in Teacher Education, 19(*4*)*, 29-38.

Heifetz, R., Grashow, A., & Linsky, M. (2009). *The Practice of Adaptive Leadership*. Boston, MA: Harvard Business Press.

How To Learn Math: For Students. (2014). Retrieved from: https://lagunita.stanford.edu/courses/Education/EDUC115-S/Spring2014/about

Koricich, A., Chen, X., & Hughes, R. P. (2018). Understanding the effects of rurality and socioeconomic status on college attendance and institutional choice in the United States. *The Review of Higher Education, 41*(2), 281-305.

Lawrence, A. & Crehan, K. D. (2001). A study on the validity evidence of the pre-professional skills test (PPST) as a screening device for entrance into teacher education programs. Paper presented at the Annual Meeting of the National Council on Measurement in Education: Seattle, WA.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: NCTM.

National Council of Teachers of Mathematics. (2014). Principles to actions: Executive summary. Retrieved from: www.nctm.org/uploadedFiles/Standards_and_Positions/PtAExecutiveSummary.pdf

Nichols, S. L., Glass, G. V., Berliner, D. C. (2012). High-stakes testing and student achievement: Updated analysis with NAEP data. *Education Policy Analysis Archives, 20*(20), 1-35.

Our Mission. (2020). Retrieved from: https://www.dewv.edu/de-info/our-mission

Perry, C. A. (2010). Motivation and attitude of preservice elementary teachers toward mathematics. *School Science and Mathematics, 111*(1), 2-10.

Praxis Core Academic Skills for Educators Tests Overview. (2020). ETS. Retrieved from: https://www.ets.org/praxis/about/core/

Praxis Core Math. (2019). Retrieved from: https://www.khanacademy.org/test-prep/praxis-math/praxis-math-lessons

Primary Education. (2019). Retrieved from: https://data.worldbank.org/indicator/SE.PRM.TCHR.FE.ZS

Promise Scholarship. (2021). Retrieved from: (https://secure.cfwv.com/Financial_Aid_Planning/Scholarships/Promise/Eligibility_Requirements.aspx)

Saldaña, J. (2009). The coding manual for qualitative researchers. Sage Publications: Thousand Oaks, CA.

SAT Understanding Scores 2018. (2018). Retrieved from: https://collegereadiness.collegeboard.org/pdf/understanding-sat-scores.pdf

Shepard, L. (1993). Evaluating test validity. In L. Darling-Hammond (Ed.), *Review of Research in Education, 19*, 405-450. Washington, DC: American Educational Research Association.

Sloan, T. R. (2010). A quantitative and qualitative study of math anxiety among preservice teachers. *The Educational Forum, 74(*3*)*, 242-256.

Standards for preparing teachers of mathematics. (2017). Retrieved from: https://amte.net/sites/amte.net/files/SPTM_ExecSummary.pdf

State assessment subject analysis. (2018). Retrieved from: https://zoomwv.k12.wv.us/Dashboard/portalHome.jsp

Steele, C. (1997). How stereotypes shape intellectual identity and performance. American Psychologist, 52 (6), 613-629.

Sun, K. L. (2018). The role of mathematics teaching in fostering student growth mindset. *Journal for Research in Mathematics Education, 49*(3), 330-355.

Teacher's Professional Resource. (n.d.). The Cycle of Math Anxiety. https://www.pinterest.com/pin/540080180287430088/

The ETS mission drives everything we do. (n.d.). Retrieved from https://www.ets.org/mission

Tooke, D. J. & Lindstrom, L.C. (1998). Effectiveness of a mathematics methods course in reducing math anxiety of preservice elementary teachers. *School Science and Mathematics, 98(*3*)*, 136-139.

Vinson, B. M. (2001). A comparison of preservice teachers' mathematics anxiety before and after a methods class emphasizing manipulatives. *Early Childhood Education Journal, 29(*2*),* 89-94.

Wakefield, D. (2003). Screening teacher candidates: problems with high-stakes testing. *The Educational Forum, 67*(4), 380-388.

Wang, Z., Lukowski, S. L., Hart, S.A., Lyons, I.M., Thompson, L. A., Kovas, Y., Mazzocco, M. M., Plomin, R., and Petrill, S. A. (2015). Is math anxiety always bad for math learning? The role of math motivation. *Psychological Science, 26*(12) 1863–1876.

Wang, Z**.,** Shakeshaft, N., Schofield, K., and Malanchini, M. (2018). Anxiety is not enough to drive me away: A latent profile analysis on math anxiety and math motivation. *PLoS ONE, 13*(2). https://doi.org/10.1371/journal.pone.0192072

Watras, J. (2006). Teacher tests, equal opportunity, and the foundations of education. *Educational Studies* 39(2), 124-134.

West Virginia Test Requirements. (2021). Retrieved from: https://www.ets.org/praxis/wv/requirements/

Yackel, E., and Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education, 27*(4), 458-477. doi:10.2307/749877