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TEACHER-PERCEIVED BARRIERS TO MATH ACHIEVEMENT AND IMPLEMENTATION OF LITERATURE-BASED RECOMMENDATIONS FOR CHANGE IN MATH INSTRUCTION IN GRADES 4 THROUGH 8

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Dissertation

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Dedication

This dissertation is dedicated to my family for the sacrifices they all made so I could achieve my professional goals. I would like to thank every grandparent, parent, aunt, uncle, sister, and friend who picked up my slack to keep my family functioning efficiently while I worked. I am especially thankful for my Aunt Marie for planting the seed in my heart to ever consider this degree. To my mother, thank you for teaching me to be a strong woman and to never let anyone push me harder than I push myself. To my father, my faithful hero, who pushed me to challenge myself and seek my final degree to take my mind off my health at the lowest physical moment of my life, thank you from the bottom of my heart. Dad, your wisdom still amazes me! To my children, Michaela, Melina, and Shane, for assuming so much responsibility early in life so I could do this and praying for me when I thought I could not finish. To my husband, Andy, who loved me every step of the way—like most of my other adventures, I could not have finished this one without you. I would also like to thank my God, for without His grace this would not have been possible. And to my lifelong friends who traveled this journey with me, Shannon, Melissa, Dawn, Jennifer, and Janine, you were each worth your weight in gold.

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Abstract

The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. I conducted research on 19 participants by collecting questionnaires online due to the COVID-19 pandemic. Participants were teachers of mathematics from Grade 4 through Grade 8. I compared participants' responses to literature-based components using predetermined coding along with emergent coding to identify new themes in this basic interpretive study. The main finding of this study was low math self-efficacy was a widespread problem among students, which must be overcome to prepare students to pursue a STEM degree due to its role in career development when focusing on mathematics as the social cognitive career theory applied to students seeking a STEM degree. Other finding of this study were teachers still used purely procedural mathematics instruction, students were not developing a strong start in mathematics, and teacher math content knowledge still needed improvement.

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Chapter I: Introduction

Adequate mathematics education was a cornerstone for college students majoring in science, technology, engineering, and mathematics (STEM) fields. With a need to increase the number of STEM majors in the United States, mathematics education required changes to better prepare students in mathematics. Though many recommendations for changes in mathematics education were evident, teachers did not implement changes in a timely manner, if at all. One of the recommendations for change in math instruction was a balance of conceptual instructional practices and procedural instructional practices (Boston, 2013; Gaddy et al., 2014; Heyd-Metzuyanim, 2015; Selling, 2016). In addition to examining the recommended changes in the mathematics classroom to increase the number of STEM majors, it was also important to examine barriers to learning mathematics and a resistance to changes in mathematics instruction. The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change.

Statement of the Problem

Jobs in STEM fields have required a high level of fluid skills among the four content areas. According to the United States Department of Commerce, "The STEM workforce has an outsized impact on a nation's competitiveness, economic growth, and overall standard of living" (Noonan, 2017, p. 11). In 2010 as a part of his *Educate to Innovate* campaign, United States President Barack

Obama launched *Change the Equation*, a nonprofit initiative aimed at improving STEM education in response to the claim the United States was falling behind foreign competitors in STEM subjects (Sabochik, 2010). The widespread concern for improvement in STEM education was evident by the stakeholders investing in the *Change the Equation* initiative. Chief executive officers from 99 companies including DuPont, ExxonMobil, Intel, and Time Warner Cable drove the *Change the Equation* initiative (Change the Equation, 2012). Many of these companies were some of the largest U.S. corporations by total revenue (Fortune 500 – CNN, 2010).

The sudden increase in STEM occupations created a shortage of STEM workers. For example, in the executive summary *STEM Jobs: 2017 Update* by the U.S. Department of Commerce, Noonan (2017) reported the U.S. Department of Labor Bureau of Labor Statistics estimated from 2007 to 2017, non-STEM occupations grew about 4% while STEM occupations grew over 24%. Further, Noonan (2017) claimed, "STEM occupations are projected to grow by 8.9 percent from 2014 to 2024, compared to 6.4 percent growth for non-STEM occupations" (p. 2). *Change the Equation* (2013) leaders reported comparisons between unemployed workers in the United States and the number of job postings over a three-year period from 2010 to 2013. Overall, there were 3.6 unemployed people for every job posting. Alternately, *Change the Equation* (2013) officials reported 1.9 STEM job postings for each unemployed STEM worker, and when narrowing the comparison to STEM occupations in healthcare, the group reported 3.2 job postings for each unemployed STEM worker in healthcare. Bayer Corporation (2014) stated only half of Fortune 1000 talent recruiters who participated in the

Bayer Facts surveys reported they found adequate numbers of qualified candidates with STEM degrees in a timely manner. The increase in demand for STEM workers was not met with enough increase in the number of college STEM graduates to meet the demand (Bayer Corporation, 2014; Change the Equation, 2013; Marksbury, 2017; Noonan, 2017).

STEM workers generally required more education than non-STEM workers. For example, Noonan (2017) compared the education level of STEM workers to the education level of non-STEM workers by comparing data from the Current Population Survey, which was a survey of households in the United States conducted by the U.S. Census Bureau for the Bureau of Labor Statistics, which was used to create monthly Employment Situation reports. Noonan reported 72% of STEM workers held a college degree, while only 34% of non-STEM workers held college degrees. Further, Noonan (2017) estimated 49% of all STEM occupations were in computer and math fields; however, only 22% of STEM college graduates earned a computer or math degree. Researchers postulated the shortage of college STEM graduates entering the workforce in the United States left the country less competitive in a global workforce (Chen & Soldner, 2013; Marksbury, 2017; Noonan, 2017; Vásquez-Colina et al., 2014; Wang, 2013).

Specifically, Wang (2013) argued, “Without question, America’s ability to maintain its global competitiveness within [STEM] fields is an issue of national importance” (p. 1081). Gottfried et al. (2013) stressed the importance of mathematics education as they claimed, “Increasing the math achievement of students in the United States is recognized as an area of special national need”

(p. 68). Likewise, Chen and Soldner (2013), on behalf of the U.S. Department of Education, stated, “Producing sufficient numbers of graduates who are prepared for [STEM] occupations has become a national priority in the United States” (p. iii).

Researchers contended a student’s decision to enter a STEM field in college manifested during the student’s secondary education (Fouad et al., 2010; Wang, 2013; Williams et al., 2016). For instance, Wang (2013) studied what influenced college STEM majors’ decisions to choose STEM fields. Wang (2013) determined students who chose a STEM major in college were directly influenced by three things: high school math achievement, initial intent to major in STEM in college, and initial postsecondary experiences. Likewise, Fouad et al. (2010) argued the most common support for college STEM majors was an existing interest in a STEM field by the time the student entered college. Wang (2013) specifically argued the decision to major in STEM fields was “directly affected by 12th-grade math achievement, exposure to math and science courses, and math self-efficacy beliefs” (p. 1081). Additionally, Wang (2013) noted a positive correlation between STEM majors in college and Grade 10 students’ positive attitudes toward learning math. Musu-Gillette et al. (2015) claimed students “who maintained the most positive ability beliefs and values, were the most likely to select a math-intensive major in college” (p. 362). Further, Musu-Gillette et al. (2015) insisted student beliefs and values developed during elementary school. Thus, changes in math education, which improved math self-efficacy, were needed early in the education process (Marksbury, 2017; Musu-Gillette et al., 2015; Petersen & Hyde, 2017; Wang, 2013) to increase the number of college STEM majors.

Adequate mathematics skills were a cornerstone of STEM majors (Wang, 2013; Williams et al., 2016). Math achievement in high school and students' positive attitudes toward learning math in high school were critical to students' decisions to major in STEM fields in college (Wang, 2013); therefore, math skills and a positive attitude toward math prior to Grade 10 were essential to students majoring in STEM fields in college rather than simply an equal component to science, technology, and engineering (Musu-Gillette et al., 2015; Wang, 2013; Williams et al., 2016). For example, Williams et al. (2016) argued math was the *foundation* for other STEM subjects. Additionally, Lubinkski and Benbow (2006) contended challenging, intellectually rigorous math-science educational opportunities increased the likelihood of being in a STEM career 20 years later.

Changes in mathematics education were needed to increase the number of STEM majors in college. The National Council of the Teachers of Mathematics (NCTM) (2000, 2013, 2014) recommended changes to improve mathematics instruction, as well as political agencies in both the United States and other countries (Change the Equation, 2013; Dowker et al., 2016; Noonan, 2017), yet teachers continued to teach mathematics without adopting the recommended changes in classrooms (Gill & Boote, 2012; Wright, 2017). The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. I used a basic interpretive study research design in this study.

Research Questions

To guide this study, I formed the first research question around mathematics instruction since researchers in extant literature presented arguments supporting more contextual mathematics instruction over purely procedural mathematics instruction (Boston, 2013; Cheng & Hsu, 2017; Gaddy et al., 2014; Heyd-Metzuyanim, 2015; Selling, 2016). I formed the second research question to identify what barriers prevented students from achieving academic success in mathematics since a solid mathematics foundation was a requirement to adequately prepare for STEM degrees and careers (Lubinkski & Benbow, 2006; Wang, 2013; Williams et al., 2016). Since researchers in extant literature indicated an increase in STEM graduates was needed in previous years, I examined previous recommendations for change in mathematics instruction which were intended to create more STEM graduates. I formed the third research question to determine if previous recommendations for change to improve mathematics instruction were reported by teachers as well as to identify what, if any, barriers which resulted in resistance to change teachers reported.

Research Question 1

How did teachers report utilizing conceptual or procedural instructional practices in elementary and middle school mathematics classrooms?

Research Question 2

What perceptions did teachers have about barriers to learning mathematics in elementary and middle school classrooms?

Research Question 3

Which, if any, of the literature-based recommended changes did teachers report, and which, if any, indicators of resistance to change did teachers report in response to a questionnaire about elementary and middle school classrooms?

Theoretical Framework

I chose social cognitive career theory (SCCT) as the theoretical framework for this research to provide a "framework for understanding three intricately linked aspects of career development: (a) the formation and elaboration of career-relevant interests, (b) selection of academic and career choice options, and (c) performance and persistence in educational and occupational pursuits" (Lent et al., 1994, p. 79) as pertained to mathematics and the role of mathematics within attaining STEM degrees in preparation for STEM careers. Lent et al. (1994) credited the framework as a derivation from Bandura's general social cognitive theory. I selected SCCT because the overall problem was a shortage of STEM graduates entering the workforce in the United States (Bayer Corporation, 2014; Change the Equation, 2013; Noonan, 2017; Sabochik, 2010), and researchers in extant literature indicated a lack of adequate math skills often deterred students from pursuing STEM degrees (Gottfried et al., 2013; Wang, 2013). Students' early perceptions of mathematics led to academic choices in high school (Williams et al., 2016), which, in turn, led to post-secondary educational decisions (Fouad et al., 2010; Wang, 2013; Williams et al., 2016) followed by occupational choices in STEM or non-STEM fields (Lubinkski & Benbow, 2006; Wang, 2013).

I focused this study on how students were equipped mathematically to prepare to seek STEM degrees and careers. Lent et al. (1994) attempted to describe processes through which career and academic interests developed, career-relevant choices formed, and performance outcomes were achieved as they constructed the SCCT. The SCCT was intended to gain insight into what shaped *career-related interests and selections* (Lent et al., 1994). In the early stages of developing the SCCT, Lent et al. (1994) limited SCCT to issues of career entry, within the period from late adolescence to early adulthood, related to preparation for and implementation of career choice. Lent et al. (1994) argued, "Once interests crystallize, it may take very compelling experiences to provoke a fundamental reappraisal of career self-efficacy and outcome beliefs and, hence, a change in basic interest patterns" (p. 89). I was particularly concerned with interests of students initially pursuing STEM degrees and careers, so the SCCT was a good fit for this research study. Additionally, Lent et al. (1994) contended the framework was "relevant to both academic and career behavior" (p. 81) and "interests and skills developed during the school years ideally become translated into career selections" (p. 81), which also confirmed the SCCT for this study; therefore, since this study was essentially about better preparing students mathematically to initially pursue STEM degrees and enter STEM careers, the SCCT was an appropriate theoretical framework for this study.

Though Lent et al. (2006) described the SCCT in the Encyclopedia of Career Development as a *relatively new theory*, the theory had already been applied in numerous countries and multiple cultural contexts (Lent et al., 2006), which indicated the theory was gaining popularity in the field of research. The SCCT evolved over time. For example, Lent and Brown (2013) argued the initial presentation of SCCT consisted of three "interconnected, models aimed at explaining interest development, choice-making, and performance and persistence in educational and vocational contexts" (p. 557), but a fourth model, satisfaction/well-being, was later added. Though the fourth model was "aimed at satisfaction/well-being in educational and vocational contexts" (Lent & Brown, 2013, p. 557), which easily applied in the school setting, I decided against including the fourth model since I found no relevant extant literature in regard to student satisfaction/well-being in mathematics classes as of the time of this study; however, the fourth model clearly created an opportunity for future research. Similarly, by 2019, a fifth model had been added to the SCCT (Lent & Brown, 2019). The fifth model highlighted how people managed developmental tasks and uncommon challenges throughout their careers (Lent & Brown, 2019). I excluded the fifth model from this study since this study was limited to students prior to career entry.

Lent et al. (1994) formed the SCCT to study career choice based on the following: how individuals developed interest in academic content and careers, how individuals made educational and career choices, and how individuals attained academic and career success. Lent et al. (1994) based SCCT on Albert Bandura's general social cognitive theory. Since SCCT consisted heavily of self-efficacy beliefs (Lent et al., 1994), and math self-efficacy beliefs were important to students choosing to pursue STEM degrees (Wang, 2013), I determined SCCT supported the research goals. Other major components of SCCT were personal goals and outcome expectations (Lent et al., 1994). I determined SCCT was a reasonable theory for the study since students who viewed mathematics as a usable tool to solve problems were more likely to engage in careers, which required a high level of understanding of mathematics, which involved outcome expectations. That is, students who viewed mathematical skills as tools to help them solve problems expected to be strong problem solvers. I understood students seeking STEM degrees had to first set earning a STEM degree as a personal goal. I also determined SCCT was open to particular domains, such as mathematics, which impacted career choice, rather than an overall academic experience.

The research questions were realistic with a focus on mathematics and the predominant role of mathematics in STEM education and careers since SCCT expanded on Bandura's general social cognitive theory and reciprocal relations with a focus on "self-efficacy, expected outcome, and goal mechanisms and how they may interrelate" (Lent et al., 1994, p. 79) as these applied to career choice. Math self-efficacy was an important part of the student decision making process, particularly as students selected mathematics courses to prepare for STEM degrees (Musu-Gillette et al, 2015; Wang, 2013). Expected outcomes included considerations of social approval and self-satisfaction (Lent et al., 1994), which may have impacted students' choices when selecting mathematics courses. Similarly, Lent et al. (1994) included the *determination to engage in a particular field* under goal mechanisms, which in this study would be STEM degree programs. The SCCT was relevant to the research questions since the overall focus of the research was career development toward STEM careers, and SCCT also focused on experiential factors and learning factors (Lent et al., 1994) which were, in this study, the role of mathematics and how it was taught to elementary and middle school students. Thus, the research questions and theoretical framework were appropriate for this study.

Significance of the Project

This research study consisted of three parts. The first part was determining if teachers reported mathematics instruction was more conceptual, balanced conceptually and procedurally, or more procedural in elementary and middle school classrooms. This was a key component of this research since researchers in extant literature argued for less purely procedural mathematics instruction (De Kock & Harskamp, 2016; Hallett et al., 2010; Heyd-Metzuyanim, 2015; Selling, 2016). Based on the analysis of the data collected in this study, I would be able to determine if elementary and middle school teachers reported teaching mathematics more conceptually as recommended in extant literature or if they reported teaching mathematics more procedurally as tradition had dictated. For example, if teachers already taught more conceptually than procedurally, school leaders could focus on other suggestions for improvement in mathematics instruction when planning for professional development. Feedback from current teachers provided the best snapshot of the status of the recommended transition to less procedural mathematics instruction since classroom observations were not possible due to the COVID-19 pandemic school closure.

In the second part of this study, I identified teacher-perceived barriers in elementary and middle school mathematics classrooms, which prevented students from mastering mathematical skills, which could impact the later decision to seek a STEM degree in college. Rather than focus on a single issue or concern identified in extant literature, I searched for evidence from teacher questionnaires to determine what, if any, learning barriers identified in extant literature were reported by elementary and middle school teachers. The barriers to learning mathematics identified in extant literature were insufficient math instruction (Gaddy et al., 2014; Latterell & Wilson, 2016; Litke, 2015; Perrin, 2012; Welder, 2012; Wright, 2017); weak math skills among teachers and prospective teachers (Chapman, 2015; Chapman & An, 2017; Jong & Hodges, 2015); low teacher confidence in teaching mathematics (Finlayson, 2014; Geist, 2015; Marksbury, 2017); student math anxiety (Finlayson, 2014; Geist, 2015; Luttenberger et al., 2018; Pletzer et al., 2016; Soni & Kumari, 2017; Wright, 2017); student low math self-efficacy and attitude toward learning mathematics (Al-Mutawah & Fateel, 2018; Finlayson, 2014; Luttenberger et al., 2018; Musu-Gillette et al., 2015; Petersen & Hyde, 2017; Wang, 2013); and teacher attitude toward learning and teaching mathematics (Geist, 2015; Jong & Hodges, 2015). The qualitative research design of this study also enabled me to include additional barriers to learning mathematics which were not included in the extant literature. This information equipped school leaders to seek and implement methods to remove these barriers. Removing or reducing these barriers may have potentially resulted in an increase in the number of students seeking STEM degrees in college and choosing STEM careers.

In the third and final part of this study, I considered multiple recommendations for changes in the mathematics classroom identified in extant literature (NCTM, 2000, 2013, 2014) as well as evidence of resistance to change also identified in extant literature (Litke, 2015; Wright, 2017). By identifying the most common recommendations for change in extant literature and determining if teachers reported these recommendations for change, school leaders were able to consider professional development opportunities which best fit teachers within a district to promote the desired changes in mathematics classrooms. I simultaneously searched for reports of resistance to recommended changes. With this knowledge, school leaders were better equipped to address and overcome the resistance to make necessary changes in mathematics classrooms to increase the number of STEM graduates.

This study was also necessary for its contribution to existing literature. This study contributed to mathematics education literature because I presented a summary of recommended changes and barriers to success in mathematics classrooms prior to Grade 10 from extant literature as well as indicators for resistance to change. The gap in the literature this study filled was I identified what, if any, recommended changes to the mathematics classrooms were actually reported to increase the number of STEM majors in college. Some previous researchers, as well as national organizations, focused on recommended changes in the mathematics classroom (Heyd-Metzuyanim, 2015; NCTM, 2000, 2013, 2014; National Mathematics Advisory Panel [NMAP], 2008; Selling, 2016) as other researchers argued changes in mathematics classrooms had not taken place (Conference Board of the Mathematical Sciences, 2001; Litke, 2015; Maloney et al., 2015; O`Meara et al., 2017; Wright, 2017). By completing qualitative research, I designed this study so resistance to recommended changes were also explored. As of the date of this study, no researcher identified a school where the recommended changes were implemented so researchers could move beyond recommendations to determine if the changes impacted the number of students who sought STEM degrees or the factors researchers indicated would impact the number of students who sought STEM degrees.

Description of the Terms

Conceptual Mathematics

Hallett et al. (2010) defined conceptual mathematics as mathematics taught through "conceptual knowledge not as memorization of separate nuggets of information but as the ability to see interconnections between knowledge" (p. 396). In short, conceptual mathematics was mathematics taught through teaching interlocked ideas and concepts which were used to solve future mathematical problems as skills were needed. For example, a student with conceptual understanding of adding two digit numbers understood *carrying the one* actually meant *carrying a number times 10 of the place of the current column* to the next column on the left because the next column on the left was worth 10 times as much as the current column in a base 10 number system.

Math Self-Efficacy

Bandura (1986) defined self-efficacy as "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances" (p. 391). Lent et al. (1994) contended "self-efficacy beliefs are concerned with one's response capabilities (i.e., *Can I do this?*)" (p. 83). Math self-efficacy refers to self-efficacy as it pertains to mathematics.

Mathematics Anxiety

Mathematics anxiety involved "feelings of tension, discomfort, high arousal, and physiological reactivity interfering with number manipulation and mathematical problem solving" (Pletzer et al., 2016, p. 1). Math anxiety ranged "from a mild tension to a strong fear of mathematics" (Finlayson, 2014, p. 100). In many cases, math anxiety delayed the development of core mathematics skills and number concepts (Richardson & Suinn, 1972).

Procedural Mathematics

Hallett et al. (2012) described procedural mathematics as a sequence of actions which generated a correct answer to a specific type of math problem without any understanding of the mathematical procedure itself. In short, students arrived at correct answers for specific math problems by following steps without any understanding of why the memorized steps lead to correct answers. For example, a student with procedural understanding of adding two-digit numbers knew to *carry the one* when needed but failed to realize the *carried one* actually represented something other than one. The student only knew to follow the procedure.

Organization of the Study

In Chapter I, I stated the problem of the study, which was a shortage of STEM majors in the United States along with evidence to support this claim. Then, I stated the research questions for this study: *Which, if any, of the literature-based recommended changes did teachers report, and which, if any, indicators of resistance to change did teachers report in response to a questionnaire about elementary and middle school classrooms? What perceptions did teachers have about barriers to learning mathematics in elementary and middle school classrooms?* Which, if any, of the literature-based recommended changes did teachers report, and which, if any, indicators of resistance to change did teachers report in response to a questionnaire about elementary and middle school classrooms? I explained the theoretical framework for this study, which was SCCT, and explained why this theoretical framework was appropriate for this study. I described the significance of the study from two viewpoints, from the perspective of a school leader and from the perspective of a researcher. Without the existence of schools which implemented these changes, there was no way to determine if the literature-based recommendations for change actually increased the number of students majoring in STEM degrees. I also included a description of terms used throughout this study and possibly unfamiliar to people other than math educators.

In Chapter II, I summarized how the extant literature supported changes prior to high school to increase the number of students pursuing STEM degrees in college. I summarized evidence in extant literature which supported a balance of conceptual and procedural instruction over purely procedural instruction. I listed the literature-based barriers to math achievement, the literature-based recommendations for change in math instruction, and the literature-based evidence of resistance to change. In Chapter III, I explained why I chose a basic interpretive study, which was a qualitative approach to this study, as well as why I collected questionnaires rather than conducting classroom visits as initially planned. I described the criterion-based requirements for participants to be included in this study and provided an overview of the process of data collection and why I chose the blended approach of using both emergent coding and predetermined codes from the extant literature. I discussed the strategies I used in this study to ensure internal validity and credibility, one of which was how I achieved triangulation in this study. I listed and discussed the limitations of this study including the decreased likelihood that a participant with low math self-efficacy beliefs or low confidence in teaching mathematics participated in this study and the access to teachers due to the COVID-19 pandemic school closures. I also described the delimitations of this study, such as limited access to only people who were members of the social media community Facebook. I described my assumptions about the study, such as my ability to interpret questionnaire responses as intended by participants, and biases in regard to this study.

In Chapter IV, I displayed the characteristics of participants of the study by education level and grade levels taught. Then I summarized the data as they applied to each research question of the study. For each research question, I listed the predetermined codes as well as additional codes that emerged from the questionnaire responses. I identified emerging codes using the process of open coding, axial coding, and emerging themes. In Chapter V, I stated the main finding of this study, which was low math self-efficacy was a widespread problem among students which must be overcome to prepare students to pursue a STEM degree. I compared and contrasted literature-based barriers to learning mathematics to emergent codes in regard to teacher-perceived barriers to learning mathematics. I highlighted teacher-reported, literature-based recommendations for change and teacher-reported, literature-based resistance to change. I summarized how teachers may use this study to facilitate positive changes at their respective schools or systems. Finally, I ended the study with ideas for future research.

Chapter II: Review of the Literature

At the time of this study, as Wang (2013) suggested, improvements in education were needed to increase the number of STEM graduates in the United States. In this introduction to the review of literature, I included an overview of the extant literature. Following the overview, I expanded the review of literature as it supported this study. Of the four subjects of STEM, math required the greatest need for improvement to increase the number of STEM majors (Fouad et al., 2010; Wang, 2013; Williams et al., 2016). For example, Fouad et al. (2010) interviewed 113 students at three levels—middle school, high school, and college—from the Midwest and Southwest to identify STEM-related barriers and supports. Fouad et al. (2010) concluded, "We see an increase over time in the number of barriers to mathematics education and careers, while we see the opposite pattern in science, that is, a decrease in the number of barriers at each education level" (pp. 371-372). These results reinforced the idea that addressing and overcoming barriers in mathematics classrooms were needed to increase the number of STEM majors in college. Similarly, Williams et al. (2016) concluded, "Students' middle school mathematics experiences help to set the academic foundation for future STEM pathways in high school, college, and beyond" (pp. 368-369). Thus, improvements in mathematics education were needed prior to high school years to produce more STEM majors in college.

Previous researchers documented approaches to mathematics instruction in extant literature. For example, previous researchers indicated a difference between students who learned mathematics procedurally and students who learned mathematics conceptually (Heyd-Metzuyanim, 2015). Students who learned mathematics procedurally memorized processes to arrive at the correct answer but lacked understanding of the mathematics itself (Heyd-Metzuyanim, 2015). Alternately, students who learned mathematics conceptually understood the interconnections between mathematical concepts (Hallett et al., 2010), which enabled students to better apply concepts as needed to solve future problems.

In addition to overly procedural instruction, other barriers to successful mathematics instruction in existing literature were as follows:

- insufficient math instruction (Gaddy et al, 2014; Latterell & Wilson, 2016; Litke, 2015; Perrin, 2012; Welder, 2012; Wright, 2017);
- weak math skills among teachers and prospective teachers (Chapman, 2015; Chapman & An, 2017; Graeber et al., 1989; Jong & Hodges, 2015; Menon, 2009; Newton et al., 2012; O`Meara et al., 2017; Perrin, 2012; Simon, 1993; Thanheiser, 2010; Thanheiser et al., 2014; Wheeler & Feghali, 1983);
- low teacher confidence in teaching mathematics (Finlayson, 2014; Geist, 2015; Gill & Boote, 2012; Marksbury, 2017; Vásquez-Colina et al., 2014);
- student math anxiety (Ashcraft & Kirk, 2001; Finlayson, 2014; Geist, 2015; Gunderson et al., 2018; Hopko, 2003; Luttenberger et al., 2018; Maloney et al., 2015; Pletzer et al., 2016; Ramirez et al., 2013; Soni & Kumari, 2017; Vukovic et al., 2013);
- student low math self-efficacy and attitude toward learning mathematics (Al-Mutawah & Fateel, 2018; Finlayson, 2014; Luttenberger et al., 2018; Musu-Gillette et al, 2015; Petersen & Hyde, 2017; Soni & Kumari, 2017; Wang, 2013; Wright, 2017); and

- teacher attitude toward learning and teaching mathematics (Geist, 2015; Jong & Hodges, 2015).

This review also included recommendations for improvement in mathematics instruction from the NMAP in 2008 and the NCTM from 2000 to 2014, as well as extant literature on the resistance to implement recommended changes in the mathematics classroom (Conference Board of the Mathematical Sciences, 2001; Litke, 2015; Maloney et al., 2015; O`Meara et al., 2017; Wright, 2017). I conducted this review by searching online academic databases. I selected peer-reviewed journals as first choices, but also included some United States government reports as well as reputable online data and information sources as needed for adequate support. Search terms included conceptual mathematics, procedural mathematics, prescriptive mathematics, change in mathematics instruction, recommendations for change to mathematics instruction, barriers to learning mathematics, math teacher skills, teacher confidence in mathematics, math self-efficacy, attitude toward mathematics, STEM and mathematics, STEM majors, STEM careers, and barriers to STEM degrees. I began the study with some of these terms while other search terms emerged during the literature review process. For example, the resistance to change in the mathematics classroom emerged rather than a history of the changes in mathematics instruction over time.

Procedural Mathematics and Conceptual Mathematics in the Classroom

Students who learned purely procedural mathematics in the classroom were unable to build on their mathematical foundations in high school (Heyd-Metzuyanim, 2015) and beyond, which left students unable to pursue

STEM degrees in college (Wang, 2013; Williams et al., 2016). Thus, teaching pure procedural mathematics was problematic (Heyd-Metzuyanim, 2015; Selling, 2016). Extant literature on mathematics research indicated a balance of procedural mathematics and conceptual mathematics created stronger math foundations for students (Boston, 2013; De Kock & Harskamp, 2016; Rittle-Johnson et al., 2015).

Problems with Pure Procedural Mathematics

Students who learned math only procedurally lacked sufficient understanding of mathematical concepts which eventually led to a lack of mathematical knowledge and skill (Hallett et al., 2012; Heyd-Metzuyanim, 2015; Selling, 2016). For example, Hallett et al. (2012) conducted a longitudinal study of Grade 6 and Grade 8 students to determine if students were more successful conceptually or procedurally in mathematics. Hallett et al. (2012) found Grade 6 students could be clustered into four categories: more conceptual, more procedural, equally strong conceptually and procedurally, or equally weak conceptually and procedurally. In contrast, within the same study and using the same sorting system, Hallett et al. (2012) attempted to sort Grade 8 students, but all Grade 8 students clustered into more conceptual or more procedural groups leaving both the equally strong conceptually and procedurally and equally weak conceptually and procedurally groups empty. This phenomenon of the two empty groups indicated students who failed to develop mathematics skills conceptually during the time period from Grade 6 to Grade 8 resorted to procedural mathematics as a survival mechanism for assessments. Comparably, Heyd-Metzuyanim (2015) summarized pure procedural mathematics "*deludes* both the student and the teacher that the student is advancing satisfactorily . . . while in fact the foundations of his or her mathematical knowledge are very weak" (p. 542).

Heyd-Metzuyanim (2015) conducted a case study of a girl Idit, who was successful in mathematics through the end of Grade 7 but was failing mathematics by the end of Grade 9. Mid-year in Grade 7, "Idit declared herself quite confident with her mathematical skills . . . a top math student" (Heyd-Metzuyanim, 2015, p. 520). Though Idit earned above average grades in mathematics in Grade 7, Idit's parents expressed concern that Idit showed signs of stress and anxiety while working on mathematics. By Grade 9, Idit described stress during math tests: "Sometimes in tests, there is this question that stresses me out. They (my parents) know that there is something that stresses me out . . . they know I know the material" (Heyd-Metzuyanim, 2015, p. 522). Heyd-Metzuyanim, after close examination, concluded Idit participated in an *artificial manner*. In other words, Idit only knew procedural mathematics, which Heyd-Metzuyanim referred to as ritual participation. Heyd-Metzuyanim (2015) concluded the case study had shown procedural mathematics had "a tendency to gradually widen until it produces general failure" (p. 542) in mathematics. Heyd-Metzuyanim (2015) argued procedural mathematics may "explain why students such as Idit, who seem to be doing fine up until the higher grades of middle school, suddenly fail, which for them can only be explained by a noncognitive factor such as math anxiety" (p. 542). Specifically, Idit followed directions to complete a routine to arrive at correct answers, thus imitating understanding mathematics, but lacked conceptual understanding of mathematics, which created a weak foundation on which to build higher level math concepts. Andrews and Brown (2015) argued math anxiety had individual and national consequences and there was an "overwhelming problem of math anxiety and avoidance in STEM-related degrees across college campuses in the United States" (p. 365). Hence, students like Idit were limited in majoring in STEM degrees.

Selling (2016) investigated barriers that high school students faced while studying mathematics. Selling (2016) warned one problem for students studying mathematics at the secondary level was learning math in a prescriptive (or procedural only) manner. Selling (2016) described a prescriptive manner as students following a set of directions, or memorized set of rules, to complete a specific mathematical task. When students learned math in only a prescriptive manner, they lacked authentic understanding of key mathematical concepts, which created a weak math foundation for students (Heyd-Metzuyanim, 2015; Litke, 2015; Menon, 2009; Selling, 2016; Thanheiser et al., 2014). Since, according to Wang (2013), students who perceived their high school math and science courses adequately prepared them for college work were likely to major in STEM degrees, students with a weak mathematical foundation were likely limited in STEM degrees choices and careers.

Balance of Procedural Mathematics and Conceptual Mathematics

In contrast to procedural mathematics was a conceptual understanding of mathematics. A conceptual understanding of mathematics meant students understood the overall mathematical ideas or concepts, as well as the relationships between the concepts, which enabled students to solve various mathematical problems (Heyd-Metzuyanim, 2015; Selling, 2016). Researchers suggested students learning only procedural mathematics was problematic but teaching mathematics procedurally in proper balance with conceptual mathematics is ideal (Boston, 2013; Cheng & Hsu, 2017; Gaddy et al., 2014; O`Meara et al., 2017; Rittle-Johnson et al., 2015). Rittle-Johnson et al. (2015) argued a bidirectional relation existed between procedural and conceptual knowledge of mathematics. In other words, procedural mathematics helped develop conceptual mathematics, and conceptual mathematics helped develop procedural mathematics. Thus, students needed a balance of procedural and conceptual mathematics to understand mathematics at the level required to pursue STEM degrees. Similarly, Boston (2013) contended teachers who taught mathematics purely procedurally "might help explain the difficulty of implementing tasks in ways that provide students with opportunities to make mathematical connections" (p. 29).

The healthy balance between procedural mathematics and conceptual mathematics needed to have a higher amount of conceptual mathematics than procedural mathematics rather than equal amounts. For instance, Hallett et al. (2010) argued children who relied on conceptual knowledge may have an advantage over peers who rely heavily on procedural knowledge. Perrin (2012) argued teachers who completed a larger number of high-level math courses in college also increased the belief that mathematics was more conceptual than procedural. Likewise, Thanheiser et al. (2014) contended, "A conceptual understanding of number and operations underlies learning of all future mathematics and other STEM subjects" (p. 219). Thus, if students developed a better conceptual understanding of mathematics, students were prepared to study STEM subjects.

The need for a balance of conceptual mathematics and procedural mathematics in the classroom extended beyond the United States. For example, Cheng and Hsu (2017) examined the profiles of instructional practices of high-performing and low-performing Grade 8 mathematics teachers from the United States, Finland, Korea, and Russia who participated in the 2011 Trends in International Mathematics and Science Study (TIMSS). Cheng and Hsu (2017) selected 10 instructional practices from the TIMSS 2011 teacher questionnaire to identify teachers using more procedural or more conceptual teaching practices. The five procedurally oriented practices were teacher explaining problem solving, ask students to memorize rules, ask students to work on problems guided by teachers, ask students to work problems together in the whole class with direct guidance, and ask students to apply facts, concepts, and procedures to solve routine problems (Cheng & Hsu, 2017). The five conceptually oriented practices asked students to work problems while teacher is occupied by other tasks, ask students to explain their answers, ask students to relate what they are learning in mathematics to their daily lives, ask students to decide on their own procedures for solving complex problems, and ask students to work on problems with no obvious solution (Cheng & Hsu, 2017). Cheng and Hsu (2017) concluded all teachers in the high-performing groups from Finland, Korea, and Russia, as well as one high-performing group in the United States, taught using more conceptually oriented practices than low-performing teachers, while only one high-performing group, which was from the United States, taught using more procedurally oriented practices.

Likewise, in the Netherlands, De Kock and Harskamp (2016) made similar claims for avoiding procedural only computer-assisted instruction for mathematics. Students completed a pre-test, an instructional lesson on how to access hints, five 30-minute lessons on computers consisting of eight word problems each over a period of three weeks, and a post-test. During the computer-based lessons, students could use hints as needed. Of the 105 students in the study, 56 students were assigned to the procedural-content hints group and 51 students were assigned to the procedural-only hints group (De Kock & Harskamp, 2016). Students in both groups opted to use hints on approximately 25% of the word problems. While both groups finished the same number of problems, students in the procedural-content hint group solved more problems correctly on the post-test. Thus, De Kock and Harskamp (2016) concluded students in the procedural-content hint group gained a higher transfer of problem-solving skills than the procedural-only group. Hence, a balance of procedural and conceptual mathematics led to more student success.

Barriers to Achievement in the Mathematics Classroom

Since math instruction needed the most improvement of the four components of STEM to increase the number of STEM graduates, it was important to identify barriers to success in mathematics. In extant literature, researchers identified six barriers to mathematics instruction: insufficient math instruction, weak math skills among teachers and prospective teachers, low teacher confidence in teaching mathematics, student math anxiety, student low math self-efficacy and attitude toward learning mathematics, and teacher attitude toward learning and teaching mathematics.

Insufficient Math instruction

The lack of high-quality math instruction was a barrier in mathematics classrooms. According to Perrin (2012), teachers failed to use suggested standards for teaching or were unaware suggested standards existed. Perrin (2012) examined teachers of Grade 7 and Grade 8 mathematics to determine the teachers' awareness levels of the NCTM's standards or Principles and Standards for School Mathematics (PSSM). Perrin (2012) selected a midsize school district in Nevada which employed 82 Grade 7 and Grade 8 mathematics teachers to conduct the study. Seventy-three of the mathematics teachers participated in the study representing 63 elementary schools, 13 middle schools, one combined middle and high school, two alternative schools, and eight charter schools. Of the 73 teachers Perrin (2012) surveyed, 27.4% of the participants claimed they were unaware that either NCTM's standards or PSSM existed (p. 469). Additionally, Perrin (2012) reported the following results: 72.6% of the participants claimed they were aware of either NCTM's standards, PSSM, or both; 30.1% of the participants either owned a copy of either NCTM's standards or PSSM or accessed PSSM online; 32.9% of participants said they had not read either NCTM's standards or PSSM; 38.4% of participants claimed they had skimmed sections of either NCTM's standards or PSSM; and only 5.5% of participants claimed to have read either NCTM's standards or PSSM completely. Teachers unaware of mathematics standards were unable to teach the recommended content.

Perrin (2012) also surveyed teachers using the Mathematics Standards Beliefs Survey (MSBS), which was designed to assess if a teacher supported NCTM's vision for mathematics instruction and NCTM's recommended standards. Perrin (2012) concluded secondary-certified teachers scored significantly higher than elementary-certified teachers on the MSBS ($p < .01$, p. 470). Perrin (2012) defined elementary-certified teachers as teachers licensed to teach kindergarten through Grade 8 and secondary-certified teachers as teachers licensed to teach Grade 7 through Grade 12. One specific response of the MSBS Perrin (2012) highlighted was secondary-certified teachers scored higher than elementary-certified teachers on the statement *Mathematics is more than a set of disjointed rules and procedures*. Perrin's 2012 finding indicated elementary-certified teachers may have taught more procedural mathematics, while secondary-certified teachers taught more conceptual mathematics. Similarly, Gaddy et al. (2014) argued a need existed for students to learn important interconnected mathematics, which also indicated a need for more conceptual mathematics. Likewise, Wright (2017) encouraged educators to develop deeper and longer-term understanding among students.

The disproportionality of procedural mathematics and conceptual mathematics in early grades may have caused students to develop misconceptions and prevented students from connecting mathematical ideas, especially when students' misconceptions in existing mathematical knowledge were learning barriers for learning algebra (Welder, 2012). Welder (2012) argued elementary and middle school teachers could prevent and correct student mathematical misconceptions prior to students studying algebra if the teachers adopted instructional strategies which viewed the curricula as *algebra preparation*. Welder (2012) identified four common misconceptions among students: improper bracket usage, a lack of understanding of equality, a lack of understanding of operational symbols, and a poor understanding of variables, which Welder (2012) referred to as letter usage. In essence, Welder (2012) argued elementary and middle school teachers needed to teach more conceptual mathematics to better prepare students to learn algebra.

Litke (2015) was also concerned with algebra instruction and investigated what algebra instruction looked like in classrooms in five urban school districts. Litke (2015) examined a sample of 75 video-recorded lessons submitted by 24 Grade 9 algebra teachers to the Measures of Effective Teaching Project. Litke (2015) designed a Quality of Instructional Practices in Algebra (QIPA) observational tool to evaluate instruction and reported 65% of observed instructional segments scored low-level on the Making Sense of Procedures section of the QIPA "indicating that procedures were presented with no attention to meaning or sense-making" (p. 129) and less than 4% of segments scored above mid-level in this domain. Latterell and Wilson (2016), likewise, reported prospective math teachers felt former teachers were ineffective due to teaching shortcuts rather than making sense of the math. In short, Litke (2015) and Latterell and Wilson (2016) described procedural mathematics instruction as the problem in mathematics classrooms.

Additionally, Litke (2015) reported 47% scored low-level on the Supporting Procedural Flexibility portion of the QIPA meaning, though a teacher mentioned there was more than one way to solve a problem, the teacher did not discuss any alternative methods to solve the problem. Without students observing various problem-solving methods, the students were left unable to connect mathematical concepts. Keiser (2012) suggested teachers provide students with opportunities to analyze other students' methods and compare ideas when solving problems. Keiser (2012) argued students observing more efficient approaches to solving problems encouraged students to adopt new strategies. Hence, students with better mathematical understanding and problem-solving skills were more likely to major in STEM degrees in college (Wang, 2013).

Weak Math Skills among Teachers and Prospective Teachers

Teacher math skills were concerns of researchers for more than 30 years. Chapman and An (2017) argued, "Mathematics teacher knowledge has been recognized as a pervasive component in teacher preparation and an important issue in mathematics education research in the last few decades" (p. 172). For example, Graeber et al. (1989) assessed 129 female prospective early education teachers enrolled in a mathematics content or mathematics methods course at a large university in the southeastern United States who already completed at least one mathematics content course. The assessment contained 13 multiplication and division problems. Fewer than 35 participants missed less than two problems, while more than 50 participants missed four or more problems (Graeber et al., 1989, p. 97). Of the participants who missed one or more of the eight most commonly missed problems, Graeber et al. (1989) selected 33 prospective teachers for interviews. Four interviewees argued it was impossible to divide a smaller number by a larger number (Graeber et al., 1989, p. 100). Thus, Graeber et al. (1989) contended instruction from these prospective teachers might perpetuate mathematical misconceptions.

Researchers suggested prospective teachers often lacked a conceptual understanding of mathematics that would be required to teach students successfully (Chapman, 2015; Chapman & An, 2017; Jong & Hodges, 2015; Menon, 2009; Newton et al., 2012; O`Meara et al., 2017). For instance, Thanheiser et al. (2014) argued prospective elementary teachers' "knowledge of whole numbers and operations is insufficient and in need of improvement" (p. 217). Researchers cited misconceptions among teachers and prospective teachers over years including the following: Wheeler and Feghali's (1983) conclusion that 15% of 52 participants responded zero was not a number when asked directly if it was a number; Graeber et al.'s (1989) conclusion that 66% of 33 interviewed teachers reversed the roles of the dividend and divisor when the divisor was greater than the dividend in story problems (p. 99); Simon's (1993) conclusion that over 75% of 33 participants were unable to find the remainder for a division problem when given the dividend, divisor, and a calculator; and Thanheiser's (2010) conclusion that only three of 33 prospective teachers enrolled in a math methods course, who had all previously completed the required math content courses for degree completion, correctly explained values of regrouped digits in two tasks in the contexts of addition and subtraction. The lack of conceptual mathematical knowledge by these elementary teachers and prospective elementary teachers created a barrier for any student trying to gain a deep understanding of mathematics from them. Elementary teachers with mathematical misconceptions were likely to pass their misconceptions along to their students (Graeber et al., 1989). Misconceptions were problematic for students studying mathematics, and Welder (2012) argued identifying and preventing student misconceptions prior to students learning algebra skills was a key component of increasing student success rates in algebra.

Other researchers expressed concern that prospective elementary teachers lacked sufficient mathematics content knowledge to adequately discern between conceptual understanding and procedural understanding when they attempted to analyze children's mathematical thinking (Bartell et al., 2013; Chapman & An, 2017). Bartell et al. (2013) recruited 54 volunteers for the study from prospective elementary teachers enrolled in an undergraduate mathematics content course in the mid-Atlantic region of the United States. Each prospective elementary teacher watched the same video of a lesson on place value taught to Grade 1 students. Prospective elementary teachers were instructed to observe two Grade 1 students in the video to identify evidence that the two Grade 1 students had a conceptual understanding of place value. Many of the prospective elementary teachers incorrectly identified evidence of procedural understanding as evidence of conceptual understanding (Bartell et al., 2013).

The lack of mathematical knowledge was not limited to elementary school teachers, as weak mathematical skills among teachers was also a barrier in middle school classrooms. For example, Menon (2009) researched 64 prospective teachers enrolled in a middle school mathematics methods course and studied the prospective teachers' understanding of multi-digit multiplication, dividing a whole number by a fraction, and comparing the volume of two cylinders. Menon (2009) argued prospective teachers in the study relied on the procedural mathematics they learned as school children rather than an adequate conceptual understanding of mathematics, which was required to successfully teach future students mathematics. Similarly, Perrin (2012) implied middle school mathematics teachers who believed math was more conceptual than procedural had more experience with various types of mathematics such as completing multiple high-level math courses in college. Thus, middle school teachers who believed math was more procedural than conceptual completed fewer high-level math courses, which may have been due to their lack of understanding conceptual mathematics. For example, when asked to design a word problem corresponding to a math question on Menon's (2009) assessment, 75% of the participants left the question blank (Menon, 2009). When asked to compare the volume of two cylinders on Menon's assessment, approximately 96% either answered incorrectly that both cylinders had the same volume or did not attempt the problem at all.

Menon (2009) reported the reasons prospective teachers gave for the struggle they had with the mathematical difficulty included the following: forgot the rule, struggled with fractions, forgot the formula, and struggled with word problems. These reasons prospective teachers provided to Menon were reasons consistent with students struggling in mathematics due to having only a procedural understanding of mathematics. Prospective teachers with only a procedural understanding of mathematics were unable to teach mathematics conceptually in class (Jong & Hodges, 2015; Menon, 2009; Newton et al., 2012; O`Meara et al., 2017).

Researchers in existing literature indicated the teacher knowledge barrier in math education was a gap in conceptual knowledge rather than procedural knowledge. For instance, Welder (2012) contended elementary and middle school teachers needed "a deeper and more flexible understanding of the mathematics they teach, so they can recognize how the structure of algebra can and should be exposed while teaching arithmetic" (p. 255). Thanheiser et al. (2014) further argued, teachers “solving a problem using the algorithms is not sufficient knowledge for teaching mathematics to children” (p. 219). Chapman and An (2017) concluded university-based teacher education programs for both in-service and pre-service teachers helped mathematics teachers improve their mathematics content knowledge and instructional practices which created hope that mathematics reform was possible.

Low Teacher Confidence in Teaching Mathematics

As Welder (2012) argued, teachers needed a conceptual understanding of mathematics to successfully prepare students to eventually study algebra. Marksbury (2017) conducted a case study of 25 teachers about teacher professional learning for STEM education in a rural setting in the northeast United States. All but two of the participants taught between kindergarten and Grade 3. Participants completed online surveys about various aspects of STEM instruction including confidence in teaching STEM subjects. Marksbury (2017) identified the lowest scoring response by a third of the participants was the self-confidence to teach algebra. Other common responses with low ratings were confidence to give students concrete experiences in learning mathematics, confidence to teach basic concepts of fractions, and confidence to locate resources for preparing mathematics lessons. Teachers seemed to have a weakness in teaching mathematical components of STEM more than any other content area. Marksbury (2017) summarized research findings as follows:

> When viewed in the context of participants’ results on the confidence in STEM instrument, it is clear these teachers are far more comfortable in general teaching practices than they are with incorporating math- and

> science-related content in teaching. Even at the elementary levels of K-3, nearly a third of participating teachers were skeptical of their ability to teach algebraic concepts, build on their students' intuitive understandings and teach as a co-inquirer with their learners. (p. 14)

Finlayson (2014) also studied teacher self-confidence. Finlayson (2014) identified low self-confidence in math and ineffective learning practices as causes for math anxiety among prospective teachers. Gill and Boote (2012) suggested teachers' low self-efficacy beliefs were related to teachers' decisions to cling to procedural mathematics in the classroom. That is, when a teacher had low math self-efficacy, the teacher was more likely to teach math only procedurally (Gill & Boote, 2012).

Additionally, Finlayson (2014) studied math anxiety. Finlayson (2014) stated "students often develop math anxiety in schools, frequently as a result of learning from teachers who are themselves anxious about their mathematical abilities" (p. 101). Likewise, Geist (2015) surveyed 31 Head Start teachers from the Appalachian region and similarly concluded "math teachers who have math anxiety themselves inadvertently pass it on to their students" (p. 334). Vásquez-Colina et al. (2014) agreed teachers passed along math anxiety to students "by modeling behaviors of their own discomfort with the subject [mathematics]" (p. 39). Elementary teachers with a lack of confidence teaching mathematics was more problematic as it also made elementary teachers less likely to incorporate math into daily lessons (Geist, 2015). Geist (2015) further added math anxiety was *especially prevalent* among early education teachers and math anxiety in teachers was related to a negative attitude toward mathematics.

Student Math Anxiety

Luttenberger et al. (2018) claimed, “Math anxiety is a widespread problem for all ages across the globe” (p. 311). Further, Luttenberger et al. (2018) argued the most prominent specific form of test and performance anxiety in educational settings was math anxiety. Math anxiety affected individuals on an emotional level, cognitive level, and physiological level, including symptoms of nervousness, compromised functioning of working memory, increased heart rate, upset stomach, and lightheadedness (Luttenberger et al., 2018). Ashcraft and Kirk (2001) argued, “Individuals with high math anxiety take fewer math courses, earn lower grades in the classes they do take, and demonstrate lower math achievement and aptitude than their counterparts with low anxiety” (p. 224). In turn, individuals with high math anxiety avoid careers that require math skills, such as STEM careers (Hopko, 2003; Luttenberger et al., 2018; Pletzer et al., 2016).

Math anxiety was negatively correlated with math achievement in students from early elementary grades through Grade 10 (Finlayson, 2014; Gunderson et al., 2018; Luttenberger et al., 2018; Maloney et al., 2015; Ramirez et al., 2013; Soni & Kumari, 2017; Vukovic et al., 2013; Williams et al., 2016; Wu et al., 2012). Researchers stated math anxiety was present in elementary students as early as Grade 2 (Sorvo et al., 2017; Vukovic et al., 2013; Vukovic, 2013; Wu et al., 2012), while other researchers identified students with math anxiety as early as Grade 1 (Maloney et al., 2015; Ramirez et al., 2013). Students who learned math only procedurally often developed math anxiety (Finlayson, 2014; Heyd-Metzuyanim, 2015), and teachers using ineffective teaching practices also contributed to the increase in math anxiety among students (Vásquez-Colina et al., 2014). Mutawah (2015) concluded math anxiety levels were the highest for students who self-identified as low mathematics achievers. Luttenberger et al. (2018) concluded math anxiety interacts with math self-efficacy and self-motivation to do math. Hence, students needed to overcome math anxiety to build positive math self-efficacy beliefs and increase their chances to pursue STEM degrees.

Teachers needed to be conscientious of math anxiety among students (Ramirez et al., 2013; Sorvo et al., 2017; Vásquez-Colina et al., 2014). Sorvo et al. (2017) encouraged teachers to consider math anxiety when planning mathematics lessons because math anxiety seemed related to lower levels of arithmetic fluency. Ramirez et al. (2013) studied 154 Grade 1 and Grade 2 students from five public schools in a large urban school district as a part of a larger study about factors that impacted early learning. Ramirez et al. (2013) argued intervention for students with math anxiety in early elementary grades was important because these students were most likely to avoid math courses in the future as well as math related careers. Similarly, Geist (2015) claimed, "Math anxious individuals will work very hard to avoid mathematics" (p. 330). Vásquez-Colina et al. (2014) also agreed math anxiety impacted students' decisions to avoid future math courses as well as STEM careers and declared a critical need for stakeholders to help students cope with and overcome math anxiety. Wu et al. (2012) concluded, "Critically, our findings underscore the need to remediate early math anxiety and its deleterious effects on math achievement in young children" (p. 9).

Finlayson (2014) argued early primary school teachers focused on success and results rather than authentic understanding, which created math anxiety and a lack of self-confidence among students. Gunderson et al. (2018) studied 634 Grade 1 and Grade 2 students and argued these early years in school were the times when children initially recognized cues about their own achievement. Further, Gunderson et al. (2018) argued this led to negative self-perception of academic achievement, which initiated the development of math anxiety. Finlayson (2014) contended constructivist teaching may help students overcome math anxiety. Constructivist teaching built knowledge on a student's existing knowledge to connect concepts and ideas while allowing the student to consider possible misconceptions and ask questions for clarity while questioning or confirming not only current concepts but concepts previously accepted true (Finlayson, 2014). Making these connections between mathematical ideas was a part of conceptual mathematics. Ward (2001) also claimed using constructivist methods in math classrooms helped students develop critical thinking skills and knowledge transfer skills as well as improved student retention of knowledge. As a result of the Ramirez et al. (2013) research study, the research team argued students aware of alternative problem-solving techniques for mathematics problems overcame the negative impact of math anxiety on mathematics achievement.

Researchers argued parental math anxiety was passed along to students (Finlayson, 2014; Luttenberger et al., 2018; Maloney et al., 2015; Soni & Kumari, 2017; Vásquez-Colina et al., 2014; Vukovic et al., 2013). Maloney et al. (2015) investigated 438 children from 90 classrooms in 29 different public and private schools in three states in the Midwest. Of the participants, 185 were in Grade 1 and 253 were in Grade 2 (Maloney et al., 2015). Maloney et al. (2015) argued children of parents, defined as primary caregivers, with high math anxiety learned less math and had more math anxiety by the end of the school year when parents provided frequent help with math homework.

Students also developed math anxiety when they noticed their teacher did not like math (Finlayson, 2014; Vukovic et al., 2013), they felt their teacher did not want to teach math (Finlayson, 2014; Vukovic et al., 2013), they felt their teacher did not understand mathematics (Vukovic et al., 2013), or they were afraid to ask questions (Finlayson, 2014). Some students reported a decrease in math anxiety just knowing someone was available to help them when needed (Finlayson, 2014).

Student Math Self-Efficacy and Attitude toward Learning Mathematics

Student attitudes toward learning math developed in early education (Musu-Gillette et al, 2015; Wang, 2013) and impacted various measurements of success in mathematics (Al-Mutawah & Fateel, 2018; Finlayson, 2014; Soni & Kumari, 2017; Wang, 2013). For instance, Soni and Kumari (2017) stated, “Children’s attitude toward mathematics also has a profound influence on their math performance” (p. 334). Researchers agreed student attitude toward learning math influenced math achievement (Al-Mutawah & Fateel, 2018; Finlayson, 2014; Soni & Kumari, 2017; Wang, 2013). Wang (2013) summarized research findings as follows:

> Exerting the largest impact on STEM entrance, intent to major in STEM is directly affected by 12th-grade math achievement, exposure to math and

science courses, and math self-efficacy beliefs—all three subject to the influence of early achievement in and attitudes toward math. (p. 1081)

Further, Wang (2013) claimed, “Not enough attention has been paid to factors relevant to interest in and entrance into STEM fields, which are arguably the first critical steps into the STEM pipeline” (p. 1083). Other researchers agreed student motivation in mathematics was connected to student achievement in mathematics (Brandenberger et al., 2018). Al-Mutawah and Fateel (2018) argued student grit and the level at which students valued mathematics were also related to student achievement. Likewise, Musu-Gillette et al. (2015) conducted a study about whether students valued mathematics and self-concept of ability. Thus, these factors needed to be addressed to increase student success in mathematics, and in turn, increase the number of STEM majors. These factors needed to be explored prior to students entering high school since math self-efficacy, as well as how much students valued learning mathematics, developed during elementary school (Musu-Gillette et al, 2015).

Vásquez-Colina et al. (2014) argued both teachers and parents contributed to the development of positive dispositions toward math. Soni and Kumari (2017) studied 595 students ranging in ages from 10-15 years along with one parent of each student in India. Soni and Kumari (2017) utilized the following instruments to measure variables: the Mathematics Anxiety Scale Short Version, the Mathematics Anxiety Scale for Elementary Students, the Mathematics Anxiety Rating Scale for Adolescents, and the Attitude Towards Mathematics Inventory. Soni and Kumari (2017) concluded the following: parental math anxiety was positively correlated to children’s math anxiety ($r = 0.91$, $p < .001$); parental math anxiety was negatively correlated to children's math attitude (r = -0.76, $p < .001$); parental math attitude was negatively correlated to children's math anxiety (r = 0.78, $p < .001$); and parental math attitude was positively correlated to children's math attitude (r = 0.87, $p < .001$) (p. 340). Likewise, Simpkins et al. (2012) concluded a mother's attitude toward studying math was transferred to her children, and Geist (2015) stated parents and teachers passed personal feelings about mathematics to their children and students, respectively. Thus, parents were key components of student math anxiety.

Musu-Gillette et al. (2015) focused on students' self-conceptions rather than the way students learned mathematics. Math self-efficacy beliefs and positive attitudes toward mathematics were factors in students' decisions to pursue math-intensive degrees, such as STEM majors, at the college level (Marksbury, 2017; Musu-Gillette et al., 2015; Petersen & Hyde, 2017; Pyzdrowski et al., 2013; Wang, 2013). Pyzdrowski et al. (2013) studied 107 students enrolled in Calculus I as part of a first-year engineering retention program at a university in the northeast United States and identified a strong positive correlation between math self-confidence and course performance. Pyzdrowski et al. (2013) identified the strongest positive correlation of their study between positive attitudes toward learning mathematics and successful course performance in an entry-level college calculus course. Wright (2017) also encouraged educators to focus on student attitudes toward learning math. Thus, the need for positive math self-efficacy was present from elementary school through college. In short, all stakeholders needed to encourage a positive attitude toward learning math and positive math self-efficacy beliefs from the time students were in elementary school to empower students to pursue higher level math courses and possibly STEM degrees.

Plenty and Heubeck (2013) argued students became less motivated to study math, in comparison with other subjects, early in high school. Furthermore, Brandenberger et al. (2018) reported there was a “significant negative trend in academic self-determined motivation across childhood through adolescence and more so in maths than in any other school subject” (p. 295). Brandenberger et al. (2018) argued the negative trend in motivation in mathematics was especially true for students identified as low-performing. Likewise, Petersen and Hyde (2017) argued the development of positive math self-efficacy was important prior to high school. Petersen and Hyde (2017) also concluded self-perceived math utility value declined throughout middle school and further claimed, “Declines in self-perceived math ability from 5th to 9th grade were associated with lower math performance in high school” (p. 453).

Petersen and Hyde (2017) stated, “Teachers, parents and researchers must work to discover the causes of the decline in math motivation across middle school in order to give students an opportunity to be competitive in STEM careers” (p. 453). Brandenberger et al. (2018) conducted quasi-experimental design research to study 348 Swiss Grade 7 math students as part of the *Maintaining and Fostering Students’ Positive Learning Emotions and Learning Motivations in Math Instruction during Adolescence* study. Brandenberger et al. (2018) used two experimental groups in the study—one group that was student only and another group that was a combined student and teacher group—as well as a control group. Participants in the experimental groups participated in an intervention program, a program which was based on self-determination theory, the concept of self-regulation, and students' emotions in regard to mathematics, aimed at increasing student motivation in mathematics (Brandenberger et al., 2018). Participants in the control group exhibited no significant changes, but participants in both experimental groups exhibited significant changes (Brandenberger et al., 2018). The student only group showed a decrease in motivation while the student and teacher combined group resulted in an increase in motivation (Brandenberger et al., 2018). Thus, teachers needed to be members of learning groups to increase student motivation.

Teacher Attitude toward Learning and Teaching Mathematics

In addition to student attitudes toward learning mathematics, teacher attitudes also played a role in mathematics instruction (Geist, 2015; Jong & Hodges, 2015). Jong and Hodges (2015) studied the attitudes of 146 prospective elementary teachers enrolled in three teacher preparation programs at different universities in the Eastern United States. Jong and Hodges (2015) conducted the Mathematics Experiences and Conceptions Surveys (MECS) four times as prospective elementary teachers progressed through their respective programs of study to examine how their attitudes evolved, but findings of the study only included results of the first three MECS, since Jong and Hodges (2015) focused this study on only prospective teachers, and the final survey was conducted after teachers taught full-time. Prospective teachers completed surveys at the following times: during the first week of the mathematics methods coursework, during the final week of the mathematics methods coursework, upon completion of student teaching, and upon completion of the first year of full-time teaching. Jong and

Hodges (2015) focused what they referred to as *attitude items of the survey* on how participants felt and thought about mathematics, specifically prospective teachers' enjoyment of mathematics and their view of mathematics as worthwhile for themselves and their students. Prospective teachers reported similar baseline results on the first MECS, including 39% of the participants reporting relatively negative attitudes toward teaching and learning mathematics (Jong & Hodges, 2015, p. 421). Similarly, Geist (2015) claimed many early education teachers did not like mathematics and noted math anxiety was especially prevalent among early education teachers.

The greatest impact on reducing negative attitudes of prospective teachers toward mathematics was enrollment in pedagogical courses which focused on conceptual understanding (Jong & Hodges, 2015). Guberman and Leikin (2013) reiterated as prospective teachers developed problem-solving expertise on multiple-solution tasks, their attitudes shifted from negative to positive. Guberman and Leikin (2013) further argued prospective math teachers solving multiple-solutions tasks in a problem-solving course developed mathematical connections, shifted from trial-and-error strategies toward systematic strategies to solve problems, developed mathematical fluency, and developed the ability to create multiple solutions to solve a problem. Thus, Jong and Hodges (2015) suggested prospective teachers, especially those with negative attitudes toward teaching and learning mathematics, may benefit from deepening content knowledge. This deepened mathematics content knowledge and mathematical connections led to a conceptual understanding of mathematics. In addition to developing a better attitude toward mathematics, Guberman and Leikin (2013) argued completing the multiple-solution problem-solving course increased the prospective teachers' ability to mediate problem-solving discussions in mathematics classrooms. Guberman and Leikin's (2013) claim supported the argument that teachers who developed the ability to discern between procedural mathematics and conceptual mathematics were better equipped to mediate math discussions in class as they gained a conceptual understanding of mathematics. Students also expressed the importance of teachers who believed in them and told them they could be successful at mathematics (Finlayson, 2014). Jamil et al. (2018) contended teacher expectations have lasting effects on elementary student achievement up to three years after a student leaves a class.

Recommendations for Change in the Mathematics Classroom

The NMAP (2008) stated the mathematics education system in the United States "is broken and must be fixed" (p. 11). In 2000, NCTM recommended a coherent, well-articulated, across grades curriculum for mathematics. The NMAP (2008) identified six elements to change to strengthen mathematical skills among Americans, of which four elements were at the classroom level. The NMAP first recommended streamlining a set of well-defined critical topics of study for students in Pre-K to Grade 8 (NMAP, 2008). In 2009, state leaders launched the Common Core State Standards Initiative (CCSSI) to develop the Common Core State Standards for Mathematics (CCSSM) for Grade K through Grade 12, released in June 2010 (CCSSI, 2019). In the United States, 41 states voluntarily adopted the CCSSM as of 2019; nine states had not adopted CCSSM in 2019: Alaska, Texas, Oklahoma, Nebraska, Indiana, Virginia, South Carolina, Florida, and Minnesota (CCSSI, 2019).

The second recommendation of the NMAP (2008) was for educators to use research about how children learned with a specific focus on advantages of students to have a strong start, an adequate balance of conceptual understanding, procedural fluency, and quick recall of basic math facts; effort, rather than inherent mathematical talent, produced mathematical achievement. Welder (2012) also recommended a strong start in mathematics and argued elementary and middle school teachers "may not teach formal algebra, but they are responsible for building a solid foundation of prerequisite algebra knowledge" (p. 256). Gunderson et al. (2017) conducted a study of 523 students from Grade 1 to college to explore their individual implicit theories of intelligence about math ability in comparison to reading and writing ability. Gunderson et al. (2017) examined two theories of intelligence regarding mathematical ability as well as reading ability and writing ability. The first theory, entity theory, was math ability was fixed and unchangeable for everyone. The second theory, incremental theory, was math ability was malleable and could be improved with effort. Gunderson et al. (2017) found reading ability and writing ability had no significant impact on achievement, but math ability impacted motivation and achievement by the time students were in high school. Further, Gunderson et al. (2017) argued theories of intelligence developed early in children but only manifested in high school and college-aged students as these students believed math ability was fixed and unchangeable. Gunderson et al. (2017) claimed adopting and promoting incremental theory, while abandoning entity theory, in mathematics early in education may improve students' motivation and achievement in math in later years.

In addition to NMAP's recommendation, multiple researchers reiterated the need for instructional balance of conceptual mathematics and procedural mathematics (Boston, 2013; Latterell & Wilson, 2016; NMAP, 2008; Selling, 2016). Selling (2016) cautioned teachers to be watchful for prescriptive (or procedural only) instruction, especially when explicitly teaching mathematical practices. One complaint among prospective high school math teachers was they remembered personal experiences with ineffective teachers who failed to explain mathematics conceptually and instead taught numerous *short cuts* for solving problems (Latterell & Wilson, 2016). Soni and Kumari (2017) encouraged teachers to incorporate real-world examples into mathematics instruction to help students make connections between mathematical concepts and real-life applications.

The third recommendation by the NMAP (2008) was for people in leadership positions to develop initiatives that not only attracted and prepared prospective teachers with strong content knowledge but also evaluated teachers effectively and strived to retain effective teachers. Curtis (2012) reported nearly 50% of new teachers left the teaching profession within the first five years (p. 781), and Latterell and Wilson (2016) claimed it was difficult to recruit and retain mathematics teachers. Chapman (2015) contended mathematical content knowledge of teachers was an *ongoing concern* in math education research. Chapman (2015) further argued teachers' mathematics "knowledge is essential to engage students in meaningful and effective mathematical experiences in the classroom in order to construct deep understanding of mathematics" (p. 313).

Researchers recommended teachers and prospective teachers develop strong mathematical content knowledge (Bartell et al., 2013; Cheng & Hsu, 2017; Thanheiser et al., 2014; Welder, 2012). Thanheiser et al. (2014) identified a need for teachers to have a *deep and multifaceted* understanding of mathematics, especially the mathematics they teach. Welder (2012) argued elementary and middle school teachers needed a *deeper and more flexible* understanding of mathematics. The National Council on Teacher Quality urged prospective elementary teachers to take a minimum of nine credit hours of mathematics content courses (Greenberg & Walsh, 2008). Bartell et al. (2013) encouraged people in charge of mathematics teacher education programs to require prospective teachers to complete a pre-requisite amount of mathematics content knowledge prior to prospective teachers analyzing children's mathematical understanding. Cheng and Hsu (2017) further recommended the United States require mathematics teachers to major in mathematics as an indicator of possessing "more profound mathematical knowledge and skills necessary for teaching so they can help the students learn math better" (p. 128).

For its fourth recommendation, the NMAP (2008) suggested instruction not be limited exclusively to *teacher-directed* or *student-centered* since different teaching practices could result in a positive impact under varying circumstances. Boston (2013) also argued a mixed methods approach facilitated connections between experiences and gains in mathematical knowledge. In 2014, Gaddy et al. (2014) recommended teachers center instructional adjustments on key components, which the researchers identified as focus, coherence, and rigor as teachers were attempting to implement the CCSSM, since the CCSSM creators used these components as design principles; therefore, teachers needed strong mathematics content knowledge, or conceptual mathematics, to help students develop coherence.

NCTM (2000) identified six principles for school mathematics: equity, curriculum, teaching, learning, assessment, and technology. The first four principles applied entirely at the classroom level. NCTM (2013) defined equity as included high expectations as well as strong support for all mathematics students and curriculum as "more than a collection of activities: it must be coherent, focused on important mathematics, and well-articulated across the grades" (p. 14). NCTM (2000) defined effective teaching as "understanding what students know and need to learn and then challenging and supporting them to learn it well" (p. 16). NCTM (2000) argued, "Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" (p. 20). In summary, this described a constructivist approach to teaching mathematics, which emphasized conceptual mathematics. In 2013, NCTM stated they supported the CCSSM as long as the standards were implemented properly. NCTM's (2014) *Principles to Actions: Ensuring Mathematical Success for All* updated the six principles for school mathematics to: teaching and learning, access and equity, curriculum, tools and technology, assessment, and professionalism (NCTM, 2014).

Brahier et al. (2014) contended the CCSSM did not "tell teachers, coaches, administrators, or policymakers what to do at the classroom, school, and district levels or how to begin making essential changes to implement these standards" (p. 656). Brahier et al. (2014) further argued NCTM's provided "direction in filling the gap between the adoption of the CCSSM and the enactment of policies and programs required for its widespread and successful implementation" (p. 656). NCTM (2014) recommended eight mathematics teaching practices:

1. Establish mathematics goals to focus learning;
2. Implement tasks that promote reasoning and problem solving;
3. Use and connect mathematical representations;
4. Facilitate meaningful mathematical discourse;
5. Pose purposeful questions;
6. Build procedural fluency from conceptual understanding;
7. Support productive struggle in learning mathematics; and
8. Elicit and use evidence of student thinking. (p. 10)

These teaching practices were aligned with an emphasis on conceptual mathematics combined with some procedural mathematics.

Previous researchers studied student factors of success in mathematics in regard to age. Gunderson et al. (2017) argued students' ideas of self-relevance in math became more evident in adolescence. Gottfried et al. (2013), as part of a 20-year longitudinal study, investigated the math intrinsic motivation and math achievement of 114 participants, ages 9-17, who were assessed annually using a comprehensive battery of standardized measures at a university laboratory. Gottfried et al. (2013) assessed math intrinsic motivation using the 26-item math subscale of the Children's Academic Intrinsic Motivation Inventory. Participants later completed surveys at 24 and 29 years of age. The mean scores of participants on the math intrinsic motivation assessment from age 9 to age 17 declined continuously from 100.22 at age 9 to 85.43 at age 17 (Gottfried et al., 2013). The mean scores of participants on the math achievement assessment from age 9 to age 11 increased from 64.02 to 88.29, but from age 11 to age 17 decreased continuously from 88.29 to 64.83 (Gottfried et al., 2013).

Gottfried et al. (2013) concluded math intrinsic motivation generally declined until leveling at age 16 and argued there was “an urgent need to prevent students’ lack of math intrinsic motivation and achievement before eighth grade” (p. 84); the study supported “the need to stimulate math intrinsic motivation and achievement in STEM academic areas in childhood to provide early roots for entry into STEM-related careers” (Gottfried et al., 2013, p. 86). Williams et al. (2016) encouraged teachers to address students’ math achievement challenges prior to high school and implement “critical interventions early in students’ educational careers that address their academic challenges, capitalize on their multilevel strengths and prepare them for future STEM pathways” (p. 380). Similarly, Wang (2013) argued factors that impacted the choice to enter a STEM degree program depended on the influence of early mathematics achievement and positive attitudes toward math. Hence, there was a need for early intervention to increase the number of STEM majors.

Resistance to Implement Recommendations in Mathematics Classrooms

The tendency of teachers to teach as they had learned or had been taught during youth was problematic when faced with recommendations for change (Litke, 2015; Wright, 2017). The Conference Board of the Mathematical Sciences (2001) referred to this phenomenon as a *vicious cycle* and claimed many prospective teachers entered college with insufficient math understanding, experienced little instruction on mathematics they would later teach, and entered classrooms inadequately prepared to teach mathematics. For example, Litke (2015) concluded algebra classrooms “in this sample in 2010 bear a striking resemblance to algebra classrooms in 1990 (and to the algebra classrooms of 1970)” (p. 6). Though a need for reform was documented, as well as mandated, change in mathematics instruction processes failed to occur (Litke, 2015; Wright, 2017). Litke (2015) summarized the lessons as largely teacher led and “despite decades of reform efforts by the mathematics education community, little engagement in highly cognitive demanding tasks, (productive) mathematical struggle, or mathematical discourse” (p. 6) was present in the lessons.

Similarly, O`Meara et al. (2017) argued, “Rote learning and an emphasis on procedural skills at the expense of conceptual understanding results in a cycle of ineffective teaching which is difficult to break” (p. 91). Masingila et al. (2012) argued only 28.9% of course supervisors of undergraduate mathematics content courses for elementary teachers among 1,926 institutions had elementary school teaching experience. Thus, researchers concluded prospective teachers were encouraged to teach in ways they never experienced by the time they entered the classroom (Chapman & An, 2017; Masingila et al., 2012). Chapman and An (2017) argued, “An important aspect of mathematics education research continues to be addressing meaningful ways to effectively support mathematics teachers’ learning and change” (p. 171).

Gill and Boote (2012) studied a Grade 8 math teacher who embraced reform as she attempted to follow recommendations made by the NCTM, which included a deep understanding of problem-solving. Gill and Boote (2012) stated the teacher exhibited inconsistent teaching methods, and in approximately 88% of observed 75-minute classes, students completed a warm-up of problem-solving or mental math as the teacher recorded homework grades based entirely on completion for the first 15-20 minutes, the teacher reviewed previous homework for 20 minutes, the teacher provided 20 minutes of direct instruction, and students worked on homework for the remainder of the class. Thus, Gill and Boote (2012) concluded the teacher had not implemented change effectively. In addition to teacher reluctance to change, parents were also reluctant to change (Maloney et al., 2015). Maloney et al. (2015) argued when teachers taught new math strategies that differed from the way parents were taught, parents insisted their children use the strategies the parents were taught when they learned mathematics, which lead to student confusion, thus resisting the new recommendations for change in math instruction.

Curtis (2012) contended high teacher turnover inhibited reform implementation in mathematics classrooms. In addition to ineffective teaching in the classroom, the shortage of mathematics and science teachers, alongside high teacher turnover, hindered student achievement (Curtis, 2012). The nonprofit National Science Resource Center began directing programs in the early 1990s to address two problems—uninspired instruction and poorly trained teachers (Mervis, 2008), which indicated these were not new issues for math education.

Summary of the Review of Literature

Of the four components of STEM, a lack of success in mathematics was the component which most often led students to choose non-STEM majors in college (Wang, 2013); therefore, it was important to identify the barriers of learning mathematics as well as the recommended changes for mathematics instruction. Students needed to overcome these barriers in mathematics to increase the number of STEM graduates. One focus of this study was to determine which of the most commonly teacher-identified barriers to students learning mathematics affected students in classrooms. A second focus of this study was to determine which recommendations for change were reported by teachers in math classrooms. Mathematics instruction limited to procedural mathematics often resulted in students with weak foundations in mathematics (Heyd-Metzuyanim, 2015). Thus, the third focus of this study was to determine how teachers described they taught mathematics, specifically, more procedurally, more conceptually, or equally procedural and conceptual in mathematics classrooms.

In Chapter III, I included a description of the methodology used in this study, as well as rationale for the chosen methodology. I described my plan for investigating the relationship between teacher-reported procedural mathematics and conceptual mathematics in classrooms. I also described the process of comparing and contrasting the literature-based barriers to learning mathematics identified in this review of literature to the teacher-perceived barriers to learning identified in this study. I summarized my plan for investigating teacher-reported implementation of recommendations for changes in the mathematics classroom and the resistance to change in classrooms. Additionally, in Chapter III, I described all aspects of this qualitative study including the design of the study, sample description, study instruments, and the data collection process.

Chapter III: Methodology

I used the SCCT as the theoretical lens to study teachers' perceptions of barriers to math achievement below Grade 10, if any; to determine which, if any, of the identified barriers teachers reported; and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. In this chapter, I described the methods used to identify instructional practices, barriers to learning mathematics, changes implemented, and teacher-reported evidence of resistance to change. To fill the gap in research examining the implementation of literature-based recommended changes in mathematics classrooms, I examined and compared the teacher-reported teaching practices to the literature-based recommended changes in the mathematics classroom of students studying mathematics prior to high school.

Research Design

For this study, I selected a basic interpretive study research design which Meriam and Tisdell (2016) referred to as a basic qualitative study. A qualitative approach typically involved observing a natural setting (Creswell, 2014), but I had to abandon classroom observations as originally planned due to the COVID-19 pandemic which caused the closure of schools. I determined a qualitative research approach provided me the best opportunity to gather data via questionnaires from teachers of mathematics in elementary and middle schools. According to Creswell (2014), qualitative research involved open-ended questions, such as the questions I developed for this study. This study also allowed for the discovery of additional factors which were not found in extant literature, only possible using a qualitative approach.

According to Merriam and Tisdell (2016), for a basic interpretive study (i.e., basic qualitative study), the researcher was interested in understanding a phenomenon and its impact on those involved. The basic interpretive research design fit this study well since I centered this study around elementary and middle school mathematics teachers with an underlying interest of how students developed mathematically and how students eventually developed career interests in response to mathematics. I determined this research design also allowed participants to be from a widespread area. Merriam and Tisdell (2016) argued the researcher in this type of study "would be interested in (1) how people interpret their experiences, (2) how they construct their worlds, and (3) what meaning they attribute to their experiences" (p. 24). All three of these characteristics were evident in this study when considering students and teachers in response to mathematics instruction. Merriam and Tisdell (2016) summarized the overall interpretation of a study was the *researcher's understanding of the participants' understanding of the phenomenon of interest*. In this study, the phenomenon of interest was mathematics instruction prior to high school.

Participants of the Study

I selected teachers from Grade 4 to Grade 8, inclusively, for the study sample. I used criterion-based, non-probability sampling since nonprobability sampling was the *method of choice* for qualitative research according to Merriam and Tisdell (2016). I solicited participants for this study via Facebook from elementary and middle school teachers who regularly taught mathematics to at least one class per day to students between Grade 4 and Grade 8 inclusively. I received 22 completed questionnaires via Google Forms, but study participants consisted of 19 teachers. Two participants submitted duplicate questionnaires, so I included only one response from each participant in the study. I verified duplicate responses were exact replications, including e-mail addresses, prior to excluding the duplicate forms. I decided to exclude one questionnaire from the study because the potential participant responded they taught only Grade 3, which indicated the participant did not meet the criteria to be included in this study.

Data Collection

I solicited teachers for the study via Facebook to follow the rules of social distancing mandated in response to the COVID-19 pandemic. I sought teachers who served students predominately below Grade 10 but preferably between Grade 4 and Grade 8 inclusively. I based this decision on the extant literature which indicated changes were needed in mathematics instruction prior to Grade 10 to increase the number of STEM degree-seeking students (Wang, 2013). I sought teachers who taught mathematics regularly at least once per day since the content focus of this research was mathematics. I developed an announcement (see Appendix A) presenting the study, which included links to the teacher questionnaire (see Appendix B) in Google Forms. I posted the announcement on Facebook, a social media platform. Due to an initial slow response rate from teachers, I used snowball sampling to increase the questionnaire response rate. According to Merriam and Tisdell (2016), snowball sampling was also known as chain sampling or network sampling. I reached participants via e-mail and requested participants to share the e-mail address of potential participants with me. I chose this type of purposeful sampling for this study, in addition to the original criterion-based sampling, to increase the number of potential participants.

In Question 1 for the teachers, I asked about the education level of each teacher to potentially make a connection between the education level of the teacher and their responses, so Question 1 was not aimed at answering a specific research question. I designed Question 2 with the intention of comparing results between grade levels, especially if differences emerged in the data. Question 2 was also not specifically aimed at answering a specific research question.

I designed Questions 3 and 4 to study the instructional practices instinctive to teachers as they initially planned lessons, specifically with the intention to look for cues of conceptual or procedural instructional practices and teacher-reported evidence of implementation of recommended changes. These two questions were intended to address Research Question 1 about procedural and conceptual instructional practices and Research Question 3 about recommended changes in mathematics instruction. I designed Questions 5 through 13 to gather data about teacher-perceived barriers to learning mathematics, which pertained to Research Question 2. Question 14 was about comparing how teachers were taught mathematics when they were in school to how they taught mathematics at the time of this study, which was aimed toward Research Question 3 about recommended changes as well as evidence of resistance to change in mathematics instruction. The final question, Question 15, pertained to complex problem solving and was designed to look for possible barriers to learning mathematics to address Research Question 2 as well as evidence of literature-based recommendations for change to address Research Question 3.

I decided a specific method for determining if a lesson was taught more procedurally or more conceptually was needed prior to collecting data. This decision was based on Merriam and Tisdell's (2016) claim, "Qualitative inquiry, which focuses on meaning in context, requires a data collection instrument that is sensitive to underlying meaning when gathering and interpreting data" (p. 2). I compared responses to the indicators of teaching conceptual mathematics or procedural mathematics as determined by Cheng and Hsu (2017). I collected all data from teachers in the spring of 2020.

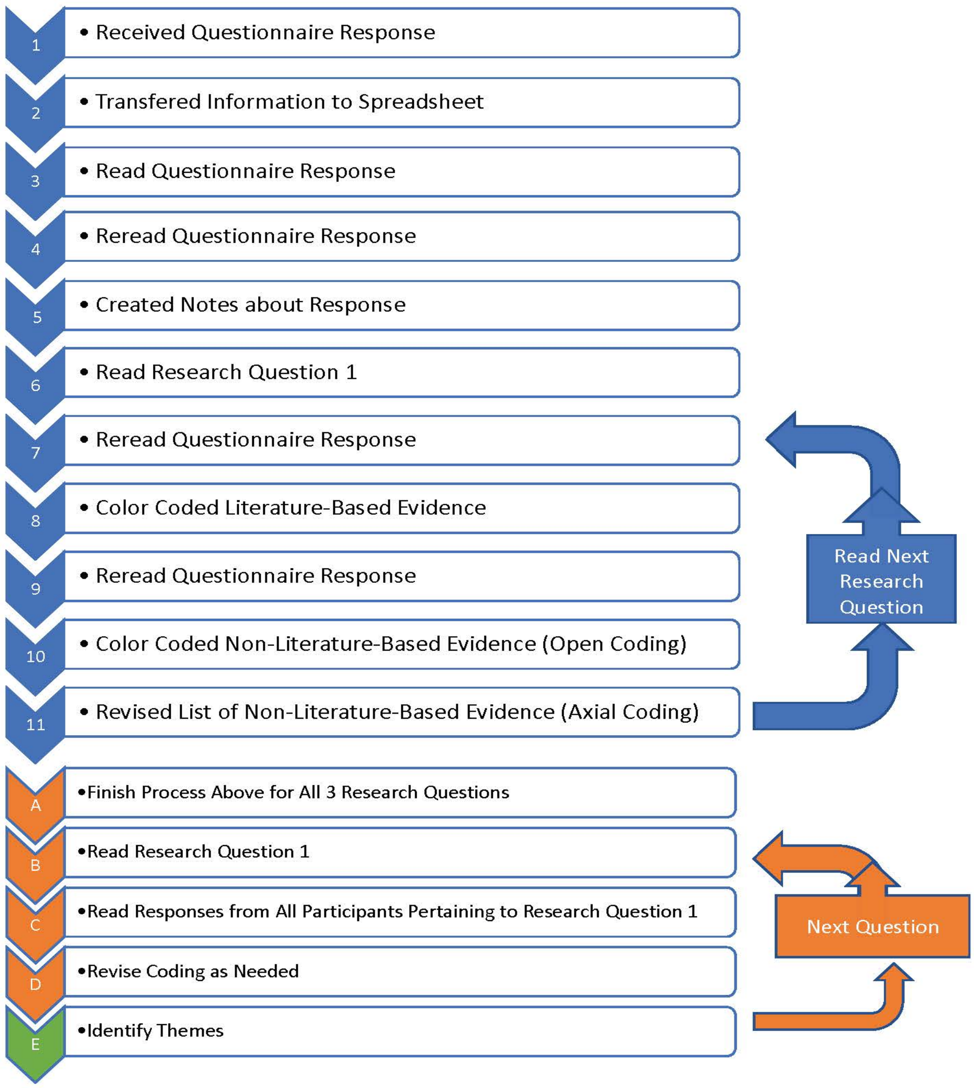
After I developed initial questionnaires for teachers, I arranged a pilot test for the questionnaire with two mathematics teachers and one administrator. According to Merriam and Tisdell (2016), pilot tests were crucial components of a good interview. As a result of the pilot test, some questions from the original draft of the questionnaires were deleted as they were deemed redundant. Additionally, two questions on the teacher questionnaire were reworded for clarification. A few questions from the original draft were also deleted because the responses from the pilot test offered no evidence of answering the research questions of this study. One question was also added to the teacher questionnaire at the recommendation of my dissertation committee. I described the final version of the teacher questionnaire in previous paragraphs.

Analytical Methods

The data analysis process started when I received the first questionnaire response (see Figure 1).

Figure 1

Data Analysis Process



I hand coded all questionnaire responses to identify common themes. Based on Creswell's (2014) suggestion, a researcher determined whether a study was best investigated using emerging codes only, predetermined codes only, or a combination of emerging and predetermined codes. For this study, I used a combination of predetermined and emerging codes to analyze the data since I compared data to themes from extant literature as well as identified new themes, if any. This open coding of data, as referred to by Merriam and Tisdell (2016), allowed me to identify additional teacher-perceived barriers to students learning mathematics, if any, or teacher-reported evidence of resistance to change beyond the predetermined literature-based themes.

Merriam and Tisdell (2016) stressed the importance of analyzing data in a qualitative study simultaneously with data collection; therefore, I compared each questionnaire response to predetermined codes based on extant literature immediately following collection. Additionally, I searched data for emerging codes after each successive questionnaire response, revisiting previous data. Merriam and Tisdell (2016) argued coding in this manner was needed to assure information from earlier interviews was not forgotten by the researcher. The view of the participants was the key focus of coding whether themes aligned with extant literature or not. Merriam and Tisdell (2016) encouraged ongoing analysis during the data collection process and stated data analyzed as it was collected was both parsimonious and illuminating.

After open coding the data, I refined the category scheme using axial coding as described by Merriam and Tisdell (2016). As such, I grouped open codes into related categories. I continuously refined coding related categories until overall themes emerged. As themes emerged in the data, I considered whether additional data would result in new information or additional data would likely result in the same themes. According to Merriam and Tisdell (2016), "Saturation occurs when continued data collection produces no new information or insights into the phenomenon you are studying" (p. 199). Once I determined new data would likely result in the same themes, saturation was achieved and, therefore, evidence was sufficient to accurately and conclusively identify themes of the study. At the point of saturation, I determined data collection needed for this study was complete and summarized findings of the study.

Trustworthiness in Research

Merriam and Tisdell (2016) stressed three components of strong qualitative research. The first component was the importance to “understand the perspectives of those involved in the phenomenon of interest” (Merriam & Tisdell, 2016, p. 244). I worked diligently to accurately capture the perspectives of teachers as they applied to students studying mathematics in elementary and middle grades. The second component was to “uncover the complexity of human behavior in a contextual framework” (Merriam & Tisdell, 2016, p. 244). In this study, I examined teacher-reported instructional practices, recommendations for changes, and teacher-reported barriers to learning in regard to learning mathematics as a major component of STEM preparation. I closely considered how these human behavior factors in the study impacted the long-term decision of selecting or not selecting a STEM major in college based on participant interaction with mathematics. The third component was to present a holistic interpretation (Merriam & Tisdell, 2016) of what happened. To meet this requirement, I analyzed each questionnaire response as a whole to consider the overall general description of the students and the literature-based attributes of STEM majors they possessed or lacked.

Merriam and Tisdell (2016) suggested two strategies to ensure internal validity and credibility that applied to this study. The first strategy was triangulation. Merriam and Tisdell (2016) identified triangulation as the best-known strategy to build internal validity of a study. I originally planned this study to include interviews, classroom observations, and document reviews with the intention of having multiple data sources to achieve triangulation. I had to abandon that plan when schools were closed in response to the COVID-19 pandemic; therefore, to have triangulation in this study, I used a less common approach to achieve triangulation, according to Merriam and Tisdell (2016), which they referred to as using multiple theories to analyze data. To achieve triangulation, I analyzed data multiple times using multiple hypotheses. For example, I first analyzed each questionnaire response looking for evidence of teacher-reported literature-based recommendations for change. Then, I analyzed each questionnaire response individually and as a complete data set as I received each additional questionnaire response. I used the same process to analyze data for evidence that recommendations for change had not been implemented. Additionally, I analyzed data for teacher-reported evidence of literature-based barriers to achievement in mathematics; teacher-perceived, non-literature-based barriers to achievement in mathematics; and teacher-reported evidence of literature-based resistance to change.

The second suggested strategy by Merriam and Tisdell (2016) to ensure internal validity and credibility that applied to this study was for the researcher to describe the researcher's position, also called reflexivity (Merriam & Tisdell, 2016). Creswell (2014) referred to this self-reflection as reflectivity in addition to reflexivity; therefore, I described my self-identified biases, dispositions, and assumptions regarding this study in this chapter.

Limitations and Delimitations

Simon (2011) described limitations of a research study as potential weaknesses of a study that were not within the control of the researcher conducting the study. The greatest limitation of this study was teachers who identified mathematics as their least desirable subject to teach may have been less likely to participate in this study because participation in this study was voluntary. I identified this limitation as a result of Merriam and Tisdell's (2016) claim participants in research studies presented themselves in favorable ways. Thus, I found it logical that a teacher with low math self-efficacy or lacking confidence in their math teaching ability possibly opted out of participating in a study about mathematics instruction; therefore, it was possible that only teachers who felt they were seen as favorable during mathematics instruction participated in the study. Access to teachers was also a limitation of the study due to school closures due to the COVID-19 pandemic.

One suggested strategy to ensure internal validity and credibility, applicable to this study as originally designed but was lost once I modified the study in response to the COVID-19 pandemic school closures, was for the researcher to be adequately engaged in the data collection process (Merriam & Tisdell, 2016). I independently analyzed and interpreted all data, but I collected data via questionnaires. According to Merriam and Tisdell (2016), when a researcher is the primary instrument of data collection, the researcher is "closer to reality than if a data collection instrument had been interjected between [the researchers] and the participants" (pp. 243-244). It was my intent to capture the perceptions of the participants accurately, but the questionnaire was interjected between me and the participants. Since I was the sole data collector, all data were collected and analyzed using the same techniques and methods. Since the same researcher collected all data for this study, there was not an additional variable, the data collector, to consider.

Simon (2011) described delimitations as limitations of a research study that were within the control of the researcher conducting the study. According to Simon (2011), delimitations aided researchers as they set the scope and boundaries of their studies. In this study, I intentionally gathered data using questionnaire responses from participants via social media due to the COVID-19 pandemic. I originally designed this study to include classroom observations, interviews, and document reviews but abandoned the original plan when schools closed with an unforeseeable date to resume normal classes. Rather than delay gathering data, I chose to use questionnaires which could be collected while practicing social distancing as required due to the COVID-19 pandemic. I listed this as both a limitation and delimitation because I could not control school closings, but I chose to collect data via questionnaires rather than wait for schools to reopen. I made this decision because there was no way to know how long it would be before schools allowed visitors into classrooms due to social distancing guidelines that would be in place even when schools reopened to students. I determined moving forward and changing to questionnaires was the best approach under the circumstances since Merriam and Tisdell (2016) argued, "The reliability of documents and personal accounts can be assessed through various techniques of analysis and triangulation" (p. 251), and I achieved triangulation by using multiple theories to analyze data.

In changing the data collection methods of this study to a questionnaire in response to the COVID-19 pandemic school closures, I added a delimitation to the study. I delimited participants to individuals with computer access, internet access, and members of Facebook. Individuals without a computer or smart device were automatically excluded from this study. Additionally, since I shared the announcement for this study on Facebook, only members of the Facebook community were included in this study. Individuals were excluded from this study if they were not Facebook members. The announcement for this study was made public and shareable on Facebook to avoid limiting study participants to only my *Friends* in the Facebook community.

Even with the aforementioned limitations, the study was worthwhile because this study provided a snapshot of the current level of teacher-reported implementation of literature-based recommendations for change in mathematics classrooms. This study also provided a snapshot of the teacher-perceived barriers to learning mathematics, which ultimately limited students' ability and desire to pursue STEM degrees and careers. Without widespread school systems where literature-based recommendations for change were implemented, it was impossible for a researcher to determine if the recommended changes in the mathematics classrooms prior to high school yielded an increase in the number of students who earned STEM degrees or entered STEM careers.

Assumptions and Biases of the Study

I identified assumptions in the study prior to collecting data. For example, I assumed participants shared a common vocabulary and could understand the questions as written by me. I also assumed questions were interpreted in the same way by all participants. Though participants had the opportunity to request clarification via e-mail or telephone, participants may have been less likely to ask for clarification using these methods than they would have been in an interview. Since I was the sole data collector, I assumed I could be subjective while analyzing data. I also assumed I accurately interpreted questionnaire responses from participants as the participants intended during the responses.

I also identified some biases in the study, such as using predetermined questionnaires. Merriam and Tisdell (2016) argued using a highly structured interview that adhered "to predetermined questions may not allow you to access participants' perspectives and understandings of the world. Instead, you get the reactions to the investigator's preconceived notions of the world" (p. 109). Since questions were predetermined, even though I carefully worded questions through a neutral stance, I may have had preconceived notions which were undetected when developing questionnaires.

Another bias of the study was I was a high school mathematics teacher for more than 20 years. As an experienced mathematics teacher, I may be biased as to how I interpreted how teachers taught lessons, especially when teachers taught vastly differently than me. With years of experience in the classroom, I had a preconceived idea of what effective math teaching looked like.

Summary of the Chapter

I chose the methodology described in this chapter to thoroughly examine the level of implementation of teacher-reported, literature-based recommended changes in mathematics classrooms prior to high school, the utilization of teacher-reported conceptual and procedural instructional practices, and the teacher-perceived barriers to learning mathematics. I designed the methodology such that it provided the data sufficient for answering the research questions of this basic interpretive study. I summarized the analysis and findings of this study in the following chapter. Since the findings of this study were consistent with the data presented, this study would be considered dependable according to Merriam and Tisdell.

Chapter IV: Analyses and Results

I conducted this basic qualitative interpretive study in Spring 2020. Of the questionnaire responses I received, I included 19 participants in my research study. Participants of this study were teachers in the United States in Grade 4 to Grade 8 who taught mathematics to a class of students at least once per day. I used SCCT as the theoretical framework for this research study. The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. I used a basic interpretive study research design in this study. I recognized the need to consistently consider how students were impacted by the instruction from the teachers who participated in this study. The goal to increase the number of students earning STEM degrees hinged on how students developed not only math skills but also their attitudes toward math and math self-efficacy beliefs.

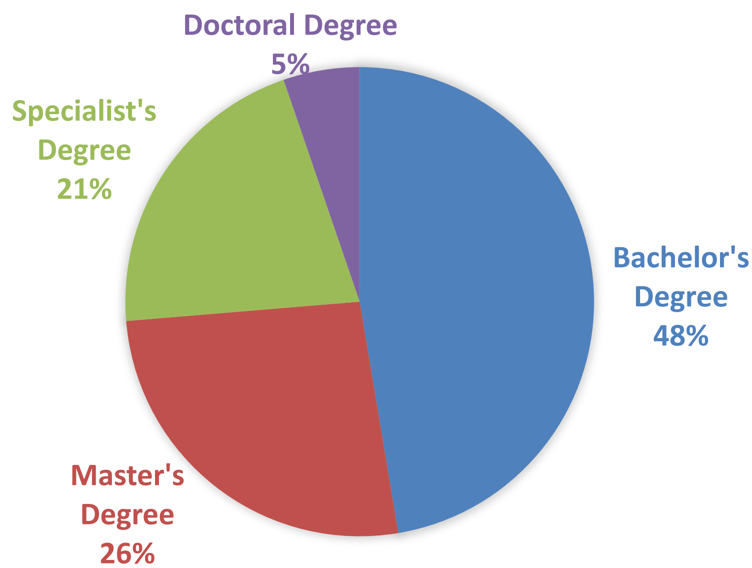
Data Analysis

I carefully analyzed each questionnaire as responses were submitted by participants via a Google Form. As themes emerged in the responses to individual questions of the questionnaire, I hand-coded the data. After analyzing 19 questionnaire responses, excluding two duplicate responses and one questionnaire response in which the respondent did not meet the criteria of the study, I determined saturation of the data was achieved.

First, I looked at the demographic information from the participants in Question 1 about education level (see Figure 2).

Figure 2

Education Level of Participants

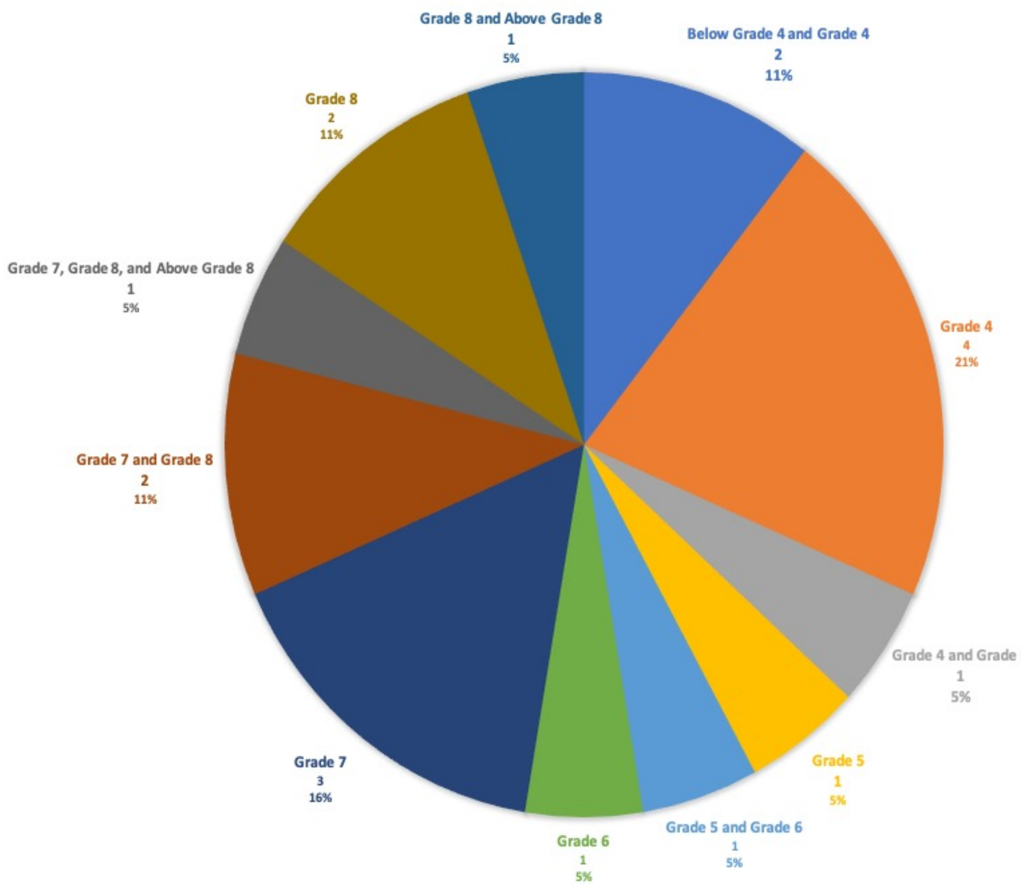


I then examined the grades taught by participants using responses from Question 2.

I included all grades taught by each participant in Figure 3 rather than limit each participant to a single represented grade since nearly 25% of the participants taught multiple grades.

Figure 3

Grade Level Taught by Participants During the 2019-2020 School Year



For example, if a teacher taught mathematics in both Grade 4 and Grade 5 in the 2019-2020 school year at least once per day, I included the participant in the category *Grade 4 and Grade 5*. Though I limited this study to teachers in Grade 4 through Grade 8, some teachers taught in one of the grades included in this study and other grades outside the scope of this study. For clarity in reporting such data, if a teacher responded they taught a grade within the scope of this study and a grade outside the scope of this study, I included the respondent as a participant, and I reported the grades taught outside the scope of this study as Below Grade 4 or Above Grade 8, as applicable.

Research Questions

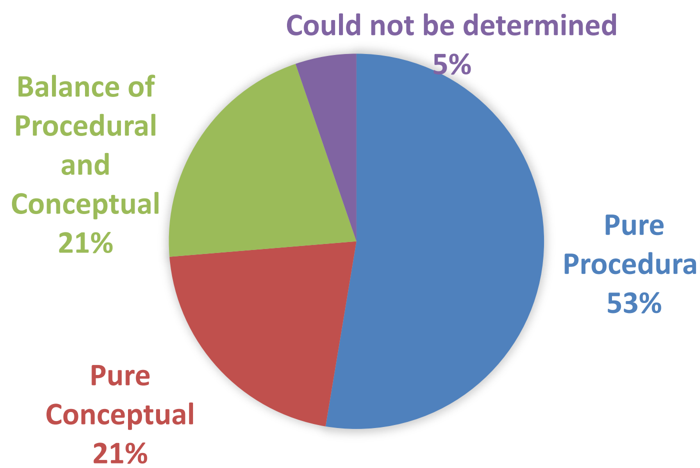
Research Question 1

How did teachers report utilizing conceptual or procedural instructional practices in elementary and middle school mathematics classrooms?

To determine whether teachers chose instructional practices that were more procedural, more conceptual, or a balance of procedural and conceptual, I asked teachers to describe the methods they used to teach students to add fractions in Question 3 of the questionnaire. Slightly more than half of the participants, 10 in total, described teaching addition of fractions using purely procedural instructional practices. Eight participants described teaching the same skill using purely conceptual instructional practices or a balance of procedural and conceptual practices. One participant's answer was vague, therefore, was not counted as any of these (see Figure 4).

Figure 4

Teacher Instructional Practices to Teach Students to Add Fractions



The data did not offer evidence that these teachers utilized of a balance of both procedural and conceptual instructional practices as recommended in extant literature when teachers described teaching adding fractions. Instead, majority of the participants described purely procedural teaching practices when teachers described teaching adding fractions. This was evidence that these participants had not reported implementation of the recommendation for change to balance procedural instruction with conceptual instruction for the skill of adding fractions.

I analyzed data collected from Question 3 and Question 4 of the questionnaire responses, particularly noting indicators of teaching conceptual mathematics or procedural mathematics. I also looked for evidence that teachers anchored math to concepts of mathematics. I transferred the information from the Google Form to an Excel spreadsheet. I read and reread the first questionnaire response when I received it. I considered the response as a whole and noted overall ideas within the response on paper. Then, I read Research Question 1, and reread the response to look for evidence in regard to Research Question 1. I specifically looked for evidence of procedural instruction or procedural understanding, such as a list of steps to get the correct answer without understanding the mathematical concepts. I also specifically looked for evidence of conceptual instruction or conceptual understanding, such as describing mathematical concepts, noting relationships between mathematical concepts, explaining the concepts behind why students performed particular steps in the problem-solving process, and evidence that the teacher expressed problem-solving concepts using multiple approaches. I color coded responses on the Excel spreadsheet as I determined they provided evidence of procedural or evidence of conceptual instruction or understanding. I repeated this process of analyzing data for each response.

I realized I needed an additional code for teachers who described an instructional approach using a balance of procedural and conceptual instructional practices or understanding which I later added. At that time, I revisited all responses to Question 3 and Question 4 and determined which of the three categories—More Procedural, More Conceptual, or Balanced Procedurally and Conceptually—best fit each response. I intentionally included time to analyze the overall data after I received each additional questionnaire response. For example, after I analyzed each response as described above, I repeated the process of reading Research Question 1 and all collected responses as a whole data set.

I noticed similar findings as participants compared and contrasted an inch to a square inch in response to Question 4. Nine participants made no connection between the two units of measure. For example, P7 simply stated, "Relate to area and perimeter." With a slightly more elaborate comparison, P10 stated, "An inch is a unit used to measure length. Square inches are used to measure area." Similarly, P8 claimed, "Inch is a unit of measurement and [square] inch is a unit of area covered." These nine participants described a procedural practice of choosing the appropriate unit for a given measurement.

Eight participants described the relationship between a linear inch and a square inch in their responses. These eight participants specifically noted the conceptual understanding of both measurements and their relation to each other. P6 provided the clearest response with conceptual understanding when he stated the following:

> An inch is a length of measurement whereas a square inch is an area model. Students must understand that a square inch is directly related to the space it takes up on a two-dimensional plane and is comprised of the length of one inch [on] each side.

The remaining two participants described general teaching practices without comparing or contrasting the two units of measure at all. In regard to comparing and contrasting interrelated units of measurement, the data did not offer evidence that these teachers reported utilization of a balance of both procedural and conceptual instructional practices as recommended in extant literature when teachers compared and contrasted an inch and a square inch. Instead, nine participants described purely procedural comparisons of when to use each measure. This was evidence that these participants had not implemented the recommendation for change to balance procedural instruction with conceptual instruction for understanding the interrelations between units of measure.

After analyzing the questionnaire responses individually for each question about instructional practices, Question 3 and Question 4 of the questionnaire, I analyzed the data from these two questions as a combined set for each participant. For example, I analyzed the combined responses to Question 3 and Question 4 from P1. I repeated this process for each participant. By analyzing the data this way, it was more apparent if a participant was more or less procedural in responding to both questions about instructional practices. I combined the Balanced Procedurally and Conceptually group and the More Conceptual group into the same category for clarity in representing data (see Figure 5) since literature-based recommendations for change were to move away from purely procedural instruction.

Figure 5

Procedural Instructional Practice Comparison

Rather than label this combined group as less procedural group, I kept both original labels in the group title. This process also allowed for a more in-depth analysis as patterns emerged within the data. Participants clearly described instructional approaches that were much more procedural than balanced procedurally and conceptually or more conceptual.

In Figure 5, ovals represented participants whose questionnaire responses left me unsure whether they were more procedural or less procedural in one of the two instructional practice questions. No participant was labeled undecided for both questions. Only three participants avoided purely procedural practices in response to both questions. Further, four participants responded with only procedural practices for both questions; therefore, I concluded saturation had been achieved for Research Question 1. Participants in this study reported more procedural practices.

Research Question 2

What perceptions do teachers have about barriers to learning mathematics in elementary and middle school classrooms?

In Question 5 of the questionnaire, participants identified the most common teacher-perceived barriers of their students learning mathematics. As I received each response, I read Research Question 2 and reread each response as I searched for evidence of literature-based barriers to students learning math, which served as predetermined codes, specifically insufficient math instruction, weak math skills among teachers, low teacher confidence, student math anxiety, student attitude and math self-efficacy beliefs, and teacher attitude toward teaching mathematics. Using the responses in an Excel spreadsheet, I color-coded responses with evidence of literature-based barriers to students learning mathematics. Then I reread the response and used emergent coding to search for evidence of teacher-perceived, non-literature-based barriers to students learning mathematics. I color-coded each newly identified, teacher-perceived barrier on the spreadsheet. Then I reread the list of teacher-perceived, non-literature-based barriers that emerged and reanalyzed all responses received as a whole. As I continued this process, teacher-perceived barriers could be grouped together (i.e., axial coding), and themes emerged from the data.

Low student math self-efficacy beliefs and math anxiety were the only predetermined codes from literature-based barriers to students learning mathematics identified by participants in responses to Question 5. Four additional themes emerged from the responses to Question 5. These themes were students' lack of prior knowledge, students gave up quickly or would not persevere to solve math problems, parent attitude toward math, and a disconnect between math and the real-world for students. One example of a response I coded Disconnect Between Math and Real World from P12 said:

> Students do not associate numbers with concrete ideas. They have a hard time recognizing that the number 3, for example, is an amount of 3 somethings. Instead it's just a concept in their mind and therefore they struggle with even simple math.

Seven participants responded students' lack of prior mathematical knowledge was a teacher-perceived barrier to learning mathematics, which made it the most common response. Four participants responded a lack of student resilience to persevere with math problems to find solutions such as students gave up quickly. Three participants responded parent attitude toward math was often passed on to students or increased math anxiety for students. Three participants responded there was a disconnect between math and the real world for students. As I analyzed the data from additional questions from the questionnaire responses, other literature-based barriers to students learning mathematics became apparent.

I continued using the process described above as I analyzed data for Question 3 through Question 13 collectively. I repeated the process of using predetermined codes I found in extant literature and using emergent coding practices of open coding to axial coding to developing themes as I analyzed the remainder of the questionnaire responses. The first two themes were participants were confident in teaching mathematics and had low teacher math anxiety. I also noted when I analyzed question responses in a group in addition to analyzing each response individually and as a whole including all previous responses. For example, I utilized the analysis process I described in this paragraph for collectively analyzing responses to Question 3 through Question 13 above to have a more robust analysis of the data.

Although I identified low teacher confidence as a literature-based barrier to students learning mathematics, 15 of the 19 participants described their level of self-confidence in teaching mathematics compared to other content areas as high in response to Question 6. Only one participant described his level of self-confidence in teaching mathematics as below average: P5 described his confidence level as *very low* in teaching mathematics.

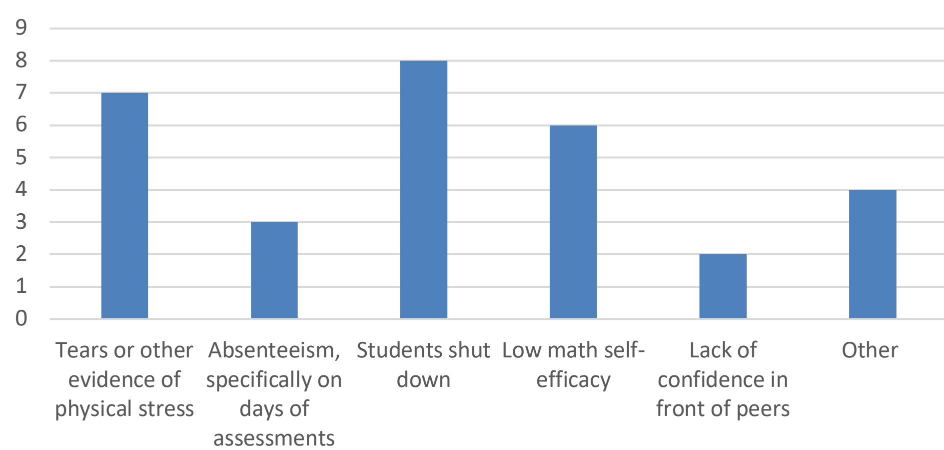
I also asked participants to describe their level of self-confidence in their overall ability to solve challenging math problems in real-life in Question 7. Overall, 13 of the 19 participants described their level of self-confidence in their ability to solve challenging math problems in real-life as high. Only one participant responded his self-confidence to solve challenging math problems was questionable. P4 wrote, "I feel confident in 4th grade level questions . . . but, anything past that I may be a little foggy on." Yet, only 11 of the 19 participants reported their self-confidence in their overall ability to teach Algebra was high in response to Question 8. Four participants described their level of self-confidence to teach Algebra as below average. Of the four participants who described their level of self-confidence to teach Algebra as low, two participants indicated they thought they could teach Algebra after completing a refresher course and one participant described his self-confidence to teach Algebra as *very, very low*.

In response to question 9 about anxiety level while preparing to teach and teaching math, only two participants reported they had anxiety above a low level. Both of these participants expressed their anxiety level depended on the topic they were teaching and stated some topics created high anxiety. One of these participants did not elaborate on specific topics which caused anxiety, but P12 explained his anxiety increased when he had to teach topics which were challenging to provide a real-world example for or were challenging because they were "hard to give the kids an understanding as to why" such as inequalities.

When analyzing that data, I identified teacher-reported evidence of student math anxiety (see Figure 6).

Figure 6

Evidence of Student Math Anxiety Reported by Teachers

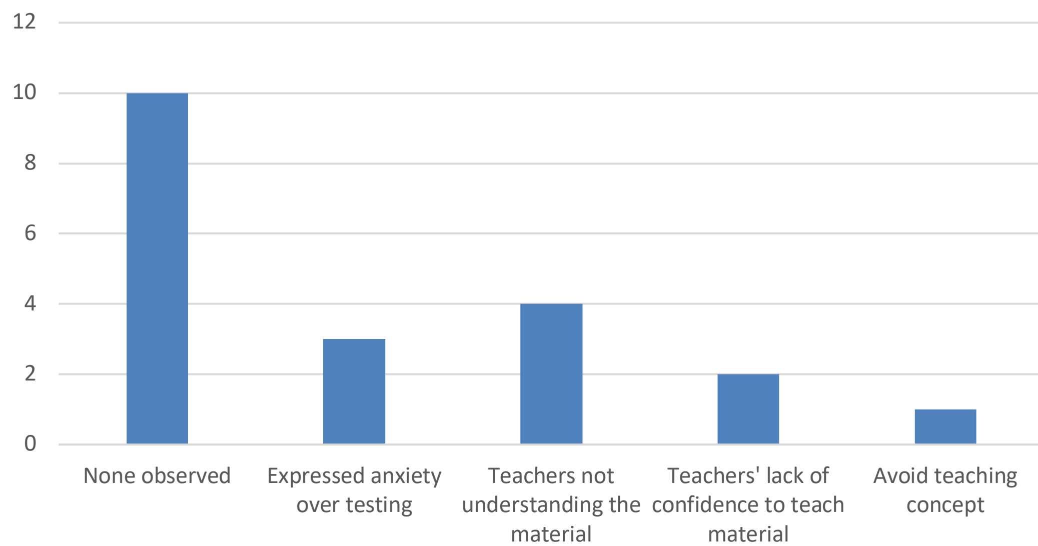


Though only one participant reported math anxiety was a common barrier to students learning mathematics in response to Question 5, participants provided more than one example of student math anxiety they witnessed at their respective schools when they responded to Question 10. If a participant reported more than one example of evidence of math anxiety at their school, each example was included in data analysis. For example, if a participant wrote tears and absenteeism were both evidence they had seen of student math anxiety at their school, I counted both tears and absenteeism in the data; therefore, the number of data reported exceeded the number of participants in this study. I noted no participant failed to list at least one example of evidence of student math anxiety. The recurring themes in response to evidence of student math anxiety were student withdrawal of effort, physical evidence such as tears, and low student math self-efficacy beliefs.

I examined evidence of teacher math anxiety in response to Question 11 (see Figure 7).

Figure 7

Evidence of Teacher Math Anxiety Reported by Teachers



While 10 participants did not report any evidence of teacher math anxiety in their schools, one participant shared a severe example and claimed, “I have seen tears and some have even left their job or asked for another subject.” Another participant wrote a teacher avoided teaching a difficult concept in response to anxiety over the material. Remaining participants responded to Question 11 in terms of their perceived cause of stress on math teachers rather than the evidence of stress they witnessed at their respective schools. One participant said some teachers do not know and understand their standards. If a participant provided more than one example of evidence, each example was included in data analysis. For example, if a participant responded expressed anxiety over testing and teachers not understanding the material, I counted one for each example; therefore, the total exceeded the actual number of participants.

Question 12 was about evidence of low math self-efficacy among students. Low student math self-efficacy was a literature-based barrier to learning. Every participant listed at least one example of teacher-reported evidence of student low math self-efficacy. Of the examples provided by participants, every example except one was within three themes. The first theme was students verbally expressed they could not do math or were not good at math. The second theme was students did not persevere to solve math problems when math was not understood easily. The third and final theme was teachers claimed the majority of their students struggled with low math self-efficacy beliefs; nine of 19 participants stated their students struggled with low math self-efficacy; one of these nine participants stated low math self-efficacy was a problem for students of all achievement levels and "my gifted and talented students think that they aren't *math people*." Another of these nine participants stated 75% of their students had low math self-efficacy beliefs. One of these nine participants wrote low student math self-efficacy was "the first challenge I take on with a new class." Though only two participants identified low student math self-efficacy beliefs as one of the most common barriers to students learning math in response to Question 5, these nine participants presented evidence that the problem not only existed in math classrooms in Grade 4 through Grade 8, but this problem permeated classrooms to the point of saturation.

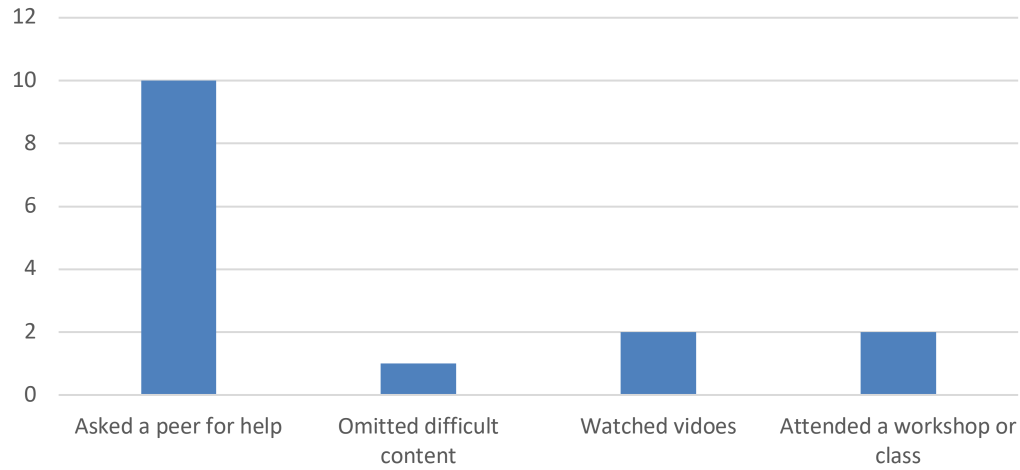
In Question 13, participants were asked to describe how they felt about teaching math in comparison to teaching other content areas. The responses to this question were important since I identified teacher attitude toward math as a literature-based barrier to learning mathematics. Of the 19 participants, 15 responded they felt varying levels of comfort ranging from at least comfortable teaching math to they enjoyed teaching math. Four of these 15 participants expressed they loved teaching math and/or they would not want to teach any other content area. Three of the remaining participants claimed math was more stressful to teach than any other subject. One of these three participants expressed they did not feel confident at all teaching math in comparison to other content areas; however, after I examined the overall responses from these individual participants, I noticed only two participants expressed characteristics of teachers with negative feelings toward mathematics.

In Question 15, participants were asked if they had been expected to teach mathematics they did not understand. The responses from this question were important to address two literature-based barriers to students learning math: insufficient math instruction and weak math skills among teachers. Approximately 68% (n = 13) of participants stated they had been asked to teach math they did not fully understand. Additionally, one participant responded to Question 11 and stated, "Some of the teachers don't know and understand their standards."

If participants responded yes to Question 15, they were redirected to Question 15a. If participants responded no to Question 15, they were redirected to submit their questionnaire responses. In Question 15a, I asked participants to explain how they responded when they were asked to teach mathematics they did not understand. Some participants responded with more than one response to the problem (see Figure 8).

Figure 8

Teachers Responses to Teach Mathematics They Did Not Understand



For example, if a participant responded they asked a peer for help and watched videos, both responses were counted in the data; therefore, there were more responses than the number of participants who answered yes to Question 15.

Research Question 3

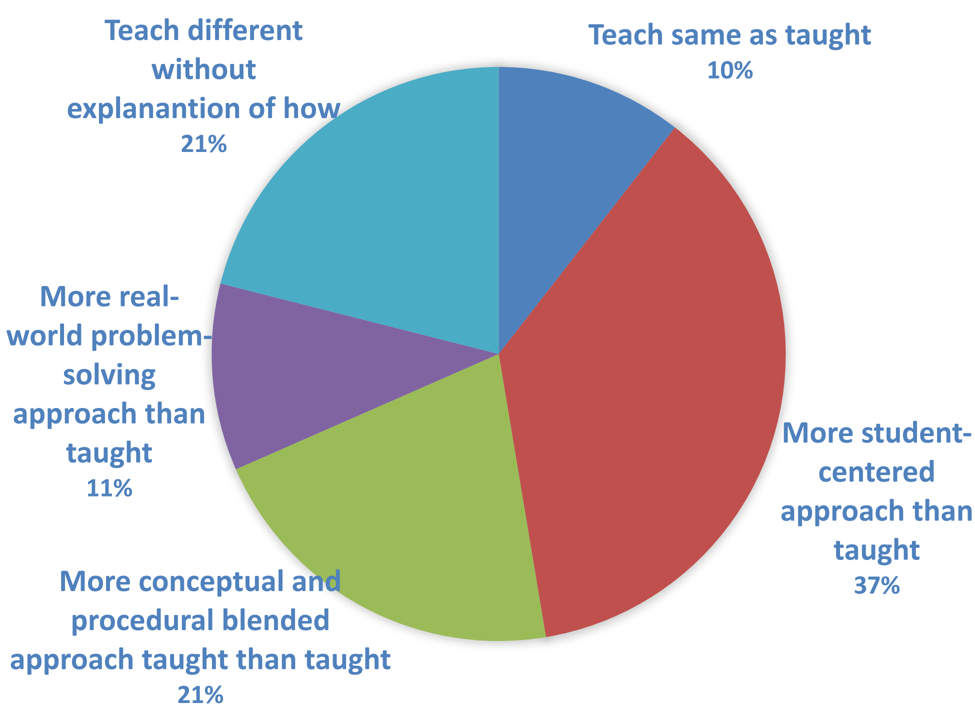
Which, if any, of the literature-based recommended changes did teachers report, and which, if any, indicators of resistance to change did teachers report in response to a questionnaire about elementary and middle school classrooms?

No participants referenced research about how students learned math, but some participants described some of the literature-based recommendations for change in their questionnaire responses. For example, one participant stated, "Students who succeed will put forth effort . . . those who don't 'practice' the concepts, are not as successful," which supported the literature-based recommendation for teachers to recognize effort rather than talent produced math achievement in students. Only one participant referenced student ability, and it was in context of low math self-efficacy beliefs among gifted and talented students.

In Question 14, teachers were asked to compare and contrast how they were taught mathematics in school to how they taught mathematics today (see Figure 9).

Figure 9

Comparison of How Teachers were Taught in School and How They Taught



I used responses to this question to determine if literature-based recommendations for change were reported by teachers as well as indicators of resistance to change. The themes of this data were teachers reported using a more student-centered approach, teachers reported using a more balanced conceptual and procedural approach, and teachers reported they taught different without any explanation or comparison of how it was different.

The second literature-based recommendation for change was a balance of conceptual understanding, procedural fluency, and quick recall of math facts. Based on the data collected and analyzed, specifically responses to Question 3 and Question 4, only three participants described an approach to teaching fractions and the difference between an inch and a square inch using conceptual understanding; therefore, saturation was achieved in regard to Research Question 3 for the recommendation to avoid purely procedural mathematics instruction. Based on the low number of participants who avoided purely procedural responses to both questions, there was a lack of evidence that participants in this study avoided purely procedural instructional practices.

The final literature-based recommendation for change was teaching mathematics using a constructivist approach, which required students to build on prior understanding of mathematical concepts. The main theme among participants was a lack of student prior knowledge. In response to Question 5, the question about identifying teacher-reported common barriers for students learning math, seven participants in this study reported a lack of prior knowledge as a common barrier to students learning mathematics, indicating the teachers considered prior knowledge of the students. Since a constructivist approach was built around teachers assessing prior knowledge of students, this evidence of teacher consideration of student prior knowledge could have been evidence of adopting a constructivist approach. One of these seven participants wrote, “They haven’t learned/retained prior knowledge/skills needed to build new ones on,” which reaffirmed a constructivist teacher mindset from the perspective of assessing student prior knowledge. From another perspective, the second part of a constructivist approach was teaching students from where they were mathematically, and I perceived the teacher's comment to mean the teacher identified a specific level of existing mathematical knowledge as a reasonable starting point rather than a plan to meet the student where they were; therefore, I could not confirm the teachers actually used a constructivist approach to teaching math.

Summary of Results

The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. To achieve this purpose, I analyzed data from 19 elementary and middle school teachers who regularly taught mathematics to at least one class per day to students between Grade 4 and Grade 8. Few participants described teaching addition of fractions and comparing and contrasting an inch to a square inch using conceptual understanding. Three predetermined codes from the literature-based barriers to student learning (i.e., low student math self-efficacy beliefs, math anxiety, and weak math skills among teachers) were evident in questionnaire responses. Participants responded their students had low math self-efficacy beliefs. Four additional themes emerged from the data as barriers to student learning, including students' lack of prior knowledge, students gave up quickly or would not persevere to solve math problems, parent attitude toward math, and a disconnect between math and the real world for students. In response to Research Question 3, 10% of the teachers reported they taught mathematics exactly how they had been taught mathematics with little evidence that literature-based recommended changes had been reported by participants in this study.

Chapter V: Discussion of the Study

The purpose of this research was to identify teachers' perceptions of barriers to math achievement below Grade 10, if any, to determine which, if any, of the identified barriers teachers reported, and to determine which, if any, previous recommendations for positive changes in mathematics classrooms teachers reported, as well as identify any teacher reports of resistance to change. The main takeaway of this study was teachers perceived students to have widespread low math self-efficacy beliefs as barriers to learning mathematics. With positive math self-efficacy beliefs being a common characteristic among STEM majors (Musu-Gillette et al., 2015; Wang, 2013), and teachers reporting their students struggled with widespread low math self-efficacy beliefs, more attention must be drawn to the problem of low student math self-efficacy beliefs.

Student math self-efficacy beliefs impacted all three interrelated components of the SCCT. For example, low student math self-efficacy beliefs deterred students from forming career-relevant interests in STEM degrees or careers (Wang, 2013). Low student math self-efficacy beliefs also deterred students from selecting academic options, such as upper level math courses in high school (Williams et al., 2016), which better prepare students to pursue STEM degrees. Students with low math self-efficacy beliefs were less likely to persist in their educational pursuit of mathematics, which could decrease their likelihood to pursue a STEM degree or STEM occupation (Musu-Gillete et al., 2015). Participants in this study reported students' low math self-efficacy beliefs is a common teacher-perceived barrier to students learning math, as is students' math anxiety, evidenced by students' tears and students' withdrawal of effort.

Even though low student math self-efficacy beliefs were a literature-based barrier to students learning mathematics, I did not expect low student math self-efficacy beliefs among students to be as widespread as it was in this study.

According to extant literature, purely procedural mathematics instruction is a barrier to students learning mathematics (Heyd-Metzuyanim, 2015; Selling, 2016). Additionally, a literature-based recommendation for change is a balance of conceptual understanding, procedural fluency, and quick recall of math facts. The combination of these two ideas resulted in the development of Research Question 1 of this study. In response to Research Question 1, according to this study, purely procedural math instruction continues to be a common practice among teachers.

The bulk of the data was in response to Research Question 2. Though low teacher confidence is a literature-based barrier to students learning mathematics, I found little evidence to support this claim in this study. There is a lack of evidence that low teacher confidence is still a barrier to students learning mathematics, based on teachers who responded they *were asked to teach math they did not fully understand* but who also express confidence that they gain understanding of the material by watching videos or working with other teachers prior to teaching students. Teachers express confidence in their ability to teach math concepts, even when they have to learn mathematics material to teach it. It is possible, however, that potential participants did not participate in this study due to low teacher math self-efficacy beliefs or low self-confidence in teaching mathematics, so these numbers may be underrepresented in this study. It is also possible these teachers felt confident in their ability to teach mathematics but did not actually understand the material. This situation is possible since researchers in extant literature, who claimed teachers lacked mathematical knowledge evaluated teachers' knowledge levels through observations or assessment instruments, and I analyzed teacher self-reports in this study due to the COVID-19 school closures. Even though most teachers report strong self-confidence in teaching math in Grade 4 through Grade 8, I am concerned with combined, related responses from over half the teachers in this study reporting *they were asked to teach math they did not fully understand* and nearly half the teachers in this study reporting *they did not feel confident in their skills to teach Algebra*. The combination of these responses indicates weak math skills among teachers, a literature-based barrier to students learning math, is still a problem. It is also concerning that teachers in Grade 4 to Grade 8 commonly teach math they do not fully understand.

In response to Research Question 3, many teachers report shifting toward a more student-centered instructional approach than a traditional teacher-directed instructional approach; however, some teachers still report using instructional practices exactly as the teachers were taught when they were in school. One literature-based recommendation for change is for teachers to use a balance of teacher-directed and student-centered instructional practices. Though the majority of the participants do not report this specific difference in comparing their individual teaching practices to how they were taught mathematics, the fact that many report the change indicates some teachers report implementing the positive recommendation for change.

Mathematical content knowledge is the focus of two parts of this study. This study does not provide evidence that students have a strong start in mathematics, which is a literature-based recommended change. Teachers frequently report students lack prior math knowledge in Grade 4 through Grade 8, which indicates a weak start for students. Additionally, strong teacher content knowledge is a literature-based recommended change. Since the majority of the teachers in this study report being asked to teach math they do not fully understand, there is a lack of evidence that this literature-based change is implemented.

This study addresses two final literature-based recommendations for change: teachers understanding and promoting that student effort produces math knowledge and math teachers utilizing a constructivist approach. Since teachers report that students do not persevere to solve math problems, there is evidence that teachers recognize effort as a key component of learning mathematics. Teachers consider student prior math knowledge as evidenced by the common theme of this study that teachers report a lack of prior math knowledge. Though identifying prior math knowledge is a component of a constructivist teaching approach, I found little evidence that teachers taught students from where they were in regard to math knowledge which was the second requirement of a constructivist approach; therefore, due to a lack of evidence in the data, teachers are not using a constructivist approach.

Implications for Practice

Due to teacher reports that student low math self-efficacy is a widespread problem among students in Grades 4 through Grade 8, teachers should assess student math self-efficacy beliefs routinely and monitor changes in student math self-efficacy beliefs. Teachers may accomplish this by adding a question at the end of quick tickets, lessons, or assessments to assess student math self-efficacy beliefs by asking students questions such as *What is your level of confidence that you can solve math problems like these correctly?* Young students may need emoji faces rather than a numerical scale to respond to this question. Another option for asking this question to middle school students would be *Which of the following best describes how confident you are that you can apply the skills you learned in this lesson to solve problems correctly?* with response choices such as the following: I am confident I can apply these skills to solve math problems correctly; I think I will be able to apply these skills to solve math problems correctly after completing, reflecting, and correcting individual practice on these types of problems; or I am concerned I will struggle to apply these skills to solve math problems correctly as I move forward.

It is important for teachers to build positive math self-efficacy beliefs among students to promote an increase the number of students pursuing STEM degrees and STEM careers. Low math self-efficacy beliefs among students impact all three interrelated components of the SCCT and, in turn, the decision to later pursue a STEM degree. Teachers should endeavor to identify root causes of student low math self-efficacy beliefs and work with students to build stronger math self-efficacy beliefs.

Identifying recommended changes to improve math instruction and implementing those changes should be a priority for every math teacher. Teachers should maintain a list of recommended changes and revisit the list often to monitor implementation. A list of questions to self-guide implementation of literature-based recommendations for change is attached to this study as a starting point for teachers in Appendix C. Teachers should self-evaluate using this list often and note which positive changes they have made, which change should be a priority next, and what barriers they can work to remove to facilitate more positive changes in the future. Since Gill and Boote (2012) argue teachers are not always good self-reporters of utilizing or recognizing conceptual teaching practices, teachers should collaborate to assess each other (e.g., ask a math specialist to observe teaching to assess conceptual teaching practices, discuss lesson ideas with a math specialist).

Math anxiety is still a teacher-perceived barrier to students learning math. Teachers should be proactive to reduce barriers to students learning math by watching for signs of student math anxiety such as physical evidence, including tears or students withdrawing effort when facing productive struggle in mathematics. Teachers should also monitor students' prior knowledge levels and offer mathematical connections to the real-world to prevent a disconnect between math and the real world for students. Following assessing students' prior knowledge, teachers should meet students where they are in regard to math knowledge and work to fill in gaps in mathematical knowledge. Hence, teachers should fully adopt a constructivist approach to teaching mathematics.

Recommendations for Further Research

This study does not provide evidence that recommended changes have been implemented widespread, especially the recommendation to teach more conceptually and to avoid purely procedural instruction. Until these recommended changes are implemented, researchers will not be able to determine if these changes result in an increase in the number of students seeking STEM degrees or careers. As teachers implement recommended changes in classrooms, researchers should study whether adopting the recommended changes impacts the number of students pursuing STEM degrees by determining if a correlation exists between implementation of recommended changes and the number of students seeking STEM degrees.

I was unable to conduct classroom observations during this study due to the COVID-19 pandemic school closures, but classroom observations would offer additional insight not apparent through a questionnaire alone; therefore, I recommend repeating this study, converting the questionnaire to an interview, and including classroom observations. Including classroom observations will allow a researcher to evaluate instruction as it is occurring to determine if it is more procedural, more conceptual, or balanced procedurally and conceptually. This would also provide valuable information about whether the teachers were self-assessing classroom strategies (e.g., what they think v. what is). The researcher should also assess the math content knowledge of the teachers during classroom observations.

This study should be modified to study a single teacher, single school, entire school system, and particular region. This would help decision-makers identify what literature-based recommendations for change are implemented and what changes still need to be implemented in their area. Researchers should strive to identify barriers to learning math in their specific school, system, or region by communicating with teachers.

My final suggestion for further research is include the additional aspects of the SCCT not addressed in this study. For example, the 4th model of the SCCT includes *satisfaction/well-being in educational and vocational contexts* (Lent &

Brown, 2013). A longitudinal study addressing satisfaction and well-being in regard to mathematics should offer insight into student perceptions about mathematics over a particular time period such as during middle school years. The 5th model of the SCCT includes *how people manage developmental tasks and uncommon challenges throughout their careers* (Lent & Brown, 2019). A researcher should conduct a longitudinal study of how people face developmental tasks pertaining to math throughout their careers and specifically focus on an individual who identified math as an *uncommon challenge*. Such a study should offer insight into how an individual overcomes math struggles to pursue and continue in a STEM career.

Conclusions of the Study

The recommendation to avoid purely procedural instruction is not evident in this study. Teachers in this study do not identify teacher math anxiety as a barrier to students learning math, which may indicate teacher math anxiety is not a barrier to students learning mathematics; however, teachers with high anxiety who teach mathematics may have been less likely to participate in this study. Lack of student prior math knowledge is a barrier to students learning mathematics more frequently than any other barrier. This indicates a widespread, strong math start has not been developed by students. With extant literature that indicates changes needing to take place early in education to develop students with higher math achievement and higher math self-efficacy beliefs, this lack of a strong math start creates greater concern that students will not be on track to pursue STEM degrees or STEM careers. Teachers must address gaps in knowledge so students can progress adequately and achieve overall success in mathematics by high school to increase the number of students seeking STEM degrees.

Though I identified multiple literature-based barriers to students learning mathematics and multiple literature-based recommendations for change in this study, one of each of these seemed highlighted throughout this study. Teachers perceive widespread student low math self-efficacy beliefs apparent in behavior students with low math self-efficacy exhibit, such as verbally expressing they *can't do math* or *aren't good at math* and completely withdrawing effort when facing productive struggle in mathematics. Teachers should strive to address and monitor students' math self-efficacy beliefs and to design and teach lessons using a more conceptual approach as a starting point to make positive changes in math education that may result in an increase in the number of students seeking STEM degrees and careers.

Teachers are not implementing literature-based recommendations for change such as a strong mathematical start for students in the early grades, strong teacher content-knowledge, and adopting a fully constructivist approach to teaching mathematic; therefore, it is critical for teachers to develop strong content knowledge to support student learning, especially in the early grades. It is also important for teachers to use a constructivist approach to teaching mathematics to address the gaps in student content knowledge since many students lack prior content knowledge across multiple grades from Grade 4 to Grade 8.

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Appendix A

Research Study Announcement

Invitation to Participate in a Research Study

Are you a teacher or administrator serving in Grade 4 through Grade 8?
I am conducting a study in which I would like you to participate!

Researcher

My name is Kimberly Summey, and I am a candidate seeking my Doctor of Education degree in Curriculum and Instruction from the Carter and Moyers School of Education at Lincoln Memorial University.

Purpose

My research is about instructional practices in mathematics classrooms prior to high school as well as barriers to learning mathematics, literature-based recommendations for change, and resistance to change.

What's involved?

No more than 30 minutes of your time.

Completing a brief questionnaire online using your internet browser.

Eligibility Requirements

Teacher: Must teach at least one math lesson each school day to the same class between (and including) Grade 4 and Grade 8.

Administrator: Must supervise teachers in at least one grade between (and including) Grade 4 and Grade 8.

Timeframe

Responses will be collected in May 2020, so please respond as soon as possible.

Additional Information

For additional information, or if you have trouble with the participation links below, please email the researcher at kimberly.summey@lmunet.edu.

Choose your role to participate in the study. (You will be redirected to the questionnaire.)

Teacher

Admin.

Thinking of a friend who may be eligible to participate and interested in the study? Please share this post so I may get a larger sample of participants.

Appendix B

Teacher Questionnaire

Research Study

My name is Kimberly Summey, and I am a candidate seeking my doctoral degree in Curriculum and Instruction from the Carter and Moyer School of Education at Lincoln Memorial University. My research is about instructional practices in mathematics classrooms in Grades 4 through 8 as well as barriers to learning mathematics. I am also investigating literature-based recommended changes for math instruction and resistance to change. My study will include questionnaires from teachers and administrators. My study will also include document reviews, when possible.

I am requesting your participation in this study which will include completing this questionnaire which should take approximately 30 minutes to complete. If you would like to provide documents in support of your responses, please email documents to kimbery.summey@lmunet.edu with "Questionnaire" in the Subject line.

* Required

1. Email address *

Informed Consent

Participation in this study will be completely voluntary. At any time, participants may opt out of responding to any question(s) or discontinue participation in the study. If at any time you discontinue the questionnaire, your responses will be deleted. Document reviews will be limited to documents used for planning or instruction of lessons in mathematics. Questionnaire responses and all other data will be kept confidential to safeguard participant privacy and to protect you and all participants from any potential harm. Your willingness to participate in this study will not impact your relationship with me or Lincoln Memorial University.

Thank you for your time and consideration to participate in this study. If you have any comments, concerns, or questions regarding the conduct of this research, please contact me, the researcher, or Dr. Cherie Gaines, my dissertation chair, at cherie.gaines@lmunet.edu or (XXX) XXX-XXXX. If you are unable to reach a member of the research team and have general questions, or you have concerns or complaints about the research study, research team, or questions about your rights as a research subject, please contact the Chair of the LMU IRB, Dr. Kay Paris at (XXX) XXX-XXXX, or by email at kay.paris@lmunet.edu.

Sincerely,
Kimberly Summey
Ed.D. Candidate, Curriculum and Instruction
Lincoln Memorial University
kimberly.summey@lmunet.edu; (XXX) XXX-XXXX

2. I HAVE READ THE ABOVE INFORMATION AND CONSENT FORM. I CONSENT THAT I AM AN ADULT, OVER 18 YEARS OF AGE, AND AGREE TO PARTICIPATE IN THIS STUDY. Do you want to participate in this research study? *

Mark only one oval.

- ( ) Yes *Skip to question 3*
- ( ) No *Skip to section 5 (Participation Declined)*

Teacher Questionnaire

3. Question #1. What is your highest level of education?

Mark only one oval.

- ( ) Associate Degree
- ( ) Bachelor's Degree
- ( ) Master's Degree
- ( ) Specialist's Degree
- ( ) Doctoral Degree
- ( ) Other: ____________________

4. Question #2. In which grade(s) do you teach mathematics at least once per day? Please check ALL that apply to you.

Check all that apply.

- [ ] Below Grade 4
- [ ] Grade 4
- [ ] Grade 5
- [ ] Grade 6
- [ ] Grade 7
- [ ] Grade 8
- [ ] Above Grade 8

5. Question #3. Explain briefly how you would teach a student to add fractions.

6. Question #4. Compare and contrast an inch to a square inch.

7. Question #5. Identify the most common barriers to learning mathematics which you notice among students in your school.

8. Question #6. Describe your level of self-confidence in teaching mathematics compared to other content areas.

9. Question #7. Describe your level of self-confidence in your overall ability to solve challenging math problems in real-life.

10. Question #8. Describe your level of self-confidence in your overall ability to teach Algebra.

11. Question # 9. Describe your anxiety level while preparing to teach and teaching math lessons in comparison to other content area lessons.

12. Question #10. Describe, if any, evidence of student math anxiety you have seen among students at your school.

13. Question #11. Describe, if any, evidence of teacher math anxiety you have seen among teachers at your school.

14. Question #12. Describe, if any, evidence you have seen that students in your class may have low math self-efficacy beliefs, that is, their belief in themselves that they can solve challenging math problems successfully.

15. Question #13. Describe how you feel about teaching mathematics in comparison to teaching other content areas.

16. Question #14. Compare and contrast the way you were taught mathematics in school to the way you teach mathematics today.

17. Question # 15. Was there ever a time when you were asked to teach mathematics you did not fully understand or a problem-solving method you did not fully understand?

Mark only one oval.

- Yes *Skip to question 18*
- No *Skip to section 4 (Please submit the questionnaire before closing your browser.)*

Question #15 follow up.

The previous question is stated below if you need to reference it.

Question # 15. Was there ever a time when you were asked to teach mathematics you did not fully understand or a problem-solving method you did not fully understand?

18. Question #15a. If so, how did you respond to the situation?

Please submit the questionnaire before closing your browser.

Thank you for your participation in this study. If you have any questions during any part of this study, please email me at kimberly.summey@lmunet.edu.

Participation Declined

You have elected to not participate in this research study. Thank you for your time. You may either click Submit or close your browser.

Appendix C

Guidelines for Implementing Positive Changes in Math Instruction

Self-Assess Questions to Promote Positive Changes in Math Instruction

1. Do I use a balance of procedural AND conceptual teaching practices in every math lessons? (Boston, 2013; Cheng & Hsu, 2017; De Kock & Harskamp, 2016; Hallett et al., 2010; Heyd-Metzuyanim, 2015; Litke, 2015; NCTM, 2014; Rittle-Johnson et al., 2015; Selling, 2016; Thanheiser et al., 2014)

2. Does my math lesson consist of a list of directions to follow to generate correct answers (procedural instruction) without connections to and between conceptual mathematical ideas (conceptual instruction)? (Boston, 2013; Cheng & Hsu, 2017; De Kock & Harskamp, 2016; Hallett et al., 2010; Heyd-Metzuyanim, 2015; Litke, 2015; Rittle-Johnson et al., 2015; Selling, 2016; Thanheiser et al., 2014)

3. Do I have a reliable support system in place for when I am asked to teach math I do not currently understand? (Chapman & An, 2017; Masingila et al., 2012; Mervis, 2008)

4. Do I strive to increase my content knowledge in mathematics? (Bartell et al., 2013; Chapman, 2015; Chapman & An, 2017; Cheng & Hsu, 2017; Greenberg & Walsh, 2008; Guberman & Leikin, 2013; Jong & Hodges, 2015; Thanheiser et al., 2014; Welder, 2012)

5. Do I balance student-centered and teacher-directed mathematics instruction? (Boston, 2013; NMAP, 2008)

6. Do I meet students where they are mathematically and use a constructivist approach to teach each student as much math as possible? (Finlayson, 2014; NCTM, 2000; Ward, 2001)

7. Do I focus on student effort rather than natural talent when I consider what a student can do mathematically? (Gunderson et al., 2017; NMAP, 2008)

8. Do I value and monitor math self-efficacy beliefs of my students? (Finlayson, 2014; Luttenberger et al., 2018; Musu-Gillette et al, 2015; Petersen & Hyde, 2017; Soni & Kumari, 2017; Wang, 2013; Wright, 2017)

9. Do I value and promote real-life connections to the math concepts I teach? (NCTM, 2014; Soni & Kumari, 2017)