IMPACTING INSTRUCTIONAL PRACTICE IN THE SECONDARY MATHEMATICS CLASSROOM: DOES MINDSET MATTER?

by

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DEDICATION

I dedicate this to my dearest partner and friend, the husband who has stood by my side for all these obsessive years of mathematics education. Thank you, Ted, for your unwavering encouragement, support, and willingness to play the devil’s advocate at every turn. I appreciate having you as my sounding board. I appreciate your calm voice of reason and restraint amidst my oftentimes Quixotic desire to fix all of education’s ills. To my three sons who survived my foray into graduate school, thank you for your patience, understanding, and willingness to eat frozen burritos while Momma slaved away at her computer. You are the best sons a mother could hope to have.

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ABSTRACT

National and international testing data reveal that current mathematics achievement falls short of the mark, supporting the claim that existing mathematical practice is insufficient to meet our students' needs. Research shows that experiential, social learning which emphasizes mathematical understanding over procedural mastery has more impact on student achievement, while widespread adoption of the Common Core State Standards for Mathematics further supports the call for transformational shifts in pedagogy. Despite all this, the behaviorist orientation which dominates much of current mathematical practice persists. The barriers to change and the ways in which various interventions address those barriers was the focus of this study, with special attention paid to the variable of teacher mindset. This study's primary purpose was to investigate the moderating effect of mindset in the context of ongoing professional development and curricular intervention on the outcome variable of instructional practice in the secondary mathematics classroom. The results of multiple linear regression analyses indicate not only that the mathematics cohort model of professional development under review was effective in shifting mathematical instructional practice among participating teachers, but that higher scores on the growth mindset continuum positively moderated the relationship between professional development intervention and shifts in the frequency with which traditional transmission instructional activities were used in the secondary mathematics classroom.

Keywords: secondary mathematics, mindset, professional development, curriculum, instructional practice

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CHAPTER ONE: STUDY OVERVIEW

Introduction

According to 2015 national and state testing data, student achievement in mathematics is alarmingly low. Only 25% of United States' twelfth-graders scored in the proficient or advanced range on the U.S. National Assessment of Educational Progress (NAEP) exam (Heitin, 2016), 41.9% of Scholastic Aptitude Test (SAT) test takers and 31% of American College Testing (ACT) test takers failed to meet college-readiness benchmarks (Adams, 2015), while less than a third of eleventh-graders scored proficient or better in mathematics on the Partnership for Assessment of Readiness for College and Careers (PARCC) and Smarter Balanced Assessment Consortium (SBAC) exams.

International data are equally dismal, revealing that in 2012, the United States ranked 27th in math among the 34 countries comprising the Organization for Economic Cooperation and Development (OECD) on the Program for International Student Assessment (PISA) exam. Only 27% of United States' students scored at or above the proficiency level, logging a performance that is worse than that of a majority of participating nations (Fleischman, Hopstock, Pelczar, & Shelley, 2010).

Current mathematics achievement in the United States clearly falls short of the mark (Peterson, Woessmann, Hanushek, & Lastra-Anadón, 2011). This presents concerns because research indicates student success in secondary mathematics is positively linked to higher-education enrollment, post-secondary degree completion and increased earnings (Adelman, 2006; Altonji, 1995; Dougherty, Mellor, & Jian, 2005; Kim, Kim, DesJardins,

& McCall, 2015; Post et al., 2010; Rose & Betts, 2001, 2004).

Though none dispute there are myriad factors outside teachers' control which influence student achievement, the school factor which most affects students' learning is teaching itself (Hiebert & Grouws, 2007; Nye, Konstantopoulos, & Hedges, 2004; Allen, Gregory, Mikami, Lun, Hamre, & Pianta, 2013). The data support the claim that existing mathematical pedagogical practice is insufficient to meet our students' needs (Fleischman et al., 2010; Mullis, Martin, Foy, & Arora, 2012).

A study of the Third International Mathematics and Science Study (TIMSS) video data reveals that United States mathematics teaching is characterized by "frequent reviews of unchallenging, procedurally oriented mathematics" (Hiebert et al., 2005, p. 116). Organizations such as the National Council of Teachers of Mathematics (NCTM), the National Science Foundation (NSF), and the National Research Council (NRC) suggest mathematics instruction needs to shift from the traditional transmission methodologies that focus on procedure and memorization to those that emphasize construction of mathematics and sense-making. Additional research aligns with these recommendations by illustrating experiential, social learning which emphasizes mathematical understanding over procedural mastery has more impact on student achievement and understanding (Bruner, 1964; Cobb, Yackel, & Wood, 1992). Widespread adoption of the Common Core State Standards (CCSS) for Mathematics further supports transformational shifts in mathematics pedagogy (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

This call for reform is not new, nor are the nation's efforts to bring about these instructional shifts. Since the early 1980's, in support of the NCTM's *An Agenda for*

Action and the *Nation at Risk* (Gardner, 1983) reports, significant financial attention has been focused on reforming mathematics curriculum and instruction. Since then, billions of dollars have been spent on both professional development and on the creation of aligned curriculum aimed at improving STEM education. According to the Fiscal Year 2015 Budget Summary and Background Information report, $2.3 billion was allocated for Improving Teacher Quality State Grants, $165 million was earmarked for Investing in Innovation (i3) to improve STEM education, $170 million supported additional STEM Innovation, and $149.7 million was spent on Mathematics and Science partnerships last year alone (U.S. Department of Education, 2015). In addition to this, the development of thirteen exemplary, comprehensive mathematics curricula has been fully funded by the NSF for use in school districts around the country (National Science Foundation, 1997).

Despite all this, the core of mathematics teaching in the United States remains strikingly similar to its traditional instruction of a century ago (Cuban, 1993; Fey, 1981; Hoetker & Ahlbrand,1969) and the behaviorist orientation which dominates much of current mathematical practice persists (Fullan, 2009; Stein, Remillard, & Smith, 2007; Hiebert, 2013). Though multiple interventions have been shown to make shallow yet measurable inroads into proximal practitioner behavior, few can claim sustainability in the long term, and even fewer maintain their effectiveness when scaled up (Garet & Yoon, 2015; Kennedy, 2016). Why is this the case?

Multiple frameworks for understanding the mechanisms of adult behavioral change populate the annals of personality, social and cognitive psychology, medicine, economics, educational counseling, mental health, appreciative inquiry, self-control, decision and choice theory, behavioral finance, educational leadership, business, organizational change, addiction, identity, mindset, and crisis management research, just to name a few. Understanding the process of change and the critical points during which new behaviors are sustained or abandoned remains an issue of concern across numerous academic and professional arenas, and the work conducted within each can lend assistance in framing the barriers to reform that have been reported by the mathematics research community.

"Regardless of how difficult you think it is to improve classroom mathematics teaching on a wide scale, it is more difficult than that" (Hiebert, 2013). Transforming teaching is hard work, fraught with pitfalls and roadblocks. Yet teachers are the mediators of professional development, curriculum, coaching, or collaborative interventions aimed at change and how teachers respond to these interventions affects their students' opportunities to learn. If interventions fail to impact teacher behavior behind the classroom door and traditional instructional practice persists despite all efforts to change it, then gaining a better understanding of why change is so difficult must become a priority.

This dissertation provides an overview of the specific instructional changes and teacher capacities being targeted by reform efforts, the barriers that cognitive, emotional, and situational variables pose to efforts aimed at these targets, and how historical interventions have sought to address these barriers. It then provides details on a study which examined the ways in which the variable of teacher mindset can improve our understanding of how instructors respond to professional development and curriculum interventions. This study contributes to the literature base by seeking to address the question: Can teacher mindset, when combined with the variables of ongoing professional development and access to curricular resources, improve predictions for shifts in mathematical instructional practice?

In chapter one, background on the concepts which inform the research proposal, the ways in which each of these concepts fit within a theoretical framework for change, and the problem this study aimed to address are provided. Then, a rationale for the study and the gap in the literature it seeks to fill are highlighted. Next, the research questions this study addressed and a brief overview of the methodology used while investigating them are given. Definitions of key terms and a brief outline of this dissertation's organization conclude the chapter.

Background and Theoretical Framework

Research indicates that shifting instructional practice to incorporate reform methodologies in the mathematics classroom requires a multi-pronged approach (Desimone, Porter, Garet, Yoon, & Birman, 2002; Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Goldsmith, Doerr, & Lewis, 2014). Various branches of study that address the characteristics of effective instruction, the capacities needed to teach mathematics using this desired pedagogy, the wide swath of interventions aimed at building these capacities, teacher responses to these interventions, and the emotional, cognitive, and situational variables related to change have populated research journals for decades. Yet the need to coordinate all of this research into a cohesive theoretical framework with the potential to positively impact instructional practice in the mathematics classroom remains largely unmet (Philipp, 2007).

Other studies across multiple academic and professional domains suggest that inconsistencies among cognitive, emotional, and situational constructs present barriers to change that are difficult to overcome (Heath & Heath, 2010). Though interventions have been shown to address some of these barriers temporarily and to elicit short-term, proximal changes in instructional practice, none can claim long-term, large-scale success (Collopy, 2003; Darling-Hammond et al., 2009; Garet & Yoon, 2015; Kennedy, 2016; Opfer & Pedder, 2011; Remillard, 2005). This indicates that further research still needs to be conducted in order to effect substantive, sustainable change. The following overview provides a brief summary of this research and provides a foundational theoretical framework for this study.

Targets of Reform

By combining what is known regarding general cognitive learning theory and the specific nature of mathematics learning, the literature base helps to delineate the characteristics of both effective mathematics instruction and the competencies of teachers who enact it. This information serves not only to focus reform efforts, but also to clarify the targets of change.

A Framework for Developing Mathematical Thinking

The framework for Developing Mathematical Thinking (DMT), as conceptualized by Brendefur and his team, emphasizes the integration of both individual student construction of new mathematical understandings which connect to previous knowledge and social construction of collective knowledge through facilitated class and small-group discourse (Brendefur, Carney, Hughes, & Strother, 2015).

According to Brendefur (2015), the DMT framework builds off of the work of Carpenter and Lehrer (1999), Freudenthal (1973, 1991), Treffers (1987) and Gravemeijer and van Galen (2003) and is characterized by opportunities for students to (a) construct coherent mental schema for interrelated mathematics concepts (Carpenter and Lehrer, 1999), (b) compare various strategies and models for solving problems (Hiebert & Carpenter, 1992, p.68), (c) progressively formalize their thinking, and (d) attend to both vertical and horizontal mathematizing (Treffers, 1987).

Teacher Capacities Needed to Enact Effective Instruction

Significant knowledge, skill, and capacity are necessary for teachers to successfully implement instruction that aligns with the reform agenda. Shulman conceptualized a domain of teacher knowledge he termed pedagogical content knowledge (PCK), which encapsulates a type of knowledge unique to teaching (Shulman, 1986). Ball and her team further developed this idea to incorporate more refined domains of knowledge needed for mathematics teaching that fit within two distinct but interrelated domains: subject matter knowledge and pedagogical content knowledge (Ball, Thames, & Phelps, 2008).

Each of these, in turn, are comprised of three subdomains. Subject matter knowledge is comprised of common content knowledge (CCK), horizon content knowledge, and specialized content knowledge (SCK). Pedagogical content knowledge is comprised of knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (Ball et al., 2008).

Yet another strand of research proposes the need for additional teacher competencies as outlined by Richardson (1996) and Thompson (1992). Combined with the domains of Shulman (1986) and Ball et al. (2008), these additional competencies yield the Teacher Education and Development Study in Mathematics (TEDS-M) framework (Döhrmann, Kaiser, & Blömeke, 2012; Tatto, Schwille, Senk, Ingvarson, Peck, & Rowley, 2008), which has been adapted to include affective-motivational characteristics considered to be critical for effective instruction. This framework includes beliefs about mathematics and the teaching and learning of mathematics, along with professional motivation and self-regulation (Döhrmann et al., 2012).

Once we clarify the targets of change, multiple questions arise. How we as a research community work to equip teachers with the knowledge and affective-motivational characteristics they need to enact effective instructional practice in a sustainable way? How do we motivate, support, monitor, and measure the change we wish to achieve? Given the history of resistance to reform efforts aimed at change, identifying and framing the barriers that impact intervention outcomes becomes critical.

Framing the Barriers to Reform

Altering adult behavior poses challenges in virtually every field, whether on an organizational or individual level. Common themes that appear to surface time and again from the snarl of constructs and theories regarding change is the claim that successful, sustained behavioral change can be linked to the coordination of contextual, emotional, and cognitive factors (Clarke & Hollingsworth, 2002; Desimone, 2009; Darling-Hammond et al., 2009; Goldsmith et al., 2014; Heath & Heath, 2010; Kennedy, 2016; Loucks-Horsley & Matsumoto, 1999; Marrongelle, Sztajn, & Smith, 2013; Opfer & Pedder, 2011). This claim aligns with Phillipp's suggestion to the research community as it moves forward in its efforts to shift instructional practice in the mathematics classroom: develop a cohesive construct which includes all the sociocultural, personality, and belief variables with the potential to impact the process (Philipp, 2007). These results also highlight common barriers that might explain why so many change efforts fail.

No matter the area of study, research reveals that cognition (the whole messy construct of teacher knowledge, beliefs, and learning), emotions (no matter how they are labeled in motivation, self-regulation, and self-efficacy literature), and a lack of sociocultural coherence between the desired behavior and the situated context in which it is enacted present the most challenging barriers to change. Underlying most of this research are theories which explain a person's basic desire for consistency and coherence among beliefs, emotions, and behavior. We can find this idea explicated in Festinger's (1957) cognitive dissonance theory, Heider's (1958) balance principle, and Osgood and Tannenbaum's (1955) congruity principle (as cited by Higgins & Kruglanski, 2000). The foundational premise of each is that humans seek equilibrium by constructing a consistent social world that makes sense. Consequently, a framework proposed by the Heath brothers was used to organize the barriers that have arisen in the mathematics education literature (Heath & Heath, 2010).

Cognitive Barriers

Research reveals teachers' existing knowledge and belief structures affect their receptivity to learning (Cohen, 1988; Darling-Hammond & Ball, 1998). Additional studies note the coherence between teacher belief and practice (Stipek, Givvin, Salmon, & MacGyvers, 2001) and posit that teachers' conceptions, images and beliefs about mathematics learning and teaching "serve as filters for making sense of the knowledge and experiences they encounter […] and may also function as barriers to change" (Feiman-Nemser, 2012). Due to their own lived experience as observers and participants within an educational system, teachers arrive at their profession fully equipped with intact, wholly integrated belief systems for instruction, learning, learners, and mathematics (Lortie, 1975). It should surprise no one, then, that such belief systems possess the potential to hinder the development and integration of new ideas and new habits of thought into practice (Ball & McDairmid, 1990; Calderhead & Robson, 1991).

Another cognitive domain that seems to hinder the appearance of coherence among beliefs and practice is that of teacher knowledge. Teachers must possess adequate knowledge in multiple domains before they can successfully implement effective mathematics instruction that aligns with the reform agenda (Shulman, 1986; Ball et al., 2008; Döhrmann et al., 2012). Lack of knowledge in any of the subdomains can adversely affect teachers' ability to effectively facilitate students' mathematical knowledge acquisition.

Emotional Barriers

Change does not occur without individuals setting and achieving goals, and goals are not set or achieved without tight coordination among emotions, motivation, cognition, behavior, and affect (Zimmerman, 1990). Emotions, whether linked to professional identity, motivation, resistance, defensiveness, relatability, or relationship skills all appear to influence outcomes (Prochaska, DiClemente, & Norcross, 1993), as do the self-regulatory strategies and perceptions of control found in self-efficacy research (Bandura, 1997).

More and more researchers are finding that teachers respond emotionally to interventions aimed at educational change (Sikes, 1992; Bailey, 2000; Lee & Yin, 2011). After analyzing the outcomes of multiple educational reform interventions, Fullan reached the conclusion that teachers' emotional responses were predominantly negative, often manifesting as anxiety, hopelessness, defensiveness, anger, and exhaustion (Fullan, 1997, pp. 229-230). Other researchers identified the reactive emotions of shame (Bibby, 2002), anger (Hargreaves, 1998; van Veen, Sleegers, & van de Ven, 2005), nervousness, anxiety, and worry (Saunders, 2013). It should come as no surprise, then, that the interplay between teacher emotions and reformists' efforts to bring about change can help predict the success or failure of an intervention (Cross & Hong, 2009).

Situational Barriers

Contextual obstacles upon the path toward change can also bring about failure. This is reflected in the sociocultural research being conducted in educational, business, medical, and social arenas. Bandura, in his studies on sociocultural change, posits that "new practices usually threaten existing status and power relations" (Bandura, 1997, p.514). When the promised advantages are delayed and the benefits do not become evident until they have been applied for a significant length of time, motivation falters and commitment to the change wanes even among the staunchest advocates of change (Bandura, 1997, p. 514).

All too often, prescribed educational reform is predicated on a narrow, technical view of teaching and learning while neglecting the complex, intellectual work and sophisticated professional judgment effective teaching requires (Bascia & Hargreaves, 2000, p.4). Government policies tend to focus on short-term behavioral skill targets and resultant measures of compliance as opposed to long-term investments in the intellectual development of teachers (Hargreaves & Fullan, 1998).

People are less likely to adopt innovative changes if they lack the accessory resources that may be needed (Bandura, 1997, p. 519). Reio criticized policy-led reform efforts, claiming that the combination of insufficient time, inadequate direction, and increased workload can have adverse effects on teacher motivation, learning, and performance (Reio, 2011). With decreased funding, heightened demands and test-score-dominated evaluations tied to job security and pay, educators are less apt to invest fully in their work. As a result, their aspirations suffer, and their performance lags (Valli & Buese, 2007). Combine these stressors with educational policies that are consistently in a state of flux, tossed about in a sea of competing educational agendas, interventions, innovative programs, and ideologies, and the resulting educational systems are not only complex, but wildly chaotic (Hargreaves, Lieberman, Fullan, & Hopkins, 2014, p.5), and it is not surprising that systemic, situational barriers against wholesale reform present challenges separate from the cognitive and emotional barriers the teachers themselves erect.

The Mathematics Research Community's Efforts to Effect a Change

The interventions aimed at mathematics instructional change come in a variety of formats: a dizzying array of professional development models, curricular materials and resources, formal to informal collaboration, and a range of general to subject-specific instructional coaching. These individual factors can be arranged and delivered in countless combinations, many of which have resulted in various levels of success.

In chapter two of this dissertation, I outline the ways in which these various interventions fit within the Heath brothers' framework for addressing the cognitive, emotional and/or situational barriers that arise within the context of change. This helps to explain both their successes and their failures while also identifying a gap in the literature.

A New Factor: Teacher Mindset

If teams of researchers who study interventions in mathematics education struggle to identify the combination of factors which best predict outcomes, could this be due, in part, to an overlooked or neglected factor? While exploring the major categories of barriers that impact the success or failure of change efforts, the reasons these barriers arise, and potential strategies for combatting them, my review of the literature also reveals that even though multiple studies have been conducted on mindset and its connections to goal orientation (Bandura & Dweck, 1985; Dweck, 2006; Dweck, Tenney, & Dinces, 1982; Leggett, 1985, as cited by Dweck & Leggett, 1988; Dweck & Elliot, 1983; Elliot & Dweck, 1988) and observable patterns of cognition-affect-behavior (Diener & Dweck, 1978, 1980; Dweck, 1975; Dweck, 2006; Dweck & Reppucci, 1973 as cited by Dweck & Leggett, 1988), no studies have examined the relationship between mathematics teachers' mindset and their engagement with interventions aimed at instructional change.

Problem Statement

In order to reliably predict whether teachers will make positive shifts in their mathematics instructional practice, it is important to identify, address, and coordinate as many influencing factors as possible. Integrating these identified factors into a cohesive framework can then assist stakeholders in maximizing the effects of their reform efforts. Attending to the variables which are linked to positive shifts in practice can provide much needed support for the goal of improving mathematics instruction.

The Idaho school district in which this study took place shares this goal, and in an effort to meet the needs of its in-service mathematics teachers, the district and its mathematics coaches integrated the known research findings into their design of a comprehensive District Mathematics Cohort (DMC) model of professional development. Their design offers ongoing pedagogical support, embedded coaching, and multiple opportunities for facilitated collaboration. The district has also adopted research-based College Preparatory Mathematics (CPM) Integrated Curriculum support materials for three of its courses on the secondary level with the intent of supporting these shifts in instructional practice. Determining the level of impact this investment of time and resources has on instructional practice among mathematics teachers is of primary interest and concern, not only for the involved district, but also for districts facing the same challenges posed by the call for mathematics reform. When instructional practice improves, which combination of factors appears to have the largest impact?

My review of the literature on effective mathematics instructional practice and the teacher capacities needed to enact it, the mechanisms of behavioral change, and the historical interventions that have sought to shift pedagogy in the mathematic classroom suggest the factors shown to negatively influence the outcomes of interventions stem from a lack of coherence among cognitive, emotional, and situational variables. Yet no research has investigated the relationship between teacher mindset as defined by Dweck and the implementation of reform methodologies.

Consequently, this study intends to explore the relationships between various combinations of teacher mindset, involvement in the DMC model of professional development, and access to its adopted CPM curriculum resources has on instructional practice. In particular, this study uses a series of paired sample *t*-tests to identify which interventions yield significant differences in the frequency with which traditional transmission or socio-constructivist instructional activities are used, and whether the impact of each varies across demographic groups. This study also uses multiple regression to investigate whether the relationship between the DMC or CPM interventions and shifts in instructional practice is moderated by teacher mindset.

Rationale

An argument could be made that mindset resides firmly in the cognitive camp and has the potential to present barriers to change due to the tensions which arise from conflicting beliefs. Yet mindset also determines emotional responses to failure (Dweck & Leggett, 1988; Dweck, 2006). While undergoing the process of change, when "everything can look like failure in the middle" (Kanter, 2003, p.11), a fixed mindset is likely to precipitate negative emotions that can impede progress.

Researchers find evidence of this in the medical field (Edmonson, 2003; Timby & Smith, 2006), industry (Carroll, 1993; Dweck, 2006), and sports (Dweck, 2006). But because there is limited evidence involving mathematics teachers, their mindset, and the ways in which their practice is impacted and there are no studies which explore mathematics teacher mindset in the context of changing instructional practice, I am interested in determining whether teacher mindset can serve as a predictor of instructional change when other cognitive and situational barriers to change are being attended to in a professional development setting.

Significance

This study has the potential to be significant because it explored whether teacher mindset moderates the relationship between various interventions and shifts in instructional practice. This relationship between teacher mindset and engagement in instructional change has not been explored before, so this study also can contribute both to the literature base focusing on mathematics reform and the literature base focusing on mindset. On a more practical level, its results could also lead to interventions aimed at shifting teacher mindset in order to help optimize effectiveness and returns on district and state reform investments.

Purpose of the Study

The purpose of this study will be to explore the relationships between and influences of professional development, curriculum, and mindset on shifts in mathematics instruction. Research indicates that professional development and curriculum are related to shifts in instructional practice, but no study has dealt specifically with mindset and its potential for inclusion in predictive models for change. This study adds the variable of mindset to existing theoretical frameworks and explores whether doing so improves our understanding of the mechanisms of change in the mathematics educational setting.

Research Questions

The following questions were formulated to guide this research study:

1. To what degree does involvement in the DMC predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?
2. To what degree does access to the CPM curricular support materials predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?
3. To what degree does involvement in the DMC, when combined with CPM curricular support materials, predict shifts in the frequency with which

secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?

4. Is the relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?
5. Is the relationship between access to the CPM curricular materials and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?
6. Is the relationship between involvement in the DMC, when combined with CPM curricular support materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?

The predicting variables in this study are (a) involvement in the district's mathematics cohort (DMC) model of professional development and (b) access to the adopted College Preparatory Mathematics (CPM) curriculum materials. The potential moderating variables are growth and fixed teacher mindset.

The outcome variables in this study are (a) the shift in the frequency with which traditional transmission instructional activities are used and (b) the shift in the frequency with which socio-constructive instructional activities are used.

The hypotheses of this study are as follows:

Hypothesis 1 (H_1): Involvement in the DMC predicts shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Null Hypothesis 1 (H_{01}): Involvement in the DMC does not predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Hypothesis 2 (H_2): Access to the CPM curricular support materials predicts shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Null Hypothesis 2 (H_{02}): Access to the CPM curricular support materials does not predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Hypothesis 3 (H_3): Involvement in the district's mathematics cohort (DMC) model of professional development, when combined with access to the CPM curricular support materials, predicts shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Null Hypothesis 3 (H_{03}): Involvement in the district's mathematics cohort (DMC) model of professional development, when combined with access to the CPM curricular support materials, does not predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices.

Hypothesis 4 (H_4): The relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is moderated by mindset.

Hypothesis 4 (H_{04}): The relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is not moderated by mindset.

Hypothesis 5: The relationship between access to the CPM curricular materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is moderated by mindset.

Hypothesis 5 (H_{05}): The relationship between access to the CPM curricular materials and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is not moderated by mindset.

Hypothesis 6: The relationship between involvement in the DMC model of professional development, combined with access to the CPM curricular materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is moderated by mindset.

Hypothesis 6 (H_{06}): The relationship between involvement in the DMC model of professional development, combined with access to the CPM curricular materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices is not moderated by mindset.

Nature of the Study

This quantitative study will use a quasi-experimental research design to examine the relationships between two predictor variables, two potential moderating variables, and two outcome variables. Independent and paired T-tests will be used to examine relationships between demographic groups and pre- and post- measures to determine differences between groups, while multiple regression analysis will be used to examine the predictive validity of involvement in the DMC model of professional development, access to CPM curriculum resources for shifts in instructional practice, and the moderating effects of mindset.

Because other variables may confound the study's results, data for gender, years of mathematics teaching experience, previous experience teaching an integrated common core mathematics course, grade level(s) taught, course(s) taught, instructional practice, mindset, involvement in the Mathematics Cohort model of professional development, and access to CPM curriculum resources were collected and analyzed for all participants via survey. The study's survey instruments were designed by current Boise State University faculty and have supporting validity evidence in previous studies. Additional details on the variables and instruments are provided in the methods section found in chapter three.

Operational Definitions

College Preparatory Mathematics (CPM) Curriculum: curriculum developed through an Eisenhower-funded grant and focused on incorporating the National Council of Teachers of Mathematics' recommendations for instructional practice. Supported by methodological research in mathematics education and aligned with the CCSS for Mathematics, the CPM curricula was designed to engage students in problem-based lessons through group discourse and discovery of core mathematical ideas. The course sequencing of topics balances the demands of procedural fluency, conceptual understanding, problem solving skill, and adaptive reasoning (CPM Educational Program Description, 2015).

District Mathematics Cohort (DMC) Model of Professional Development: professional development designed to incorporate the results of multiple professional development studies outlined in the research. In particular, the DMC model of professional development was built on the framework of mathematics instruction proposed by the initiative for Developing Mathematical Thinking (DMT). It provided both intensive mathematics coaching support and a collaborative structure within which to study and implement best practices, develop and sequence mathematical tasks and assessments, and incorporate the CCSS for Mathematical Practice and Content into instructional methodologies.

Developing Mathematical Thinking (DMT) Framework: A theoretical framework used to connect student and teacher activity within a classroom setting in ways that optimize student construction of new mathematical knowledge. Instructional practice that fits within the framework is characterized by activities which (1) take students' ideas seriously, (2) encourage multiple strategies and models, (3) press students conceptually, (4) address misconceptions, and (5) focus on the structure of mathematics (Brendefur et al., 2015).

Fixed Mindset: an implicit, entity stance from which attributes such as intelligence, creativity, and talent are believed to be fixed, invariant characteristics that remain stable regardless of the situation or circumstances (Dweck, 2006; Sternberg, 1995).

Growth Mindset: an implicit, incremental stance from which attributes such as intelligence, creativity, and talent are believed to be malleable, subject to change, and to possess the potential for growth and development (Dweck, 2006; Sternberg, 1995).

Social-Constructivist Instructional Practices: facilitative pedagogical practices which activate students' prior knowledge of mathematics, and then build upon it through collective construction of new knowledge via social discourse and student action (Cobb, Wood, & Yackel, 1993; Simon, 1995; Steffe & D'Ambrosio, 1995).

Traditional Transmission Instructional Practices: objective-driven, didactic pedagogical practices characterized by student reception and rehearsal of instructional content, facts, procedures and skills and predicated on the theory that teachers' words and actions "can carry meanings in and of themselves that are waiting to be apprehended by students" (Cobb, 1988).

Organization of Remaining Chapters

Chapter one (a) outlined the background and problem leading to this research study, (b) supplied a rationale, significance, and purpose for the study, (c) provided the research questions investigated and the nature of the study designed to answer the questions, and (d) listed operational terms and their definitions used within the dissertation.

Chapter two provides an overview of the relevant research conducted across a wide swath of mathematics education and psychological domains. Chapter three entails a detailed description of the methodology employed in the study. Chapter four supplies the findings arising from the investigation, along with the quantitative analyses that support them. Chapter five offers a discussion as it relates to the research questions and how the study’s findings fit within the existing literature. Potential implications for future research are provided.

CHAPTER TWO: LITERATURE REVIEW

Introduction

This literature review is arranged into five broad, interconnected themes. The first theme outlines the current state of mathematics achievement in the United States and highlights the need for pedagogical reform. The second theme clarifies the targets of reform by outlining both the components of effective mathematics instruction and the identified teacher domains of knowledge and capacities needed to implement this instruction. The third theme provides a framework within which the multiple barriers to mathematics reform are identified and categorized. The fourth theme summarizes the ways in which various types of interventions aimed at reform have sought to address these identified barriers. Lastly, the fifth theme explores how the previously unexamined variable of teacher mindset may have the potential to provide additional insight into the failure and success of these interventions. The chapter's conclusion recommends further research into the relationship between mindset and mathematics reform efforts.

Because the research in each of these areas could easily fill several libraries, the goal of this chapter is not to exhaustively recount the full range of studies that have been conducted in each realm. Rather, this chapter aims to connect the multiple findings within each area of research into one cohesive narrative. To help facilitate the delivery of this narrative, a framework for change as conceptualized by Chip and Dan Heath in their book, *Switch: How to Change Things When Change Is Hard*, will be used to organize the various research findings and discussions as they relate to shifting mathematics teachers' practice. This framework will not only help to situate the barriers and successes that have repeatedly arisen over decades of intervention aimed at instructional change, but it will also lend credence to the supports this study's participants will receive and help to explain the potential role teacher mindset, as conceptualized by Dweck and as a subconstruct of teacher beliefs, could play on the effectiveness of these supports.

Theme 1: A Need for Mathematics Reform

Student Achievement

According to 2015 national testing data, only 25% of U.S. twelfth-graders score in the proficient or advanced range on the U.S. National Assessment of Educational Progress (NAEP), indicating a significant decrease from the 2013 NAEP results. Fourth and eighth graders, along with high school seniors, have all lost ground in mathematics over the past two years. Most disconcerting is the significant drop in math scores for the lowest achievers. Between 2013 and 2015, students at or below the 10th percentile in mathematics went down an average of four points (Heitin, 2016).

On the Partnership for Assessment of Readiness for College and Careers (PARCC) and Smarter Balanced Assessment Consortium (SBAC) exams, the average proficiency rate from third through eighth grades was only 41% across the twelve states reporting scores in 2015, with only a third of California's students proficient at the low end. Older students fared even worse; across the twelve reporting states, less than a third of eleventh-graders scored proficient or better in mathematics (Herk, 2015).

The same proficiency trends can be seen in college entrance exams. Graduating seniors in 2015 posted a ten-year low performance on the College Board's Scholastic Aptitude Test (SAT) exam, indicating that 41.9% of recent graduates are not on track to succeed on the post-secondary level. American College Testing (ACT) performance is equally dismal; its report shows another year of flat growth and indicates only 28% of graduating seniors met college-readiness benchmarks in all four subjects, while a full 31% of test takers failed to meet the benchmarks in any subject (Adams, 2015).

International data are not any better, revealing that in 2012, Americans ranked 27th in math among the 34 countries comprising the Organization for Economic Cooperation and Development (OECD) on the Program for International Student Assessment (PISA). The OECD defines mathematics literacy as:

> An individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen (OECD 2009, p.84).

To put this definition in context, the PISA measures levels of mathematics literacy on a scale of one to six. Students performing at a level 4 of mathematics literacy can work effectively with explicit models for complex concrete situations and are comfortable with a range of mathematical representations. They can complete higher-order tasks in unfamiliar contexts and are capable of carrying out sequential processes. Students performing at a level 2 can interpret and recognize situations that require only direct inference, extract information from a single source, and work with a single representational mode. Using this scale, only 27% of U.S. students scored at or above the proficiency level 4 while 23% scored below level 2. This performance is worse than that of a majority of participating nations (Fleischman et al., 2010). Current mathematics achievement in the United States of America falls short of the mark (Peterson et al., 2011).

Causes and Consequences of Poor Achievement

Given the data of our students' performance both on a national and international scale, many support the claim that existing mathematical pedagogical practice is insufficient to meet our students' needs (Fleischman et al., 2010; Mullis et al., 2012). Though none dispute there are myriad factors outside teachers' control which influence student performance, research has shown the school factor which most affects students' learning is teaching itself (Hiebert & Grouws, 2007; Nye et al., 2004; Pianta & Hamre, 2009). A study of the Third International Mathematics and Science Study (TIMSS) video data revealed that US mathematics teaching is characterized by "frequent reviews of unchallenging, procedurally oriented mathematics" (Hiebert et al., 2005, p.116). Though teaching quality of this sort may not directly cause limited learning, it can certainly be associated with lower student performance and conceptual understanding.

Research also indicates that student success in secondary mathematics is positively linked to higher-education enrollment, post-secondary degree completion and increased earnings (Adelman, 2006; Altonji, 1995; Dougherty at al., 2005; Kim et al., 2015; Post et al., 2010; Rose & Betts, 2001; Rose & Betts, 2004). According to the Bureau of Labor Statistics, the 2015 difference between median weekly earnings for those with a high school diploma and those with a bachelor's degree is $663 per week, $34,500 per year, or over a million dollars in lifetime earnings. This gap in earnings widens even further when considering the field in which degrees are earned. For the 16.2% of 2012 college graduates earning STEM degrees, their full-time employment rates are 7% higher and their annual earnings outstrip non-STEM majors' by a whopping $15,500 per year (Cataldi, Siegel, Shepherd, & Cooney, 2014).

It makes sense, then, that improved teacher quality can be linked both to economic benefit for the country as a whole (Hanushek, 2011) and to student achievement (Darling-Hammond, 2000) and future financial health. Improving mathematics teaching is of paramount importance.

Theme 2: Targets of Reform

The claim that we need to improve mathematics teaching is well supported. But articulating what, exactly, this improved instruction entails and identifying the teacher competencies needed to enact it are a bit more challenging. What does the desired instruction look like in practice and how does it differ from the current enacted instruction? By combining what is known regarding general cognitive learning theory and the specific nature of mathematics learning, the literature base helps to delineate the characteristics of both effective mathematics instruction and the competencies of teachers who enact it. This information serves not only to focus reform efforts, but also to clarify the targets of change.

Thus, the goals for this theme of the literature review are twofold. First, I will outline the five components of effective mathematics instruction which have been linked to students' development of mathematical understanding. Then, I will provide an overview of the various knowledge domains and affective-motivational characteristics researchers have deemed necessary for successful enactment of the desired mathematical practice. This clarity of target and the gap between where we are and where we want to be will support the third theme of this literature review, where I address why instructional practice in the mathematics classroom remains so resistant to change.

Learning Theories' Role in Defining Effective Instruction

Over a century of research has produced a wide range of learning theories, beginning with those espoused by Thorndike and Dewey, progressing through those of Skinner, Piaget and Vygotsky, and further into those of Bloom, Bruner, Ausubel, Gagne, and Lave and Wenger. When applied to mathematics education, Goldin (2003) observed that many fervid proponents of behaviorism, radical constructivism, social constructivism, or affective perspectives focus on discounting the legitimacy of other theories rather than looking for complementary uses of each. Simon (2009) agreed with this assessment, proposing that each theory is well-suited for use in particular ways.

According to Simon, these learning theories can be viewed first as tools, wherein each offers a range of applicability to specific types of work, and second, as lenses through which various mathematical situations can be studied. Because the important work of mathematics education is enacted at multiple levels, involves multiple groupings (individual, small group, entire class, school, district, etc.), and can be interpreted in multiple ways, it behooves researchers to be conversant in the various ways these theoretical lenses and tools can be applied to different instructional tasks and settings (Cobb, 1988; Sfard, 2003). As Simon (2009) so eloquently states:

> Although some research is generated within a particular theoretical perspective, larger problems within the field of mathematics education—problems that are not grounded in a particular theoretical orientation …—require that we find ways to bring together research done from different theoretical perspectives and generate research programs that make use of multiple perspectives. (Simon, 2009, p. 488).

Blending theories in this way was first seen in Cobb, Yackel, and Wood’s work (1992) and continues today (Cobb, 2007; Dweck, 2015; Galbraith, Stillman, & Brown, 2010, Goos & Williams, 2013; Hennessey, Higley, & Chesnut, 2012; Lerman, 2013; Rasmussen & Stephan, 2008; Schwarz, Dreyfus, & Hershkowitz, 2009; Simon, 2013; Stillman, Cheung, Mason, Sheffield., Bharatah, & Ueno, 2009; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Williams & Huang, 2014). The evolution of and blending of these learning theories have led organizations such as the National Council of Teachers of Mathematics (NCTM), the National Science Foundation (NSF), and the National Research Council (NRC) to suggest that mathematics instruction should shift from the current "traditional" methodologies that focus on procedure and memorization to those that incorporate interactions between and among teachers, students, and content (Stigler & Hiebert, 2004; Cohen, Raudenbush, & Ball, 2003; Jacobs, Lamb, & Phillipp, 2010; Wood, 1993) while emphasizing important mathematics ideas, evidence-based argument, social construction of mathematics, and sense-making (Billings & Fitzgerald, 2002; Corey, Peterson, Lewis, & Bukarau, 2010; Hennessey, Higley, & Chesnut, 2012; Murphy & Mason, 2006).

By examining the differences between instructional practice in various countries, researchers illustrate that experiential, social learning which prioritizes mathematical understanding and problem solving over procedural mastery has more impact on student achievement (Cobb et al., 1992; Hiebert & Carpenter, 1992; Stigler & Hiebert, 2004). These findings are further supported by widespread adoption of the Common Core State Standards (CCSS) for Mathematics, which also call for transformational shifts in mathematics pedagogy (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

Taken together, the research suggests that the ideal reform mathematics classroom is more student-centered than its traditional counterpart and that the reform-oriented instructor focuses on the connections between and among standards as opposed to disjointed topics and skills. Students take an active, central role in the classroom, articulate their reasoning while problem solving, and assume responsibility for their mathematics learning. Rather than relying on the didactic practice of lecturing, while students passively listen, teachers provide opportunities for student-led exploration of mathematical content, facilitate productive mathematics discussions, engage students in authentic problem solving scenarios, and attend to student thinking.

A Framework for Developing Mathematical Thinking

Of course, rattling off a list of desired characteristics of a reform mathematics classroom does not necessarily help identify the shifts in any sort of visible, auditory, or measurable way. Describing the practices concretely and in terms of teacher and student behavior is important. Fortunately, much of this work is being completed by Brendefur and his team. Informed by both a cognitive and social perspective, Brendefur’s framework for effective mathematics teaching, Developing Mathematical Thinking (DMT), emphasizes the integration of both individual student construction of new mathematical understandings which connect to previous knowledge and social construction of collective knowledge through facilitated class and small-group discourse (Brendefur et al., 2015). The DMT framework builds off of the work of Carpenter and Lehrer (1999), Freudenthal (1973, 1991), Treffers (1987) and Gravemeijer and van Galen (2003) and is characterized by opportunities for students to (a) construct coherent mental schema for interrelated mathematics concepts (Carpenter and Lehrer, 1999), (b) compare various strategies and models for solving problems (Hiebert & Carpenter, 1992, p.68 as cited by Brendefur, 2015), (c) progressively formalize their thinking, and (d) attend to both vertical and horizontal mathematizing (Treffer, 1987, as cited by Brendefur, 2015).

To target each of these criteria, the DMT framework incorporates five distinct areas of teacher focus and instructional behavior (see Figure 1).

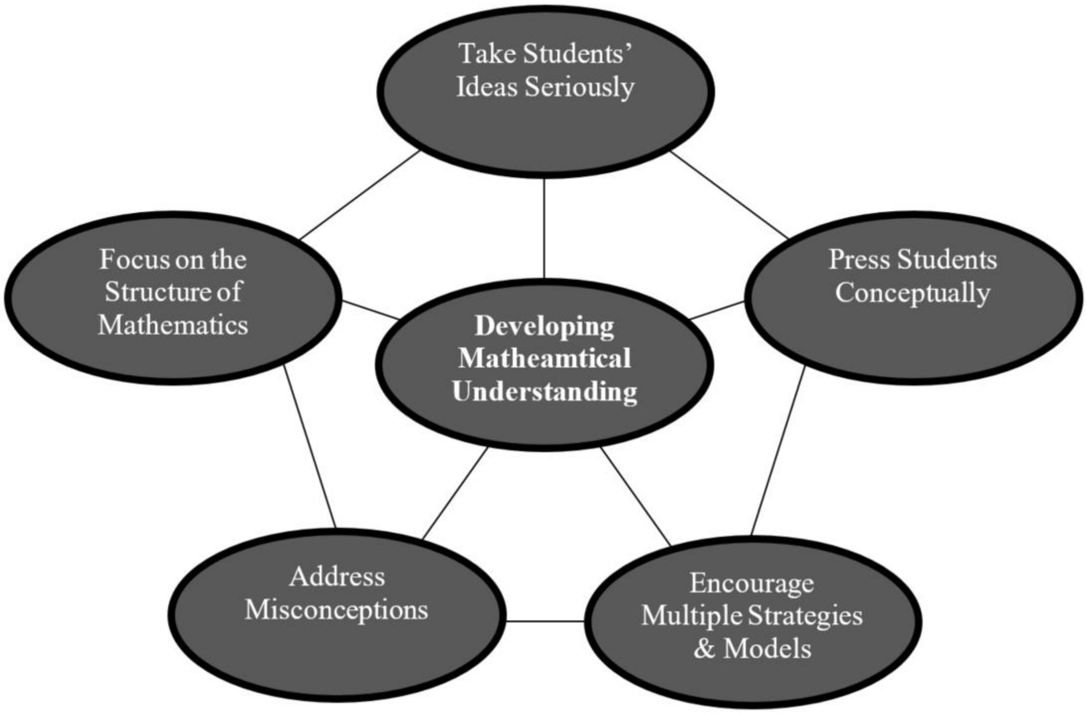

Figure 1. Developing Mathematical Thinking (DMT), Brendefur et al. (2013).

The first core attribute of effective mathematics instruction is Taking Students' Ideas Seriously (TSIS). This entails eliciting students' prior knowledge and intuitive understandings of new mathematical ideas, accepting and building upon their initial strategies even if they are not yet formalized or efficient, and helping students to then connect their initial understandings to those used more widely in the field of mathematics. This attribute is seen in practice when teachers pose high-access problems to which there are multiple solutions, accept students' strategies as valid, and provide avenues for students to explain and revise their thinking in a safe, inclusive environment.

The second core attribute is Pressing Students Conceptually (PSC). This focuses on helping students articulate the connections between their own and others' strategies and representations. This also entails progressive formalization, a process whereby teachers help students transition from less efficient, case-specific representations and thinking to more efficient, generalizable understandings. It is within this area of practice that teachers ask probing questions, introduce formal vocabulary, and guide students toward the more efficient mathematical conventions and methodologies for solving problems.

The third core attribute is Encouraging Multiple Strategies and Models (EMSM). This focus area goes hand-in-hand with PSC, with its emphasis on seeing the correctness in others' representations and thinking. With its attention to representations, teachers help students build both flexibility and fluency by pressing them to articulate the benefits and drawbacks of different models and strategies. Evidence of this in practice would include teachers guiding students to articulate the key information that different representations provide for the problem at hand, thereby illustrating an understanding of the benefits and drawbacks of each.

The fourth core attribute is Addressing Misconceptions (AM). It is in this area that teachers diagnose student errors in order to understand the underlying misconception that caused them. Utilizing common misconceptions as opportunities to address incorrect student thinking rather than simply directing students in the correct application of a procedure can assist students in adjusting their existing schema to facilitate new learning. In practice, teachers attend to the underlying errors in thinking and use models and discussion to ameliorate the issue, rather than applying a superficial and temporary "fix" of redirection and procedure rehearsal.

The fifth core attribute is Focusing on the Structure of Mathematics (FSM), and entails significant teacher understanding of each mathematical domain's fundamental building blocks and the connections between them. Teachers engaged in this practice treat mathematics as an interconnected whole rather than a series of disjointed topics and skills, and their language use and discourse facilitation highlights this focus on structure. Rather than emphasizing rote memorization and drill, teachers highlight the foundational aspects of mathematical procedures, draw connections to other related procedures, and link each to their students' individual strategies and thinking.

Teacher Capacities Needed to Enact Effective Instruction

Given the list of core attributes above, it is clear that significant knowledge, skill, and capacity are necessary for teachers to successfully implement instruction that aligns with the reform agenda. Shulman conceptualized a domain of teacher knowledge he termed pedagogical content knowledge (PCK), which encapsulates a type of knowledge unique to teaching (Shulman, 1986). Ball and her team further developed this idea to incorporate more refined domains of knowledge needed for mathematics teaching and provided the ubiquitous "egg" (Ball et al., 2008) which illustrates the interconnected domains of mathematical knowledge for teaching (see Figure 2).

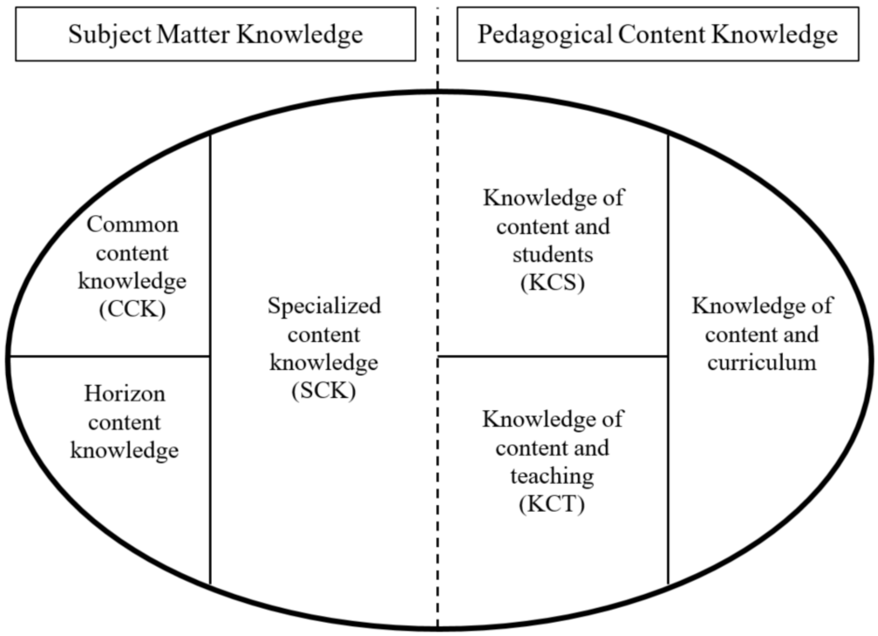

Figure 2. Domains of mathematical knowledge for teaching, Ball et al. (2008).

Through her research, Ball and her colleagues worked to explicate the ways in which "teaching demands a simultaneous integration of key ideas in the content with ways in which students apprehend them" and to answer the question, "What do teachers need to know and be able to do in order to teach effectively?" (Ball et al., 2008). In their work, they identified several different domains of mathematical knowledge for teaching that involve (a) knowing the content well enough to solve the mathematical problems assigned to students, (b) identifying and quickly analyzing learner errors when they occur, (c) assessing nonstandard approaches to solving problems, (d) explaining and representing rationales for procedures, and (e) generalizing specific mathematical models (Ball et al., 2008).

In keeping with Shulman's initial theory, Ball and her team retained the two major categories of subject matter knowledge and pedagogical content knowledge he initially posited. However, each of these domains were divided into three distinct subdomains. Within subject matter knowledge, Ball and colleagues include common content knowledge, specialized content knowledge, and horizon content knowledge. *Common content knowledge* is defined to be the mathematical knowledge and skill used outside the instructional setting. This contrasts with *specialized content knowledge*, which includes knowledge that is specific to teaching and only used in that setting. It encompasses both a level of mathematics unpacking for pedagogical purposes and analysis of student thinking for errors and viability of nonstandard approaches. Lastly, *horizon content knowledge* includes a teacher's understanding of the vertical relationships between mathematical topics and allows instructors to attend to the foundational aspects of the content they are responsible for teaching.

Within the larger pedagogical content knowledge domain, we find the subdomains of knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum. *Knowledge of content and students* allows teachers to coordinate what they know about both students and mathematics in order to predict potential areas of confusion and to facilitate progression along trajectories of learning as evidenced through written and spoken language. *Knowledge of content and teaching* integrates pedagogical and mathematics knowledge in ways that foster the design and sequencing of instruction. Finally, *knowledge of content and curriculum* equips teachers with the tools they need to coordinate instruction and student learning through the effective use of curriculum and materials.

The tight coordination of knowledge within each of these domains is what allows teachers to select meaningful tasks for students, sequence them to optimally elicit and develop students' conceptual understanding, calibrate difficulty level in order to surface misconceptions and potential stumbling blocks, and then address student missteps in ways that facilitate collective understanding and conceptual growth in mathematics. Is it no wonder that subsequent studies on teacher facility within each of these knowledge domains link pedagogical content knowledge to improved student mathematics achievement on both the elementary (Hill, Rowan, & Ball, 2005) and secondary levels (Baumert et al., 2010)?

But is teacher knowledge enough? Some would claim not. We find this stance in yet another strand of research that proposes the need for additional teacher competencies as outlined by Richardson (1996) and Thompson (1992). Combined with the domains of Shulman (1986) and Ball (2008), these additional competencies yield the TEDS-M framework (Döhrmann et al., 2012; Tatto et al., 2008), which has been adapted to include affective-motivational characteristics considered to be critical for effective instruction (see Figure 3).

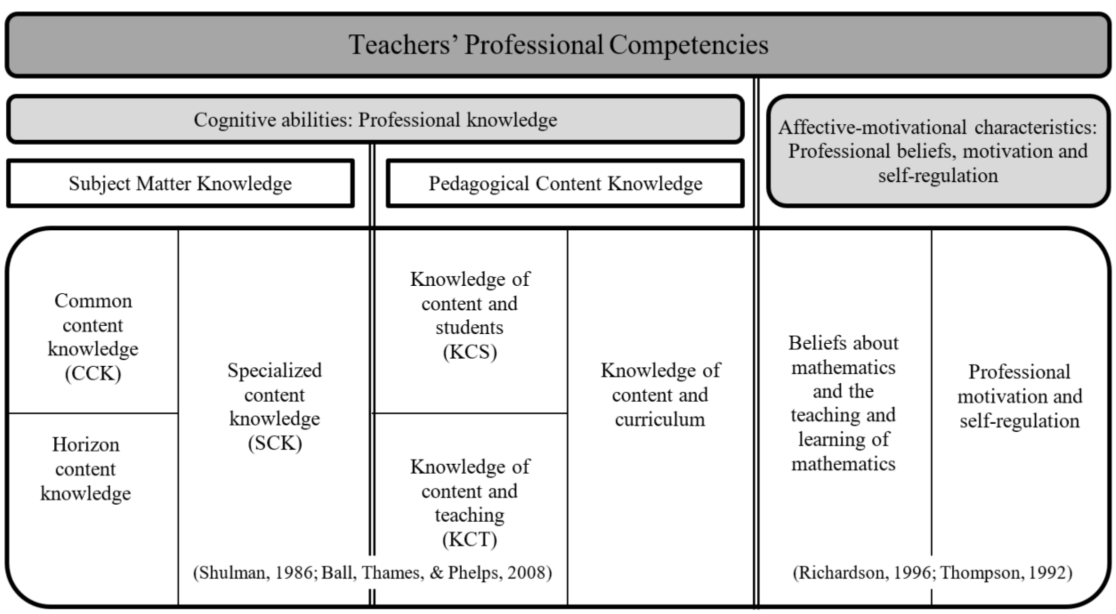

Figure 3. Teachers' professional competencies. Adapted from Teacher Competencies by Döhrmann et al. (2012).

This framework suggests that not only is it necessary for effective teachers to possess sufficient knowledge in each of the domains of mathematical knowledge for teaching proposed by Shulman and Ball, but they also need to possess the affective-motivational characteristics that support reform-based instruction.

Outcomes of the Measures of Effective Teaching (MET) Project (Cantrell & Kane, 2013), where Kane and colleagues use student achievement data to identify effective classroom practices (Kane & Cantrell, 2010), and Kimball's work in correlating student achievement to teacher evaluation scores in content and pedagogical knowledge, lesson coherence, flexibility and responsiveness, and students' cognitive engagement (Kimball, White, Milanowski, & Borman, 2004) further support the claim that how teachers coordinate the roles of instructor and student in the classroom matters.

The question becomes, then, how do we as a research community work to equip teachers with the knowledge and affective-motivational characteristics they need to enact effective instructional practice in a sustainable way? How do we motivate, support, monitor, and measure the change we wish to achieve? Given the history of resistance to reform efforts aimed at change, identifying and framing the barriers that impact intervention outcomes becomes critical. For this reason, I now turn to the third theme of this literature review.

Theme 3: Barriers to Reform

As documented in the first theme, most researchers in the mathematics education world are aware that the call for reform is not new, nor are the nation's efforts to institute this desired change. Over the past decades, significant investments have been made in the design and implementation of professional development programs and on the creation of aligned curriculum aimed at eliciting and then sustaining change in teachers' classroom behaviors. Yet the core of mathematics teaching in the US remains strikingly similar to its traditional instruction of a century ago (Cuban, 1993; Fey, 1981; Hoetker, & Ahlbrand, 1969) and the behaviorist orientation which dominates much of current mathematical practice persists (Fullan, 2009; Stein et al., 2007; Hiebert, 2013). Though multiple interventions have been shown to make shallow yet measurable inroads into proximal practitioner behavior, few can claim sustainability in the long term, and even fewer maintain their effectiveness when scaled up. Why is this the case?

Multiple frameworks for understanding the mechanisms of adult behavioral change populate the annals of personality, social and cognitive psychology, medicine, economics, educational counseling, mental health, appreciative inquiry, self-control, decision and choice theory, behavioral finance, educational leadership, business, organizational change, addiction, identity, mindset, and crisis management research, just to name a few. Understanding the process of change and the critical points during which new behaviors are sustained or abandoned remains an issue of concern across numerous academic and professional arenas, and the work conducted within each can lend assistance in framing the barriers to reform that have been reported by the mathematics research community.

"Regardless of how difficult you think it is to improve classroom mathematics teaching on a wide scale, it is more difficult than that" (Hiebert, 2013). Transforming teaching is hard work, fraught with pitfalls and roadblocks. Yet it is clear that teachers are the mediators of professional development, curriculum, coaching, or collaborative interventions aimed at change and how teachers respond to these interventions affects their students' opportunities to learn.

If interventions fail to impact teacher behavior behind the classroom door, if traditional instructional practice persists despite all efforts to change it, then gaining a better understanding of why change is so difficult must become a priority. The literature on the relationship between change and teacher beliefs, conceptions, affect, self-efficacy, motivation, mindset, attribution, etc., all reveal significant overlap with the research on learning, cognition, and psychology. Unfortunately, the connections between these various factors and concepts remain unwieldy and unmapped. When psychologists switched their focus from behaviorism and lifted the lid on Pandora's black box of cognition, the connections between stimuli and response lost much of their clarity and became much more challenging to trace. A multitude of new constructs arose, many of which elude all efforts of measurement and fail to meet consensus in their definitions (Philipp, 2007).

Developing a Framework for Change

So how do we, as a mathematics teaching profession, construct a framework to coherently connect the seemingly disparate theories and concepts in a way that will support our efforts to effect change? If transforming practice is our goal, coordinating the various factors which precipitate and support change is necessary. But which constructs subsume the others? What are the relationships between them? How do we build a theoretical framework that allows us to articulate the mechanism of change within our discipline and the interactions between the internal and external forces at play?

I propose that the first step should be to identify the variables that pose barriers to change, followed by research that examines how best to address these barriers. Though exhaustively mapping out the mechanisms of change itself has merit, understanding how change happens is not as beneficial to the goals of reform as understanding why change efforts fail. Fortunately, research on the psychology of change and the difficulties encountered in precipitating it have been the focus of research in multiple professional and academic arenas and each lends credence to the repeated claims that arise.

Altering adult behavior poses challenges in virtually every field, whether on an organizational or individual level. Common themes that appear to surface time and again from the snarl of constructs and theories regarding change is the claim that successful, sustained behavioral change can be linked to the coordination of contextual, emotional, and cognitive factors (Clarke & Hollingsworth, 2002; Desimone, 2009; Darling-Hammond et al., 2009; Goldsmith et al., 2014; Heath & Heath, 2010; Kennedy, 2016; Loucks-Horsley & Matsumoto, 1999; Marrongelle et al., 2013; Opfer & Pedder, 2011). This claim aligns with Phillipp's suggestion to the research community as it moves forward in its efforts to shift instructional practice in the mathematics classroom: develop a cohesive construct which includes all the sociocultural, personality, and belief variables with the potential to impact the process (Phillipp, 2007). These results also highlight common barriers that might explain why so many change efforts fail.

Consequently, I will address the three primary categories of barriers that repeatedly arise regardless of context and then use these as an initial framework for organizing my review of the literature on change (see Figure 4).

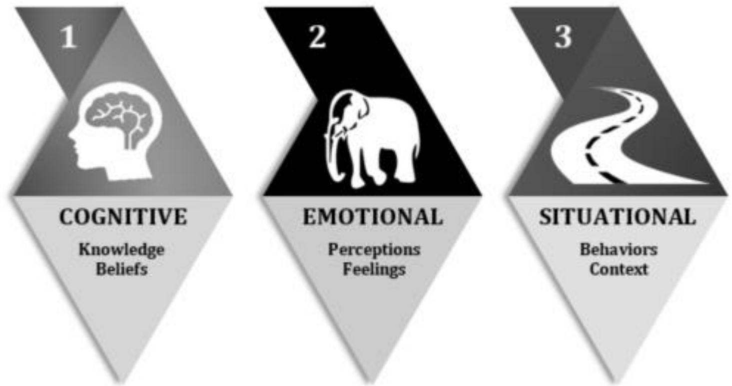

Figure 4. Categories of barriers. Adapted from Heath and Heath. (2012).

No matter the area of study, research reveals that cognition (the whole messy construct of teacher knowledge, beliefs, and learning), emotions (no matter how they are labeled in motivation, self-regulation, and self-efficacy literature), and a lack of sociocultural coherence between the desired behavior and the situated context in which it is enacted present the most challenging barriers to change. Though I jeopardize the clarity that arises from clean definitions and precise specificity of terminology, sorting the multitude of fine-grained variables from each specific fields' research into these umbrella constructs will allow me to address the barriers more succinctly and in a more coherent fashion than were I to exhaustively track the connections and nuances of meaning within each construct's encompassed terms. I will grant that there are hundreds, if not thousands, of research articles that explore the full scope of constructs and concepts I have so cavalierly combined. But for the sake of expediency and readability, I am opting to review the literature on change by using a wider, more holistic, lens.

In addition to providing an overview of these three primary barrier categories, I will also address the proposed reasons as to why these barriers are so challenging to overcome using a research-supported framework of implementation for both small and large scale change. This framework will help lay the groundwork for the fourth theme of this literature review, where I will highlight the successes, both recent and historical, of various interventions aimed at shifting mathematics teachers' pedagogical practice.

Cognitive Barriers

The stark contrast between Thompson's 1992 handbook chapter on teacher beliefs, knowledge, perception, and conceptions and Philipp's subsequent 2007 handbook chapter on the same research topics illuminates the complexity of the cognitive construct and how it has changed in the past few decades. Thompson's synthesis of the literature, an overview of a century of research on teacher beliefs, is concise and well-structured, a clean treatise that outlines the spectrum of teacher beliefs regarding the nature of mathematics, the distinction between beliefs, knowledge, and conceptions, and the contested relationships between these beliefs and mathematics teaching and learning. Despite Pajares' claim that teacher beliefs present a "messy construct" (Pajares, 1992), the various pieces and parts being researched at that time were still manageable. Fast forward twenty-five years, and the nice, neat correlations and summaries between various sub-constructs becomes increasingly more labyrinthian.

Despite this complexity, multiple studies that seek to tease out the nuances of the knowledge and belief constructs serve to highlight why cognitive factors can pose such a significant barrier to change. Research reveals teachers' prior beliefs and experiences affect their receptivity to learning (Cohen, 1988; Darling-Hammond & Ball, 1998). Additional studies note the coherence between teacher belief and practice (Stipek et al., 2001) and posit that attempts aimed at shifting instructional practice remain minimally effective if teacher beliefs remain unchanged (Ball & Cohen, 1996; Collopy, 2003; Davis & Krajcik, 2005; Remillard, 2005).

Underlying most of this research are theories which explain a person's basic desire for consistency and coherence among beliefs, emotions, and behavior. We can find this idea explicated in Festinger's (1957) cognitive dissonance theory, Heider's (1958) balance principle, and Osgood and Tannenbaum's (1955) congruity principle (as cited by Higgins & Kruglanski, 2000). The foundational premise of each is that humans seek equilibrium by constructing a consistent social world that makes sense. When new information elicits the perception of inconsistency, it is often met with resistance or outright rejection. Classic examples from mathematics and science include the revolutionary ideas of the earth being round, planets orbiting the sun, and parallel lines intersecting. Until a new conception or schema that eliminates inconsistencies can be created to accommodate these seemingly contradictory ideas, new learning does not occur (Piaget, 1970; Anderson, Kline, & Beasley, 1979). Yet building new conceptions, overhauling existing belief systems, and altering behaviors to achieve alignment and reclaim equilibrium is hard work; is it any wonder that effecting change in teacher practice is perceived to be such a Sisyphean task?

<u>Beliefs</u>

Teachers' conceptions, images and beliefs about mathematics learning and teaching "serve as filters for making sense of the knowledge and experiences they encounter […] and may also function as barriers to change" (Feiman-Nemser, 2012). Due to their own lived experience as observers and participants within an educational system, teachers arrive at their profession fully equipped with intact, wholly integrated belief systems for instruction, learning, learners, and mathematics (Lortie, 1975). It should surprise no one, then, that such belief systems possess the potential to hinder the development and integration of new ideas and new habits of thought into practice (Ball & McDairmid, 1990; Calderhead & Robson, 1991). Nor should it surprise any that many mathematics teachers' conception of effective instruction features clear presentations of efficient solutions to example problems, provision of coherent content explanations, and scaffolded lectures delivered to orderly classrooms of attentive students (Ball, 1988).

Challenges arise for some because the reform mathematics agenda poses significant deviations from these conceptions. Time and again, research illustrates that if an intervention's theoretical foundation does not align with teachers' beliefs, their implementation and integration of the intervention's promoted change does not occur (Chavez-Lopez, 2003; Collopy, 2003; Remillard & Bryans, 2004; Wilson & Goldenberg, 1998). We find these tensions in four primary areas of teacher beliefs.

First are beliefs about mathematics itself. If teachers possess an instrumentalist as opposed to dynamic stance, they are more likely to present mathematical ideas and concepts as fixed techniques to be used in specific ways to solve specific problems (Thompson, 1992; Dossey, 1992). This is in direct contrast to the more socially negotiated, evolving and constructed nature of mathematics advocated by reformists.

Second are beliefs about the act of teaching itself and the locus of authority and control in the classroom. When the mathematics classroom is believed to yield better student learning when operating in a more teacher-centered fashion (Ball, 1988), convincing a teacher to adopt a more student-centered stance when they perceive it to be unwieldy, unpredictable, inefficient, and chaotic is likely to be met with resistance.

Third are beliefs about learning itself, as teachers can position themselves in a behaviorist, constructivist or socio-cultural camp. Strict adherence to any single learning theory can pose barriers when flexibility and the ability to adapt is needed to fluidly manage a reform classroom (Simon, 2009).

Lastly are beliefs about the role of students within the classroom and the degree of involvement they claim while acquiring new knowledge. If a teacher casts students in the role of passive recipient and views them as mere receptors of knowledge transmitted through direct instruction, then they are less likely to engage students in the more active, exploratory, social role of sense-making and knowledge acquisition espoused by reformists (Stipek et al., 2001).

Given that each area of belief presents a continuum upon which a teacher may reside, opportunities for cognitive resistance to reform efforts abound. Incorporating reform methodologies into pedagogical practice when they conflict with deeply-held convictions about mathematics, teaching, learning, and learners creates dissonance, disequilibrium, and discomfort. It is not surprising, then, that a teacher's willingness to revisit and revise these beliefs can pose barriers to reform (Darling-Hammond & Ball, 1998). Combine this with the facts that adult learning is an iterative process akin to "tinkering," where teachers test out, adjust, incorporate, reflect upon, and then revise or reject new techniques, ideas, or materials based on how well they align with their existing goals and lived experience (Huberman, 1995), and the success of an intervention becomes even more tenuous. Teachers' propensity to draw conclusions regarding best practices based on small, non-random samples of their own students further compounds this tension, as humans tend to seek out, process, and remember feedback that supports their initial stance (Swann, 1987).

What, then, of teachers who claim to hold reformist beliefs, and yet still enact instructional practices that suggest otherwise? Mathematics educational research literature is filled with accounts of teachers who espouse beliefs consistent with the reform agenda while their practices do not appear to align. Are these counter-examples to coherence theory, or is something else happening? Several researchers aimed to find out. Their studies reveal that context, teacher knowledge, and the prioritization of competing values can all led to the appearance of inconsistency when in fact, the beliefs which activate particular behaviors do align with teachers' instructional decisions (Raymond, 1997; Skott, 2001, Cooney, Shealy, & Arvold, 1998). Because of this, Phillipp recommends that researchers adopt the stance that contradictions between beliefs and practice do not occur; instead, it is the researcher's task to better understand the teachers' perspectives and all underlying contextual variables so that the perceived inconsistencies can be resolved (Phillipp, 2007).

Knowledge

One cognitive domain that seems to hinder the appearance of coherence among beliefs and practice is that of teacher knowledge. As outlined in this chapter's second theme, teachers must possess adequate knowledge in multiple domains before they can successfully implement effective mathematics instruction that aligns with the reform agenda (Shulman, 1986; Ball et al., 2008; Dohrmann et al., 2012). Lack of knowledge in any of the subdomains of common content knowledge, horizon content knowledge, specialized content knowledge, knowledge of content and students, knowledge of content and teaching, or knowledge of content and curriculum can adversely affect teachers' ability to effectively facilitate students' mathematical knowledge acquisition.

What this can mean in practice is that even if teachers believe students learn best by collectively engaging in interesting tasks that afford multiple solution strategies, they may struggle to identify or create these tasks because they do not know the mathematics well enough to do so. Even if they believe students should construct their own knowledge by building off their initial informal understandings, they may struggle to identify the correct, generalizable mathematics embedded in a student's nonstandard approach to solving a problem. They may struggle to identify, select, and appropriately sequence students' work in ways that assist social construction of mathematical understandings and progressive formalization of mathematics' interconnected concepts if they lack knowledge of content and students. They may inadvertently reinforce student misconceptions because they are unable to identify them or else possess the same misconceptions themselves. Lack of knowledge can pose a barrier to change, as teachers who believe student-centered instruction is best may still replicate the teacher-centered experiences of their own learning in order to compensate for the superficial or incomplete understandings they themselves hold. The fact that few teacher preparation programs offer opportunities to acquire this knowledge (Ball et al., 2008) further strengthens these barriers to change.

Additional barriers that fall under the cognitive umbrella stem from humans' laudable capacity for analysis and decision-making. Being able to analyze the various pathways toward a goal, weigh the pros and cons of each, assess the myriad options and potential outcomes available at any decision point, and then make an informed choice that leads to action are all skills which enable teachers to adapt to and function within the dynamic and complex classroom setting. Yet when too many competing beliefs, demands, and needs fill the teachers' horizon, they can get mired in analysis, suffer from decision paralysis, and essentially spin their wheels because they lack the clarity needed to move forward in productive ways.

For this reason, it becomes necessary to shift our focus toward the emotional components required in decision making. Without clear directions that fuel both motivation and emotional coherence, we run the risk of trapping people in the ruminations of cognitive thought (Guthrie, 1935, as cited by Higgins & Kruglanksi, 2000). The sheer number of decisions that teachers make on any given day can exhaust their mental resources (Vohs, Baumeister, Schmeichel, Twenge, Nelson, & Tice, 2014), thereby making it even more challenging to learn or to implement a plan for behavioral change if its translation from theory to practice is unclear or vague.

It is not enough to demand that teachers incorporate more student-centered, constructivist methods into their teaching; it is not enough to equip them with the knowledge they need and to convince them intellectually that these methods are better. We must make the behaviors we want emotionally accessible as well.

Emotional Barriers

Let us assume, for the moment, that a teacher's beliefs align with the reform agenda and that he or she intellectually embraces the pedagogical changes we desire. Let us assume, too, that the knowledge domain requirements are met and the teacher has the cognitive resources to design and implement reform-based instruction in the classroom. Is intellectual, cognitive alignment with the targeted behavior enough to elicit and sustain change? If beliefs and knowledge do not pose a barrier, are the hurdles cleared? The literature answers this question with a definitive no.

Change does not occur without individuals setting and achieving goals, and goals are not set or achieved without tight coordination among emotions, motivation, cognition, behavior, and affect (Zimmerman, 1990). Theories about the role emotions play at various points in the process of change abound, and the points in the process during which emotional components are deemed most critical vary from researcher to researcher. Regardless of the theory or researcher selected, one can ignore neither the preponderance of relapse and recidivism that accompanies any change effort nor the negative emotional factors which precipitate its abandonment.

Explicating the range of emotional factors and the relative strengths of their contribution to the failure and/or success of individuals or organizations seeking to change behavior remains elusive. But emotions, whether linked to professional identity, motivation, resistance, defensiveness, relatability, or relationship skills all appear to influence outcomes (Prochaska et al., 1993), as do the self-regulatory strategies and perceptions of control found in self-efficacy research (Bandura, 1997).

To supply one example of the emotion's role in change, Bandura distinguished between the cognitive processes of acquisition and the emotional processes of motivation which underpin the performance or enactment of specific behaviors. He focused on individuals' self-efficacy, or their beliefs in "their capabilities to produce desired effects by their actions" (Bandura, 1997). "People need firm confidence in their efficacy to mount and sustain the effort required to succeed. Thus in ongoing pursuits, perceived personal efficacy predicts the goals people set for themselves and their performance attainments" (Mone, Baker, & Jeffries, 1995). The cognitive belief that a goal is attainable and the emotional motivation to pursue it are both critical factors in any successful change process.

Professional identity, a relatively new construct which has been conceptualized as a "framework established and maintained through interaction in social situations, and negotiation of roles within the particular context" (Cross & Hong, 2009, p. 278) helps to situate the stage upon which the interface of self, emotions, and change occur. Multiple researchers claim that teachers' identities are constructed through a complex coordination of the technical, cognitive, and emotional components of teaching in concert with the cultural, social environments within which they work (Nias, 1996; Hargreaves, 1994; Van Zoest & Bohl, 2005). Thus, individuals who are undergoing change often experience emotional responses due to perceived threats to or reinforcement of professional identity.

When viewed from a sociological perspective, emotions can be viewed as dependent upon and activated by interactions between the environment and individuals (Schutz, Aultman & Williams-Johnson, 2009). During the process of change, individuals assess where they are in relation to where they want to be and then calibrate their assessment both in terms of coherence with their professional identity and in terms of the social networks within which they operate (Hochschild, 1990). If their perceived "location" is perceived to align with an individual's goals and values, a pleasant emotional response ensues. However, if the individual experiences conflict, his or her emotional response is negative (Schutz et al., 2009).

Consequently, as teachers transition their instructional practice, their emotional responses range from worry and anxiety to enjoyment and confidence (Schmidt & Datnow, 2005; Saunders, 2013). The adoption of innovations that require complex skills are particularly fraught with fear of failure, intimidation, and apprehension about outcomes. (Bandura, 1997, p. 514). Being aware of this spectrum of response and providing supports to reduce feelings of isolation and anxiety during the journey of change are therefore critically important (Beatty, 2007; Fullan & Hargreaves, 1992; Harris, 2004; Lee and Yin, 2010).

Because mathematics generates stronger negative emotional reactions than any other school subject (Hoyles, 1982), engaging in instructional change in this area involves a renegotiation of identity under conditions that are often perceived as emotionally threatening (Barton, Paterson, Kensington-Miller, & Bartholomew, 2005). Change efforts can elicit feelings of vulnerability and instability when long-held principles and practices are challenged by new expectations and policies or when the standards by which effective teaching are judged are shifted (Kelchtermans, 1996).

It should come as no surprise, then, that more and more researchers are finding that teachers respond negatively to interventions aimed at educational change, especially when the reform efforts stem from large-scale policy mandates which overlook or marginalize teachers' knowledge, skills, voices, perspectives, and emotions (Sikes, 1992; Bailey, 2000; Lee & Yin, 2011). After analyzing the outcomes of multiple educational reform interventions, Fullan reached the conclusion that teachers' emotional responses were predominantly negative, often manifesting as anxiety, hopelessness, defensiveness, anger, and exhaustion (Fullan, 1997, pp. 229-230). Other researchers identified the emotions of shame (Bibby, 2002) and anger (Hargreaves, 1998; van Veen et al., 2005) as being precipitated by the perceived threats and stressors imposed by change. Another study revealed that feelings of nervousness, anxiety, and worry arise when teachers navigate organizational structures while also managing the logistics of new pedagogical practices (Saunders, 2013). Confidence can erode under the stress associated with adopting new instructional methodologies and self-efficacy can falter when the demands of innovation are heightened by stressors of limited time and resources (Saunders, 2013; van Veen et al., 2005). It should come as no surprise, then, that the interplay between teacher emotions and reformists' efforts to bring about change can help predict the success or failure of an intervention (Cross & Hong, 2009).

Under conditions characterized by the negative emotions precipitated by change, individuals often engage in social defenses in an effort to preserve stability (James, 2011). Two of these defenses which manifest as significant barriers to change are routines and resistance (James, 2010, 2011). Routines, or habitual practices that have been rehearsed to the point of automaticity, provide comfort and a release from uncertainty. Resistance, or the "direct refusal to accept information or to defy or oppose a request of some kind" is doubly heightened when the targets of change are the very routines that otherwise would serve as a defense mechanism against anxiety (James & Connolly, 2000). Is it any wonder that teachers' emotional responses to interventions can pose barriers to successful change?

Situational Barriers

Disappointingly, even if both cognitive and emotional barriers are addressed, success is still not guaranteed. Situational obstacles upon the path toward change can also bring about failure. This is reflected in the sociocultural research being conducted in educational, business, medical, and social arenas. Bandura, in his studies on sociocultural change, posits that "new practices usually threaten existing status and power relations"

(Bandura, 1997, p.514). When the promised advantages are delayed, and the benefits do not become evident until they have been applied for a significant length of time, motivation falters and commitment to the change wanes even among the staunchest advocates of change (Bandura, 1997, p.514). Altering the practices of social systems such as schools can pose challenges, as those who work within schools and those who are serviced by the schools may have a vested interest in preserving the status quo.

If we set aside the barriers presented by well-established schooling traditions and systemic adherence to “the way things have always been done,” we still encounter challenges when top-down, unfunded mandates and accountability measures communicate that teachers are incompetent, selfish, and self-serving (Bullogh, 2011) and when the punitive, as opposed to rewarding, tenor of school reform elicits a “culture of unhappiness” and demoralization within educational settings (Bottery, 2003).

All too often, prescribed educational reform is predicated on a narrow, technical view of teaching and learning while neglecting the complex, intellectual work and sophisticated professional judgment effective teaching requires (Bascia & Hargreaves, 2000). Government policies tend to focus on short-term behavioral skill targets and resultant measures of compliance as opposed to long-term investments in the intellectual development of teachers (Hargreaves & Fullan, 1998). Rather than providing additional preparation time to accomplish the newly prescribed policy goals, teachers often find themselves in front of students for an even greater portion of their work day, “totally absorbed in the immediacy of the work (Bascia & Hargreaves, 2000).

People are less likely to adopt innovative changes if they lack the accessory resources that may be needed (Bandura, 1997, p. 519). Reio criticized policy-led reform efforts, claiming that the combination of insufficient time, inadequate direction, and increased workload can have adverse effects on teacher motivation, learning, and performance (Reio, 2011). With decreased funding, heightened demands and test-score-dominated evaluations tied to job security and pay, educators are less apt to invest fully in their work. As a result, their aspirations suffer, and their performance lags (Valli & Buese, 2007).

Combine these stressors with educational policies that are consistently in a state of flux, tossed about in a sea of competing educational agendas, interventions, innovative programs, and ideologies, and the resulting educational systems are not only complex, but wildly chaotic:

> "Few of the existing theories and strategies of educational change equip educators to cope effectively with these complex, chaotic, and contradictory environments […] Rational theories of planned change that move through predictable stages of implementation or 'growth' are poorly suited to schools where unexpected twists and turns are the norm rather than the exception in the ways they operate" (Hargreaves et al., 2014).

Taken together, it is not surprising that whenever site- or department-based successes are scaled up, the systemic, situational barriers against wholesale reform present challenges separate from the cognitive and emotional barriers the teachers themselves erect.

Given this host of barriers to reform, be they cognitive, emotional, or situational, it might appear that the cause is a lost one and that all efforts toward mathematics pedagogical reform are doomed to fail. To combat this defeatist position, I now turn to the ways in which instructional change has been successfully implemented. Over the past few decades, the research community has provided, through its tireless efforts to support teachers and equip them with the knowledge and skills they need to teach mathematics successfully, multiple instances of success. Taken together, we can find rays of hope and potential avenues for sustainable change. It is toward these efforts that I now turn to the fourth theme of my literature review.

Theme 4: The Mathematics Research Community's Efforts to Effect a Change

As noted earlier, the call for reform in mathematics education is not new, nor are the nation's efforts to improve both teacher and teaching quality. Since the early 1980's, in support of the NCTM's *An Agenda for Action* and the *Nation at Risk* reports, significant financial attention has been focused on reforming mathematics curriculum and instruction. Since then, billions of dollars have been spent on both professional development and on the creation of aligned curriculum aimed at improving STEM education. According to the Fiscal Year 2015 Budget Summary and Background Information report (http://www2.ed.gov), $2.3 billion was allocated for Improving Teacher Quality State Grants, $165 million was earmarked for Investing in Innovation (i3) to improve STEM education, $170 million supported additional STEM Innovation, and $149.7 million was spent on Mathematics and Science partnerships last year alone. In addition to this, the development of thirteen exemplary, comprehensive mathematics curricula has been fully funded by the NSF for use in school districts around the country (http://www.nsf.gov).

The purpose of this section is to provide researched support for the various ways external interventions intended to shift mathematics teachers' knowledge and practice have addressed the barriers arising from cognitive, emotional, or situational concerns. These interventions come in a variety of formats: a dizzying array of professional development models, curricular materials and resources, formal to informal collaboration, and a range of general to subject-specific instructional coaching. These individual factors can be arranged and delivered in countless combinations, many of which have resulted in various levels of success. By providing a brief overview of how various components of each have addressed the barriers outlined in Theme 3, the intent of this section is to highlight a potential combination of intervention factors that might be conducive to effecting a sustainable change in mathematics teachers' practice.

The Framework for Change Revisited

In keeping with the organization of barriers to change outlined in the third theme, I continue with the Heath brothers' framework to help coordinate the cognitive, emotional, and situational factors involved. By synthesizing the various bodies of research focused on change, the Heath brothers fashioned their theoretical framework based, in part, on Jonathan Haidt's metaphor in which the mechanisms of change are mediated by the imbalance of control between the intellectual (mind aka Rider) and emotional (heart aka Elephant) halves of our brain (Haidt, 2006, as cited by Heath & Heath, 2010). Their framework can best be summarized by the revised graphic below and is characterized by its three primary directives: (1) Direct the Rider, (2) Motivate the Elephant, and (3) Shape the Path (see Figure 5).

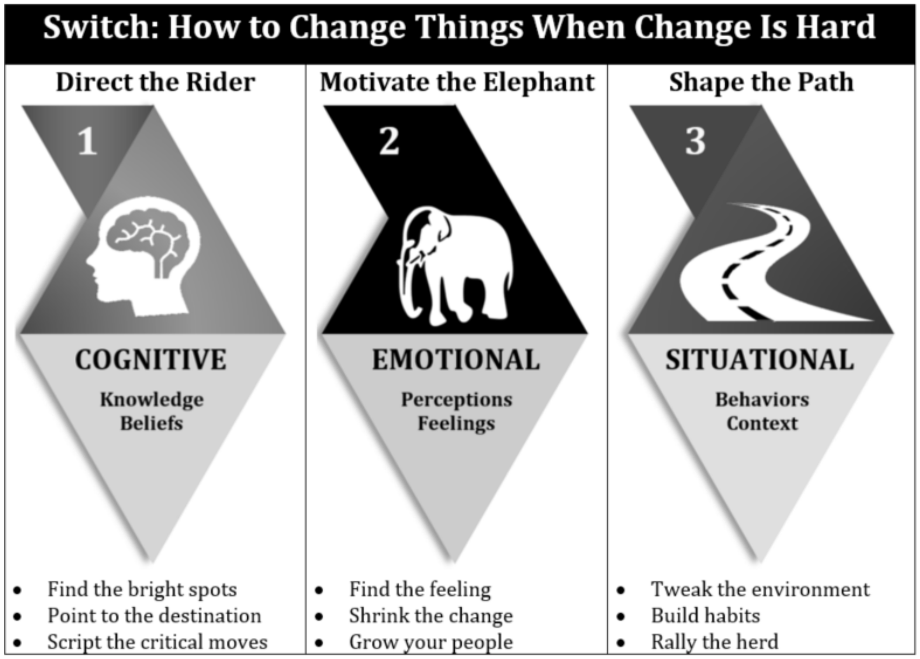

Figure 5. Switch: how to change things when change is hard. Adapted from Heath and Heath. (2010).

In their framework, they emphasize the tensions that arise when the rider, or the intellectual half of the brain, is metaphorically perched atop a giant, emotional elephant. The rider's job, despite being wholly outweighed by the elephant, is to maintain a firm hold on the reins and keep the elephant on the path. If the elephant's desires differ from those of the rider, the rider can draw on his/her reserves of strength to keep the elephant traveling in the right direction. But as many already recognize, that reserve of strength can be quickly depleted, especially if the path is littered with additional or unanticipated obstacles.

To address the multitude of cognitive (rider), emotional (elephant), and situational (path) barriers that arise in any change effort, the Heath brothers posit potential tools that can be used within each category. They claim that the cognitive barriers perceived as resistance often stem from a lack of clarity and can be successfully mitigated by providing crystal-clear direction or by "Directing the Rider." Emotional barriers, traditionally ascribed to laziness, are often precipitated by the exhaustion of self-regulation resources. Research they cite indicates that when the rider and elephant are working at cross purposes, the elephant will win every time. As a result, the Heath brothers advocate getting the elephant on board by activating emotional buy-in. That is, they claim "Motivating the Elephant" is of critical importance in successfully enacting change. Lastly, the Heath brothers theorize that often, the barriers perceived to be a people problem are symptoms of the situation in which the people are embedded. They suggest that by "Shaping the Path," or by altering situations and the surrounding environments to better support the targets of change, the chances of success are improved.

This framework and its proposed strategies for combatting the barriers that arise in the wake of mathematics reform efforts are supported by research in the field of adult learning, or andragogy, as conceptualized by Knowles (1968). Decades of study that build off the early work of Thorndike, Bregman, Tilton, Woodyard, and Lindeman have yielded four basic tenets for impacting adult knowledge and behavior:

Tenet 1

First, as an individual grows, his/her self-concept becomes increasingly self-directed. When placed in a compulsory situation that strips him/her of the ability to self-direct, resentment and resistance are likely outcomes. Heath and Heath's theoretical framework for change suggests that fostering both emotional and intellectual buy-in so that personal goals and the intervention's goals align can help to combat this barrier.

Tenet 2

Second, as a person matures, he/she accumulates experience and knowledge through which all new learning is filtered. Transmission techniques of traditional professional development, delivered by external “experts,” are therefore less effective than those which build upon experience and personal reflection via discussion, field experiences, team projects, and other activities and/or social interactions within the educational community being targeted for change. Educational situations which devalue or ignore an adult’s lived experience are far less likely to meet with success. For this reason, proffering solutions that diverge from the way things have always been done can cause challenges and meet with resistance. To combat this, finding colleagues from within the system, identifying those who have already changed and are experiencing greater levels of success, and then enlisting their aid so that new learning can focus on the homegrown instances of success within the community can help.

Tenet 3

Third, an adult’s readiness to learn depends largely on the tasks required for adequate performance of his/her evolving social, situated roles, whether through their work, their personal relationships, or their communities. A fundamental assumption of andragogy is that adults will be ready to learn when the knowledge they need is required to meet the demands of their perceived roles. When adults feel that they are already competently fulfilling their perceived roles as mathematics educators, convincing them to change their practice will remain a challenge. This again points to the need to coordinate both rider and elephant variables. Highlighting the need for improvement in ways that appeal to both cognitive and emotional sides of the debate can move teachers forward in productive ways.

Tenet 4

Lastly, adults tend to have a problem-centered orientation to new learning. That is, they will learn when they are confronted with challenges that they deem interesting, achievable, and relevant to their own lived experience and work. Shifting their focus from problems that need to be solved toward solutions that work can help streamline the process and clarify the path to improvement.

By incorporating what is known about how adults learn into the framework for change provided by the Heath brothers, efforts to precipitate changes in teachers' pedagogical practice can be more clearly assessed and better, more informed decisions about professional development design, coaching protocols, collaboration structures, and curricular supports can be made. Thus, it is with these recommendations in mind that my review now turns to the most prevalent interventions and supports used to foster adult learning within the mathematics educational setting and the various ways in which they align with the framework for enacting change. I begin with the Heath brothers' first recommendation: Direct the Rider.

Direct the Rider: Addressing Cognitive Barriers

Directing the Rider consists of three interrelated components: finding the bright spots, pointing to the destination, and scripting the critical moves. *Finding the bright spots* helps to combat the tensions wrought by conflicting beliefs and to illustrate that yes, even in teachers' personal communities with their own students, families, colleagues, and administrators, they can impact students' mathematics achievement in positive ways.

Pointing to the destination helps to quantify and specify the end goal, removing the potential for over-analysis, rumination, and rationalization that erode the ability to make productive decisions regarding instruction. Lastly, *scripting the critical moves* helps to support the first two components by identifying essential decision points along the path toward change and eliminating the wiggle room and decision paralysis that can cause teachers to fall back on their habitual patterns of practice.

Find the Bright Spots

Given the general adult's propensity to focus on the negative (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001), the fact that innovative practices can have mixed effects across the social landscape, and practitioners' pervasive perception that interventionists tend to oversell their product, some teachers may be wary of abandoning practices of established utility that enjoy public and social support. This can result in those with insecure status postponing their adoption of new practices until they can see the benefits of innovation by early adopters within their own communities (Bandura, 1997).

Without ready access to success stories from within a teacher's personal sociocultural system, the perceived risks of change often outweigh the risks of adhering to traditional practice. Little persuades more than witnessing effective practices in use by colleagues, and enlisting the aid of successful early adopters in encouraging others to try the new methodologies has been shown to support efforts toward change (Ostlund, 1974; Rogers & Shoemaker, 1971 as cited by Bandura, 1997).

Researchers have found evidence to support these claims regarding bright spots in professional development programs that connect to practice and focus on student learning

(Darling-Hammond et al., 2009). These programs provide opportunities for (a) teachers to observe examples of instructional strategies which yield desired student learning outcomes (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010), (b) practice-based learning where teachers examine artifacts from their own and colleagues' work to identify what's working and what's not (Ball & Cohen, 1999; Driscoll, 1999; Hawley & Valli, 2000; Mumme & Seago, 2002), and (c) lesson study formats where teachers reflect upon their own and colleagues' practice as it relates to student achievement (Bryant & Driscoll, 1998).

Each of these can place teachers in reflective states of cognitive disequilibrium (Thompson & Zeuli, 1999), raise their awareness of discrepancies between what they believe they are teaching and what students learn (Bryant & Driscoll, 1998), and lead to transformational thinking. When observing local bright spot classrooms where student learning is evident, teachers are more likely to see the value of new instructional strategies and try them out with their own students (Loucks-Horsley et al., 2010).

We find additional evidence of the effectiveness of bright spots in collaboration and coaching/mentoring research. Collaborative experiences are shown to be effective in two overarching types of scenarios. First, professional learning that focuses on student work analysis as a means of enhancing teacher knowledge and practice helps focus entire groups of teachers on replicating instructional strategies that work (Love, Stiles, Mundry, & DiRanna, 2008; DiRanna, Osmundson, Topps, Barakos, Gearhart, Cerwin et al., 2008). Second, when collaborative groups are guided by experienced content experts or mentors who have experience in the classroom and who engender trust within the colleagues whom they lead, teacher knowledge and skill has been shown to increase (Devine, Houssemand, & Meyers, 2013; Feger, Woleck, & Hickman, 2004; Sailors & Shanklin; 2010).

No matter its conceptualization, situated instructional coaching as it is enacted in schools and districts tends to reside somewhere along a continuum (Lipton & Wellman, 2003) from mentor-protégé, content-based coaching/consulting by experts (West & Staub, 2003) to partnership peer-coaching among equals (Devine et al., 2013; Knight, 2004, 2006, 2008, 2009, 2011; Neufeld & Roper, 2003; Showers & Joyce, 1996; Walpole & McKenna, 2012) and current research indicates that when instructional coaches possess pedagogical knowledge, content expertise, and interpersonal capabilities, they are more likely to effect positive changes (Borman & Feger, 2006; Ertmer et al., 2005; Kowal & Steiner, 2007). Thus, when teachers focus on the bright spots of instructional strategies which yield positive outcomes in student learning or are led by coaches/mentors who embody the bright spots of desired mathematics instructional knowledge, practice, and skill, the cognitive barriers that often challenge reform efforts can be overcome.

But what if we rely solely on the assumption that mimicking bright spots, altering behavior, and then learning from the evidence that arises is the best way to address cognitive barriers stemming from teachers' beliefs and gaps in knowledge? Multiple studies indicate that the relationship between belief and behavior is bidirectional. Changes in belief and knowledge can precipitate changes in behavior, while changes in behavior can also precipitate changes in beliefs and knowledge. But does this always work? Can we rely on the cognitive effects of behavioral change? It appears that in some cases we can, while in others we cannot.

The Heath brothers' recommendation to direct the rider includes not only the provision of bright spots, but also a disclaimer that without clear directions to fuel both motivation and emotional coherence, we court paralysis by trapping people in the ruminations of cognitive thought (Guthrie, 1935, as cited by Higgins & Kruglanksi, 2000). Even with bright spots in view, the sheer number of decisions that teachers make on any given day can exhaust their mental resources (Vohs, Baumeister, Schmeichel, Twenge, Nelson, & Tice, 2014) and make it more challenging to learn or to implement a plan for behavioral change. If the translation of theory to practice is unclear or vague, as is often the case with the complex practice of teaching mathematics, commitment to change can waver. It is not enough to demand that teachers incorporate more student-centered, constructivist methods into their teaching; it is not enough to convince them intellectually that these methods are better. We need to provide clear targets and the vision to support these targets. We, in short, need to *point to the destination.*

Point to the Destination

Without providing clarity on the end goal and quantifying the target using a measurable, pithy motto, deemed *pointing to the destination* by the Heath brothers, we can run the risk of overwhelming and confusing teachers while simultaneously placing them in a position they must maintain through active, deliberate exertion of their exhaustible self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998). This aligns with Locke and Latham's finding that "specific, difficult goals consistently led to higher performance than urging people to do their best" (Locke & Latham, 1990).

The rider is a thinker and planner, the cognitive workhorse who can get distracted by issues that invite analysis and contemplation. If there is no external referent associated with the ambiguous “improve your mathematical instruction” directive, teachers can spin their wheels. Combine this with a diverse classroom full of students who have their own combination of needs, desires, and behaviors to address, and the prospect of encountering problems in need of solving can often overwhelm, derail, and paralyze even those with the best of intentions. Knowledge and beliefs are not enough to change behavior, and generic, vague prescriptions to change practice without the provision of clear end goals that quantify the overall destination being targeted can muddy the path and lead to abandonment of the cause.

Support for this claim can be found in the literature on designing professional development, where commitment to vision and standards is key (Loucks-Horsley et al., 2010). Hiebert suggests a similar stance when he claims that “without stable and well-defined learning goals, efforts to improve teaching keep shooting at different targets, and the targets keep changing” (Hiebert, 2013). Clear goals that align with vision and foster immediate accountability through explicit measurement of student learning can be likened to “ports of call on the journey toward improvement” (Dufour & Eaker, 1998). These destination points can be in the form of student learning goals (Schmoker, 2002), teacher learning goals, desired teacher practice, or organizational targets (Loucks-Horsley et al., 2010). Guskey (2000) advocates effective goal design which also incorporates plans for both goal assessment and the types of evidence that will be gathered to monitor and gauge progress.

One of the more recent conceptualization of effective professional development as outlined by Darling-Hammond in her *Professional Learning in the Learning Profession: A Status Report on Teacher Development in the United States and Abroad* (Darling-

Hammond, Wei, Andree, Richardson, & Orphanos, 2009) supports these claims. In her report, she provides four primary recommendations that continue to populate the literature. These recommendations have been supported by later analyses, with disclaimers that the relationships between these components may be curvilinear and subject to the Goldilocks Principle (Nuthall and Alton-Lee,1993).

Her third recommendation states that professional development should align with school improvement priorities and goals. This means that assessments, certification requirements, evaluation, and teacher learning should be integrated (Loucks-Horsley et al., 1999). Charging school or district leadership with the task of providing ongoing, purposeful professional development, balancing the control between various levels of authority while remaining flexible with how that control is coordinated, and maintaining consistency of focus over time can help to keep teacher, administrative, and system goals aligned. This alignment can be fostered via iterative cycles of collaborative work within and across schools/districts (Borasi & Fonzi, 2002; Borko, 2004; Yoon, Duncan, Lee, Scarloss & Spapley, 2007; Whitehurst, 2002), partnerships with industry or post-secondary programs (Marrongelle et al., 2013), and coaching (Yoon, Duncan, Lee, Scarloss, & Spapley, 2007).

Yet establishing a coherent vision, highlighting the end goals, and setting a community's teachers on the path toward improvement is still not enough. When school leadership sets clear top-level direction while failing to get involved in the details, change efforts can still stall. This is, in large part, because the most challenging part of change resides in the details of implementation. We need to provide teachers with concrete, easily-remembered steps that they can enact without having to weigh competing options.

Research suggests that “modeling the desired competencies, guided enactments to build proficiencies, and generalized applications of the new ways that verify their functional value” can promote positive outcomes (Goldstein, 1973; Latham & Saari, 1979; and Rosenthal & Bandura, 1978, as cited in Bandura, 1997). For this reason, I move to the next component of directing the driver: *scripting the critical moves*.

<u>Script the Critical Moves</u>

The Heath brothers make this recommendation based on their review of the literature focused on decision-making. Big-picture vision is rarely enough; lofty goals need to be translated into small-scale behaviors that provide a clear pathway through the bewildering array of choices that teachers face every day. Why? Because having too many choices at any decision point results in decision paralysis (Baumeister et al., 2008; Sethi-Iyengar, Huberman & Jiang, 2004; Iyengar & Lepper, 2000; Redelmeier & Shafir, 1995; Schwartz, 2003; Fisman, Iyengar, Kamenica, & Simonson, 2006, as cited by Heath & Heath, 2010). Too many choices overload the intellectual rider and debilitate its decision-making capability. The anxiety precipitated by such paralysis serves to enhance the appeal that ingrained, autopilot routines possess and helps to highlight why too many choices and/or the ambiguity that often accompanies unfamiliar decision points can derail change efforts.

Evidence to support these claims can be found in Darling-Hammond’s first and second recommendations for effective professional development (Darling-Hammond et al., 2009). Professional development should be connected to practice, focus on student learning, and address the teaching of specific curriculum content within the teachers’ individual classrooms. It should combine both subject matter and curriculum (Ball &

McDiarmid, 1990; Bell et al., 2010; Blank et al., 2008; Borasi & Fonzi, 2002; Borko, 2004; Desimone, 2009; Elmore, 2002; Niess, 2005; Shulman, 1986; Whitehurst, 2002; Yoon et al., 2007), model effective instructional strategies and teaching methods (Borko, 2004; Carpenter, Fennema, & Frank, 1996; Elmore 2002; Kennedy, 2016), and utilize materials that are practice-based (Ball & McDiarmid, 1990; Borko & Putnam, 1998; Elmore, 2002; Greeno, 1994; Hawley & Valli, 1998, Putnam & Borko, 2000; Seago, 2004), are relevant to teachers' daily work (Greeno, 1994, Hawley & Valli, 1991), are coherent (Yoon et al., 2007), are situated within the teachers' own classrooms (Ball & Cohen, 2000; Brown, Collins, & Duguid, 1989; Huberman, 1995), and promote active analysis of student thinking (Crockett, 2002; Loucks-Horsley et al., 1999; Kennedy, 2016).

Because teachers construct their own understanding of children's mathematical realities, professional development targeted toward improving mathematics instruction needs to provide opportunities for teachers to construct their own knowledge about what it means for students to learn (Cobb & Steffe, 2011) so that they understand the instructional moves that should be made before they resort to making decisions on the fly.

We can also find evidence of scripting the critical moves in successful curricular interventions. The 1989 publication of the NCTM's *Curriculum and Evaluation Standards for School Mathematics*, combined with extensive funding from the National Science Foundation (NSF), gave rise to a sharp increase in reform curricula which offer pedagogical and content support to teachers (Remillard, 2000). Because many reform curricula authors' goal is to impact student learning of mathematics, attending to the numerous intermediate factors which can affect the achievement of that goal is essential. One common approach for this is for standards-based curricula to be designed with an educative intent for the teachers who will use them. They are designed to speak *to*, as opposed to *through*, the teacher (Stein et al., 2007).

The underlying theory behind this strategy implies that curricular materials are not the sole, or even the primary, agent for providing student learning opportunities. Rather than attempting to create the “teacher proof” materials seen in more traditional curricula (Cohen & Barnes, 1993, p. 215), reform curriculum authors recognize and attend to the fact that the teachers who are interpreting and enacting the materials play a critical role in student learning (Davis & Krajcik, 2005; Remillard, 2005; Stein et al., 2007). This has led to the inclusion of various styles of teacher notes which provide (a) strategies for material use, (b) outline the significance of a lesson’s mathematical ideas, (c) offer suggestions on how students may think or converse about the content, and/or (d) recommend additional tips for classroom implementation. These efforts to script the critical moves needed to teach mathematics effectively illustrates the assumption that teachers’ enactment of the curriculum and subsequent student experience with the curriculum may not align with the authors’ intentions unless additional support is provided (Stein et al., 2007).

This leads to questions about how features of curricular materials might influence their use by teachers (Stein et al., 2007). It is suggested that the educative goals of curriculum should be to help teachers anticipate students’ thinking, support teachers’ learning, assist teachers in fostering content connections among their students, and facilitate teacher adaptation of quality base materials to specific classroom needs (Davis

& Krajcik, 2005; Frykholm, 2005). The material's text and the form in which the text is presented (Weinberg & Weisner, 2011), alignment with standards (Herbel-Eisenmann, 2007; Martin et al., 2001), and the quality, format, and content of teacher materials (Kim, Achubang, Lewis, Hoe, Reinke, & Remillard, 2010; Newton & Newton, 2006; Stein & Kim, 2009; Stylianides, 2007; Watanabe, 2001) all serve as predictors for teachers' interpretation and enactment. That is, curriculum content can only impact instructional practice to the degree that it supports the central task of enacting curriculum (Ball & Cohen, 1996).

Fortunately, multiple researchers have found that reform mathematics curricular materials can and do support teacher learning in these areas (Choppin, 2008; Collopy, 2003; Drake & Sherin, 2009; Lloyd, 2008a; 2008b; Remillard, 2000; Remillard & Bryans, 2004; Schneider, Krajcik, & Blumenfeld, 2005; Schneider & Krajcik, 2002; Schneider, 2006; Van Zoest & Bohl, 2002). Teacher materials shown to impact teacher learning provide not only prospective student approaches to tasks, but also make the author's inclusion and development of instruction tasks transparent. That is, providing information as to why the content is pedagogically important, rather than simply prescribing an instructive approach, tends to be more supportive of teacher learning (Stein & Kim, 2009). By scripting the critical moves in this way, teachers can experiment with new behaviors and gain new understandings that will enable them to make informed decisions when necessary.

Analytical, intellectual appeals that (a) point to success stories which can be replicated, (b) provide data to support and sell the big picture change being sought, and (c) offer clear, scripted moves to direct a teacher toward the end goals of reform teaching can elicit cognitive agreement and even precipitate initial steps in the right direction. However, they alone do not satisfy the requirements for successful change. Knowing where we want to go, how to get there, and rationally understanding the reasons why we want to embark on the journey are not enough to ensure success. How many of us know the requirements for optimal health yet still do not adhere to recommended behaviors on a regular basis because doing so feels too hard? It is here that the next category of barriers comes into play.

Addressing emotional barriers is the reason that the Heath brothers' second directive to motivate the elephant is critical. The rider can only muscle the emotional elephant along the path toward change for so long before exhaustion sets in. If the visceral emotions that drive the elephant are not aligned with the cognitive rider's proposed direction, the change effort will be abandoned. Stealing another hour of sleep will triumph over a morning run, chocolate will trump carrots, and backsliding into the comfortable, didactic, worksheet-driven modes of traditional teaching will hijack an instructor's best efforts at reform. If we want long-lasting reform that sticks, we must enlist the aid of the emotional elephant. Teachers must *feel* the need for change and possess a gut-level conviction that change is necessary. For these reason, I now turn to the Heath brothers' second directive: Motivate the Elephant.

Motivate the Elephant: Addressing Emotional Barriers

Dennis Sparks (1997) wrote, "It's been said that someone who has a 'why' can endure any 'how'; few things are more important to motivation than purpose that is regarded as profoundly and morally compelling" (pp. 24-25, as cited by Loucks-Horsley et al., 2010). Research indicates that the highest rated motivations for electing a teaching career include the intrinsic value of teaching and the desire to make a social contribution, shape the future, and work with the upcoming generation of children (Richardson & Watt, 2006). Teaching is a socioemotional career, an emotional practice that arouses feelings in students, their parents, the surrounding community and within the practitioners themselves (Denzin, 1984). Thus, the emotional labor associated with teaching provides multiple implications for educational change (Bascia & Hargreaves, 2000).

When reform efforts prioritize content over teachers' and students' emotional lives, when the act of teaching is reduced to technical implementation of detailed curriculum requirements at the expense of the socioemotional factors necessary to provide the safe, supportive culture in which learning is more likely to take place (Mortimore, Ammons, Stoll, Lewis, & Ecole, 1988), connections between teachers and their communities are threatened. Strip out the emotion and we erode much of the motivation teachers possess to serve their students (Noddings, 1996, 2013). Without enlisting the emotional support that a motivated elephant provides and without triggering the feelings required to get the elephant moving in the direction of change, it is unlikely that the long-term behavioral change will happen. This leads to the Heath brothers' next recommendation: *find the feeling*.

Find the Feeling

According to the results of a study in which over 400 people across 150 companies were interviewed regarding change efforts within their organizations, the sequence of change that yielded the highest level of success was not the *analyze-think-change* sequence that often starts with charts of data, informative PowerPoint presentations, and appeals to the intellectual rider. Instead, it was the *see-feel-change* approach that wrought success. In these situations, the desired change was marketed in much the same way that advertisement campaigns are waged. Rather than providing a firehose of information meant to *teach*, these successful change efforts relied on visual representations of an idea that triggered emotions and motivated the elephant to start moving (Kotter & Cohen, 2002). In other words, when emotions are tapped first, motivation is triggered, and change is more likely to occur.

We find support for this in motivation research where a distinction is drawn between two different types of focus: promotion versus prevention. For those operating under a promotion focus, the strategy involves an eager pursuit of one's goals. Those with a promotion focus tend to seek affective, emotional goals generated by nurturance needs and strong ideals. By contrast, a prevention focus is characterized by vigilant avoidance of an undesired state. The motivations and behaviors of those with a prevention focus features active evasion of cognitive dissonance generated by security needs, strong "oughts," and a sense of responsibility (Higgins, 1997). Though teachers ought to teach standards established by national, district, and school policy and they ought to attend to their responsibility to instruct mathematics using methods that work, making an initial pitch for transformation as a host of "oughts" may not be the most effective route to success. Might it be better to first tap into teachers' emotional ideals and the reasons they chose an educational career in the first place? Might it be better to have them see and feel the need for change themselves?

I have been unable to find any successful interventions in the literature that offer explicit reference to emotional buy-in, though I would suspect that many of the successes and failures that have been reported would have traceable emotional roots were the researchers to look for them. In Theme 3, we saw that failed efforts could be linked to participating teachers' feelings of frustration, fear, anger, anxiety, disenfranchisement, and marginalization. By contrast, can the successes be linked to positive emotional engagement? Did exposure to the evidence of student thinking provided by the intensive cognitive guided instruction of Carpenter and his colleagues trigger emotional buy-in among participants (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989)? Did observing the positive learning outcomes in another's classroom, as evidenced by collaboration and lesson study research (Ball & Cohen, 1999; Driscoll, 1999; Bryant & Driscoll, 1998; Fernandez, 2002, 2005; Hawley & Valli, 2000; Loucks-Horsley et al., 2010; Mumme & Seago, 2002), trigger an emotional response which in turn promoted a willingness to try something new? Did the success of the Transforming East Alabama Mathematics (TEAM-Math 2000) have anything to do with the emotions connected to their central goal of ensuring *all* students receive high-quality mathematics education (Martin, Strutchens, Stuckwisch, & Qazi, 2011)? Were the Railside teachers who were unhappy with their students' achievement emotionally motivated to create different mathematical learning experiences so their students could improve (Boaler & Staples, 2008)? Perhaps thinking about what our interventions *show* to teachers and the *feelings* that are triggered because of it might be worth further exploration.

<u>Shrink the Change</u>

Even when feelings are harnessed for the cause, perceptions that the change is too big or unattainable can still derail efforts toward change (Allen, 2001; Bandura & Schunk, 1981; Crum & Langer, 2007; Nunes & Dreze, 2006; Ramsey, 2007; de Shazer, Dolan, Korman, Trepper, McCollum, & Berg, 2007 as cited by Heath & Heath, 2010). Without shrinking the change into manageable, bite-sized pieces that provide immediate dividends, convincing the elephant to continue the difficult journey toward change can present hurdles that are rarely cleared. Bandura references this in his work, claiming that "if new practices were instantly beneficial, change would be welcomed" (Bandura, 1997) and posits that "aspirations translated into attainable interim goals that convey a sense of progress also serve as motivators to help sustain efforts to realize hoped for changes" (Bandura, 1991; Locke & Latham, 1990).

This reality is echoed in Darling-Hammond's first recommendation that effective professional development must be intensive and ongoing to afford ample opportunity to make small adjustments to practice in specific contexts and to reflect upon the results with colleagues and/or coaches (Darling-Hammond et al., 2009). Her second recommendation, which promotes a focus on students learning and the teaching of specific curriculum content, also serves to shrink the change into more manageable chunks. Rather than advocating a wholesale overhaul of every aspect of mathematics instruction, professional development that focuses on developing teachers' specific content knowledge and analysis of student thinking linked to that content (e.g. fractions, integer operations, functions, etc.) has been shown to be more effective (Boston & Smith, 2009; Brendefur et al., 2013; Carpenter et al., 1996).

Similarly, Loucks-Horsley warns that teacher learning is an iterative process that requires adequate time to tinker with new strategies, calibrate emotional responses, reflect with colleagues, and receive follow-up system support (Loucks-Horsley et al., 2010). This claim aligns with adult learning theory and provides additional evidence that shrinking the change through ongoing professional development that is embedded in the day-to-day practice of teaching can help to defray anxiety and the accompanying "implementation dip" that occur as teachers struggle to integrate new strategies into their instruction (Hall & Hord, 2006).

In addition to shrinking the change, maintaining progress toward a large, seemingly insurmountable end goal can also be supported by what the Heath brothers call *growing your people*, and this suggestion aligns with the professional identity work being conducted in educational and psychology research. Like parents who feed their children vegetables despite the backlash, perhaps building a mathematics teacher identity that values pressing students to engage in the mathematical practices can shore up the emotional resources needed to resist student or parent pushback.

Grow Your People

When the change we want is poorly funded and the resources to enact it are limited, it sometimes becomes necessary to fuel public, community commitment to the cause and to shift both personal and group identities. This often entails relabeling oneself as the type of person who enacts the desired change. The Heath brothers cite multiple instances of this, recounting scenarios in which intellectual appeals would have made little difference and large-scale policy decisions related to the change provide little to no support (March, 1994; Dweck, 2006; Edmonson, 2003; Freedman & Fraser, 1966; Kanter, 2003; Krattenmaker, 2001; https://www.rare.org/; Weiner-Davis, 1992; Whitney, Trosten-Bloom, & Cooperrider, 2003 as cited by Heath & Heath, 2010.) But by attaching favorable descriptors to personal and group identities and then harnessing the gut-level strength of the elephant, hurdles that otherwise cannot be overcome are made scalable.

We find supportive evidence of this in mathematics education research that focuses on identity, adult learning, and change. Underlying much of this research is Wenger's conception of identity as situated in communities of practice and adult learning through the lens of identity construction (Wenger, 1998). Teacher change can be viewed in terms of the ways in which teachers construct "narratives of professional identity." These narratives combine experiences in both the positional identity, which is grounded in an individual's position in various communities such as school, and the figured identity, which involves less context-specific localization and affords more generalizable characteristics such as being a mathematics teacher (Anderson, 1983; Boaler & Greeno, 2000; Schifter, 1996 as cited by Hodgen & Askew, 2007). It is emotionally challenging to engage in professional change (Clarke, 1994), so teachers need "a compelling reason to undertake the task of transforming their practice" (Goldsmith & Schifter; 1997). For some, this compelling reason arises from shifts in identity toward that of becoming a more effective mathematics teacher (Hodgen & Askew, 2007).

When it comes to the decisions that either bring about change or doom it to fail, March (1994) posits that professional identity, the identity a person seeks out and cultivates in a sociocultural context, becomes inexorably linked to a person's self-image. Thus, perceptions of professional identity inform decisions that are coherent with other emotional, cognitive, and situational variables. Aligning professional identities with the goals of change will contribute to success far more than any incentives or consequences a program might otherwise seek to provide. When an individual teacher faced with a choice that either moves him/her further along the path toward effective mathematics teaching or away from it, the option we want selected needs to provide a definitive answer to the question, "What would someone like me do in this situation?" (Heath & Heath, 2010).

The good news is that new identities can gain a foothold very easily (Freedman & Fraser, 1966). The bad news is that adopting new behaviors that fit with this new identity can be hard and oftentimes fraught with incidences of failure. Negative feedback in the early stages can pose challenges in shifting to reform methodologies, especially when students and parents resist the changes teachers enact. When teachers' small steps meet with complaints rather than positive reinforcement and emotional benefits, commitment to change can falter (Bandura, 1991).

For this reason, I now turn to the third component of the Heath brothers' framework for change: *shaping the path*. Even when we provide clear direction to the rider and bolster emotional determination and commitment in order to motivate the elephant, the work involved in effecting change is still not easy. Failure is bound to occur, no matter how well we have attended to the first two components of the framework. And when those failures do occur, we need to have external structures and supports in place to help smooth the journey and to eliminate the "situation problems" that are so frequently perceived as "people problems."

Shape the Path: Addressing Situational Barriers

This section addresses the persistent human tendency to ignore situational forces that influence others' behaviors (Ross, 1977 as cited by Heath & Heath, 2010), deemed the "Fundamental Attribution Error." This error reflects our propensity to ascribe undesired behaviors to personal character failings rather than the situations in which people find themselves. We see this in the narratives populating the political landscape where “teachers are under attack as incompetent, selfish, and self-serving” (Bullough, 2011) rather than recognizing that their professional situations are characterized by multiple stressors, too few resources, and insufficient levels of support (Bascia & Hargreaves, 2000).

It turns out that making even small adjustments to the environment can pay large dividends when it comes to supporting the behaviors we want. The Heath brothers highlight this in several ways, pointing out how traffic engineers paint the roads and install signs so that obeying traffic laws in easy, Amazon offers a quick 1-Click ordering option, and mandated “quiet hours” for software developers and airline pilots reduce errors and improve productivity (Heath & Heath, 2010). With each example, they illustrate that environmental tweaks possess the potential to increase wanted behaviors and decrease the amount of self-control, rider muscle needed to keep the elephant on the path toward change.

Tweak the Environment

Applying this particular strategy to shaping the path involves two separate, but interrelated, prongs: adjust the environment so the behaviors we want become easier and the behaviors we do not want become not only harder, but virtually impossible. Research on reform curricula provides evidence of this strategy in practice, where adopted curricula and the supports they provide remove some of the guesswork from teaching decisions and make both teacher learning and the use of student-centered, investigative tasks easier (Collopy, 2003; Davis & Krajcik, 2005; Frykholm, 2005; Kim et al., 2010; Newton & Newton, 2006; Remillard, 2000; Stein & Kim, 2009; Stein et al., 2007; Trafton, Reys, & Wasman, 2001; Stylianides, 2007; Watanabe, 2001).

Additional evidence in support of this claim can be found in the research on collaboration, where teachers are provided dedicated contract time for collaboration. When teachers who initially worked in isolation are given time to reflect on instructional practice with peers who teach the same content (Butler et al., 2004; Chazan et al., 1998; Hiebert & Morris, 2012; Morris & Hiebert, 2011) or to plan lessons and focus on student work (Brendefur & Frykholm, 2000; Hunter & Back, 2011; Morris & Hiebert, 2011; Prevost, 1993; Zaslavsky & Leikin, 2004), teacher learning and their use of reform instructional strategies increase.

By the same token, something as simple as arranging student desks in groups could perhaps increase the amount of sociocultural learning and student discourse in the classroom. Designing school schedules so that teachers who share course preparations also have common preparation times might foster collaborative partnerships that would otherwise not happen. Having a trusted instructional coach on hand to answer pedagogical questions or to help address problems of practice could make it easier to seek and receive help. A 2008 analysis of evaluation findings from 25 different professional development programs for mathematics and science teachers in 14 states conducted by Blank and colleagues also suggests that in-school support is more likely to produce measurable effects in teacher knowledge and/or instructional practices (Blank et al., 2008). Tweaking the environment in this way could very well help pave the way toward the adoption of new behaviors and leads us to the next section of shaping the path: *building habits.*

<u>Build Habits</u>

Though adjusting the environment to make it easier to develop new behaviors is helpful, it sometimes is not enough when unexpected stressors intrude and either the rider or elephant become distracted. When self-regulatory systems are always running, exhaustion will inevitably set in. So, working to routinize these new behaviors, to convert them into habits, can combat the inevitable roadblocks that arise to threaten movement toward change. This is due in large part because habits are essentially autopilot behaviors which do not require oversight from the rider. And though habits can stem from the environments in which they are built and the social settings which support them, they often require mental work as well.

To make this mental work easier, it can help to establish “action triggers” which preload decisions, preserve self-control, and pass behavior cues onto the environment (Gollwitzer, 1999, as cited by Heath & Heath, 2010). In the case of mathematical practices, we might establish an action trigger where teachers always revoice a student response to a question without evaluating it, thereby placing the evaluation back in the hands of the class (Smith & Stein, 2011). Or, a teacher could preload an instructional decision by responding with an open question (Manouchehri, 2003) every time a student suggests a nonstandard solution to a problem.

Research on motivation indicates that “responding repeatedly in the same manner to the same stimulus event can create a stored association between the event and the response”, thereby effectively producing a habit (Hull, 1943). This procedural learning (Smith, 1993) can produce the response we want without requiring mediation by either the elephant or rider (Bargh, Chen, & Burrows, 1996). By identifying actions that we want and associating them with the triggers that can bring them into play, we can short-circuit the reluctance that stems from emotion and the decision paralysis that stems from too much thought. Of course, if the trigger is too vague (e.g. when students are not engaged, I will ask a high-level question) or if the behavior is perceived to be too challenging (e.g. I will provide specific feedback to all students' written responses), we still risk relapse and a return to old patterns of behavior. It is for this reason that we now move to the final recommendation for shaping the path: *rally the herd*

Rally the Herd

During periods of reform, teachers tend to experience similar emotional responses as they move through the stages of implementation (Hall & Hord, 2006) and the struggle most teachers experience during their adoptions of new instructional practices can result in a relapse into old habits if system supports and adequate opportunities to debrief with colleagues coping with the same stressors are not in place (Fullan, 2009, 2015). As people undergo change and work to adopt new instructional patterns of behavior, the biggest challenge is maintaining motivation and keeping the elephant on the path. It is here that harnessing the influence and support of other people can shore up defenses and keep change efforts on track.

As a species, humans come equipped with a finely-tuned ability to read and interpret social cues. From childhood on, we look to those around us to learn how to behave, which actions lead to rewards we want, and which choices lead to consequences we would prefer to avoid (Higgins, 1997). We have social antennae that are specifically tuned to the social worlds in which we live, and we are constantly calibrating our behaviors in response to our dual, and sometimes conflicting, needs for belonging to a group and differentiating ourselves from it (Brewer, 1991). This ability to gauge our performance based on others' cues is helpful when we are in new or unfamiliar situations. When we do not know what to do, we look to those who do and simply mimic their behaviors. Behaviors are contagious (Christakis & Fowler, 2007; Kremer & Levy, 2008; as cited by Heath & Heath, 2010).

This system can sometimes break down, though, in situations of change where no one has clarity on which behaviors are best (Latane & Darley, 1968) or when separate groups with whom an individual identifies promote different behaviors (Gresalfi & Cobb, 2011). What this means for intervention efforts is that we must attend to social signals, as they possess the power to either deliver or derail the change we want. Whether rational or not (Brewer, 1991), when an elephant is on an unfamiliar path, it will follow the herd. Establishing or highlighting group norms that support the change effort will go a long way toward rallying the herd.

We find support for this in the research on professional development, collaboration, curriculum, and coaching. Darling-Hammond (2009), in her recommendations for effective professional development, claims that professional development should build strong working relationships among teachers. Borasi and Fonzi's (2002) suggestions, along with those presented by the National Center for Improving Student Learning & Achievement in Mathematics and Science (2002) at the Wisconsin Center for Education Research align with this recommendation, supporting the claim by indicating that "high quality" professional development is intense, content-focused, and provides opportunities for embedded peer-collaboration (Borasi & Fonzi, 2002; Hunter & Back, 2011; Whitehurst, 2002). Others posit that for teachers to integrate the professional development into their classroom practice so that student achievement might be impacted, the professional development program must be supported by ongoing school collaboration (Avalos, 2011; Yoon, Duncan, Lee, Scarloss & Spapley, 2007).

Teachers working within a reflective collaborative structure can leverage the educative potential of created or adopted curricular materials and their subsequent adaptations (Hiebert & Morris, 2012; Lewis et al., 2012) while multiple, recurring opportunities to collaborate with colleagues at the same school or within the same content area, grade level, or department facilitates teacher growth more effectively than when teachers work in isolation (Butler et al., 2004; Chazan et al., 1998; Hiebert & Morris, 2012; Morris & Hiebert, 2011).

Collaborative work in the areas of lesson planning, reflection, and revision has also been shown to build teacher knowledge and improve classroom practice through a focus on student learning and the types of mathematical tasks that are assigned (Brendefur & Frykholm, 2000; Hiebert, Morris & Glass, 2003; Hunter & Back, 2011; Morris & Hiebert, 2011; Prevost, 1993; Zaslavsky & Leikin, 2004). Additional evidence of this can be found in adaptations of the Japanese model of lesson study, whereby teachers collaboratively investigate, plan, enact, observe, reflect, and revise instruction of mathematical concepts (Fernandez, 2005; Hunter & Back, 2011; Lewis, Perry, & Hurd, 2009). Building group competencies through collaborative efforts has the potential to improve instruction through changed teacher content knowledge and beliefs and the development of shared curricular resources.

These claims are further supported by Bandura’s work in collective self-efficacy, or “a group’s shared belief in its conjoint capabilities to organize and execute the courses of action required to produce given levels of attainments" (Bandura, 1997) and other studies which illustrate that collective efficacy is a predictor of students' mathematics achievement (Bandura, 1993; Goddard, Hoy, & Hoy, 2000; Goddard, Hoy, & Hoy, 2004; Hoy, Sweetland, & Smith, 2002). Some researchers have even gone so far as to suggest that collective efficacy is the "primary catalyst in school organizations supporting student achievement" (Whitney et al., 2003). A comprehensive review of literature reveals that there is a positive correlation between collective teacher efficacy and student performance (Ramos, Costa, Pontes, Fernandez, & Nina, 2014) while multiple syntheses of over 1200 studies ranks collective teacher efficacy as the number one factor influencing student achievement (Hattie, 2008; Eells, 2011). Given the scope of these analyses, it is no surprise that:

> People's beliefs in their collective efficacy influence the type of future they seek to achieve, how they manage their resources, the plans and strategies they construct, how much effort they put into their group endeavor, their staying power when collective efforts fail to produce quick results or encounter forcible opposition, and their vulnerability to discouragement (Bandura, 1997, pp. 478.)

If interventions can rally the herd and equip groups of teachers with a collective identity which includes the belief that challenges can be overcome, teachers, students and their learning all benefit (Petersen, 2008). When assessments, certification requirements, evaluation, and teacher learning are integrated (Loucks-Horsley & Matsumoto, 1999) and change is a coherent part of the strategic direction of a school or district (Sparks, 2002), success is within reach.

Except when it is not. This confounding lack of consistency in outcomes has led leading professional development researchers to lament,

> More than a decade has gone by and we and other colleagues around the country have been engaged in rigorous experimental studies of professional development

> and I think we still don't know, based on the work so far, what features really make professional development effective. And so it's been a somewhat discouraging decade perhaps, in that respect (Garet & Yoon, 2015).

If teams of researchers who study interventions in mathematics education struggle to identify the combination of factors which best predict outcomes, could this be due, in part, to an overlooked or neglected factor?

Themes 3 and 4 outlined the major categories of barriers that impact the success or failure of change efforts, the reasons these barriers arise, and potential strategies for combatting them. Included in the Heath brothers' analysis of why change efforts succeed or fail is an examination of Dweck's work and the potential influence of mindset on an individual's commitment to stay on the path. For this reason, I turn to my final question and the focus of Theme 5: "Does teacher mindset influence the effectiveness of interventions aimed at improving mathematics instruction?"

Theme 5: A New Factor: Teacher Mindset

In Carol Dweck's early work, she and her colleagues explored the underlying factors which led to two distinct and observable patterns of cognition-affect-behavior: the maladaptive *helpless* response and the more adaptive *mastery-oriented* response (Diener & Dweck, 1978, 1980; Dweck, 1975; Dweck & Reppucci, 1973 as cited by Dweck & Legett, 1988). The helpless pattern is characterized by avoidance of challenge and the abandonment of behaviors which precipitate failure while the mastery-oriented pattern features the active pursuit of challenge and persistence in the face of obstacles. These patterns have the potential to impact teacher engagement in change efforts, as tolerance for and reaction to incidences of failure upon the path toward improvement can be related to an individual's persistence toward a goal.

The existence of these two patterns among children with equal abilities and the resultant effect of these patterns on their subsequent development led to further study and associations with goal classifications directly linked to these patterns: *performance goals* and *learning goals* (Dweck & Elliot, 1983). As their labels imply, performance goals are characterized by the pursuit of favorable competence judgments and learning goals are characterized by a desire to increase competence.

Dweck and her colleagues hypothesized that the types of goals individuals set and how they then interpret and react to the feedback they receive while targeting these goals are related to the different response patterns they had observed. Not surprisingly, the helpless response pattern and the pursuit of performance goals tend be highly correlated, while the mastery-oriented pattern and learning goals correlate as well (Elliott & Dweck, 1988). Their research suggested that each type of goal activates an entire suite of commands, decision and inference rules, and consequences in the cognitive, affective, and behavioral domains. These findings align with those of studies examining the relationship between goal orientation and teacher participation in learning activities (Hurtz & Williams, 2009; Runhaar, Sanders, & Yang, 2010) and help-seeking behavior (Runhaar, et al., 2010).

However, this work did not explain why participants with the same ability levels who were placed in the same situations would select such different goals. For this reason, Dweck and her colleagues shifted their focus toward Sternberg's research, where he sought to "understand the nature and use of people's implicit theories of intelligence" (Sternberg, 1985). They next hypothesized that different implicit theories about one's own abilities, or self-theories, would correlate to an individual's goal orientation. The two stances they examined were the *entity view* and the *incremental view*. The entity view is a stance from which attributes such as intelligence are believed to be fixed, invariant characteristics that remain stable regardless of the situation or circumstances. By contrast, the *incremental view* is characterized by the belief that these same attributes are malleable, with the potential for growth and development.

As suspected, those who subscribed to an entity view were more likely to choose performance goals while those who possessed an incremental view were more likely to pursue learning goals (Bandura & Dweck, 1985, Dweck et al., 1982; Leggett, 1985, as cited by Dweck & Leggett, 1988). These findings led to the conceptualization of a social-cognitive model that connects implicit theories of intelligence with goals and goal-oriented behavior using a triad of cognitive, affective, and behavioral lenses. These findings and the direction of Dweck and her colleagues' subsequent work as it pertains to the construct of mindset are summarized in Table 1.

Table 1. Dweck & Leggett's Model of Implicit Theories as They Relate to Cognitive, Affective, and Behavioral Patterns. Adapted from Dweck & Leggett. (1988).

	Entity		Incremental	
Mindset	Fixed Mindset (Cognitive, social, personality attributes are fixed traits)		Growth Mindset (Cognitive, social, and personality attributes are malleable qualities)	
Goal Orientation	Performance		Learning	
Perceived ability	High Cognitive factors Social factors Personality factors	Low Cognitive factors Social factors Personality	High Cognitive factors Social factors Personality	Low Cognitive factors Social factors Personality
Behavior Pattern	Mastery Oriented Seek challenge High persistence	Helpless Avoid challenge Low persistence	Mastery Oriented Seek challenge that fosters learning High persistence	
Cognitive and Affective	Loss of belief in efficacy of effort, given low ability attribution		Continued belief in efficacy of effort: effort self-instruction instead of low ability attribution; positive rule emphasizes utility of effort	

Mechanisms when faced with obstacles	Defensive withdrawal of effort: effort confirms low ability judgment; inverse rule creates conflict between task requirements and goal			No defense required: Effort is consonant with task requirements and goal		
	Attention divided between goal (worry about outcome) and task (strategy formulation and execution_			Undivided, intensified attention to task that directly serves goal		
	Negative affect can interfere with concentration or can prompt withdrawal			Affect channeled into task		
	Few intrinsic rewards from effort to sustain process			Continuous intrinsic rewards for meeting challenge with effort		
Generalized to External Attributes	Attributes of people and world are fixed or uncontrollable			Attributes of people and world are malleable		
Goal Orientation	Judgment: goal is to make positive or negative judgment of attributes			Development: goal is to understand and improve attributes		
Predicted pattern	Cognition	Affect	Behavior	Cognition	Affect	Behavior
	Rigid, oversimplified thinking	Evaluative affect such as contempt	Low initiation of and persistence toward change	Process analysis	Empathy	Mastery-oriented goal pursuit

I have added the new terminology of Dweck's later work to the table, as the concepts of *growth mindset* and *fixed mindset* have become synonymous with those of an incremental or entity stance, respectively. Of note are the potential relationships between these results and an individual's willingness to engage in and sustain efforts toward change. If an individual possesses an entity view combined with a perception of low ability, is he/she less likely to set and achieve the learning goals necessary to make progress toward change? Will those with a growth mindset be more likely to persist in the face of failure as they make the arduous trek toward change?

According to more recent research, students from elementary school through college who possess a growth mindset exhibit greater motivation, earn higher grades, perform better on achievement tests, and fare better in difficult courses (Aronson, Fried, & Good, 2002; Blackwell, Trzensniewski, & Dweck, 2007; Grant & Dweck, 2003; Hong, Chiu, Dweck, Lin, & Wan, 1999) or across challenging transitions (Blackwell, at al., 2007). Research also indicates that praising challenge-seeking behaviors, diligence, focus, and perseverance as opposed to innate ability or intelligence can foster growth mindset development and persistence in goal attainment (Cimpian, Arce, Markman, & Dweck, 2007).

But what might this mean in the context of teacher response to intervention efforts? Unfortunately, there has been limited work on the impact of teachers' mindsets on their willingness to engage in activities targeting change. The one study available that is tangentially related to this question claims that teachers who have a fixed mindset are less likely to engage in voluntary professional learning activities such as reading professional literature, asking for feedback, observing a colleague's teaching, or inviting a colleague to watch their own teaching (Gero, 2013). Gero's study prompted Dweck to hypothesize that novice teachers with a fixed mindset are more likely to leave the profession, while those with a growth mindset are more likely to persist through the challenges and continue to develop their skills (Dweck, 2015). This hypothesis has yet to be tested.

What has been studied, though, are the relationships between goals, motivation, attributions, and anxiety, as researchers seek to tease out the specific ways in which "goal orientation interacts with confidence to set in motion of sequence of specific processes that influence, in turn, task choice, performance, and persistence" (Elliott & Dweck, 1988). A study in organizational psychology found that performance goals are associated with a desire for certain and easy success resulting in praise (Button, Mathieu, & Zajac, 1996). This finding led to further research which illustrated people who pursue learning goals are more likely to undertake challenging tasks (VandeWalle, Cron, & Slocum, 2001). Meanwhile, Dweck and her colleagues have continued to study the relationships between mindset, goal orientation, and reaction to feedback as it relates to behavior, affect, and beliefs about self-efficacy.

As noted in Table 1, when children with a fixed mindset encounter obstacles, a debilitating factor is lowered self-efficacy (Leggett & Dweck, 1988). Would the same hold true for adults? A study conducted by Wood and Bandura suggests it may. Their research claims that when those with a stable entity theory of intelligence encounter difficulties, they suffer a loss of self-efficacy. By contrast, those with a malleable incremental theory of intelligence responded to challenges as if they were a "normative part of any acquisition process rather than serving as indicators of basic personal deficiencies." As a result, their self-efficacy remains unaffected (Wood & Bandura, 1989).

Research reveals that teachers with low self-efficacy doubt their ability to impact student learning, are more likely to avoid situations they perceive to be beyond their capabilities, and either reduce their efforts or quit when faced with challenges (Ashton & Webb, 1986). "When self-efficacy is low, failures are perceived as intimidating and may lead to avoidance" (Elliott & Church, 1997). Teachers with low self-efficacy also tend to shift the responsibility for student learning (or lack of it) to external factors beyond a teacher's control (Winfield, 1986). When a student's failure is deemed a symptom of parent disengagement, transience, poverty, lack of community support, or systemic issues within the schools, teachers are less apt to examine their own practice as a factor in student achievement (Knapp & Shields, 1990).

By contrast, when those with a growth mindset encounter obstacles, their feelings of self-efficacy remain intact. They maintain their efforts as required by the assigned task or desired goal (Leggett & Dweck, 1988; Wood & Bandura, 1989). Teachers with high self-efficacy tend to believe they can impact students and are therefore more effective (Landson-Billings, 1994). Failures, when they arise, “can be perceived as an intriguing challenge” (Elliott & Church, 1997). Effective teachers also tend to believe that all students are capable of learning, and they communicate this belief via high expectations. As a result, their instruction tends to be more coherent, rigorous, and academically challenging (Delpit, 1988; Gay, 2000).

Let us return, then, to the fact that changing instructional practice is a challenging task and that successfully implementing change efforts requires overcoming the cognitive, emotional, and situational barriers that arise. An argument could be made that mindset resides firmly in the cognitive camp and has the potential to present barriers with belief tensions. Yet mindset also determines emotional responses to failure (Dweck, 2006; Leggett & Dweck, 1988). While undergoing the process of change, when “everything can look like failure in the middle” (Kanter, 2003), a fixed mindset is likely to precipitate negative emotions that can impede progress. Researchers have found evidence of this in the medical field (Edmonson, 2003; Timby & Smith, 2006), industry (Carroll, 1993; Dweck, 2006), and sports (Dweck, 2006). But there is limited evidence involving mathematics teachers, their mindset, and the ways in which their practice is impacted. There are no studies which explore mathematics teacher mindset in the context of changing instructional practice. For this reason, I am interested in determining whether teacher mindset has the potential to act as a moderator to enhance (or diminish) the effects on instructional practice when other cognitive and situational barriers are being attended to in a professional development setting.

Though this literature review has also revealed a gap in the research involving the success of interventions that trigger positive emotional buy-in, the illustrated connection between mindset and the emotional and behavioral responses to failure provides enough of a research base to warrant additional study in the area of mathematics professional development. Existing research supports the hypothesis that teacher mindset and instructional change are related, but it has not been explicitly studied. Consequently, this study seeks to explore that relationship.

CHAPTER THREE: RESEARCH METHOD

Introduction

When a professional development intervention aimed at shifting instructional practice is designed to address the elements shown to be effective, to what degree do quality curricular resources and teacher mindset affect outcomes? To date, no published studies examine the relationship between teacher mindset and the effectiveness of professional development or curricular interventions, though research on how mindset impacts an individual's engagement in change efforts has been conducted. This study addressed this gap in the literature by examining the relationship between mathematics teachers' instructional practice, their access to curricular resources, and their mindset. This chapter provides a detailed summary of the research methods used to explore these relationships as outlined in the research questions below.

Research Questions

<u>Intervention Effects</u>

1. To what degree does involvement in the DMC predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?
2. To what degree does access to the CPM curricular support materials predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?
3. To what degree does involvement in the DMC, when combined with CPM

curricular support materials, predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?

Moderation Effects of Mindset

4. Is the relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?
5. Is the relationship between access to the CPM curricular materials and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?
6. Is the relationship between involvement in the DMC, when combined with CPM curricular support materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?

To explore the answers to these question, a quasi-experimental research study involving both elementary and secondary mathematics teacher participants was conducted. Survey data were collected and then analyzed using independent-samples and paired-samples *t*-tests as outlined by Field (Field, 2013), and multiple regression analysis protocols as outlined by Muijs (Muijs, 2011), Field (Field, 2013) and Pedhazur (Pedhazur, 1997). The key outcome variables for the study were shifts in the frequency with which both traditional transmission and socio-constructivist mathematics instructional practices were employed in the participants' classrooms. Measures of self-reported shifts in pedagogical practice were used to determine the degree of change over the course of the instructional school year.

Setting and Participants

The population of interest for this study was all secondary mathematics teachers in the United States of America, a group that nationwide comprises only 1% of the teaching population and 13.8% of the secondary teaching population. Mathematics is the major field of study for 64.5% of these educators. The demographic information for this population is given in Table 2.

Table 2. Demographic Information for Secondary Mathematics Teachers in the United States of America

	Mathematics 13.8%
Gender	
Male	42.7%
Female	57.3%
Race	
White	81.5%
Black	6.4%
Hispanic	6.2%
Asian	4.1%
American Indian/Alaska Native	0.6%
Two or more races	1.1%
Years of Experience	
0 to 3	11.6%
3 to 9	33.8%
10 to 20	34.5%
More than 20	20.1%
Education Level	
Less than bachelor's	2.6%
Bachelor's	41.0%
Master's	49.8%
Specialist or doctoral	4.8%
Age	
under 30	20.9%
30-39	28.1%

40-49	24.7%
50-59	18.1%
60+	8.3%

Note. Table information compiled using data retrieved from demographic tables available on https://nces.ed.gov/programs/digest/d14/tables/dt14_209.50.asp and http://www.sde.idaho.gov/site/finance_tech/annual_stat_reports/2010%20Annual%20Statistical%20Report.pdf

The scale of this study was necessarily reduced due to time, manpower, and financial resources. Consequently, the study population was limited to a large, urban district in the state of Idaho. Demographic details were not available for secondary mathematics educators in either the state of Idaho nor in the district. An assumption was made that secondary mathematics teacher demographics are similar to the secondary teacher demographics for the district provided in Table 3.

The study population consisted of all district mathematics teachers who taught secondary mathematics courses (n = 128) during the 2015-2016 school year. To ensure a representative sample of the study population was selected, the district's mathematics supervisor sent out the study's initial survey to all 128 prospective participants. The district's team of four secondary mathematics coaches also followed up with each prospective participant and the researcher emailed reminders to each prospective participant to maximize participation.

Because of the small numbers of teachers available and their predetermined assignment to groups by the district and its administration, randomized assignment to interventions was not an option. However, because membership in the DMC professional development cohort group was determined by building principals and motives for assignment varied, the cohort group had the potential to be representative of the district's secondary mathematics teachers as a whole. Furthermore, curricular materials were adopted for only three courses in the secondary sequence, so again, control over which teachers had curricular support was not random even though the group who received support had the potential to be representative of all secondary mathematics teachers in the involved district.

Participants who completed all components of the study consisted of 52 secondary public school teachers in the involved district who currently teach mathematics. Detailed demographic information about all participants is available in Appendix F and a summary of the information is also provided in Table 3.

Table 3. Demographic Information for Secondary Teachers in This Study's School District

		Secondary 100.0% *n* = 852	Mathematics 15.0% *n* = 128	Secondary Study Participants *n* = 52
Gender				
	Male	43.0%	43% (55)	28.8% (15)
	Female	57.0%	57% (73)	71.1% (37)
Years of Experience Reported by District			*Assumed*	*Assumed*
	0 to 9	54.0%	54.0% (69)	46.1% (24)
	10 to 19	32.4%	32.4% (41)	34.6% (18)
	20 or more	13.6%	13.6% (17)	19.2% (10)
Years of Experience Reported on Survey				
	0-2			11.4% (6)
	3-5			21.1% (11)
	6-10			13.4% (7)
	11-15			8.0% (4)
	More than 15			46.1% (24)

Note. District demographic information was available only all secondary teachers and was provided by the district's human resources office. Years of experience bands did not match those used in the study's survey.

As indicated by Table 4, all participants taught secondary mathematics and were either members of the DMC (n = 32) or not (n = 20) during the year that this study was conducted. Of these participants, some would have access to the CPM curricular resources (*n* = 31) and the remainder would not (*n* = 21).

Table 4. Secondary Teachers' Involvement in Interventions

	Involved in DMC	Not Involved in DMC	Total
Access to CPM	19 (37%)	12 (23%)	31 (60%)
No Access to CPM	13 (25%)	8 (15%)	21 (40%)
	32 (62%)	20 (38%)	52 (100%)

Efforts were made to maximize the number of participants through repeated contacts by the researcher and by involving district administration, mathematics coaches, and department chairs in the recruitment.

Research Design and Approach

This quantitative study used a quasi-experimental research design to examine the relationship between two predictor variables, two moderator variables, and two outcome variables. Data on both traditional transmission and socio-cultural instructional practices, the outcome variables, were collected using pre- and post- administrations of A Mathematical Practice Survey (Carney, Brendefur, Hughes, & Thiede, 2015). Data on demographics, professional development, access to curriculum materials, and mindset were gathered both at the beginning and end of the school year, again using demographic survey questions and pre- and post- administrations of the Mindset Survey (Brendefur & Thiede, 2012). All survey data were collected using Qualtrics software version 2017.04 (Qualtrics, Provo, UT).

Data were collected using surveys as opposed to interviews and observations because of resource constraints and the larger number of data points that can be collected within a limited time frame. The self-report instruments used were selected because they had been used in previous studies involving similar research questions and were found to meet reliability and construct validity requirements (Brendefur & Thiede, 2012; Carney et al., 2015).

Multiple *t*-tests and multiple regression analyses were used to examine the hypothesized relationships between participant demographics, mindset, involvement in the DMC model of professional development, and access to CPM curriculum resources at they pertain to shifts in instructional practice.

Of particular interest in this study was the potential moderating effect of mindset on the variables of DMC involvement and access to CPM curricular materials. The conceptual model for this effect when the predictor variable is dichotomous and the moderator variable is continuous is outlined in Baron and Kenny's article (Baron & Kenny, 1986). These proposed relationships yield potential path models of the form shown in Figure 6, and were analyzed using multiple linear regression and SPSS v.24.

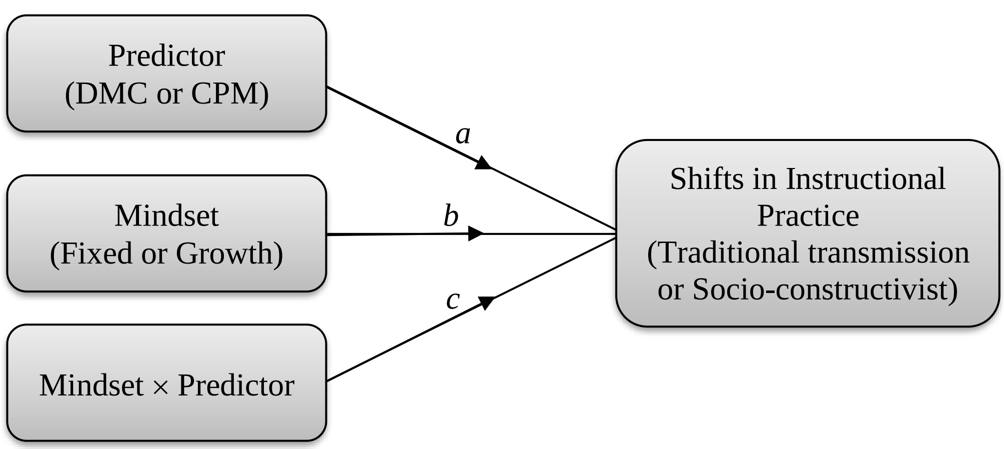

Figure 6. Moderator model. Adapted from Baron & Kenny. (1986).

The hypothesized direction of the moderating interaction was that higher scores on the growth mindset scale (corresponding to more of a growth perspective) and higher scores on the reversed fixed mindset scale (corresponding to less of a fixed perspective), would enhance the impact of an intervention on shifts in instructional practice. The expected outcome was that the moderating interaction would yield a greater decrease in the frequency of use of traditional transmission instructional activities and a greater increase in the frequency of use of socio-constructivist instructional activities.

According to G*Power 3.1.9.2, any multiple regression analysis involving a predictor variable, a moderating variable, and the interaction term (essentially three predictors) would require 48 participants to ensure the study's ability to detect a medium effect size of 0.25 with $\alpha = 0.05$, and power = 0.8. Dependent (matched pairs) *t*-tests to detect potential differences between demographic groups and their instructional practice outcomes that meet the same effect size, alpha, and power criteria would require 45 participants. Because the number of secondary participants ($n = 52$) meet these thresholds, testing the hypothesized relationships was reasonable.

Data Collection

The study's survey documents, recruiting materials, and email communications were submitted as part of the Institutional Review Board (IRB) application and approved for use by the Boise State University IRB committee prior to dissemination. The initial round of surveys, with two rounds of follow-up emails, were administered in person on the day of the first DMC meeting in the fall of 2015 and the final round of surveys, again with one in-person request and two rounds of follow-up emails, were administered at the final grade band meetings of the DMC in the spring of 2016. See Appendix D for additional information on the survey administration protocol. For all contacts, a link to the survey was provided. All participants who participated in both rounds of the survey were assigned a number based on their date and time of the study's second survey completion and then five random participants from the list (using Microsoft Excel 2016's RAND()*(96-1)+1 command) were selected to receive $25.00 gift cards to a location of their choice.

A total of 128 prospective individuals were solicited to participate in the study. 62 (48.4%) responded to the first survey in the fall. In the second round of the survey, only those who had responded in the fall were solicited. Of those 62 initial participants, 52 (83.9%) also completed the survey in the spring. The reason non-responders elected not to participate in either round is not known. Of the 52 secondary mathematics teachers who did participate in the survey for both rounds, 32 were involved in the DMC model of professional development and 20 were not. All participants answered enough items to generate usable scaled data. Additional details on respondents and their demographics is available in Appendix F.

Variables and Measures

Predictor Variables. This study also examined two predictor variables: involvement in the district's mathematics cohort (DMC) model of professional development and access to the adopted College Preparatory Mathematics (CPM) curriculum materials.

Professional Development: The dichotomous variable of professional development indicated whether participants were members of the DMC intervention. The assumption was made that membership in the cohort indicated participation in all parts of the professional development intervention as it was enacted by the district's mathematics coaching team and instructional support faculty.

The DMC model of professional development was designed to incorporate the results of multiple professional development studies outlined in the research. In particular, the DMC was built on the framework of mathematics instruction proposed by the initiative for Developing Mathematical Thinking (DMT) and provided a collaborative structure within which to study and implement best practices, develop and sequence mathematical tasks and assessments, and incorporate the CCSS for Mathematical Practice and Content into instructional methodologies. Building principals nominated one to two participants from each elementary and secondary school in the district for membership in the cohort. Of the 76 DMC participants, 33 were secondary mathematics teachers.

The goals of the DMC professional development model were to improve the quality and accountability of instruction, equip teachers with the needed content and pedagogical content knowledge to provide course instruction consistent with adopted state standards and college and career readiness, foster improved understanding of current curriculum goals and objectives, build teacher capacity through technology integration, and offer strategies for differentiation. Learning objectives which support the goals of the program included development of a growth mindset as it pertains to mathematics instruction, translation of the mathematical practice standards into usable classroom strategies for student engagement and productive problem solving, deepening content knowledge, building capacity for unit development (including identification, editing, or creation of rich, sequenced problem solving tasks and assessments), and refining current understandings of the purposes and forms of both formative and summative assessment.

Participants received a $3000 stipend to meet the cohort’s requirements. These requirements included attending a minimum of 45 instructional hours of training, studying researched best practices in mindset, instruction, and assessment, participating in collegial dialogue on this research, preparing and teaching lessons which incorporate new understandings gained through work with the cohort, assessing instruction and reflecting on ways to improve, sharing ideas via a district-sponsored, grade-level-specific online collaboration tool under the facilitative oversight of the coaching and instructional support team, using student achievement on standardized measures and classroom assessments to foster reflection, creating a reflective video reflection of how one lesson was transformed, and keeping a reflection journal throughout the year-long cohort.

Three full-day, full-cohort sessions to launch the cohort were conducted in August before school was in session. Four additional full-day pull-out sessions of training for each grade-band's or secondary course's teachers was scheduled during the school year, with additional online sessions to build a community of practice and to accommodate the requirements for shared reflection and collaboration provided in an ongoing, iterative format. Mathematics coaches also met individually with each cohort member to set personal instructional goals for improvement that targeted an area of the Developing Mathematical Thinking (DMT) framework (Brendefur, Carney, Hughes, & Strother, 2015).

This framework, developed by a team of Boise State University researchers, is currently framing professional development throughout the state of Idaho and is equipping practitioners with a common vocabulary with which to discuss mathematics pedagogy. The components of the framework include five main domains shown to improve student development of mathematical thinking: Taking Students Ideas Seriously, Addressing Misconceptions, Encouraging Multiple Strategies and Models, Pressing

Students Conceptually, and Focusing on the Structure of Mathematics (Brendefur et al., 2015). Participants incorporated their selected area of focus into their lesson planning. Their district mathematics coach observed the enactment of this lesson using the DMT Observational Tool, and facilitated a post-conference using the tool and its framework to focus the conversation. This cycle of setting goals, incorporating the goals into lesson planning and implementation, observation, and collaborative post-reflection was repeated a total of four times over the course of the year.

Curriculum. The second predictor variable was a dichotomous categorical variable which indicated a participant’s access to the district’s adopted College Preparatory Mathematics (CPM) Integrated Curriculum materials. Due to consistent feedback from teachers regarding their frustration with the lack of instructional materials to support CCSS implementation in their mathematics classrooms, the district purchased these materials for teacher use in their Integrated Math I, Math II, and Math III courses.

CPM was developed through an Eisenhower-funded grant and focused on incorporating the National Council of Teachers of Mathematics’ recommendations for instructional practice. Supported by methodological research in mathematics education and aligned with the CCSS for Mathematics, the CPM curricula was designed to engage students in problem-based lessons through group discourse and discovery of core mathematical ideas. The course sequencing of topics balances the demands of procedural fluency, conceptual understanding, problem solving skill, and adaptive reasoning (CPM Educational Program Description, 2015). The year of this study was the first year district teachers had an organized set of resources provided for these courses, so reception and use of these materials was expected to be high.

Anticipated barriers to this adopted curricula's use were the perceived mismatch between the more traditional transmission methodologies historically enacted by district mathematics teachers and the instructional model of the CPM curricula, with its emphasis on collaborative learning, social construction of mathematical ideas, exploratory problems of inquiry, and spiraled delivery of interconnected mathematical ideas. To help support teachers in their enactment of this curriculum, exhaustive teacher guides, digital support, multiple hard copy and online material access points were provided and four sequenced orientation and implementation seminars facilitated by CPM staff were scheduled as well. Attendance in these seminars was voluntary.

Moderator Variables. This study involved the exploration of two potential moderating variables: growth and fixed mindset. Teacher mindset was conceptualized using two constructs, one for growth and one for fixed. Both are continuous variables measured on an interval scale from 1 (low) to 5 (high), while professional development and curriculum are both dichotomous, nominal variables.

Teacher mindset. The Mindset Survey, developed by Brendefur and Thiede of Boise State University in 2012, was used to operationalize and measure the independent variables of fixed and growth mindset as defined by Dweck (Dweck, 2006, 2015; Dweck & Legget, 1988; Dweck & Elliot, 1983; Elliott & Dweck, 1988; Hong et al., 1999). Data were collected on these variables at both the beginning and end of the school year and were recorded as scaled values.

The instrument was developed using Dweck's framework for mindset (Dweck, 2006) and initially contained 30 Likert scale items (15 for growth and 15 for fixed) on a 5-point scale from strong disagreement to strong agreement. The growth items were comprised of statements that indicate students' capacity to learn is malleable, responds to effort, and can change over time. The fixed items were comprised of statements that indicate student's capacity to learn is static, remains constant over time, and cannot be changed through effort. All 30 items were administered to 96 elementary teachers in Year 1 of a three-year Improving Teachers Monitoring of Learning (ITML) project being conducted at Boise State University.

Following this administration, an exploratory factor analysis was used to identify those items which held together best for each construct. Using this information, the survey was then reduced to 9 items for each scale and given to researchers familiar with Dweck's work for review. When the items were independently sorted into the categories of growth and fixed, there was perfect agreement among reviewers. Reliability scores for the 9 item scales were computed and the scales were shown to be unidimensional and to have good internal-consistency reliability with a Cronbach's $\alpha = 0.82$ for the Growth scale and a Cronbach's $\alpha = 0.89$ for the Fixed scale. Year 2 data were used to conduct confirmatory analyses. The items were shown to clearly measure the latent variables under study. Analysis also reveals that the constructs were inversely related with a correlation near -0.5. Another round of confirmatory factor analyses for the instrument will be conducted once the data from Year 3 has been collected. Published evidence to support the use of the Mindset Survey instrument are still pending.

For this study's sample, scaled scores were calculated by computing each participant's mean score on the fixed items and on the growth items. For ease of analysis, the fixed items were reversed. For each initial scale, a score of 1 corresponded to very low growth (or high fixed) mindset and a score of 5 corresponded to very high growth (or low fixed) mindset. Reliability scores for both scales indicated good internal-consistency with a Cronbach's $\alpha = 0.82$ for the Growth scale and a Cronbach's $\alpha = 0.87$ for the Fixed scale. The scaled measures of the constructs continue to be related with a significant correlation of $r = 0.72$, $p < 0.05$.

The strong correlation between the two scales indicates that scores within either scale fit within a fixed-growth continuum. In this manner, high scores on either scale correspond to more of a growth perspective, while low scores on either scale correspond to more of a fixed perspective.

Outcome Variable. The continuous dependent variable of mathematical instructional practice was operationalized by a team of researchers at Boise State University and was measured in this study using A Mathematical Practice Survey (Carney et al., 2015). This instrument was developed as a self-report survey on the frequency of instructional practices which aligned to the DMT framework and operationalized the constructs of its five dimensions as enacted using either a traditional transmission or social-constructivist lens and perspectives of student, teacher, and tasks and activities. This matrix generated 30 different "cells" to populate with survey items.

An initial 74 Likert items using a scale of 1-5 were written and submitted to six university level mathematics educators for review. This review helped establish content validity and provided feedback which resulted in revision or removal of items deemed inaccurate. A three-phase cyclical process of administration, analysis, and revision led to a final refinement of the items down to one question per cell in the original framework.

Both exploratory and confirmatory factor analyses were conducted to assess fit to the theoretical construct, the hypothesized latent variables of transmission and social-constructivist based learning theories. The items were found to cleanly measure the constructs and to correlate significantly. Internal consistency was good for both scales: Cronbach α = 0.90 for the social-constructivist items and Cronbach α = 0.86 for the transmission items. Pearson's r calculations establish high levels of correlation (social-constructivist: $r = 0.37$, $p < 0.05$ and transmission: $r = -0.45$, $p < 0.05$).

The survey's ability to detect change in instructional practice was confirmed using a Wilcoxon signed-rank test with a social-constructivist score of $Z = 22.718$, $p < 0.001$ and a transmission score of $Z = 20.072$, $p < 0.001$. To provide evidence supporting the relationship between teachers' self-reported survey scores and their observed practice, a correlation analysis was performed (Carney et al., 2015).

For this study's respondents to the initial survey, principal component analysis was again conducted to refine the pre- and post-scaled values generated by each participant. For both the traditional transmission items and the socio-constructivist items, the methodology advocated by Muijs (Muijs, 2012) and Field (Field, 2013) and which included consideration of cross-loading, eigenvalues, and the component scree plot was used to reduce the number of items utilized in each scale.

For the socio-constructivist scale, the 15 items were reduced to 10 items that explained 45.6% of the variance. For the traditional transmission scale, the 15 items were reduced to 9 items that explained 51% of the variance respectively. Internal consistency remained high for both scales: Cronbach α = 0.91 for the social-constructivist items and Cronbach α = 0.92 for the traditional transmission items.

Scores for both scales were computed by calculating the mean response (1 = never, 2 = 2-3 times a year, 3 = once a month, 4 = 2-3 times a month, 5 = once a week, 6

= 2-3 times a week, 7 = daily) for each participant both at the beginning of the year and at the end of the year. The two scales showed a weak, non-significant correlation (r = -0.177, p = 0.086), further supporting the claim that these two constructs are not two ends of a single continuum and should be measured independently (Carney et al., 2015).

Histograms showing the distribution of initial scores on both the Social-Cultural Scale and the Traditional-Transmission Scale are shown in Figure 7.

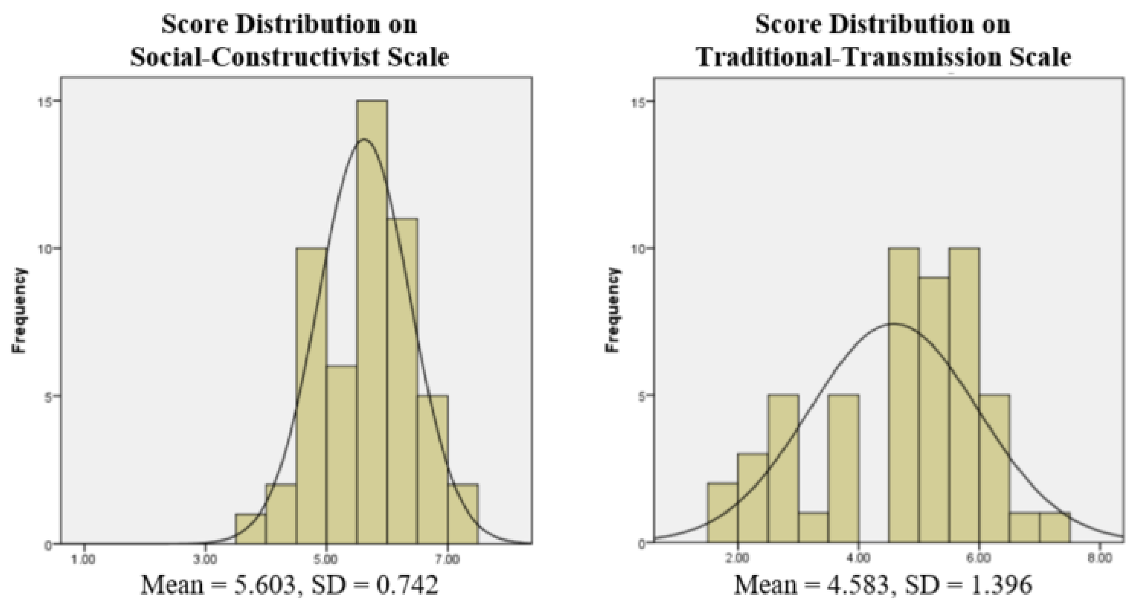

Figure 7. Histogram of secondary teachers' reported use of pre-intervention instructional activities

Additional details on these analyses for these scales can be found in Appendix G.

Threats to Validity

Experimenter Bias. Sources of potential bias in this study could have stemmed from the researcher's direct involvement with the hosting school district and its enacted professional development processes, her own experiences in navigating the transition to reform curricula, and her previous position as a secondary mathematics teacher within the district. Her role as a district insider may have inhibited her ability to collect accurate data from the participating teachers. Efforts to counteract this prospective bias included an external review by experts on the university level and an opportunity for participants to suggest changes to the findings' interpretations.

Additional sources of bias and error may have arisen due to the self-reported nature of the survey data and the timing of the data collection during the first and last quarters of the instructional year when fatigue, frustration, and stress were at their peak. The fact that all district teachers had taken a state-mandated Mathematics Thinking Initiative course that aligns with the DMT framework could have diminished effects as well. Because this was also the first year of the district's adoption of curricular materials to support the new integrated CCSS courses being taught on the high school level, the timing of the adoption may have also impacted teacher use of the materials and perceptions of their instructional practice.

Assumptions. Several assumptions were made in the design of this survey and regarding the participants and the instruments used.

(1) The survey sample represented not only mathematics teachers within the involved district, but also mathematics teachers in the state of Idaho.

(2) The instrument used to measure the frequency of use for both transmission instructional and socio-constructivist instructional activities accurately measured the instructional practice constructs and reflected participants' true frequency of use despite the self-report nature of the survey (Mayer, 1999 as cited by Carney, 2015).

(3) The mindset survey as administered accurately measured the mindset construct.

Limitations. The study's generalizability was limited by the relatively small sample size and the fact that all participants came from the same district. The fact that participant teachers were simultaneously facing the differentiation challenges of mixed-ability, detracked classrooms may have differentiated this population from other populations of mathematics teachers undergoing the transition to full CCSS implementation and the adoption of reform methodologies.

Variance in the participants' age, teaching experience, prior exposure to CCSS mathematics courses, the level of coursework being taught, unfamiliarity with specific mathematical content, the cumulative effects of multiple factors outside of the researchers' control, and teachers' previous experiences with professional development trainings, collaboration, and familiarity with the provided curricular materials could have also impacted the survey results in unanticipated ways. Further, the amount of time required to complete the survey may have played a role in the completeness and thoroughness of participant responses. Whether the findings would remain the same if the surveys were to be completed at different times is not known.

Delimitations. The interventions being studied were limited to those made available for involved district's teachers. Though there are other professional development models and curricular resources that could have been deemed appropriate for study, this project focused only on the relationships between these specific interventions, the involved participants' mindset scores, and their instructional practices. Consequently, this restriction of scope also limited the generalizability of this study.

Due to time constraints and the scheduling of the district's mathematics cohort model of professional development, data were gathered earlier than anticipated. This resulted in the study being designed and data being collected prior to the completion of the literature review. Further study involving qualitative data collection and analysis is necessary to supply additional support for this study's findings, and were not integrated into this phase of the study due to limited resources and incomplete observational data from the district's mathematics coaches.

Additional delimitations could be attributed to the survey instruments themselves and the assumption that they validly and accurately measured the constructs they aim to measure. Given the self-reporting nature of each, and the potential interaction between participants' individual perceptions of these constructs and the terminology with which they are described, the measures' scaled scores may not be accurate indicators of a teachers' actual instructional practice or mindset.

Due to the large number of questions on the Instructional Practice Survey, principal component analysis (PCA) was conducted to refine the scaled measures for the sample population under study. The details of this analysis are available in Appendix G. PCA was not conducted for the mindset survey, however, as the instrument had already been reduced to nine items per construct, and the Cronbach's alpha score for the original instrument indicated good internal reliability.

A final delimitation arose from the decision to limit the number of variables under consideration. Though the literature suggests that there are a range of factors which influence both an individual's capacity and willingness to change and a multitude of system, school, administrative, psychological, physical, and professional variables which can impact a mathematics teacher's instructional practice, the scope of this study was narrowed to three: professional development, curriculum, and mindset. This narrowing allowed only a partial picture to be drawn and as such, generated more questions than it answered.

Data Analysis

Analyses of the scaled dependent and independent variable values were conducted to confirm univariate conditions of normality and to identify potential outliers that might have influenced the results. Demographic independent *t*-test analyses were then conducted to determine whether there are significant differences between cohort groups and non-cohort groups based on the potentially confounding variables of grade band, years of mathematics teaching experience, and gender. Paired-samples *t*-tests were also conducted to determine whether significant changes in the dependent variables had occurred and if so, whether demographic groups responded differently to the DMC and CPM interventions.

Following these preliminary data analyses, verification that the study's data also conformed to the assumptions for multiple linear regression, the bivariate conditions of collinearity and linearity, and the multivariate conditions of multicollinearity, homoscedasticity, and the normality of residuals for the three predictor variables were also completed. Once confirmation was found, multiple regression analysis was conducted to determine whether there were main or interactive effects for each predictor variable. Lastly, additional multiple linear regressions were run to test whether mindset acted as a moderator variable to influence the relationship between shifts in instructional practice and DMC involvement and/or CPM access. SPSS 24.0 was used to conduct all analyses.

Ethical Considerations

The Boise State University Social and Behavioral Institutional Review Board granted approval (Protocol# 108-SB15-128) to conduct this study. The hosting district's review board, superintendent, and all involved teachers granted their approval as well. Informed consent was obtained with both surveys and the protocol for obtaining it was approved by the Boise State IRB committee. Participants' involvement was voluntary and each was provided the option to withdraw from the study at any time. To protect participant privacy, all data were coded to eliminate identifying information. All digital artifacts from the study are kept in a secure, password-protected electronic file folder. There were no non-digital artifacts to protect.

Because the involved district administration and coaching staff bear responsibility for the DMC implementation, any digital and non-digital data they or their staff collected are maintained, stored, and overseen by them. Guaranteeing the anonymity and protection of these data are not within the purview of this study.

Summary

This quantitative study used a quasi-experimental research design to examine the relationship between two predictor variables, a moderating variable, and two outcome variables. Data on both traditional transmission and socio-cultural instructional mathematics practices, the outcome variables, were collected using pre- and post-administrations of A Mathematical Practice Survey (Carney et al., 2015). Data on demographics, involvement in the district's mathematics cohort (DMC) model of professional development, access to the College Preparatory Mathematics (CPM) curriculum materials, and mindset were gathered both at the beginning and end of the school year, again using demographic survey questions and pre- and post- administrations of the Mindset Survey (Brendefur & Thiede, 2012).

A total of 96 mathematics teachers participated in both rounds of the study: 76 in the cohort and 53 secondary educators. A multiple linear regression analysis was conducted to determine whether significant differences in instructional practices occurred following involvement in the DMC professional development and/or CPM curriculum interventions. Subsequent multiple linear regression analyses examined the degree to which mindset moderated the effect of each of these interventions. Chapter four supplies the findings that arose from this investigation, along with the quantitative analyses that support them. Chapter five offers a discussion as it relates to the research questions and how the study's findings fit within the existing literature. Potential implications for future research are also provided.

CHAPTER FOUR: RESULTS

Introduction

This chapter provides the quantitative analyses' results as they pertain to the study's research questions involving the relationships between shifts made in instructional practice, the DMC and CPM interventions, and the potential moderating effect of mindset. To address these questions, this chapter first provides the results of independent *t*-test analyses for subgroups of participants. These tests determined whether demographic groups both within and without the DMC or with and without access to the CPM curricular materials were statistically similar prior to any intervention occurring.

Next, the results of a series of paired sample *t*-tests are provided. These tests were used to identify whether significant shifts in instructional practice (whether via changes in frequency of use for traditional transmission or socio-constructivist instructional activities) occurred over the course of the study. A multiple linear regression analysis was then conducted to determine which intervention prediction variables had significant main or interaction effects. For those interventions that yielded measurable and statistically significant change for subgroups, follow-up linear regression analyses were conducted. Additional multiple linear regression analyses were used to investigate whether the relationship between the interventions and shifts in instructional practice was moderated by teacher mindset.

Questions 1-3 Preliminary Analyses

Research questions 1 through 3 each required a determination as to whether the secondary subgroups were statistically similar, whether significant changes in either of the outcome variables occurred, and whether the assumptions for multiple linear regression were met. Once these conditions were verified, a multiple regression analysis using all potential variables of influence allowed the list of all predictor variables of interest to be examined simultaneously. For predictor variables that had a significant effect, additional follow-up analyses were conducted.

Secondary subgroup analysis

Frequencies, means, and standard deviation statistics for subgroups within the secondary participants who completed enough survey items to generate initial scaled scores (*N* = 52) are provided in Table 5.

Table 5. Secondary Participants' Outcome Variable Scaled Score Means and Standard Deviations by Demographic Subgroup

	Demographic Subgroup	N	%	Mean	Standard Deviation	Std. Error Mean
Pre-Socio-constructivist scale score[1]	In DMC	32	61.5%	5.48	0.791	0.140
	Not involved in DMC	20	38.5%	5.80	0.622	0.139
	Access to CPM	31	59.6%	5.66	0.714	0.128
	No access to CPM	21	40.4%	5.52	0.790	0.172
	All	52	100%	5.60	0.742	0.103
Pre- Traditional transmission scale score[2]	In DMC	32	61.5%	4.86	1.166	0.206
	Not involved in DMC	20	38.5%	4.14	1.638	0.366
	Access to CPM**	31	59.6%	4.17	1.392	0.250
	No access to CPM**	21	40.4%	5.20	1.184	0.258
	All	52	100%	4.58	1.396	0.194
	In DMC	32	61.5%	4.07	0.634	0.112

	Not involved in DMC	20	38.5%	4.01	0.607	0.136
Fixed Mindset scale score[3]	Access to CPM	31	59.6%	4.09	0.592	0.106
	No access to CPM	21	40.4%	3.97	0.663	0.145
	All	52	100%	4.04	0.619	0.086
Growth Mindset scale score[4]	In DMC	32	61.5%	4.24	0.598	0.106
	Not involved in DMC	20	38.5%	4.20	0.487	0.109
	Access to CPM	31	59.6%	4.28	0.551	0.099
	No access to CPM	21	40.4%	4.14	0.559	0.122
	All	52	100%	4.22	0.553	0.077

**Significant differences between means.
[1] Score of 1 represents never using socio-constructivist instructional activities and score of 7 represents daily usage.
[2] Score of 1 represents never using traditional transmission instructional activities and score of 7 represents daily usage.
[3] Score of 1 represents strong agreement with fixed mindset items and score of 5 represents strong disagreement with fixed mindset items (original item scores were reversed) so scale is in the same direction as Growth Mindset scale on the mindset continuum.
[4] Score of 1 represents strong disagreement with growth mindset items and score of 5 represents strong agreement with growth mindset items.

There was no significant difference between means on any of the initial scaled scores for secondary teachers based on DMC involvement, years of experience teaching mathematics, or gender. Independent samples *t*-tests revealed several statistically non-significant differences between means for these subgroups of secondary participants.

In particular, those involved in the DMC model of professional development (N = 32, M = 5.477, SD = 0.791) and those not involved in the DMC model of professional development (N = 20, M = 5.804, SD = 0.622) did not differ significantly on the Pre-Social-Constructivist scaled score variable, $t(50) = 1.571$, $p = 0.122$. Nor did those involved in the DMC model of professional development (N = 32, M = 4.858, SD = 1.166) and those not involved in the DMC model of professional development (N = 20, M = 4.141, SD = 1.638) differ significantly on the Pre-Traditional-Transmission scaled score variable, $t(31.045) = 1.705$, $p = 0.098$.

There were no significant differences between experience levels as determined by one-way ANOVA analysis ($F(4, 47) = 0.565$, $p = 0.689$).

Females ($N = 37$, M = 5.621, SD = 0.802) and males ($N = 15$, M = 5.558, SD = 0.589) did not differ significantly on the Pre-Social-Constructivist scaled score variable, $t(35.227) = 0.317$, $p = 0.753$. Females ($N = 37$, M = 4.414, SD = 1.414) and males ($N = 15$, M = 5.000, SD = 1.305) did not differ significantly on the Pre-Traditional-Transmission scaled score variable either, $t(50) = 1.384$, $p = 0.172$.

There was, however, a significant difference between means for the pre-traditional transmission scaled score for those secondary teachers who had access to the CPM curriculum materials ($N = 31$, M = 4.17, SD = 1.39) during the study and those who did not ($N = 22$, M = 5.20, SD = 0.71), $t(50) = 2.78$, $p < 0.05$. Though Cohen's effect size value ($d = 0.25$) could be deemed small, when it is interpreted in relation to the instructional practice scale and the classroom context in which this study is situated, the difference could be considered significant both in terms of the frequency of traditional transmission activity use and student engagement with and learning of mathematics. A scaled score of 5 (indicating weekly usage) is noticeably different from a scaled score of 4 (indicating 2-3 times per month usage).

The difference between these subgroups at the advent of the study and before having access to the CPM curricular resources could be attributed to the prior year's teaching experience. 24 of the 31 secondary teachers who were going to receive access to the CPM curricular materials taught an integrated secondary CCSS mathematics course with the support of district mathematics coaches. This experience may have resulted in participants having already shifted their traditional transmission instructional practice.

This difference between groups may also mask any potential impact of access to the CPM curriculum, as teachers who had already taught an integrated CCSS mathematics course prior to having access to the CPM support materials reported a significantly lower initial frequency of traditional transmission activity use than those who had not. Further analysis for question 2 will explore this possibility.

Outcome Variable Analysis

Once differences between secondary subgroups had been investigated, the next analyses examined whether secondary subgroups responded differently in terms of shifts made to their instructional practice. However, this analysis was only appropriate if shifts in instructional practice were made. Determining this again involved two paired samples *t*-tests, the results of which are given in Table 6.

Table 6. Secondary Participants' Paired Samples *t*-test Statistics

	Pre- Socio-constructivist scale scores	Post- Socio-constructivist scale scores	Pre- Traditional transmission scale scores	Post- Traditional scale scores
N	52	52	52	52
Mean	5.603	5.623	4.583	4.098
Standard Deviation	0.742	0.735	1.396	1.274
Standard Error Mean	0.103	0.102	0.194	0.177
Paired differences	Socio-constructivist		Traditional transmission	
Mean	0.026		-0.484	
Standard Deviation	0.619		1.094	
Standard Error Mean	0.086		0.152	
95% Confidence Interval of the Difference [Lower, Upper]	[-0.197	0.146]	[0.180	0.789]
t	0.259		3.194	
df	51		51	
Significance (2-tailed)	0.768		< 0.05	

As evidenced by Table 6, the frequency of both types of instructional activities changed. The reported frequency of social-constructivist instructional activity use increased slightly, but not significantly ($t(51) = 0.297$, $p = 0.768$). However, the reported frequency of traditional transmission instructional activity use decreased significantly ($t(51) = 3.194$, $p < 0.05$). Therefore, subsequent analyses for the remaining questions of this study involving secondary participants were limited to the change in frequency of traditional transmission activity use. A traditional transmission change score, T_Change = (post- traditional transmission score) – (pre- traditional transmission score) was calculated for each participant to facilitate this analysis.

Prior to conducting multiple linear regression analyses, tests to confirm that assumptions for multiple linear regression had been met were also conducted. Details of these tests and their outcomes are provided in Appendix H.

Multiple Linear Regression Analysis

Because all the assumptions for multiple linear regression analysis were met, an analysis was conducted with all potential impacting variables to determine which variables had a significant impact. As evidenced by the significance values in Table 7, the only variable with the potential to have a significant effect was involvement in the district's mathematics cohort (DMC) model of professional development. Due to this determination, further analysis was only conducted for question 1.

Table 7. Correlation Statistics for Prospective Predictor and T_Change Variables, Version 1

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-.096	.371		.258	.797		
DMC	-.991	.472	-.445	2.100	.041	.402	2.485
CPM	-.151	.479	-.069	.173	.753	.383	2.608
CPMxDMC	.327	.610	.145	.536	.595	.245	4.074

Question 1 Analyses and Results

Question 1: To what degree does involvement in the DMC predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?

Testing the normality and homogeneity of variance on the dependent variable, T_Change, for each subgroup yielded the statistics found in Table 8 and the histograms found in Figure 8.

Table 8. DMC Statistics for T_Change Distribution for Secondary Participants

		N	Mean	Standard Deviation	Variance	Skewness	Kurtosis
DMC Involvement	No	20	0.005	0.917	0.840	0.512	-0.509
	Yes	32	-0.791	1.097	1.203	0.388	-0.151

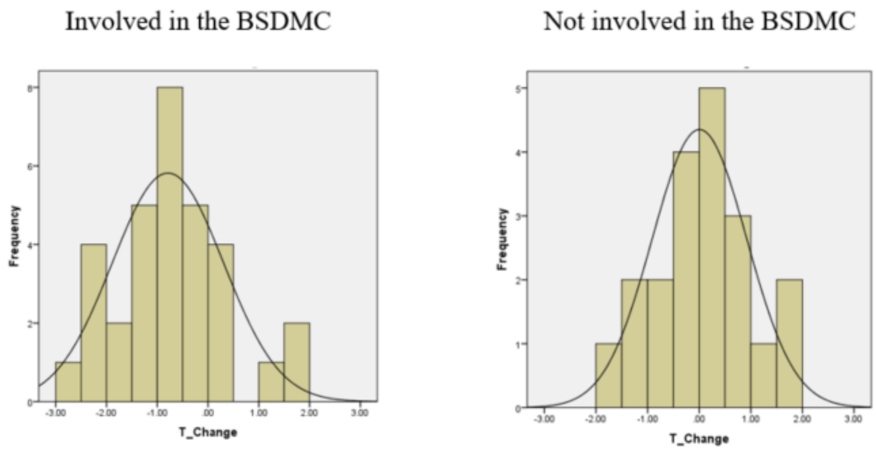

Figure 8. **Histogram of the frequency distributions of traditional transmission change variable for secondary participants involved and not involved in the DMC**

An independent samples *t*-test revealed a statistically significant difference between means for secondary participants involved in the DMC model of professional development (N = 32, M = -0.791, SD = 1.097) and those not involved in the DMC model of professional development (N = 20, M = 0.005, SD = 0.917) on the traditional transmission change variable, $t(50) = 2.705$, $p < 0.05$. Though Cohen's effect size value ($d = 0.20$) could be deemed small, when it is interpreted in relation to the instructional practice scale and the classroom context in which this study is situated, the effect could be considered significant both in terms of the frequency of traditional transmission activity use and student engagement with and learning of mathematics.

This significant difference between means for those involved in the cohort and those who were not indicated involvement in the DMC model of professional development had an effect on the change in frequency with which traditional transmission instructional activities are used. To determine the strength and direction of that effect, further linear regression analysis was conducted.

Prior to conducting a linear regression analysis, the assumptions of linear regression were checked. Because the predictor variable of involvement in the DMC was a dichotomous variable, normality only needed to be tested for the traditional transmission change variable. Confirmation that there were no outliers, that the standardized residual plot had evidence of homoscedasticity, and that residuals were normally distributed were also supplied (Muijs, 2011). Details on the testing done for assumptions are provided in Appendix I.

Because the assumptions for linear regression were met, a simple linear regression was calculated to predict the change in the frequency of traditional transmission instructional activity use, T_Change, based on DMC involvement. DMC involvement was coded as a dummy variable with 0 = no involvement and 1 = involvement. A significant regression equation was found ($F(1, 50) = 7.315$, $p < 0.05$), with an R^2 of 0.128. Participants' predicted T_Change is equal to 0.005 – 0.796×(DMC involvement). On average, T_Change decreased 0.796 when the participant was involved in the DMC model of professional development. That is, the frequency with which the use of traditional transmission instructional activities decreased significantly for secondary participants involved in the DMC and the null hypotheses H_{02} was rejected.

Questions 2 & 3 Analyses and Results

Question 2: To what degree does access to the College Preparatory Mathematics (CPM) curriculum support materials predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?

A simple linear regression was calculated to predict shifts in the frequency of traditional transmission activity use based on access to the CPM curriculum resources. A non-significant regression equation was found ($F(1, 50) = 0.031$, $p = 0.861$), with an R^2

of 0.001. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -0.517 + 0.055·CPM access when CPM is coded either as 0 (no access) or 1 (access) and the shift in the frequency of traditional transmission activity use is measured on a 1-7 scale with 1 corresponding to never using an instructional activity and 7 corresponding to daily usage. Consequently, the null hypotheses, H_{03}, was not rejected.

Question 3: To what degree does involvement in the DMC, when combined with CPM curricular support materials, predict shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices?

A simple linear regression was calculated to predict shifts in the frequency of traditional transmission activity use based on a combination of DMC involvement and access to the CPM curriculum resources. A non-significant regression equation was found ($F(1, 50) = 1.388$, $p = 0.244$), with an R^2 of 0.027. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -0.349 + -.0370·(DMCxCPM) access when CPM is coded either as 1 (involvement in DMC and access to CPM) or 0 (either no involvement in DMC or no access to CPM curriculum) and the shift in the frequency of traditional transmission activity use is measured on a 1-7 scale with 1 corresponding to never using an instructional activity and 7 corresponding to daily usage. Consequently, the null hypotheses, H_{04}, was not rejected.

Question 4 Analyses and Results

Question 4: Is the relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset (fixed or growth)?

To answer question 4, two multiple linear regression analyses were used. The first involved the predictor variables DMC, FixedMS, and DMC×FixedMS, and the dependent variable T_Change. The second used the predictor variables DMC, GrowthMS and DMC×GrowthMS. Prior to conducting either analyses, the assumptions for multiple linear regression needed to be checked. Details of the assumptions' analyses are provided in Appendix J.

Because all the assumptions needed to run a multiple linear regression analysis were met, an examination of whether the model was improved by inclusion of the moderator interaction variables was conducted.

Without the moderator interaction variables, the multiple linear regression on T_Change using FixedMS and DMC involvement as predictor variables yielded the information found in Tables 9, 10, and 11.

Table 9. Model Summary for FixedMS and DMC Involvement Regressed on T_Change

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.371[a]	0.138	0.103	1.03637

a. Predictors: (Constant), FixedMS, DMC

The model explained approximately 13.8% (10.3% adjusted) of the variability in T_Change, which was reasonable considering the multitude of factors which can impact changes in instructional practice.

Table 10. ANOVA Model Summary for FixedMS and DMC Involvement on T_Change

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.414	2	4.207	3.917	0.026[a]
	Residual	52.629	49	1.074		
	Total	61.043	51			

a. Predictors: (Constant), FixedMS, DMC

There was a significant effect of FixedMS and DMC on T_Change at the $p < 0.05$ level for the conditions [F(2, 49) = 4.207, $p < 0.05$].

Table 11. Coefficients for FixedMS and DMC Involvement Regression on T_Change

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	*t*	Sig.	Tolerance	VIF
1	(Constant)	-0.712	0.969		-0.735	0.466		
	DMC	-0.806	0.296	-0.362	-2.727	0.009	0.998	1.002
	FixedMS	0.179	0.235	.101	.762	0.450	0.998	1.002

Involvement in the DMC model of professional development was a significant predictor of T_Change (b = -0.806, t = 2.727, $p < 0.05$), while FixedMS (b = 0.179, t = 0.762, p = 0.450) was not.

The regression equation that can be used to predict T_Change is:

T_Change = -0.712 - 0.806(DMC) + 0.179(FixedMS), indicating that involvement in the DMC model of professional development decreased the frequency with which teachers used traditional transmission instructional activities 0.806 units on the traditional transmission scaled continuum from 1 to 7. This also indicated that for every unit increase on the fixed mindset scale, teachers' use of traditional transmission instructional activities increased 0.179 units on the traditional transmission scaled continuum from 1 to 7.

Without the moderator interaction variables, the multiple linear regression on T_Change using GrowthMS and DMC involvement as predictor variables yielded the information found in Tables 12, 13, and 14.

Table 12. Model Summary for GrowthMS and DMC Involvement Regressed on T_Change

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.357[a]	0.128	0.092	1.042

a. Predictors: (Constant), GrowthMS, DMC

The model explained approximately 35.7% (12.8% adjusted) of the variability in T_Change, which was reasonable considering the multitude of factors which can impact changes in instructional practice.

Table 13. ANOVA Model Summary for GrowthMS and DMC Involvement on T_Change

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.793	2	3.897	3.586	0.035[a]
	Residual	53.250	49	1.087		
	Total	61.043	51			

a. Predictors: (Constant), GrowthMS, DMC

There was a significant effect of GrowthMS and DMC on T_Change at the $p <$ 0.05 level for the conditions [F(2, 49) = 3.897, $p < 0.05$].

Table 14. Coefficients for GrowthMS and DMC Involvement Regression on T_Change

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	*t*	Sig.	Tolerance	VIF
1	(Constant)	-0.045	1.133		-0.040	0.968		
	DMC	-0.796	0.297	-0.357	-2.677	0.010	0.999	1.001
	GrowthMS	0.012	0.264	0.006	0.045	0.964	0.999	1.001

Involvement in the DMC model of professional development was a significant predictor of T_Change (b = -0.796, t = 2.677, p < 0.05), while GrowthMS (b = 0.012, t = 0.045, p = 0.964) was not.

The regression equation that can be used to predict T_Change is:

T_Change = -0.045 - 0.796(DMC) + 0.012(GrowthMS), indicating that involvement in the DMC model of professional development decreased the frequency with which teachers used traditional transmission instructional activities 0.796 units on the traditional transmission scaled continuum from 1 to 7. This also indicated that for every unit increase on the growth mindset scale, teachers' use of traditional transmission instructional activities will increase 0.012 units on the traditional transmission scaled continuum from 1 to 7.

To test the moderating effects of mindset, both the standard SPSS protocols for performing a multiple linear regression on DMC, the mindset variable, and the interaction variable (FixedMS×DMC or GrowthMS×DMC) and an alternate method developed by Hayes (Hayes & Matthes, 2009; Hayes & Rockwood, 2016) and highlighted by Field (Field, 2013) were used. Since Hayes & Matthes' method is traditionally utilized following discovery of a main interaction effect and in studies with a large sample size, its results should be interpreted with caution. However, it is included in this analysis because it accounts for both the continuous nature of the mindset variables and the lack of meaning of a score of zero on either of the mindset scales. This alternate approach, which uses a custom analysis PROCESS tool available as an add-on to SPSS, integrates a grand mean centring methodology on the predictor variables, automatically computing the interaction term, and providing a simple slopes analysis (Aiken & West, 1991; Rogosa, 1981, as cited by Field, 2013). This enables a comparison of regression equation slopes at different levels of the moderator variable in terms of their significance, their direction, and their magnitude, and allows for a more granular determination of whether the relationship between DMC involvement and T_Change changes as mindset changes.

To clarify, consider the adjusted Figure 9 adapted from a graphic available in Field's chapter on moderation (Field, 2013, p. 397).

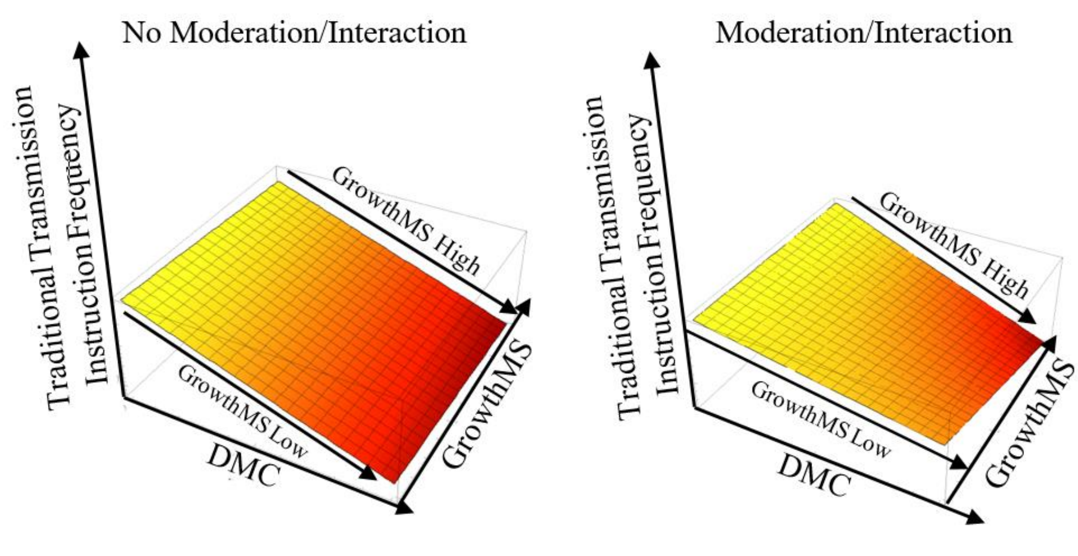

Figure 9. Difference between moderation interaction and no moderation interaction with continuous GrowthMS variable

With the interaction graph shown on the right, the hypothesized interaction generates higher T_Change scores at the upper end of the growth mindset scale and lower

T_Change scores at the lower end of the growth mindset scale than can be seen in the no moderation model on the left.

Running the PROCESS tool analysis to test moderation with DMC involvement as the independent variable, FixedMS as the moderator, and T_Change as the dependent variable yielded interesting results.

The first output provided the same type of information as the traditional SPSS multiple linear regression found using the predictor variables DMC, FixedMS, and DMC×FixedMS. It generated the regression equation's *b* values, their associated standard errors (adjusted for heteroscedasticity) and confidence intervals, and compared them to zero using a *t*-test. If mindset did indeed moderate the relationship between DMC involvement and T_Change, it would appear as a significant interaction.

An examination of the resulting information recorded in Table 15 revealed that the regression model approached significance and explained 13.8% (8.4% adjusted) of the variance (F(3, 48) = 2.318, p = 0.087).

Table 15. Model Summary for Linear Regression with DMC Involvement, FixedMS, and FixedMS Moderator Interaction Term on T_Change

R	R^2	Adjusted R^2	MSE	F	*df1*	*df2*	p
0.371	0.138	0.084	1.096	2.318	3	48	0.087

As shown in Table 16, the interaction term is not significant, b = -0.025, 95% CI [-1.197, 1.148], p = 0.967.

Table 16. Coefficients for Linear Regression with DMC Involvement, FixedMS, and FixedMS Moderator Interaction Term on T_Change

Model	*b*	Standard Error	*t*	*p*	95% Confidence interval
Constant	-0.484	0.156	-3.104	0.003	[-0.798, -0.171]
FixedMS	0.180	0.320	0.562	0.577	[-0.463, 0.822]
DMC	-0.807	0.307	-2.624	0.012	[-1.425, -0.189]
DMC× FixedMS	-0.025	0.583	-0.042	0.967	[-1.197, 1.148]

However, if the moderation effects were interpreted at different levels of FixedMS, an examination of the simple slopes yielded the following regression equations:

(1) When FixedMS was one standard deviation below its sample mean, there was a nonsignificant negative relationship between FixedMS and DMC involvement, b = -0.792, 95% CI [-1.734, 0.151], t = 1.689, p = 0.098.

(2) When FixedMS was at its sample mean, there was a significant negative relationship between FixedMS and DMC involvement, b = -0.807, 95% CI [-1.425, 0.189], t = 2.624, $p < 0.05$.

(3) When FixedMS was one standard deviation above its sample mean, there was a nonsignificant negative relationship between FixedMS and DMC involvement, b = -0.822, 95% CI [-1.785, 0.141], t = 1.715, p = 0.093.

In practical terms, it appears the interaction between DMC involvement and FixedMS became more pronounced the higher up the reversed fixed mindset scale a participant moved, even though the interaction was only significant for those near the mean score on the fixed mindset scale.

Another approach to simple slopes analysis that examines additional moderator values at more frequent and smaller deviations from the FixedMS mean is the Johnson-

Neyman method. For each value of FixedMS on the centred version of the FixedMS variable, this method computes the interaction effect, *b*, and its significance for the relationship between participation in the DMC and T_Change (Field, 2013). By computing this for a denser range of FixedMS values, the boundaries of the zone of significance around the FixedMS mean can be determined. In this case, the boundaries for significance were [-0.44, 0.446], as shown in Table 17.

Table 17. Conditional Effect of DMC on T_Change at Select Values of the Centred Moderator Fixed MS

FixedMS	Effect	Standard Error	*t*	*p*	LLCI	ULCI
-1.598	-0.768	0.975	-0.787	0.435	-2.728	1.193
-1.471	-0.771	0.905	-0.852	0.398	-2.59	1.048
-1.343	-0.774	0.835	-0.927	0.359	-2.453	0.905
-1.215	-0.777	0.766	-1.014	0.316	-2.318	0.763
-1.087	-0.78	0.699	-1.117	0.27	-2.185	0.624
-0.959	-0.783	0.632	-1.239	0.222	-2.055	0.488
-0.832	-0.786	0.568	-1.383	0.173	-1.929	0.357
-0.704	-0.79	0.507	-1.556	0.126	-1.81	0.231
-0.576	-0.793	0.45	-1.76	0.085	-1.698	0.113
-0.448	-0.796	0.399	-1.994	0.052	-1.598	0.007
-0.44	-0.796	0.396	-2.011	0.05	-1.592	0
-0.321	-0.799	0.356	-2.243	0.03	-1.515	-0.083
-0.193	-0.802	0.325	-2.468	0.017	-1.455	-0.149
-0.065	-0.805	0.309	-2.607	0.012	-1.426	-0.184
0.063	-0.808	0.31	-2.604	0.012	-1.432	-0.184
0.191	-0.811	0.329	-2.465	0.017	-1.473	-0.15
0.318	-0.815	0.363	-2.246	0.029	-1.544	-0.085
0.445	-0.818	0.407	-2.011	0.05	-1.635	0
0.446	-0.818	0.407	-2.008	0.05	-1.636	0.001
0.574	-0.821	0.46	-1.786	0.08	-1.745	0.103
0.702	-0.824	0.517	-1.593	0.118	-1.864	0.216
0.829	-0.827	0.579	-1.429	0.16	-1.991	0.337
0.957	-0.83	0.643	-1.29	0.203	-2.124	0.463

Zone of Significance

This indicated that for those with FixedMS scores within 0.44 of the mean, the interaction effect on T_Change was significant and increasingly more strongly negative as a participant's score moved higher on the FixedMS scale (indicating more of a growth mindset perspective because the scores were reversed for this study's analyses). Again, these results should be interpreted with caution since the sample size for this study was small.

Running the PROCESS tool analysis again to test interaction effects with DMC involvement as the independent variable, GrowthMS as the moderator, and T_Change as the dependent variable also yielded interesting results.

Again, the first output provided the same type of information as the traditional SPSS multiple linear regression run with the predictors DMC, GrowthMS, and DMC×GrowthMS. It generated the regression equation's *b* values, their associated standard errors (adjusted for heteroscedasticity) and confidence intervals, and compared them to zero using a *t*-test. If mindset did indeed moderate the relationship between DMC involvement and T_Change, it would appear as a significant interaction.

An examination of the resulting information recorded in Table 18 revealed that the regression model approached significance and explained 12.8% (7.4%) of the variance (F(3, 48) = 2.361, p = 0.083).

Table 18. Model Summary for Linear Regression with Fixed Mindset Moderator Interaction Term on T_Change

R	R^2	Adjusted R^2	MSE	F	*df1*	*df2*	p
0.358	0.138	0.074	1.109	2.361	3	48	0.083

As shown in Table 19, the interaction term was not significant, b = -0.090, 95% CI [-1.351, 1.170], p = 0.886.

Table 19. Coefficients for Linear Regression with Fixed Mindset Moderator Interaction Term on T_Change

Model	b	Standard Error	t	p	95% Confidence interval
Constant	-0.484	0.155	-3.122	0.003	[-0.795, -0.172]
GrowthMS	0.021	0.336	0.061	0.952	[-0.656, 0.697]
DMC	-0.797	0.305	-2.613	0.012	[-1.411, -0.184]
DMC×GrowthMS	-0.090	0.627	-0.144	0.886	[-1.351, 1.170]

However, if the moderation effects were interpreted at different levels of GrowthMS, an examination of the simple slopes yielded the following regression equations:

(1) When GrowthMS was one standard deviation below its mean, there was a nonsignificant negative relationship between GrowthMS and DMC involvement, b = -0.747, 95% CI [-1.666, 0.171], t = 1.636, p = 0.108.

(2) When GrowthMS was at its mean, there was a significant negative relationship between GrowthMS and DMC involvement, b = -0.797, 95% CI [-1.411, 0.184], t = 2.613, $p < 0.05$.

(3) When GrowthMS was one standard deviation above its mean, there was a nonsignificant negative relationship between GrowthMS and DMC involvement, b = -0.847, 95% CI [-1.787, 0.092], t = 1.813, p = 0.076.

In practical terms, it appeared the interaction between DMC involvement and GrowthMS became more pronounced the higher up the growth mindset scale a participant moved, even though the interaction was only significant for those near the mean score on the growth mindset scale.

As with the FixedMS moderator analysis, the Johnson-Neyman method provided analysis of slopes for additional GrowthMS scores at more frequent and smaller deviations from the GrowthMS mean. For each value on the centred version of the GrowthMS variable, this method computed the interaction effect, *b*, and its significance for the relationship between participation in the DMC and T_Change (Field, 2013). By computing this for a denser range of GrowthMS values, the boundaries of the zone of significance around the GrowthMS mean can be determined. In this case, the boundaries were [-0.372, 0.441], as shown in Table 20.

Table 20. Conditional Effect of DMC on T_Change at Select Values of the Centred Moderator GrowthMS

GrowthMS	Effect	Standard Error	*t*	*p*	LLCI	ULCI	
-1.335	-0.677	0.884	-0.765	0.448	-2.455	1.102	
-1.23	-0.686	0.823	-0.834	0.408	-2.34	0.968	
-1.124	-0.696	0.762	-0.914	0.365	-2.227	0.836	
-1.019	-0.705	0.701	-1.005	0.32	-2.116	0.705	
-0.913	-0.715	0.643	-1.113	0.271	-2.007	0.577	
-0.808	-0.724	0.585	-1.238	0.222	-1.901	0.452	
-0.702	-0.734	0.53	-1.385	0.172	-1.799	0.331	
-0.597	-0.743	0.477	-1.558	0.126	-1.703	0.216	
-0.491	-0.753	0.428	-1.758	0.085	-1.614	0.108	
-0.385	-0.762	0.385	-1.981	0.053	-1.536	0.011	
-0.372	-0.764	0.38	-2.011	0.05	-1.527	0	Zone of Significance
-0.28	-0.772	0.348	-2.216	0.031	-1.473	-0.071	
-0.174	-0.782	0.322	-2.429	0.019	-1.428	-0.135	
-0.069	-0.791	0.307	-2.576	0.013	-1.409	-0.174	
0.037	-0.801	0.306	-2.612	0.012	-1.417	-0.184	
0.142	-0.81	0.32	-2.533	0.015	-1.453	-0.167	
0.248	-0.82	0.346	-2.372	0.022	-1.514	-0.125	
0.353	-0.829	0.381	-2.176	0.035	-1.595	-0.063	
0.441	-0.837	0.416	-2.011	0.05	-1.674	0	
0.459	-0.839	0.424	-1.977	0.054	-1.691	0.014	
0.565	-0.848	0.473	-1.795	0.079	-1.798	0.102	
0.67	-0.858	0.525	-1.634	0.109	-1.913	0.197	
0.776	-0.867	0.58	-1.495	0.141	-2.033	0.299	

This indicated that for those with GrowthMS scores ranging from 0.372 below the mean to 0.441 above the mean, the interaction effect on T_Change was significant and increasingly more strongly negative as the GrowthMS scores became larger (indicating more of a growth mindset perspective). Again, due to the small *n* of this study and the lack of an overall moderating effect, these results should be interpreted with caution.

To answer question 4, the null hypothesis H_{05} was not rejected due to the lack of an overall moderation effect.

Questions 5 & 6 Analyses and Results

Question 5: Is the relationship between access to the CPM curricular materials and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?

Because the preliminary analyses for questions 1 through 3 indicated that access to CPM curricular support materials did not have a main effect, we can assume that there will not be a significant interaction involving mindset (Frazier, Tix & Barron, 2004). A non-significant regression equation was found ($F(3, 48) = 0.554$, $p = 0.648$), with an R^2 of 0.033. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -2.342 + 2.362·CPM + 0.460·FixedMS – 0.578·(FixedMS×CPM) when CPM is coded either as 0 (no access) or 1 (access), FixedMS is measured on a 1-5 scale with 1 corresponding to strongly fixed and 5 corresponding to strongly growth, and the shift in the frequency of traditional transmission activity use is measured on a 1-7 scale with 1 corresponding to never using an instructional activity and 7 corresponding to daily usage.

Similar analysis with the GrowthMS variable yields non-significant results as well. A non-significant regression equation was found ($F(3, 48) = 0.669$, $p = 0.576$), with an R^2 of 0.040. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -2.413 + 3.439·CPM + 0.458·GrowthMS – 0.806·(GrowthMS×CPM). Consequently, the null hypotheses, H_{05}, was not rejected.

Question 6: Is the relationship between involvement in the DMC, when combined with CPM curricular support materials, and shifts in the frequency with which secondary mathematics teachers use traditional transmission (or social-constructivist) instructional practices moderated by mindset?

Because the preliminary analyses for questions 1 through 3 indicated that a combination of DMC involvement and access to CPM curricular support materials did not have a main effect, we can assume that there will not be a significant interaction involving mindset (Frazier, Tix & Barron, 2004). A non-significant regression equation was found ($F(3, 48) = 0.1.924$, $p = 0.138$), with an R^2 of 0.107. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -2.415 + 3.665·(CPM×DMC) + 0.517·FixedMS – 0.995·(FixedMS×CPM×DMC) when CPM×DMC is coded either as 1 (involvement in the DMC and access to the CPM curriculum resources) or 0 (either no involvement in the DMC or no access to the CPM curriculum resources), FixedMS is measured on a 1-5 scale with 1 corresponding to strongly fixed and 5 corresponding to strongly growth, and the shift in the frequency of traditional transmission activity use is measured on a 1-7 scale with 1 corresponding to never using an instructional activity and 7 corresponding to daily usage.

Similar analysis with the GrowthMS variable yields non-significant results as well. A non-significant regression equation was found ($F(3, 48) = 1.584$, $p = 0.205$), with an R^2 of 0.090. Participants' predicted shift in the frequency of traditional transmission activity use is equal to -2.280 + 3.948·(CPM×DMC) + 0.464·GrowthMS – 1.015·(GrowthMS×CPM×DMC). Therefore, the null hypotheses H_{07} was not rejected.

Summary

Chapter four provided the detailed analyses conducted to test the hypotheses regarding proposed relationships between shifts teachers made in their instructional practice and two different interventions: the district's mathematics cohort (DMC) model of professional development and support provided via adopted College Preparatory Mathematics (CPM) curricular materials. Further analyses were conducted to determine the degree to which mindset moderated these relationships. Chapter five provides a detailed discussion of the findings with respect to chapter two's theoretical framework regarding change, implications of the analyses results, and recommendations for future study.

CHAPTER FIVE: CONCLUSION

Introduction

The purpose of this study was to explore the relationships between and influences of a large, urban Idaho district's mathematics cohort (DMC) model of professional development, newly adopted reform mathematics curriculum, and mindset on shifts in secondary mathematics teachers' instructional practice. Research indicates that professional development and curriculum are related to shifts in instructional practice, but no study has dealt specifically with mindset and its potential for inclusion in predictive models for change. To help address this gap in the literature, this study added the variable of mindset to existing theoretical frameworks and explored whether doing so improved our understanding of the mechanisms of change in the mathematics education setting.

This chapter summarizes the results presented in chapter four and is comprised of three sections. The results of data analyses related to the study's research questions are presented, situated within the literature base reviewed in chapter two, and then interpreted as to their predictive utility in the secondary mathematics educational setting. Next, the implications of this study's findings are outlined with consideration paid to the study's limitations. Lastly, the chapter concludes with recommendations for further research and an overall conclusion.

Summary of Findings

Three primary findings emerged from the analysis of this study's data. First, the DMC model of professional development intervention had a significant effect on secondary mathematics teachers' practice. As hypothesized, involvement in the mathematics cohort led to a decrease in teachers' frequency of traditional transmission instructional activity use. Second, access to the CPM curricular materials did not have a significant effect on secondary mathematics teachers' practice, either as a stand-alone intervention or through interaction with DMC involvement. And last, mindset, as measured on both fixed and growth mindset scales, did not have a significant interaction effect with either of the predictor variables.

Discussion and Conclusions

Does the District's Mathematics Cohort Model of Professional Development Matter?

The data indicate that for secondary mathematics teachers, involvement in the DMC model of professional development had a significant effect on instructional practice, as measured by decreases in the frequency of traditional transmission instructional activity use. These findings align with anticipated results, as the DMC model of professional development addressed the cognitive, emotional, and situational barriers to change in ways recommended by a host of researchers in the educational, psychological, and business fields (Bandura, 1997; Clarke & Hollingsworth, 2002; Darling-Hammond et al., 2009; Desimone, 2009; Goldsmith et al., 2014; Heath & Heath, 2010; Kennedy, 2016; Loucks-Horsley & Matsumoto, 1999; Marrongelle et al., 2013; Opfer & Pedder, 2011; Phillipp, 2007).

By attending to each component of the Switch framework (Heath & Heath, 2010) for change outlined in chapter two, those involved in the DMC model of professional development were set up for success. The clarity of vision needed to addressed cognitive barriers was accomplished through clear alignment with the DMT model for effective instruction, deliberate sharing of peer successes, and coaching support to assist when critical challenges arose. Emotional buy-in and motivation was fostered by early and ongoing feedback and support, collaborative goal setting, celebration of small and large successes, and a cohort model that fostered both a positive group identity and a growth mindset. Situational barriers were addressed through appropriate funding and support of the DMC, with stipends and released time for participants, intensive district support via adoption of a coherent vision for what good mathematics instruction entails, the coaching to assist with its implementation, and administrative support across and within individual buildings.

Does Curriculum Matter?

The data did not indicate that access to the reform College Preparatory Mathematics (CPM) curricular materials had a significant effect on secondary mathematics teachers' instructional practice, either as a primary intervention or through interaction with the DMC model of professional development. A variety of explanations for these findings are plausible, not the least of which align with the findings in the literature regarding the variable and inconsistent influence of curricular resources (Ball & Cohen, 1996; Collopy, 2003; Davis & Krajcik, 2005; Herbel-Eisenmann, 2007; Kim et al, 2010; Newton & Newton, 2006; Stein & Kim, 2009; Stylianides, 2007; Watanabe, 2001; Martin et al., 2001; Remillard, 2005; Stein et al., 2007; Weinberg & Weisner, 2011).

When curriculum use is supported by intensive professional development, shifts in practice are more likely to occur (Stein et al., 2007). But in this study, the combined effects of involvement in the DMC and access to the CPM curriculum was not significantly more effective than involvement in the DMC alone. This is not to say that the CPM curriculum support did not have an impact on individual teacher's instructional practice. Rather, because this study did not involve case study analysis of individual teachers' responses to the CPM curriculum, no determination at the granular level was made. Nor can a claim be made that the CPM curriculum will continue to have insignificant effects, as prolonged exposure to and increased familiarity with the materials may lead to longer term effects that are beyond the scope of this study.

Does Mindset Matter?

Finally, though the data indicate that the relationship between involvement in the DMC model of professional development and shifts in the frequency with which secondary mathematics teachers use traditional transmission instructional practices was not moderated by mindset in the overall model, PROCESS analysis reveals a "zone of significance" (Aiken & West, 1991; Rogosa, 1981; Hayes & Matthes, 2009 as cited by Field, 2013) around the sample's mean mindset scores. In this study, the concepts of growth and fixed mindset, as coined by Dweck and her colleagues, built off Sternberg's research, where he sought to "understand the nature and use of people's implicit theories of intelligence" (Sternberg, 1985). The entity, or fixed mindset, view is a stance from which attributes such as intelligence are believed to be fixed, invariant characteristics that remain stable regardless of the situation or circumstances. By contrast, the incremental, or growth mindset, view is characterized by the belief that these same attributes are malleable, with the potential for growth and development.

Multiple linear regression analysis on the moderating effects of mindset via the Johnson-Neyman method resulted in zones of significance near the centred sample mindset means, indicating that the moderating effects on secondary teachers' frequency of traditional transmission instructional activities use were significant and increasingly more negative as the mindset scores became larger (indicating more of a growth mindset perspective). These results, though they should be interpreted with caution due to the lack of an overall moderating effect, suggest the directional relationships between behavioral change and mindset can potentially be used to interpret and predict changes in the secondary mathematics educational setting. These preliminary findings align with the literature, as those who possess more of a growth mindset exhibit greater motivation to pursue challenging goals (Aronson, Fried, & Good, 2002; Blackwell, Trzensniewski, & Dweck, 2007; Grant & Dweck, 2003; Hong, Chiu, Dweck, Lin, & Wan, 1999) and fare better across difficult transitions (Blackwell, at al., 2007; Dweck, 2006; Leggett & Dweck, 1988).

Limitations and Delimitations of the Research

This study's generalizability was limited by the relatively small sample size and the fact that all participants came from the same urban Idaho district. Because of a lack of availability to demographic data on the district's secondary mathematics teachers, an assessment of the representative nature of the participant sample could not be made. Therefore, the study's participant sample may not be representative of the district's, let alone all, secondary mathematics teachers. Furthermore, secondary mathematics teachers were not randomly assigned to the study's interventions. All participants were either selected by a district principal or were volunteers. The fact that participant teachers were simultaneously facing the differentiation challenges of mixed-ability, detracked classrooms may have also differentiated this population from other populations of mathematics teachers undergoing the transition to full CCSS implementation and the adoption of reform methodologies.

Variance in participants' prior exposure to CCSS mathematics courses, the level of coursework being taught, unfamiliarity with specific mathematical content, the cumulative effects of multiple factors outside of the researchers' control, and teachers' previous experiences with professional development trainings, collaboration, and familiarity with the provided curricular materials could have also impacted the study results in unanticipated ways.

Further, the amount of time required to complete the survey may have played a role in the completeness and thoroughness of participant responses. Whether the findings would remain the same if the surveys were to be completed at different times is not known.

Time, money, and a lack of human resources also limited the scope of this study. Though supplementing the quantitative survey data with follow-up interviews and observations would have served to validate the data more fully, not enough qualitative data was generated to warrant inclusion in the study.

A final delimitation could be attributed to the instruments themselves and the assumption that they validly and accurately measured the constructs they aim to measure. Given the self-reporting nature of each, the clustering of scores at the growth end of the mindset continuum, and the potential interaction between participants' individual perceptions of these constructs and the terminology with which they are described, the measures' scaled scores may not be accurate indicators of a teachers' actual instructional practice or mindset. In particular, further analysis and refinement of the Mindset Survey to establish validity is needed. Given the lack of published evidence to support the use of the Mindset Survey, results arising from its use must be interpreted with caution.

Implications for Future Research

In chapters one and two, the need for change in mathematics instruction and the barriers that have arisen in response to decades of various reform efforts were delineated. The literature indicates that large-scale reform in the mathematics classroom remains frustratingly out of reach (Hiebert, 2013). The core of mathematics teaching in the US remains strikingly similar to its traditional instruction of a century ago (Cuban, 1993; Fey, 1981; Hoetker, & Ahlbrand, 1969) and the behaviorist orientation which dominates much of current mathematical practice persists (Fullan, 2009, 2015; Stein et al., 2007; Hiebert, 2013). Though multiple interventions have been shown to make shallow yet measurable inroads into proximal practitioner behavior, few can claim sustainability in the long term, and even fewer maintain their effectiveness when scaled up. Why is this the case?

This research was conducted to explore this question in part by examining the relationships between and influences of a large, urban Idaho district's mathematics cohort (DMC) model of professional development, newly adopted reform mathematics curriculum, and mindset on shifts in secondary mathematics teachers' instructional practice. The literature base indicates that professional development and curriculum are related to shifts in instructional practice, but no study had dealt specifically with mindset and its potential for inclusion in predictive models for change. Consequently, this study sought to address this gap in the literature and provides an additional framework within which continued explorations of the relationships between teacher mindset and changes in mathematics instructional practice can be conducted.

The Switch framework for change (Heath & Heath, 2010) outlined in chapter two suggests that explicit coordination of cognitive, emotional, and situational variables can yield better outcomes when targeting shifts in mathematics instructional practice. As indicated by the literature, there are myriad ways in which these variables can be combined. This study suggests that including mindset measures can improve our understanding of how other variables interact and leads to a number of additional directions to pursue through mathematics education research.

A first potential direction to pursue involves further development and refinement of the Mindset Survey to confirm its validity and reliability. This would require additional field-testing across larger groups of participants than were provided in this study, along with detailed item, principal component, and confirmatory factor analysis.

A second potential direction to pursue involves an examination of the relationship between mindset and the cognitive barriers to instructional change. In what ways does mindset relate to teacher belief systems for instruction, learning, learners, and mathematics? Are those with more of a growth mindset less likely to view mathematics through an instrumentalist, as opposed to a dynamic, lens (Thompson, 1992; Dossey, 1992)? Are they more likely to place the locus of authority and control in the classroom with the students, as opposed to the teacher (Ball, 1988)? Are they more flexible in their perceptions about learning itself? And what student roles are they more likely encourage: passive recipient and mere receptors of knowledge transmitted through direct instruction or active, exploratory, social sense-makers (Stipek et al., 2001)?

What relationship can be found between a mathematics teacher's mindset and their acquisition of the knowledge, skills, and capacities necessary for successful implement of instruction that aligns with the reform agenda? Are those with a growth mindset more likely to persevere through the challenges of improving within each of the interconnected domains of mathematical knowledge for teaching (Ball et al., 2008)?

A third potential direction to pursue involves an examination of the relationship between mindset and the emotional barriers to instructional change. Research indicates that mindset determines emotional responses to failure (Dweck, 2006; Leggett & Dweck, 1988), but the scope of the research has not extended to mathematics education nor teachers' responses to interventions aimed at instructional reform. Yet when emotions, whether linked to professional identity, motivation, resistance, defensiveness, relatability, or relationship skills all appear to influence outcomes (Prochaska et al., 1993), as do the self-regulatory strategies and perceptions of control found in self-efficacy research (Bandura, 1997), it makes sense that an underlying relationship between the emotional responses to intervention that mathematics teachers express and their mindset may exist. What is that relationship? And to what degree does it impact intervention outcomes?

A fourth potential direction to pursue involves an examination of the relationship between mindset and situational barriers to instructional change. Would communities, schools, or departments characterized by a fixed mindset erect more situational barriers to reform than those characterized by a growth mindset? Would those characterized by a growth mindset be more flexible and adaptive in their responses to change efforts and the challenges that arise when enacting them?

A final potential direction to pursue involves the question of whether teacher mindset can be influenced through intervention. If mindset does indeed moderate responsiveness to interventions, as hypothesized in this study, then could we improve outcomes by first attending to mindset and instituting plans to help teachers develop more of a growth mindset? Could interventions aimed at shifting teacher mindset help optimize the effectiveness of district and state reform efforts? Perhaps by attending to mindset and including it in our models for change, we can start to turn the tide of resistance and effect lasting, large-scale change.

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APPENDIX A

Survey Items from the Instructional Practice Instrument

Table A.1 Instructional Practice Survey Items

Items intended to measure the frequency with which teachers and students engage in student-centered activities:	Items intended to measure the frequency with which teachers and students engage in traditional activities:
As the **classroom teacher,** I:	As the **classroom teacher,** I:
Encourage discussion of the connections between various models and strategies.	Present only the standard method of solving a task or performing an algorithm.
Emphasize the use of multiple models for recording and communicating student thinking.	Demonstrate for the class the correct way to use a particular procedure or model before they start solving problems.
Use incorrect or inappropriate strategies as learning opportunities in small or whole class discussion.	Focus on students mastering a particular model or procedure before examining related procedures or models.
Facilitate discussion about underlying mathematical concepts (e.g. composing or decomposing number).	Avoid student errors and misconceptions when a topic is first introduced by explaining how to solve a problem before they start.
Facilitate small group or whole class discussion on student thinking.	Explain the steps to a procedure or algorithm when I introduce new topics.
Classroom tasks and activities:	**Classroom tasks and activities:**
Are selected because they provide opportunities for students to explain the mathematics behind an answer.	Are primarily directed by the sequence of a textbook or curriculum resource.
Are selected to lead students to make connections between various models and algorithms.	Primarily focus on repeatedly drilling the steps to a particular procedure.
Are based on their potential to encourage discussions of students' mathematical ideas.	Focus on repeated practice of a model or procedure.
Include the intentional presentation of solution strategies containing misconceptions for students to analyze and correct.	Focus on rehearsing mathematical procedures to avoid student confusion.
Are selected because the problem's context may focus students on generating a particular model.	Are selected because they allow students repeated practice to learn a procedure.
Students:	**Students:**
Examine their misconceptions or the misconceptions of other students through small group or whole class discussions.	Take notes on how to perform each step in a procedure or algorithm.
Solve problems that allow for several different approaches.	Are encouraged to work independently practicing a particular model or procedure with little or no discussion of ideas.
Analyze the connections between various models and procedures.	Repeatedly practice a particular model or procedure when a math topic is first introduced to avoid developing misconceptions or incorrect procedures.

Describe the underlying mathematics behind how a particular model or algorithm works.	Learn by copying down examples from a teacher demonstration.
Are encouraged to discuss their mathematical ideas in pairs, small-group, and/or whole class discussions.	Solve problems involving repeated practice of a model or procedure.

APPENDIX B

Survey Items from the Mindset Instrument

Table B.1 Mindset Survey Items

Items intended to measure fixed mindset	Items intended to measure growth mindset
You have a certain amount of physical ability, and you can't really do much to change it.	With effort, you can change your math ability quite a bit.
You can learn new things, but you can't really change your basic creativity.	Your level of intelligence is highly related to the amount of effort you put into learning information.
You have a certain amount of math intelligence, and you can't really do much to change it.	Intelligence is a processing capacity and can be improved over time.
Not everyone can be smart at math.	Your level of intelligence can change with effort.
You have a certain amount of talent and you can't really do much to change it.	The brain is like a muscle. When it is stretched/challenged, it grows.
You have a certain amount of creativity, and you can't really do much to change it.	You can change the amount of talent you have in various areas with effort.
You can learn new things, but you can't really change your basic intelligence.	Your level of creativity can change with effort.
Your math ability is something that you can't change very much.	No matter who you are, you can significantly change your intelligence level.
You can learn new math skills, but you can't really change your math intelligence.	Your level of creativity is highly related to the amount of effort you put into cultivating it.

APPENDIX C

Qualtrics Form of the Complete Survey

Information and IRB Consent Form

BOISE STATE UNIVERSITY

This survey is designed to gather information about your beliefs regarding mathematics learning and your classroom mathematics instructional practice. When answering the questions, please keep in mind that every effort should be made to answer each question honestly and to the best of your ability. We will make every effort to keep the information we collect confidential, and you will not be identified in any report. The survey should take 10-15 minutes to complete.

If at any time before, during, or after the study, you have questions about the study, please contact one of the principal investigators: Tatia Totorica at (208) 867-6736 or Jonathan Brendefur at (208) 426-4650. Either will be happy to answer any questions you may have. You can also contact the Institutional Review Board, which is concerned with the protection of volunteers in research projects, at (208) 426-5401 or humansubjects@boisestate.edu. The researchers will make every effort to protect your confidentiality. However, if you are uncomfortable answering any of the following questions, you may leave them blank.

By completing this survey, you indicate that you understand the conditions of this study and voluntarily agree to participate.

Sincerely,
Tatia Totorica, Doctoral Student
Jonathan Brendefur, PhD
Boise State University

What is your first name?

What is your last name?

What is your email address?

What is your gender?

Male

Female

How many total years have you taught mathematics?

- 0-2
- 3-5
- 6-10
- 11-15
- more than 15

How many years have you taught mathematics in the Boise School District?

- 0-2
- 3-5
- 6-10
- 11-15
- more than 15

Have you already taught a CCSS or Integrated high school mathematics course?

- Yes
- No

If you answered yes to the previous question, did you teach the CCSS or Integrated high school mathematics course in the Boise School District?

- Yes
- No

What mathematics course(s) will you teach this year? (Select all that apply.)

Elementary level (CCSS K-5)	Algebra 1/Math I
CCSS 6	Geometry/Math II
Honors Math 6	Algebra 2/Math III
CCSS 7	Advanced Math Topics
Compacted 7/8	Precalculus
CCSS 8: Pre-Algebra	AP Statistics
Math in the Workplace I, II, or III	AP Calculus (AB or BC)

What grade level(s) will you teach this year? (Select all that apply.)

K	7
1	8
2	9
3	10
4	11
5	12
6	

Are you a participant in the BSD Mathematics Cohort?

Yes

No

Will one or more of the courses you teach be supported by access to the CMP Core Connection resource materials? (This refers to the Core Connection materials that support the Integrated Algebra 1, Geometry, and Algebra 2 courses.)

Yes

No

Mathematics Instructional Practice - Teacher

Indicate for each statement the frequency with which you engage in the particular instructional practice.

As the **classroom teacher**, I:

	Daily	2-3 Times a Week	Once a Week	2-3 Times a Month	Once a Month	2-3 Times a Year	Never	Not Applicable
Present only the standard method of solving a task or performing an algorithm.	○	○	○	○	○	○	○	○
Demonstrate for the class the correct way to use a particular procedure or model before they start solving problems.	○	○	○	○	○	○	○	○
Focus on students mastering a particular model or procedure before examining related procedures or models.	○	○	○	○	○	○	○	○
Encourage discussion of the connections between various models and strategies.	○	○	○	○	○	○	○	○
Emphasize the use of multiple models for recording and communicating student thinking.	○	○	○	○	○	○	○	○
Avoid student errors and misconceptions when a topic is first introduced by explaining how to solve a problem before they start.	○	○	○	○	○	○	○	○
Explain the steps to a procedure or algorithm when I introduce new topics.	○	○	○	○	○	○	○	○
Use incorrect or inappropriate strategies as learning opportunities in small or whole class discussion.	○	○	○	○	○	○	○	○
Facilitate discussion about underlying mathematical concepts (e.g. composing or decomposing number).	○	○	○	○	○	○	○	○
Facilitate small group or whole class discussion on student thinking.	○	○	○	○	○	○	○	○

Other comments?

Mathematics Instructional Practice - Tasks and Activities

Indicate for each statement the frequency with which you engage in the particular instructional practice.

Classroom tasks and activities:

	Daily	2-3 Times a Week	Once a Week	2-3 Times a Month	Once a Month	2-3 Times a Year	Never	Not Applicable
Are selected because they provide opportunities for students to explain the mathematics behind an answer.	○	○	○	○	○	○	○	○
Are primarily directed by the sequence of a textbook or curriculum resource.	○	○	○	○	○	○	○	○
Primarily focus on repeatedly drilling the steps to a particular procedure.	○	○	○	○	○	○	○	○
Focus on repeated practice of a model or procedure.	○	○	○	○	○	○	○	○
Are selected to lead students to make connections between various models and algorithms.	○	○	○	○	○	○	○	○
Focus on rehearsing mathematical procedures to avoid student confusion.	○	○	○	○	○	○	○	○
Are based on their potential to encourage discussions of students' mathematical ideas.	○	○	○	○	○	○	○	○
Include the intentional presentation of solution strategies containing misconceptions for students to analyze and correct.	○	○	○	○	○	○	○	○
Are selected because they allow students repeated practice to learn a procedure.	○	○	○	○	○	○	○	○
Are selected because the problem's context may focus students on generating a particular model.	○	○	○	○	○	○	○	○

Other comments?

Mathematics Instructional Practice - Students

Indicate for each statement the frequency with which students engage in the learning event.

Students:

	Daily	2-3 Times a Week	Once a Week	2-3 Times a Month	Once a Month	2-3 Times a Year	Never	Not Applicable
Examine their misconceptions or the misconceptions of other students through small group or whole class discussions.	○	○	○	○	○	○	○	○
Solve problems that allow for several different approaches.	○	○	○	○	○	○	○	○
Analyze the connections between various models and procedures.	○	○	○	○	○	○	○	○
Describe the underlying mathematics behind how a particular model or algorithm works.	○	○	○	○	○	○	○	○
Take notes on how to perform each step in a procedure or algorithm.	○	○	○	○	○	○	○	○
Are encouraged to work independently practicing a particular model or procedure with little or no discussion of ideas.	○	○	○	○	○	○	○	○
Are encouraged to discuss their mathematical ideas in pairs, small-group, and/or whole class discussions.	○	○	○	○	○	○	○	○
Repeatedly practice a particular model or procedure when a math topic is first introduced to avoid developing misconceptions or incorrect procedures.	○	○	○	○	○	○	○	○
Learn by copying down examples from a teacher demonstration.	○	○	○	○	○	○	○	○
Solve problems involving repeated practice of a model or procedure.	○	○	○	○	○	○	○	○

Other comments?

BOISE STATE UNIVERSITY

Please indicate your level of agreement with the statements below.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
You have a certain amount of physical ability, and you can't really do much to change it.	○	○	○	○	○
With effort you can change your math ability quite a bit.	○	○	○	○	○
You can learn new things, but you can't really change your basic creativity.	○	○	○	○	○
You have a certain amount of math intelligence, and you can't really do much to change it.	○	○	○	○	○
Not everyone can be smart at math.	○	○	○	○	○
You have a certain amount of talent, and you can't really do much to change it.	○	○	○	○	○
Your level of intelligence is highly related to the amount of effort you put into learning information.	○	○	○	○	○
Intelligence is a processing capacity and can be improved over time.	○	○	○	○	○
Your level of intelligence can change with effort.	○	○	○	○	○

You have a certain amount of creativity, and you can't really do much to change it.	○	○	○	○	○
The brain is like a muscle. When it is stretched/challenged, it grows.	○	○	○	○	○
You can learn new things, but you can't really change your basic intelligence.	○	○	○	○	○
Your math ability is something that you can't change very much.	○	○	○	○	○
You can change the amount of talent you have in various areas with effort.	○	○	○	○	○
Your level of creativity can change with effort.	○	○	○	○	○
You can learn new math skills, but you can't really change your math intelligence.	○	○	○	○	○
No matter who you are, you can significantly change your intelligence level.	○	○	○	○	○
Your level of creativity is highly related to the amount of effort you put into cultivating it.	○	○	○	○	○

BOISE STATE UNIVERSITY

I am willing to participate in a follow-up survey that will be conducted in the spring. I understand that by participating in both the fall and spring surveys, I will be entered into a drawing for one of five $25 gift cards to a location/vendor of my choice.

Yes

No

If selected, I would be willing to have Tatia Totorica interview me and/or observe my class(es) to collect additional anonymous data relevant to her dissertation. I understand that by agreeing to this and by participating in all parts of the study, I will be entered into a drawing for a new 16GB, Wi-Fi capable iPad mini 3.

Yes

No

Thank you very much for your responses! Your time is very valuable, and I appreciate your willingness to assist me in my research!

Tatia Totorica
tatiatotorica@boisestate.edu

APPENDIX D

Survey Implementation Process

Round 1, Day 1: Mathematics coaches for the involved district presented a PowerPoint slide with the link to the survey during the first meeting of the cohort, the researcher presented the purpose of the study and assured all participants of anonymity, and time during the first cohort session was dedicated to its completion. The mathematics coordinator for the district followed up with an *initial email* to all district secondary mathematics instructors not in the cohort. The email explained the purpose of the survey, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

Round 1, Day 7: The researcher followed up with a *second email* to those secondary mathematics teachers not in the cohort who had not participated. The email explained the purpose of the survey, the importance of their response, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

Round 1, Day 14: The researcher followed up with a *third email* to those secondary mathematics teachers not in the cohort who still had not participated. The email explained the purpose of the survey, the importance of their response, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

Round 2, Days 1-6: Mathematics coaches for the involved district again presented a slide with the link to the survey to all cohort members on the final day of their grade-band cohort meeting. The distribution of the survey for this occurred in stages due to the staggered nature of the final meetings. The researcher was present at each of four meetings to explain the importance of the post-survey and again assured all participants of anonymity.

Round 2, Day 7: The researcher sent out an *initial email* to those secondary mathematics teachers not in the cohort who had participated in the first round of the survey and to those cohort members who had been absent for the final meeting. The email explained the purpose of the survey, the importance of their response, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

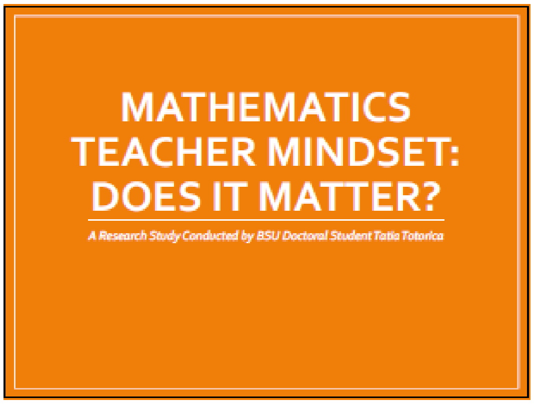
Round 2, Day 14: The researcher sent out a *second email* to those secondary mathematics teachers not in the cohort who had participated in the first round of the survey but had not participated in the second round yet. The email explained the purpose of the survey, the importance of their response, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

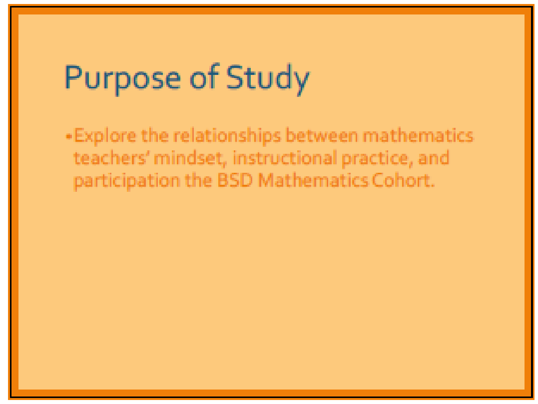
Round 2, Day 21: The researcher sent out a *final email* to those secondary mathematics teachers not in the cohort who had participated in the first round of the survey but had not yet participated in the second round. The email explained the purpose of the survey, the importance of their response, a link to access the survey, the intended use for participant responses, and an assurance of anonymity.

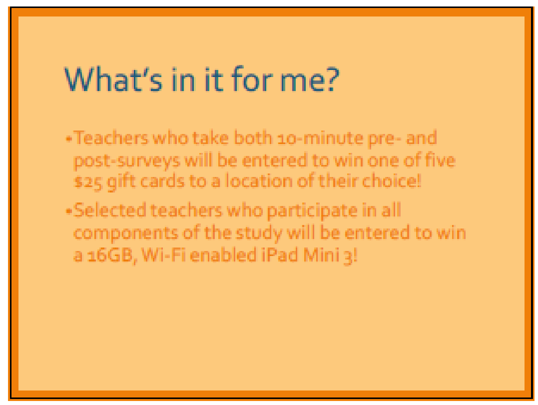
APPENDIX E

Recruitment Materials

Cohort Slides







Round 1: First Email

Hello, fellow Math Teachers,

I need your help! My name is Tatia Totorica, and I am currently working on my EdD dissertation through BSU.

I'm interested in exploring the relationship between teachers' mathematics instruction, their beliefs regarding the way mathematics should be taught and how students learn, and various supports that are in place to help with the district's Idaho Core math courses.

However, I can't conduct this study data without the willing participation of secondary math teachers like you! I'm hoping that you're willing to give me a few minutes of your time to fill out the survey available via this LINK. (If the link doesn't work, try typing in www.tinyurl.com/Totorica-TPS into your browser instead.)

Everyone in the [DMC] has already taken the survey (thank you!!), and it took them, on average, about 10 minutes. So if you can carve 10 minutes out of your insanely busy schedule to help me out, I would really appreciate it!

I will send out the same survey in the spring to measure any shifts that occur, and if you select to participate in both rounds, you will be entered into a drawing for one of five $25 gift cards to a location of your choice.

A small subset of teachers (8-16 teachers) will also be selected for follow-up observations and interviews, so if you are in this group and participate in all components of the study, you will be entered in a drawing for a new 16 GB, Wi-Fi capable iPad Mini 3.

Thank you in advance for contributing your voice to my study! I really appreciate your time!

Round 1: Second & Third Emails

Hello again, fellow Math Teachers,

I still need your help and am hoping you'll be willing to give me a few minutes of your time. As you know, my name is Tatia Totorica, and I am currently working on my EdD dissertation through BSU.

I'm interested in exploring the relationship between teachers' mathematics instruction, their beliefs regarding the way mathematics should be taught and how students learn, and various supports that are in place to help with the district's Idaho Core math courses.

However, I can't conduct this study data without the willing participation of math teachers like you! I'm hoping that you're willing to contribute your responses to the survey available via this LINK. (If the link doesn't work, try typing in www.tinyurl.com/Totorica-TPS into your browser instead.)

Everyone in the [DMC] has already taken the survey and it took them, on average, about 10 minutes. So if you can carve 10 minutes out of your insanely busy schedule to help me out, I would really appreciate it!

I will send out the same survey in the spring to measure any shifts that occur, and if you select to participate in both rounds, you will be entered into a drawing for one of five $25 gift cards to a location of your choice.

A small subset of teachers (8-16 teachers) will also be selected for follow-up observations and interviews, so if you are in this group and participate in all components of the study, you will be entered in a drawing for a new 16 GB, Wi-Fi capable iPad Mini 3.

Thank you in advance for contributing your voice to my study! I really appreciate your time!

Tatia Totorica

Round 2: First Email

Hello, again, fellow [District] Mathematics Teachers,

I still need your help, and so I'm soliciting you again! In order for my study to have its required statistical power, I need post-data on every one of you, so if you can please take a few minutes to fill out the attached form, I would be VERY grateful! I promise, it doesn't take a ton of time and the help it provides to me is immeasurable!

Before school's out for the year, please consider giving me a few more minutes of your time to fill out the follow-up survey available here: ${l://SurveyLink?d=Take the survey}

If the link doesn't work, you can copy and paste the URL below into your internet browser:
${l://SurveyURL}

Remember, too, that if you elect to participate in this second round of the survey (you're already one round down!), you will be entered into a drawing for one of five $25 gift cards to a location of your choice. A small subset of teachers (8-16 teachers) will also be selected for follow-up interviews, so if you are in this group and participate in all components of the study, you will be entered in a drawing for a new 16 GB, Wi-Fi capable iPad Mini 3. Thank you in advance for contributing your voice to my study! I really appreciate your time!

Tatia Totorica
tatiatotorica@boisestate.edu
(208) 867-6736

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

Round 2: Second and Third Emails

Hello, again, fellow [District] Mathematics Teachers,

I still need your help, and I'm hoping that the (second) third time I request it is the charm! In order for my study to have its required statistical power, I need post-data on every one of you, so if you can please take a few minutes to fill out the attached form, I would be VERY grateful! I promise, it doesn't take a ton of time and the help it provides to me is immeasurable!

Before school's out for the year, please consider giving me a few more minutes of your time to fill out the follow-up survey available here: ${l://SurveyLink?d=Take the survey}

If the link doesn't work, you can copy and paste the URL below into your internet browser:
${l://SurveyURL}

Remember, too, that once you submit this second round of the survey (you're already one round down!), you will be entered into a drawing for one of five $25 gift cards to a location of your choice. A small subset of teachers (8-16 teachers) will also be selected for follow-up interviews, and if you are in this group and participate in all components of the study, you will be entered in a drawing for a new 16 GB, Wi-Fi capable iPad Mini 3. Thank you in advance for contributing your voice to my study! I really appreciate your time!

Tatia Totorica
tatiatotorica@boisestate.edu
(208) 867-6736

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

APPENDIX F

Participant Demographic Information

Table F.1 Frequency of Grade Level for All Secondary Survey Respondents

Secondary Grade Levels	Cohort	Non-Cohort	Totals
5th-6th	2	0	2
6th	7	1	8
6th-8th	1	0	1
6th-9th	1	0	1
7th	1	2	3
7th-8th	0	1	1
7th-9th	5	2	7
8th	3	1	4
8th-9th	2	2	4
9th	1	1	2
10th	1	1	2
10th-11th	0	1	1
9th-12th	3	1	4
10th-12th	8	2	10
11th-12th	0	1	1
12th	0	1	1
Totals	35	17	52

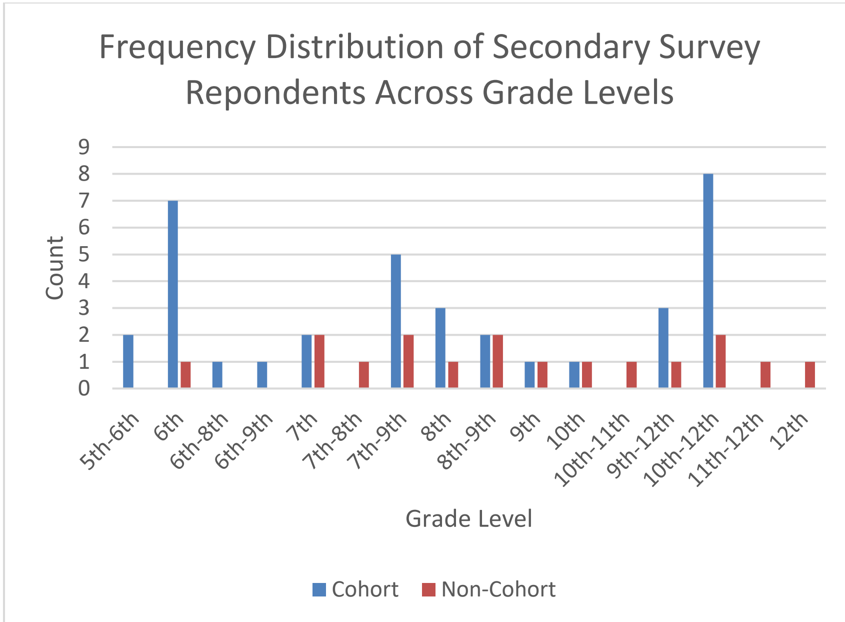


Figure F.1 Histogram of the frequency distribution of all secondary survey respondents across grade levels

Table F.2 Frequency Distribution of All Secondary Survey Respondents' Gender Across Grade Bands and Cohort Involvement

	Cohort	Non-Cohort	Totals
Secondary Females	23	14	37
Secondary Males	9	6	15
Totals	**32**	**20**	**52**

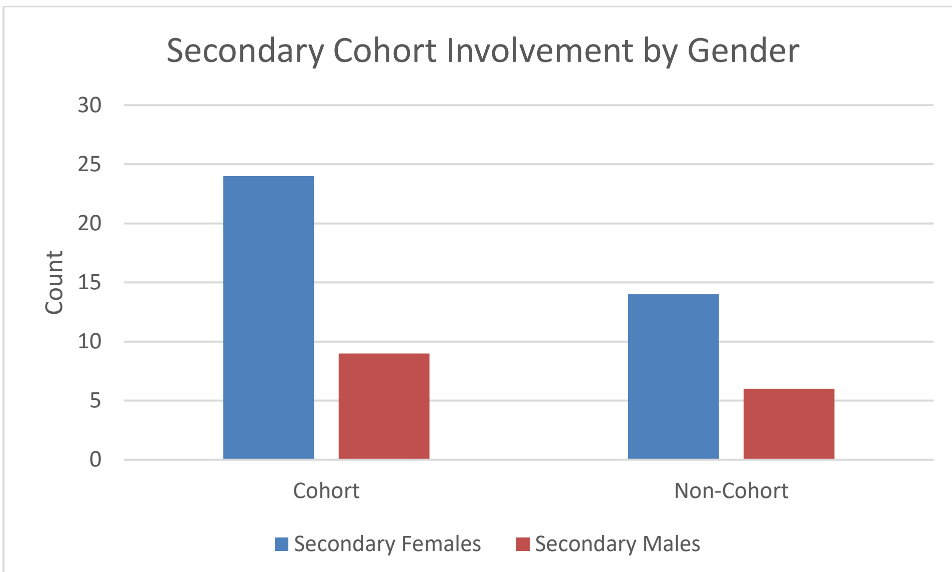


Figure F.2 Histogram of the frequency distribution of all secondary survey respondents' grade band and cohort involvement by gender

Table F.3 Frequency Distribution of All Secondary Survey Respondents' Years of Experience Teaching Mathematics

Years of Experience	Cohort	Non-Cohort	Totals
0-2	6	0	6
3-5	8	4	12
6-10	3	4	7
11-15	2	2	4
15+	14	10	24
Totals	**33**	**20**	**53**

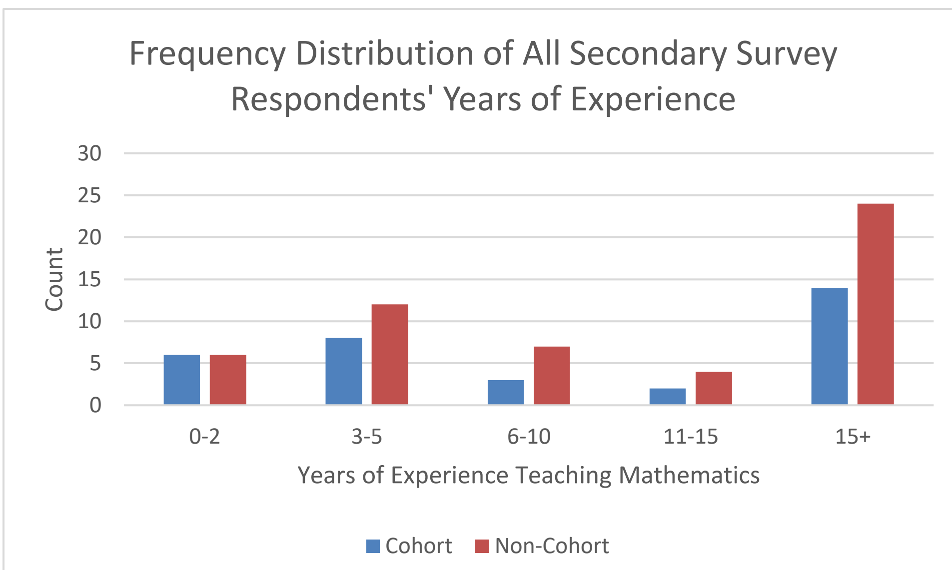


Figure F.3 Frequency distribution of all survey respondents' years of experience teaching mathematics

APPENDIX G

Principal Component Analysis (PCA) of Instructional Practice Scales

Table G.1 Traditional Transmission Component Matrix

	Component		
	1	2	3
T1_Q1_1 - Present only the standard method of solving a task or performing an algorithm.	0.562	0.373	-0.470
T2_Q1_2 - Demonstrate for the class the correct way to use a particular procedure or model before they starts solving problems.	0.762	0.236	-0.004
T3_Q1_3 - Focus on students mastering a particular model or procedure before examining related procedures or models.	0.557	0.300	-0.524
T4_Q1_6 - Avoid student errors and misconceptions when a topic is first introduced by explaining how to solve a problem before they start.	0.574	0.616	0.079
T5_Q1_7 - Explain the steps to a procedure or algorithm when I introduce new topics.	0.800	0.156	-0.044
T6_Q3_2 - Are primarily directed by the sequence of a textbook or curriculum resource.	0.446	0.419	0.684
T7_Q3_3 - Primarily focus on repeatedly drilling the steps to a particular procedure.	0.784	0.008	0.305
T8_Q3_4 - Focus on repeated practice of a model or procedure.	0.674	-0.309	-0.005
T9_Q3_6 - Focus on rehearsing mathematical procedures to avoid student confusion.	0.806	-0.320	0.025
T10_Q3_9 - Are selected because they allow students repeated practice to learn a procedure.	0.792	-0.158	0.000
T11_Q5_5 - Take notes on how to perform each step in a procedure or algorithm.	0.756	-0.121	0.072
T12_Q5_6 - Are encouraged to work independently practicing a particular model or procedure with little or no discussion of ideas.	0.569	-0.185	0.048
T13_Q5_8 - Repeatedly practice a particular model or procedure when a math topic is first introduced to avoid developing misconceptions or incorrect procedures.	0.832	-0.230	-0.006
T14_Q5_9 - Learn by copying down examples from a teacher demonstration.	0.847	-0.003	-0.027
T15_Q5_10 - Solve problems involving repeated practice of a model or procedure.	0.803	-0.306	-0.082

Extraction Method: Principal Component Analysis.
a. 3 components extracted.
b. 1st component explains 51% of variance

Table G.2 Traditional Transmission KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.896
Bartlett's Test of Sphericity	Approx. Chi-Square	775.545
	df	105
	Sig.	0.000

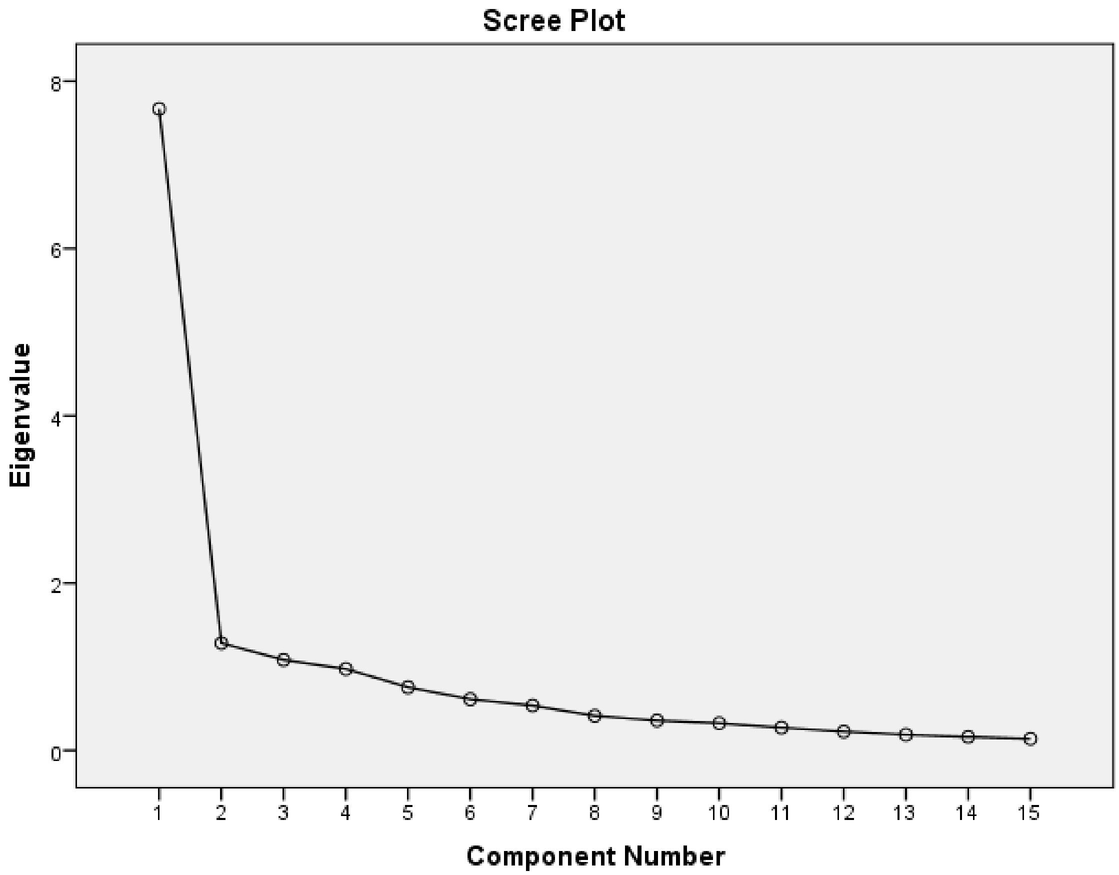


Figure G.1 PCA scree plot for traditional transmission survey items.

Table G.3 Socio-Constructivist Component Matrix

	Component		
	1	2	3
SC1_Q1_4 - Encourage discussion of the connections between various models and strategies.	0.725	-0.203	0.135
SC2_Q1_5 - Emphasize the use of multiple models for recording and communicating student thinking.	0.787	-0.177	0.254
SC3_Q1_8 - Use incorrect or inappropriate strategies as learning opportunities in small or whole class discussion.	0.228	0.474	0.656
SC4_Q1_9 - Facilitate discussion about underlying mathematical concepts (e.g. composing or decomposing number).	0.743	-0.209	0.220
SC5_Q1_10 - Facilitate small group or whole class discussion on student thinking.	0.721	-0.150	0.265
SC6_Q3_1 - Are selected because they provide opportunities for students to explain the mathematics behind an answer.	0.763	-0.243	-0.018
SC7_Q3_5 - Are selected to lead students to make connections between various models and algorithms.	0.739	0.034	-0.350
SC8_Q3_7 - Are based on their potential to encourage discussions of students' mathematical ideas.	0.879	-0.027	0.011
SC9_Q3_8 - Include the intentional presentation of solution strategies containing misconceptions for students to analyze and correct.	0.569	0.560	0.154
SC10_Q3_10 - Are selected because the problem's context may focus students on generating...	0.254	0.502	-0.518
SC11_Q5_1 - Examine their misconceptions or the misconceptions of other students through small group or whole class discussions.	0.556	0.483	-0.074
SC12_Q5_2 - Solve problems that allow for several different approaches.	0.766	-0.102	-0.135
SC13_Q5_3 - Analyze the connections between various models and procedures.	0.809	0.064	-0.225
SC14_Q5_4 - Describe the underlying mathematics behind how a particular model or algorithm works.	0.722	0.152	-0.101
SC15_Q5_7 - Are encouraged to discuss their mathematical ideas in pairs, small-group, and/or whole class discussions.	0.453	-0.382	-0.211
a. 3 components extracted.			
b. 1st component explains 45.6% of variance.			

Table G.4 Socio-Constructivist KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.975
Bartlett's Test of Sphericity	Approx. Chi-Square	7928.984
	df	105
	Sig.	0.000

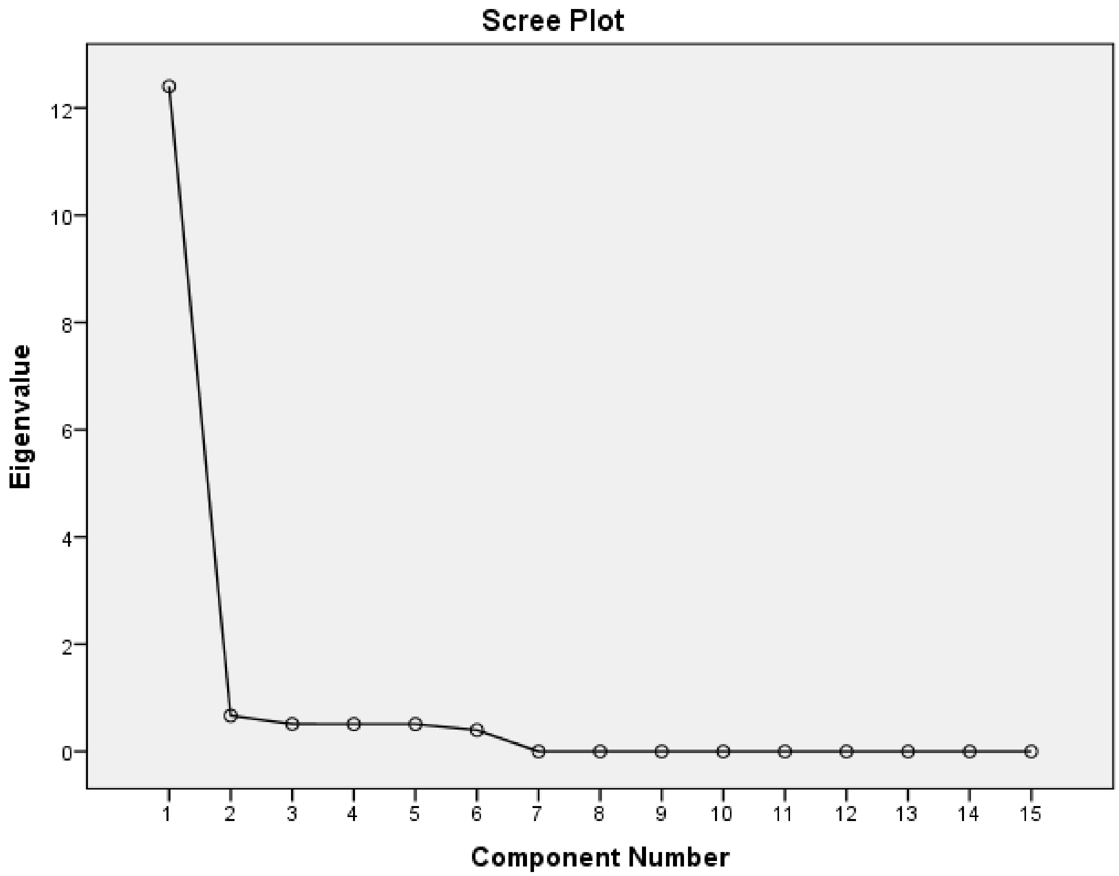


Figure G.2 PCA scree plot for socio-constructivist survey items.

APPENDIX H

Pre-Analysis of Assumptions for Multiple Linear Regression

Assumption 1 of bivariate collinearity for predictor variables was met for all variables, as evidenced by the nonsignificant, weak correlations between the variables shown in Table H.1.

Table H.1. Bivariate Correlations for All Prospective Variables

	DMC	CPM	T_Change
DMC	1		
CPM	-0.024	1	
T_Change	-0.357**	0.025	1

** Correlation is significant at the 0.01 level (2-tailed).

Assumption 2 of linearity between the predictor variables and outcome variables was met because all predictor variables for questions 2-4 were dichotomous.

Assumption 3 for univariate normality and lack of outliers for the continuous outcome variable was met, as evidenced by the statistics and frequency distribution provided in Figure H.1.

	T_Change
N	52
Mean	-0.485
Std. Deviation	1.094
Variance	1.197
Skewness	0.112
Kurtosis	-0.462

Shift in Frequency of Traditional Transmission Activity Use (T_Change)

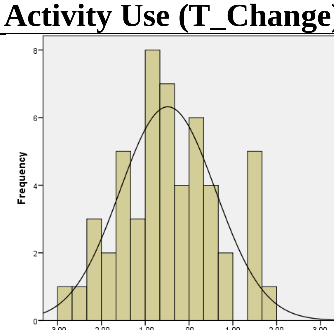


Figure H.1. Univariate Statistics for T_Change Variable with Its Frequency Distribution

Assumption 4 of multicollinearity was met. The predictor variables were not highly correlated with one another, as evidenced by the tolerance levels greater than 0.1 and VIF levels less than 10 shown in Table H.2.

Table H.2. Correlation Statistics for Prospective Predictor and T_Change Variables, Version 1

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-.148	.435		.340	.735		
DMC	-.971	.485	-.436	2.002	.051	.386	2.589
CPM	-.086	.495	-.039	.173	.863	.364	2.746
CPMxDMC	.332	.637	.147	.520	.605	.228	4.379
Years of Experience	.291	.303	.134	.959	.343	.942	1.061
Gender	.197	.333	.082	.591	.557	.944	1.059

Assumption 5 of homoscedasticity was met, as evidenced by the standardized residual plots shown in Figure H.2. Note that no points lay beyond ±3 standard deviations from the zero line, there were no curved residuals, and the clustering of residuals did not change appreciably along the horizontal axis.

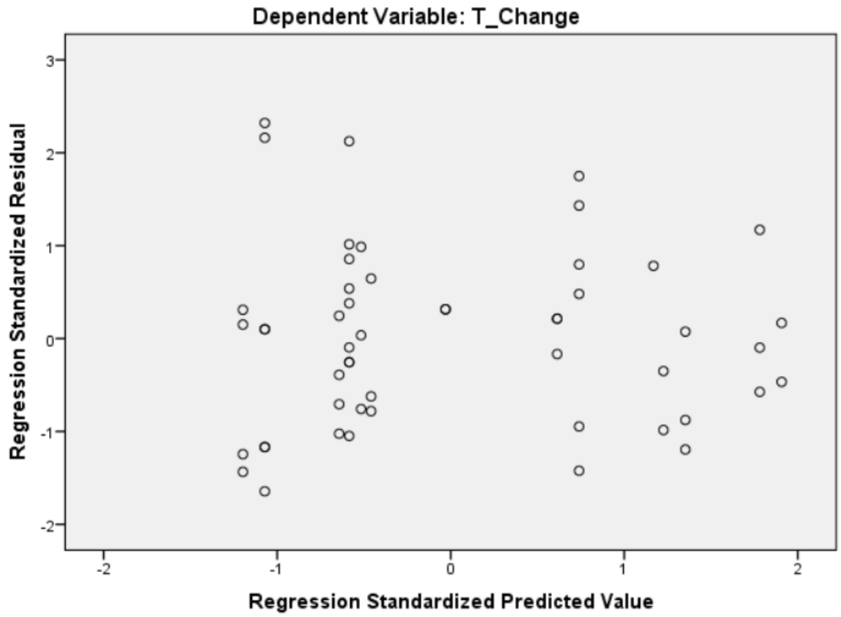


Figure H.2. Scatterplot for all potential influencing variables regressed on T_Change

Assumption 6 of linearity for the partial residual plots was met. Figure H.3 provides evidence of this, as the scatter plots were either random or linear, with no evidence of curvature.

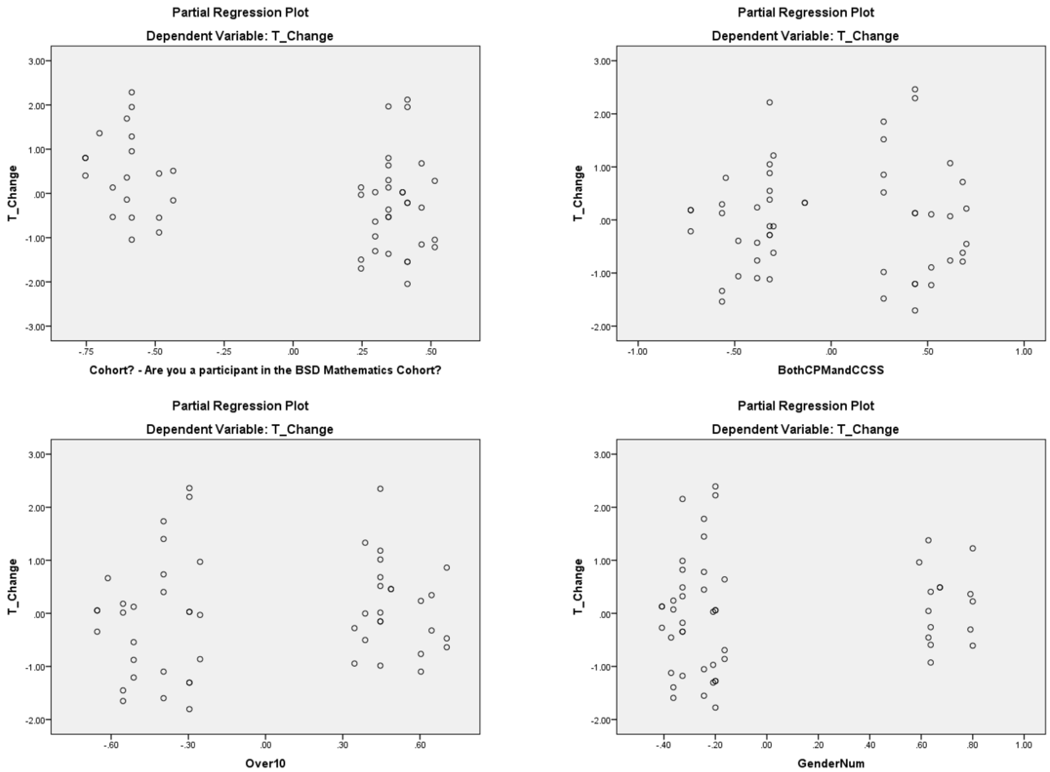


Figure H.3. Scatterplots of standardized residuals

Lastly, the assumption for normality of residuals was met, as evidenced by the histograms of residuals shown in Figure H.4.

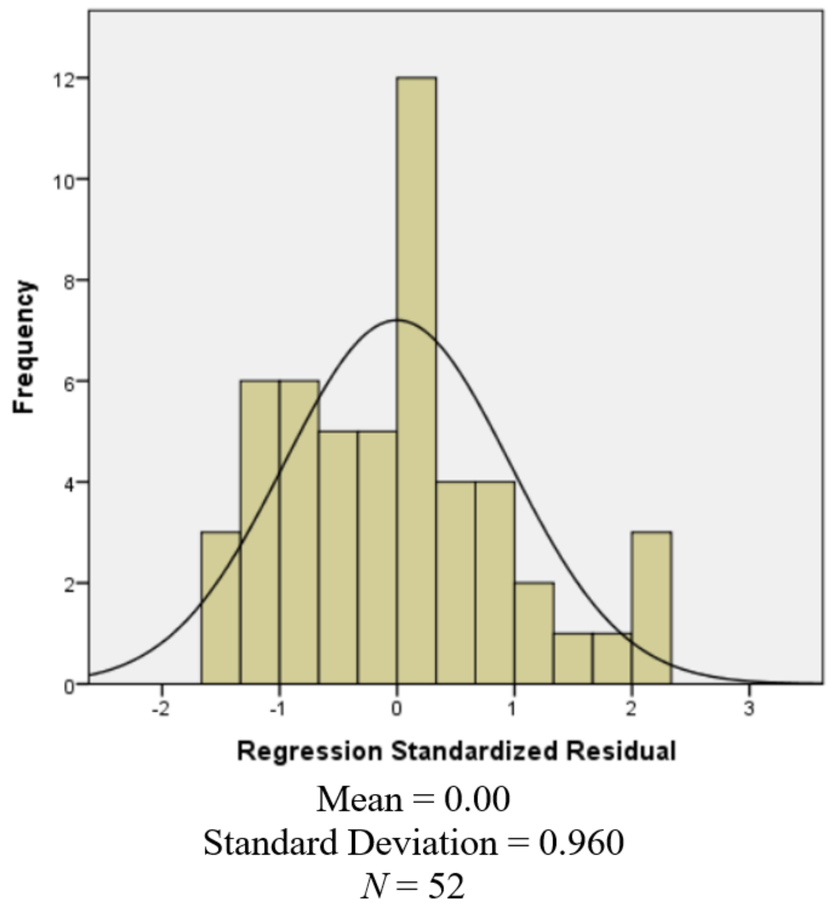


Figure H.4. Histograms of residuals

APPENDX I

Question 1 Analysis of Assumptions for Linear Regression

Assumption 1: The traditional transmission change variable was normally distributed with a mean of -0.485, a standard deviation of 1.094, a 95% confidence interval of [-0.789, -0.180], a variance of 1.197, a skewness of 0.112, and kurtosis of -0.462. All statistics were within the range of acceptability and the Shapiro-Wilk test, with a significance of 0.446, further supported the claim that the traditional transmission change variable was normally distributed. A graph of the traditional transmission change variable distribution is provided in Figure I.1.

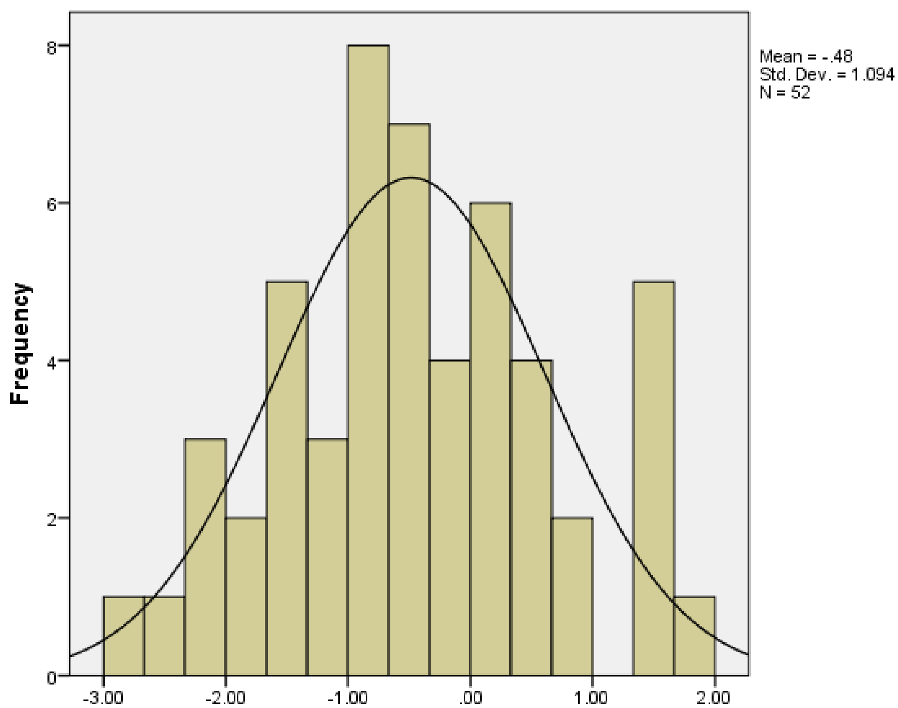


Figure I.1. Histogram of the frequency distribution of traditional transmission change variable for secondary participants

Assumption 2: There were no outliers, as indicated by the lack of outlier designation on the box plot for the traditional transmission change variable supplied in Figure I.2.

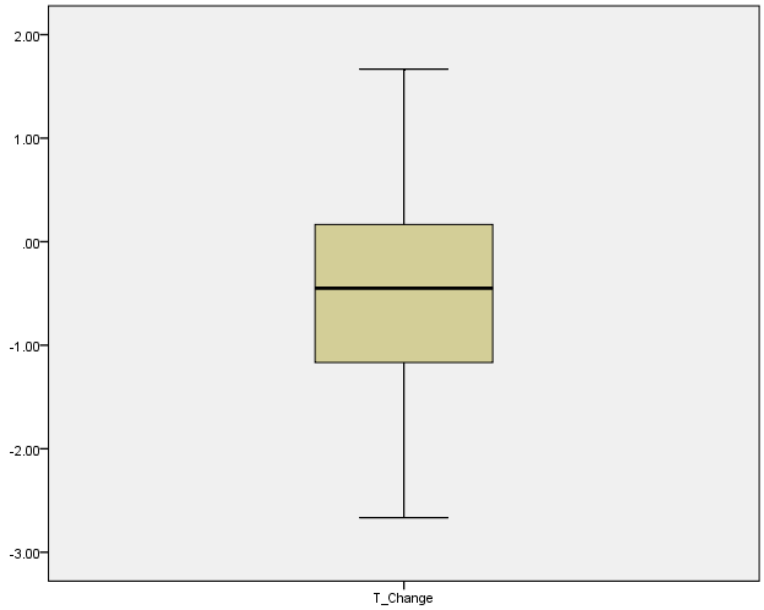


Figure I.2. Box plot of traditional transmission change variable for secondary participants

Assumption 3: The scatterplot of standardized residuals shown in Figure I.3 does not have any points beyond ±3 standard deviations from the zero line, nor does it have any curved residuals or a clustering of residuals that spreads with horizontal movement. The condition for homoscedasticity was met.

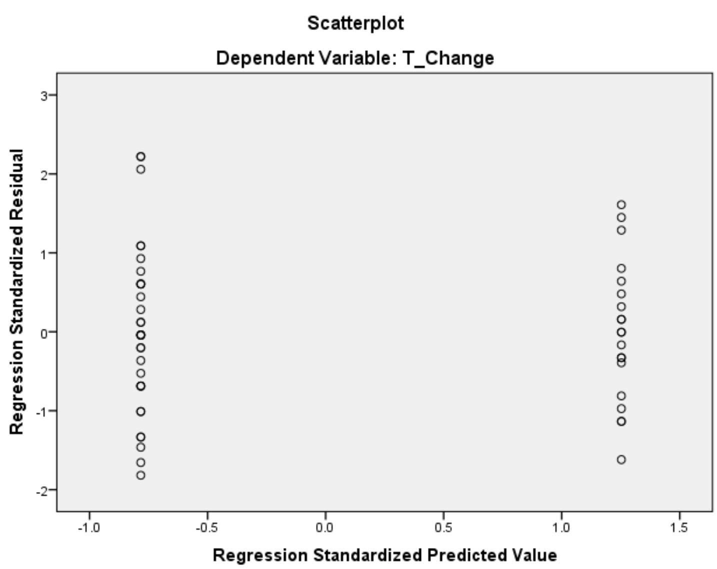


Figure I.3. Scatterplot of standardizes residuals for secondary participants' predicted traditional transmission change based on DMC involvement

Assumption 4: The histogram of residuals appears to fit the requirement for normality of residuals, as indicated in Figure I.4.

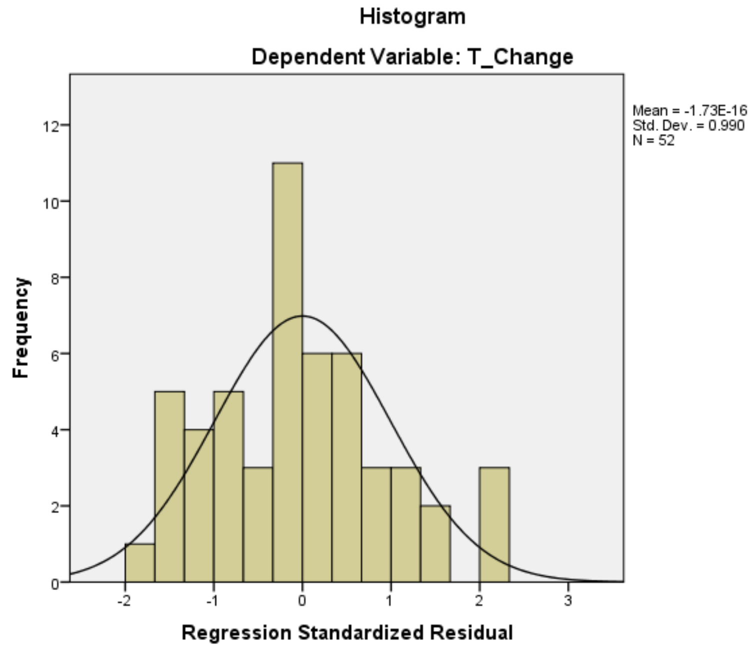


Figure I.4. Histogram of standardized residuals for secondary participants' predicted traditional transmission change

APPENDIX J

Question 1 Analysis of Assumptions for Linear Regression

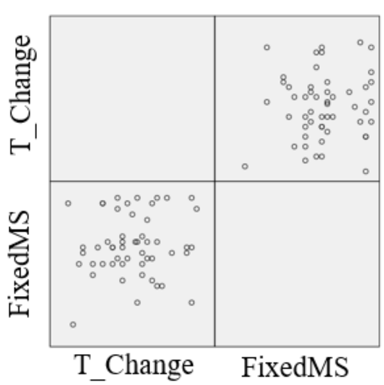
Assumption 1 of bivariate collinearity for predictor variables was met, as evidenced by the nonsignificant, weak correlations between each proposed model's predictor variables shown in Table I.1.

Table I.1. Bivariate Correlations for Mindset and DMC Involvement

		FixedMS	GrowthMS	DMC	T_Change
Fixed Mindset Scaled Score (FixedMS)	*r*	1			
	Sig. (2-tailed)				
Growth Mindset Scaled Score (GrowthMS)	*r*	0.752**	1		
	Sig. (2-tailed)	.000			
DMC Involvement	*r*	.048	.035	1	
	Sig. (2-tailed)	.736	.805		
T_Change	*r*	.084	-.007	-.357**	1
	Sig. (2-tailed)	.555	.963	.009	

** Correlation is significant at the 0.01 level (2-tailed).

Assumption 2 of linearity between the predictor variables and outcome variable was met. As shown in Figure J.1, the scatter plots of the continuous predictor and outcome variables are scattered, with no visible evidence of curves in the relationships.



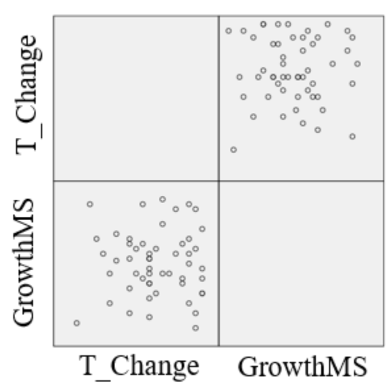


Figure J.1. Scatter plots of mindset variables against T_Change

Assumption 3 for univariate normality and lack of outliers for each continuous predictor and outcome variable was met, as evidenced by the statistics in Table J.1 and the frequency distributions in Figure J.2.

Table J.1. Univariate Statistics for Mindset and T_Change Variables

	FixedMS	GrowthMS	T_Change
N	52	52	52
Mean	4.043	4.224	-0.485
Std. Deviation	0.619	0.553	1.094
Variance	0.383	0.306	1.197
Skewness	-0.104	-0.348	0.112
Kurtosis	-0.253	-0.614	-0.462

Fixed Mindset Scaled Score (FixedMS)

Growth Mindset Scaled Score (GrowthMS)

Shift in Frequency of Traditional Transmission Activity Use (T_Change)

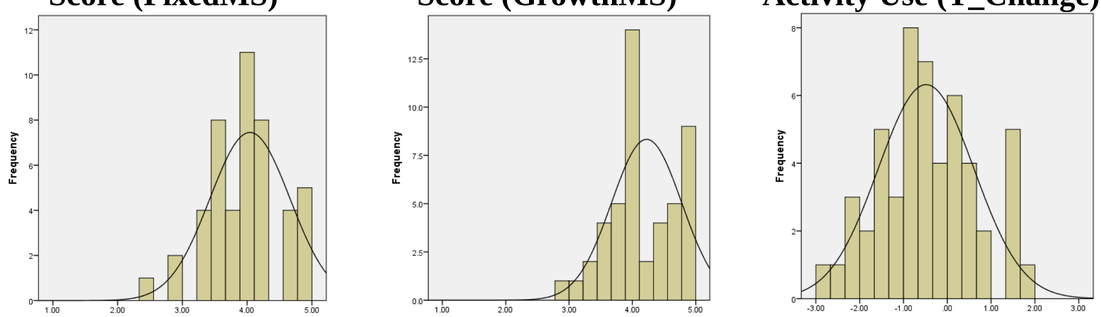


Figure J.2. Mindset and T_Change univariate frequency distributions

Assumption 4 of multicollinearity was met. The predictor variables were not highly correlated with one another, as evidenced by the tolerance levels greater than 0.1 and VIF levels less than 10 shown in Table J.2.

Table J.2. Correlation Statistics for Mindset and T_Change Variables

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
Model 1								
1	(Constant)	-0.712	0.969		-0.735	0.466		
	DMC	-0.806	0.296	-0.362	-2.727	0.009	0.998	1.002

	FixedMS	0.179	0.235	0.101	0.762	0.450	0.998	1.002
Model 2								
2	(Constant)	-0.045	1.133		-0.040	0.968		
	DMC	-0.796	0.297	-0.357	-2.677	0.010	0.999	1.001
	GrowthMS	0.012	0.264	0.006	0.045	0.964	0.999	1.001

Assumption 5 of homoscedasticity was met, as evidenced by the standardized residual plots shown in Figures J.3 and J.4. Note that no points lay beyond ±3 standard deviations from the zero line, there were no curved residuals, and the clustering of residuals did not change appreciably along the horizontal axis.

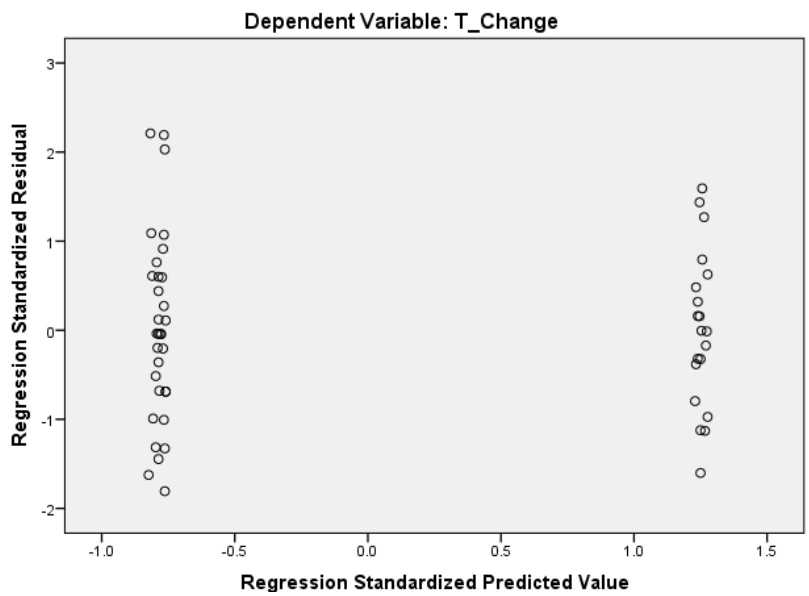


Figure J.3. Scatterplot for FixedMS and DMC regressed on T_Change

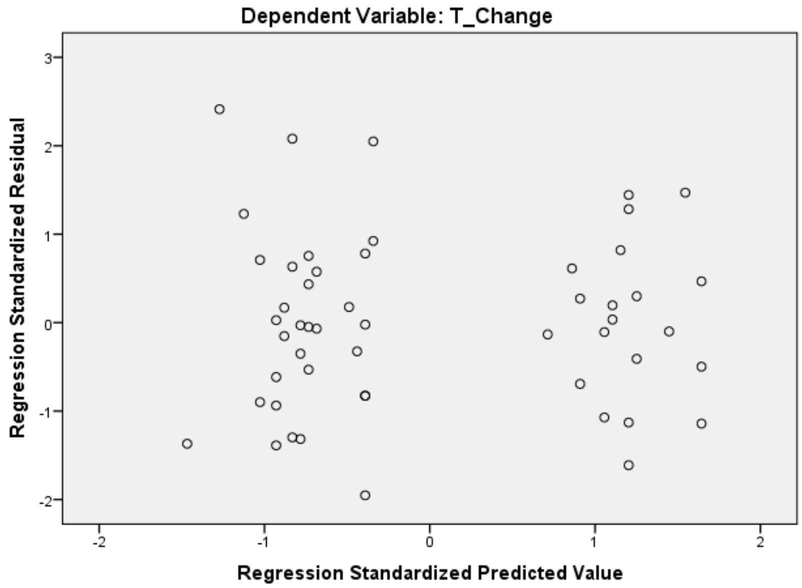


Figure J.4. **Scatterplot for GrowthMS and DMC regressed on T_Change**

Assumption 6 of linearity for the partial residual plots was met. Figure J.5 provides evidence of this, as the scatter plots were either random or linear, with no evidence of curvature.

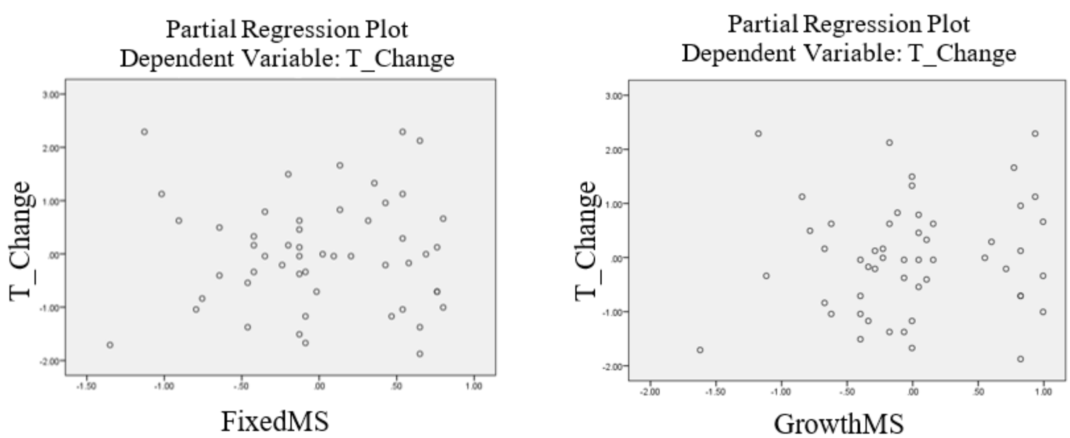
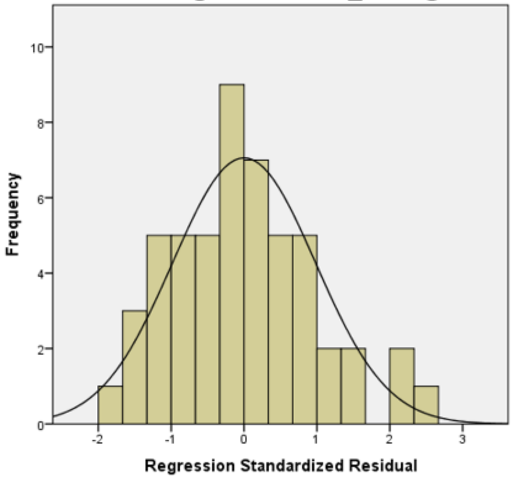


Figure J.5. **Scatterplot of standardized residuals**

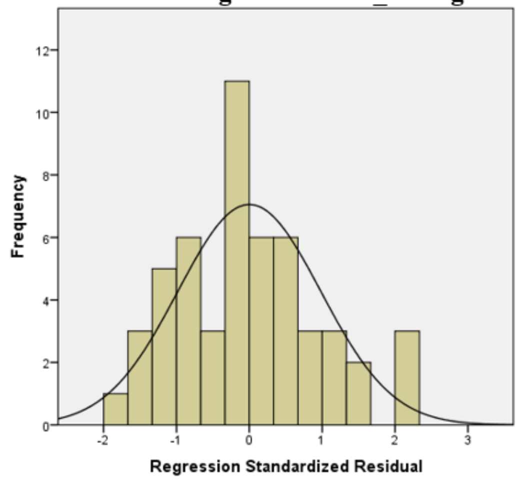
Lastly, the assumption for normality of residuals was met for both models, as evidenced by the histograms of residuals shown in Figure J.6.

Histogram of residuals for FixedMS and BSDMC regression on T_Change



Mean 0.000
Standard Deviation = 0.980
N = 52

Histogram of residuals for GrowthMS and BSDMC regression on T_Change



Mean 0.000
Standard Deviation = 0.980
N = 52

Figure J.6. Histograms of residuals

APPENDIX K

Institutional Review Board Approval

The research done in this dissertation has been approved by the Boise State University Institutional Review Board, IRB protocol number 108-SB15-128.