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Effect of Student-Centered Instructional Strategies on Mathematics Achievement of Elementary Students

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Abstract

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by

Keisha Knight Scott

MA, University of South Carolina, 2013

BS, Benedict College, 2007

Project Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

To promote learner-centered mathematics instruction and improve student outcomes, district leaders sought to implement research-based instructional strategies in the 2018-2019 school year. These strategies were being implemented at Elementary School A but not at Elementary School B during the following school year. The purpose of this mixed-methods study was to investigate the implementation and outcomes of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse for district students in Grades 2–5. Weimer's learner-centered teaching principles served as the theoretical framework for the study. Quantitative methods were used to test whether a difference in mathematical achievement, as measured by the Math Inventory, exists between students at Elementary School A and Elementary School B. Open-ended interviews and typological analyses were used to explore the ways in which teachers implemented research-based instructional strategies at Elementary School A. ANCOVA results yielded a nonsignificant difference ($\alpha = .01$) between Elementary School A and Elementary School B for all grades, $F(1,137) = .43$, $p = .51$; $F(1,129) = .24$, $p = .63$; $F(1,135) = 1.27$, $p = .26$; $F(1,125) = 4.76$, $p = .03$. The most salient qualitative theme, for all grades, was lacking implementation fidelity, which may explain the nonsignificant findings. A policy recommendation is that district leaders develop and implement standard operating procedures for assessing and measuring implementation fidelity. Results from this study could alter the way in which teachers deliver mathematics instruction across the district with the potential to improve mathematics achievement for all students.

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Dedication

This dissertation is dedicated to my mother, Carolyn E. Knight, who lost her battle to cancer during this process. It was her constant voice in my head and appearances in my dreams that provided me with the motivation to finish my doctoral degree that I began in 2013.

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The completion of my doctoral journey would not have been possible without the love and support of my family. To my mom (who is no longer with me physically) and my dad, thank you for your continued motivation and encouragement to complete this process. To my siblings, thank you for your words of encouragement and prayers. To my daughters, thank you for sacrificing some of our mommy/daughter time as I worked to accomplish this goal.

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To my colleagues and friends, thank you for your support, motivation, and willingness to provide assistance if I ever needed it. To my best friend/doctoral buddy, thank you for always believing in me and motivating me to become a member of the 2% population. Last but most importantly, I thank God for giving me the strength to endure this journey, and I look forward to seeing and experiencing what he has planned for my future.

Table of Contents

List of Tables

List of Figures

Section 1: The Problem

The Local Problem

The problem in the local school district was that the mathematics learning environment for the student population demonstrated a one-way instructional setting where the content was delivered, and very limited learner-centered practices were seen. The implementation of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions was not the norm in the school district, according to the district's elementary mathematics consultant. Three quarters of the mathematics block was spent with students focusing solely on the teacher without any form of collaboration and self-directed learning, as evidenced by the school and district-based administrators' teacher observations, the consultant noted.

In wanting to transition the mathematics learning environments from teacher-centered to learner-centered and improve student outcomes, district leaders focused district- and school-based mathematics professional development on the implementation of research-based instructional strategies during the 2018–2019 academic school year, the director of early childhood and elementary education stated. Although not mandated by school-based leadership, some of the principals encouraged teachers in their buildings to implement research-based instructional strategies with the help of the curriculum resource teacher and the district elementary math consultant. As a result, some teachers were implementing research-based instructional strategies, and some were not.

During the spring of 2018-19 academic school year, an analysis of teachers' lesson plans and classroom observations conducted by school-based administrators and the district's math consultant revealed that Elementary School A appeared to be implementing research-based instructional strategies, the director of elementary education stated. In Elementary School A classrooms, students explored mathematics using manipulatives and engaging in group discussions. Also, teachers were observed assisting small groups of students and facilitating whole group discussions as students shaped their learning. Furthermore, the same analysis revealed continued teacher-centered learning environments at Elementary School B. Based on observations, an average of 45 minutes of the 60-minute math block is spent with teachers lecturing in a traditional manner (i.e., standing in front of the classroom providing instruction). This high level is problematic because teacher-centered learning environments result in limited opportunities for students to engage in hands-on activities, small group investigations, problem-solving tasks, and classroom discourse (Van de Walle et al., 2014).

Although Elementary School A appeared to be implementing research-based instructional strategies compared to the traditional teacher-centered learning environment in Elementary School B, it is unknown whether these changes have improved mathematics achievement. In addition, the level of implementation fidelity as it pertains to the research-based instructional strategies was unknown. For the purpose of this study, implementation fidelity occurs when students are engaged in research-based instructional strategies on a daily basis constituting 50% of the mathematics instructional block for an entire academic school year. District personnel primarily used the Math Big 3 Observational Tool to determine whether a school was implementing research-based strategies.

Although research has shown that hands-on activities, small group investigations, problem-solving tasks, and classroom discourse, when implemented with fidelity, will increase student mathematical achievement (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; Woodward et al., 2012), it has yet to be determined if the implementation has resulted in improved mathematics achievement in Elementary School A. Instructional strategies are a critical factor because of their role in maximizing student achievement; the mathematical achievement of students is directly aligned with the delivery of instruction, research shows (Ashley, 2016; Black, 2007). Yet, research-based instructional strategies, as shown by Hattie (2009), have yielded moderate effects of 0.49, 0.61, and 0.82 for a year to a year and a half of student growth, (Vacha-Haase & Thompson, 2004) Students with limited learning experiences through the use of research-based instructional strategies are hindered from constructing their knowledge regarding mathematical concepts (Van de Walle et al., 2014). Thus, students cannot take ownership of what they are learning and rely heavily on the teacher (Kariippanon et al., 2018).

Over the last several decades, researchers have sought to identify research-based instructional strategies that increase students' mathematical proficiency. In 1995, D'Ambrosio et al., identified twelve instructional strategies to promote mathematics achievement. Based on their research, the most effective strategies should involve the following six things: (a) relating mathematics to real-world experiences of young people, (b) writing and talking about mathematics, (c) working cooperatively to solve problems, (d) exploring mathematics concepts with hands-on materials, (e) using calculators and computers, and (f) constructing one's mathematical knowledge. Grouws and Cebulla

(2000) recommended 10 techniques for increasing student achievement in mathematics: (a) opportunity to learn, (b) focus on meaning, (c) learning new concepts and skills while solving problems, (d) opportunities for both invention and practice, (e) openness to student solution methods and student interaction, (f) small group learning, (g) whole-class discussions, (h) number sense, (i) concrete materials, and (j) student use of calculators. Additionally, Shellard and Moyer (2002) found that an effective mathematics classroom encompasses three critical components: (a) teaching for conceptual understanding, (b) developing children's procedural literacy, and (c) promoting strategic competence through meaningful problem-solving investigations. Therefore, providing students with opportunities to engage in the aforementioned instructional strategies has the potential to positively impact their mathematical achievement.

In 2009, Hattie published *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*, a book that highlights 138 instructional strategies and their effectiveness level as it pertains to student achievement. Of the 138 instructional strategies, Hattie noted that several have been integrated into the mathematics curriculum and classroom. These strategies range from self-reporting grades to mobility. In addition, to measure whether the difference between two means in the studies were practically significant, Hattie reported effect sizes based on Cohen's *d* (Cohen, 1988). The effect size values are .20, .50, and .80, respectively, for small, medium, and large. Any difference observed from 0 is considered different, but an effect size provides an additional quantifiable measure into differences. For the purpose of this study, I analyzed the implementation of the following strategies identified by Hattie by teachers at Elementary

School A: classroom discussions (*d* = 0.82), problem-solving teaching (*d* = 0.61), teaching strategies (*d* = 0.60), cooperative vs. individualistic learning (*d* = 0.59), small group learning (*d* = 0.49), and cooperative learning (*d* = 0.41). Hattie's research revealed an average effect size of 0.40 standard deviations, which indicates the level where student achievement is enhanced and can be noticed through real-world differences (Hattie, 2009). Thus, the instructional strategies measured for their impact on math achievement for this study should increase student achievement, as concluded by Hattie.

In summary, students should be engaged in highly interactive tasks that encourage them to explore problems, formulate ideas, and check their mathematical ideas with others through discussions and collaboration (McREL, 2010). It is through these types of learning experiences that students construct their knowledge and understanding of the content. Instructional strategies are a critical factor to maximizing student achievement; indeed, research shows the mathematical achievement of students is directly aligned to the delivery of instruction (Ashley, 2016). Students who are exposed to more learner-centered activities demonstrate higher levels of proficiency on standardized assessments (National Center for Education Statistics, 2013).

In the remainder of this section, I will discuss the significance of the problem for both elementary school sites and the district. The research questions (RQs) for this study will be shared and used to review current research regarding implementing research-based instructional strategies and student achievement. The literature review informed the development of the capstone project (see Appendix A) I developed to address the practice problem. I will discuss the project in further detail in Section 3.

Rationale

Evidence of the Problem at the Local Level

In the local school district, the students are performing below proficiency. As evidenced by the Math Big 3 Observational Tool (see Appendix B) results compiled at the district level, Elementary School A's leadership is encouraging teachers to implement research-based instructional strategies and Elementary School B's leadership is not. During 2014–2015, 2015–2016, and 2016-2017 school terms, no state accountability ratings were given as a result of the state transition to a single accountability system, according to the district's annual report cards for 2015-2017. State education officials observed a decline in the mathematical achievement of students in the district, the report cards show. Data from the 2015 administration of the ACT Aspire statewide assessment revealed proficiency percentages of 36.7% at the district level and 39.3% at Elementary School A and 30.4% at Elementary School B.

In 2016, the South Carolina State Board of Education assessed the South Carolina College and Career Ready Standards through a newly adopted assessment known as SC Ready. This assessment categorizes students into the following four areas: does not meet expectations, approaches expectations, meets expectations, and exceeds expectations. Three of the most recent administrations of this statewide assessment revealed proficiency percentages of 32.9% in 2016, 29.8% in 2017, and 32.5% in 2018 at the district level, according to annual report cards for 2016-2018. These percentage values resulted in over 65% of the district's third- through fifth-grade student population scoring in nonproficient categories. Table 1 illustrates the percentage of students who demonstrated proficiency at the third- through fifth-grade levels. In the district overall, 43.5% of third-grade, 33.1% of fourth-grade, and 36.5% of fifth-grade students demonstrated proficiency on the 2018 administration of SC Ready. These data substantiate that instructional changes are warranted as a low percentage of third- through fifth graders perform proficiently.

Table 1

District 2018 SC Ready Data

Grade level	Percentage proficient
3rd	43.5%
4th	33.1%
5th	36.5%

An analysis of the 2018 SC Ready data as it pertains to the four performance levels also reveals significant challenges in the district regarding mathematical proficiency. Based on the data presented in Table 2, a low percentage of students continue to score at the highest proficiency level, which is Exceeds Expectations. At the district level, only 15.4% of third through fifth grade students scored at the Exceeds Expectation Performance Level.

Table 2

2018 SC Ready District Performance Levels (Percentage of Students)

Performance level	Percentage of students
Does Not Meet Expectations	40.3%
Approaches Expectations	27%
Meets Expectations	17.1%
Exceeds Expectations	15.4%

Teacher observations conducted by administrators and district personnel indicate that most of the mathematics block features direct instruction by teachers, according to the director of elementary education. During observations, students can be seen taking on the role of passive learners as they receive knowledge instead of creating their own, the director noted. There is minimal time provided for students to explore mathematical concepts. This is problematic because, through exploration, students develop a deeper mathematical understanding of a concept as they manipulate and discuss their findings with peers (Van de Walle et al., 2014). The lack of exploratory experiences provided during math instruction creates a knowledge barrier as students are unable to build their understanding of the concept. The inability to create one's knowledge makes it difficult for students to apply concepts in new and unfamiliar situations (Van de Walle et al., 2014).

In addition, an analysis of district-level common formative assessments reveals ineffective instructional strategies as students are continuously not mastering the mathematical concepts that are assessed. Common formative assessments are five-question miniassessments created by the district-level elementary math consultant to measure students' mastery of state mathematics standards. Many of the instructional strategies implemented within the classrooms to address mathematical skills are procedural-based. Learning procedures before gaining a conceptual understanding of the content makes it easier for students to forget steps when solving tasks, according to the external math consultant. Thus, students are again not allotted time to build their understanding of the concept through hands-on activities, problem-solving tasks, small group collaboration, and classroom discourse.

The district curriculum team's initial analysis of teacher observations, teacher lesson plans, principal data team meetings, and assessment data prompted district leaders to focus on the implementation of research-based instructional strategies such as hands-on activities, problem-solving tasks, small group collaboration, and classroom discourse. To improve student outcomes, district leaders started focusing district- and school-based mathematics professional development on implementing research-based instructional strategies during the 2018-2019 academic year. It is through the implementation of these tasks that learner-centered classrooms could be transformed into student-centered learning environments, the executive director noted. Although some school-based administrators have embraced this new way of instruction in the district, it has yet to be determined if these research-based instructional strategies have resulted in improved mathematics achievement. Thus, the goal of this study was to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group instruction, problem-solving tasks, and classroom discourse in the district. Specifically, I compared impacts on students in Grades 2-5 at Elementary School A to those at Elementary School B, which was not implementing the research-based instructional strategies mentioned.

Evidence of the Problem from the Professional Literature

Teacher-centered learning environments provide limited opportunities for students to engage in hands-on activities, problem-solving tasks, small group instruction, and classroom discourse (Van de Walle et al., 2014). These types of environments foster classrooms where students work independently, and collaboration is discouraged. In addition, teacher-centered learning environments give teachers complete control of the learning process, placing them as the primary resource as it pertains to content knowledge (Lancaster, 2017). Most teacher-centered learning environments feature a lecture-style format in which teachers disseminate information to students as they take notes. During this time, students' minds often wander as they become disinterested in the information being presented, the external math consultant, noted.

Student-centered learning environments place the ownership of learning into the hands of the student. In student-centered learning environments, students can be seen actively engaging in the learning process as they manipulate materials, collaborate with peers to solve problems, and engage in class discussions to solidify their understanding. Also, student-centered learning environments encourage students to work together to achieve a common goal instead of working against one another (Lancaster, 2017). For this reason, cooperative learning is an instructional strategy that complements the student-centered learning environment. Johnson and Johnson (1999) found that students who participate in cooperative learning have higher achievement, greater productivity, longer retention, increased intrinsic motivation, and higher levels of reasoning and critical thinking than students taught through other approaches to learning.

Research has shown that activities such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse increase students' mathematical achievement when implemented (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; Woodward et al., 2012). Additionally, students should be engaged in highly interactive tasks that encourage them to explore problems, formulate ideas, and check their mathematical ideas with others through discussions and collaborations (McREL, 2010). It is through these types of learning experiences that students construct their knowledge and understanding of the content. As Ashley (2016) observed, the mathematical achievement of students is directly aligned to the delivery of instruction. Students who are exposed to more learner-centered activities demonstrate higher levels of proficiency on standardized assessments (National Center for Education Statistics, 2013).

Definition of Terms

ACT Aspire: A vertically scaled, standards-based assessment that monitors student growth and progress toward college and career readiness and is administered to third- through eighth-graders (ACT Aspire, 2016).

Classroom discussions: A sustained exchange between and among teachers and their students with the purpose of developing students' capabilities or skills and/or expanding students' understanding--both shared and individual--of a specific concept or instructional goal (Witherspoon et al., 2016).

Hands-on activities: Activities that require students to actively be involved in their learning as they manipulate materials to build conceptual understanding (Shaw, 2002).

HMH Math Inventory (MI): An adaptive, research-based assessment that reliably measures math ability and progress from kindergarten to Algebra II in significantly less time than traditional assessments. It assesses student's math abilities and performance based on the Quantile Framework for Mathematics (Houghton Mifflin Harcourt, 2017).

National Assessment Educational Progress (NAEP): The largest continuing and nationally representative assessment of what U.S. students know and can do in mathematics and reading (National Center for Education Statistics, 2020).

Proficient: One of three NAEP achievement levels, representing solid academic performance for each grade assessed (National Center for Education Statistics, 2020).

Problem-solving tasks: Tasks that require learners to engage in an ongoing activity in which they take what they already know to discover what they do not know (Maxey, 2013).

Quantile Framework for Mathematics: A scientific approach that evaluates the difficulty of mathematical skills and concepts as well as a student's ability to learn new mathematical concepts. (MetaMetrics, 2017).

Quantile Measure: A measure that describes what the student is capable of understanding based on their responses from the Math Inventory assessment (MetaMetrics, 2017).

South Carolina Palmetto Assessment of State Standards (SCPASS): A statewide assessment administered to students in Grades 3 through 8 to measure student performance on the South Carolina State Standards (South Carolina Department of Education, 2017).

SC READY: A statewide assessment administered to students in Grades 3 through 8 to measure student performance on the South Carolina College and Career Ready Standards (South Carolina Department of Education, 2017).

Small group instruction: A highly effective instructional strategy used by teachers to differentiate instruction for students (Meador, 2015).

Student-centered learning environments: The provision of instruction in a less structured environment that allows students to influence the time and character of instruction, their approach to learning tasks, and their participation in an open exchange of ideas (Hancock et al., 2002)

Teacher-centered learning environments: The provision of instruction in a highly structured environment where the teacher organizes the learning tasks, establishes classroom objectives, presents materials to support only those objectives, and creates the timetable and methods to achieve those learning tasks (Hancock et al., 2002).

Significance of the Study

This study addressed a local problem of student mathematical achievement in the district's elementary schools. The purpose of the study was to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group instruction, problem-solving tasks, and classroom discussions for district students in Grades 2-5. The results from this study provided information regarding the lack of implementation fidelity as it pertains to the implementation of research-based instructional strategies. Based on the study's findings, an implementation fidelity framework was created that would assist teachers with the implementation of research-based instructional strategies as they planned their mathematics instruction. This could benefit not only teachers, but administrators, instructional support staff, and students in the local setting as well. Struggling learners may benefit the most as they could be afforded the opportunity to experience learning in an environment centered on them. Increasing the academic achievement of students can empower them to excel in everyday tasks and future career endeavors (Waller, 2012).

This study could alter how teachers deliver mathematics instruction across the district as more intentional implementation practices could be put in place to ensure that research-based instructional strategies are being implemented with fidelity. Exposure to more learner-centered learning environments could increase the percentage of struggling students who are deemed proficient on state standardized assessments, district benchmarks, and nationally normed assessments. Leaders of schools with student populations similar to Elementary School A may be more willing to implement a learner-centered learning environment in mathematics. This implementation could create a shift in the mathematics learning environment from one solely focused on the teacher to one that holds students accountable for their learning, making math meaningful and relevant. If the results show that learner-centered instruction is being implemented with fidelity, but does not increase student outcomes, then the administration may decide to explore other avenues for improving student mathematical achievement.

Research Questions and Hypotheses

As research by D'Ambrosio et al., (1995), Grouws and Cebulla (2000), Hattie (2009), and Gay (2012) shows, a variety of research-based instructional strategies such as hands-on activities, problem-solving tasks, small group instruction, and classroom discussion have been found to increase student mathematical achievement. The professional development in the school district focused on these research-based instructional strategies. I obtained approval from the district's office of research to obtain data for the two schools, Elementary School A and Elementary School B, analyzed in this study. I used district learning walk data in the area of mathematics to determine the treatment and control school for this study. During the "learning walk," the Math Big 3 Observational Tool (see Appendix B), was used by district level administrators and instructional support staff, to evaluate the instructional learning environment with an emphasis on the implementation of research-based instructional strategies. Elementary School A was identified as the treatment school because it was evident throughout the data collected that research-based instructional strategies were being implemented. Elementary School B was identified as the control school because it was not evident throughout the observation that research-based instructional strategies were taking place (see the Data Collection and Analysis subsection in Section 2 for specific details). The descriptive statistics in Tables 3-6 provide adequate support that the two schools are congruent on important covariates such as gender and ethnicity. Furthermore, a reliable and valid covariate was used to ensure that students were equivalent on the primary outcome of interests, math performance. The following RQs and hypotheses underpinned this study:

RQ1 (Quantitative): Is there a difference ($\alpha = .05$) in mathematical achievement, as measured by Math Inventory (MI), between students at Elementary School A who have experienced research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) and those who have not at Elementary School B?

$H_0 1$: There is no statistically significant difference in mathematical achievement between students who have experienced research-based instructional strategies and those who have not.

$H_A 1$: There is a statistically significant difference in mathematical achievement between students who have experienced research-based instructional strategies and those who have not.

RQ2 (Qualitative): In what ways are teachers implementing research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) at Elementary School A?

Review of the Literature

There is a large amount of literature on improving the achievement of nonproficient math students regarding types of interventions. Since the 1960s, attempted solutions have fallen into one of four reform categories: preschool, teacher, instructional, and standards-based (Porter, n.d.). As Porter (n.d.) observed, preschool reformers focused on the academic achievement of students who attended preschool programs, which showed early gains in achievement that were not sustained. Those spearheading the teacher reform category focused on teacher quality and the effect it has on student achievement. Instructional reformers focused on interventions and how they could improve student achievement. The standards-based reform category focused on the standards movement, which emphasized the concept of student achievement.

My focus in this study was on the instructional reform category. I measured the interventions of hands-on activities, small group instruction, problem-solving tasks, and classroom discussions to determine their impact on improving students' mathematical achievement. In the review of literature, I will examine these instructional interventions (hands-on activities, small group instruction, problem-solving tasks, and classroom discussions) after providing an overview of the theoretical (constructivist theory) and conceptual frameworks (Weimer's learner-centered teaching) for the study. I used educational research databases that I accessed from Walden University Library along with ERIC, SAGE, and Google Scholar, to find relevant research.

Theoretical Framework

Bruner's (1966) constructivist theory served as the theoretical framework for this study. The constructivist theory identifies learning as an active process where the learner constructs new ideas or concepts based on their current or past knowledge (Fiorella & Mayer, 2016; McLeod, 2019; Teachnology, 2018). During this process, the learner matriculates through the following three phases: enactive representation (action-based), iconic representation (image-based), and symbolic representation (language-based), according to Bruner (1966). The process of acquiring and retaining knowledge can be attributed to experiences. Without the appropriate experiences, one cannot expect information to be learned and connections to be made without the development of gaps. Teachers, as the experts, have to create learning environments where student activities are guided, behavior is modeled, and examples are provided to transform student discussions into meaningful communication (Flynn, 2005; Lee & Hannafin, 2016; Sammons, 2018). Constructivism is the foundation for mathematics reform as published by The National Council of Teachers of Mathematics (2000). Classrooms have to evolve where problem-solving, concept development, and the construction of learner-generated solutions are the primary components (Liljedahl et al., 2016; Lunenburg, 2011). Creating these types of learning environments requires teachers to make five changes in their practices, as identified by Weimer. These changes include (a) the balance of power, (b) the function of content, (c) the role of the teacher, (d) the responsibility for learning, and (e) the purpose and processes of evaluation (Weimer, 2002).

Bruner's constructivist theory informed the development of the qualitative RQ and the design approach. In this study, I sought to determine to what extent research-based instructional strategies are implemented within the mathematics classroom through an analysis of teacher lesson plans and teacher interview responses. The lesson plan analysis protocol that I created based upon Weimer's (2013) learner-centered teaching practices focuses on the experiences teachers provide for students as they engage in the mathematical learning process. There are five changes that educators must make in their practices.

When students are given the opportunity to identify what and how they would like to learn, they are motivated as they are given some control over learning, which connects to Weimer's (2002) change in teaching practice of the balance of power. Engaging students in the hard and messy work of learning and including explicit skill instruction connects to the function of content as the educator must provide experiences that allow the students to learn through the enactive, iconic, and symbolic representation phases of learning. Engaging students in the hard, messy work of learning, including explicit skill instruction and encouraging collaboration, connects to the role of the teacher as the teacher should serve as a facilitator during the learning process. Students who take ownership of their learning process reflect on what they are learning and how they are learning it, thus connecting to Weimer's change in teaching practice of the responsibility for learning. When teachers create learning experiences, it allows them to obtain authentic data regarding students' knowledge and mastery of the content through conversations. This encourages collaboration and student reflection on what and how they are learning and includes explicit skill instruction, which connects to the purpose and process of evaluation.

I designed the interview questions to gain an understanding of how teachers viewed, understood, and implemented learner-centered strategies in their mathematics classrooms. In addition, they were created to correlate with Weimer's (2013) five changes in teaching practices and learner-centered principles, specifically Questions 2 (Please describe the learner-centered activities you are currently or have in the past implemented during your mathematics instruction?) and 5 (Describe a typical math lesson in your classroom). Participant responses to these two questions alone elicited meaningful insight about the application of Weimer's learner-centered teaching practices and Bruner's constructivist theory. An analysis of teacher lessons and interview responses provided the necessary data to determine whether participating teachers had created the learner-centered learning environments implied by the constructivist theory as it should be evident that students are actively involved in their learning process.

Conceptual Framework

Weimer's (2002) learner-centered teaching principles will serve as the conceptual framework for this study. Weimer (2013) identifies five key characteristics of learner-centered teaching. Learner-centered teaching occurs when: (a) students engage in the hard, messy work of learning, (b) includes explicit skill instruction, (c) students are encouraged to reflect on what they are learning and how they are learning it, (d) students are motivated by having some control over the learning processes, and (e) collaboration is encouraged (Weimer, 2013). Through the practices of learner-centered teaching, the primary focus is placed on the student as a learner and improving his/her success.

The incorporation of hands-on activities, small group instruction, problem-solving tasks, and class discussions exemplify the characteristics of Weimer's learner-centered teaching and Bruner's constructivist theory. By exploring these instructional strategies, learners become active participants throughout the learning process as they engage in mathematical learning experiences that encourage social interaction (Apriliyanto et al., 2018; Powell & Kalina, 2009). Implementing hands-on activities grounded in Weimer's learner-centered teaching and Bruner's constructivist theory requires students to take a lead role in learning, taking ownership of the ideas they create and their conclusions (White, 2012). Through hands-on activities, opportunities become available for cooperative learning or small group instruction where students can explore and make connections between concepts and concrete representations (Hidayah et al., 2018; White, 2012). Mathematical classroom discussions give students an avenue to express their ideas (Ghousseini & Herbst, 2016; Huinker & Bill, 2017; Peressini et al., 2004) as they engage in problem-solving activities (Boaler & Greeno, 2000; Langer-Osuna, 2017) which simultaneously structure or restructure their thinking (Hiebert & Wearne, 1993), exemplifying the last three characteristics of Weimer's learner-centered teaching. The qualitative research question will explore the ways in which teacher participants use these constructs of Weimer's learner-centered teaching.

The concrete-representational-abstract (CRA) instructional approach is a mathematical intervention that supports Weimer's learner-centered principles and Bruner's concept of constructivism. The purpose of the CRA instructional approach is to provide students with a thorough understanding of the mathematical concept or skill being taught (MathVIDS, 2017; Peltier & Vannest, 2018; Putri et al., 2018). Weimer's learner-centered principles are supported as CRA's learning progression critical elements include: (a) using appropriate concrete objects to teach particular math concept/skill, (b) using appropriate drawing techniques or appropriate picture representations of concrete objects, (c) using appropriate strategies for assisting students in moving to the abstract level of understanding for a particular math concept/skill, and (d) when teaching at each level of understanding, using explicit teaching methods (MathVIDS, 2017). These components meet all five of Weimer's (2013) learner-centered principles.

Bruner (1977) referred to the concrete-representational-abstract process as enactive, iconic, and symbolic. Through the sequential three-stage process, students can construct their knowledge as they manipulate mathematical concepts through hands-on activities, represent what they have created physically then write a matching symbolic equation. Most importantly, the exploration of math concepts and skills through hands-on manipulatives will help students formulate or derive their mathematical procedures (Omotayo & Adeleke, 2017; Van de Walle et al., 2014, 2019). This gives students the foundational and conceptual knowledge necessary to apply newly generated knowledge to unfamiliar mathematical situations.

Teaching mathematics conceptually requires learning experiences where students can engage in hands-on exploration, small group investigations, problem-solving tasks, and classroom discussions. Students acquire conceptual understanding when they are able to

> provide evidence that they can recognize, label, and generate examples of concepts; use and interrelate models, diagrams, manipulatives, and varied representations of concepts; identify and apply principles; know and apply facts and definitions; compare, contrast, and integrate related concepts and principles; recognize, interpret, and apply the signs, symbols, and terms used to represent concepts. (Balka et al., 2015, p. 2)

Each of these research-based instructional strategies provides students with opportunities to make connections between prior and newly acquired knowledge (Balka et al., 2015; Mest, 2018). Through the manipulation of concrete materials, students can collaborate with their peers to verbalize mathematical thoughts, reasoning, and results, thus solidifying conceptual understanding for abstract ideas (Balka et al., 2015).

Hands-On Activities and Improving Mathematical Achievement

To develop every student's mathematical proficiency, leaders and teachers must strategically integrate the use of manipulatives, both concrete and virtual, within mathematics instruction at all levels (National Council of Supervisors of Mathematics, 2013). Incorporating hands-on activities in mathematics makes learning fun and comprehensible for all students (Furner & Worrell, 2017; Kukey et al., 2019). As they participate in these activities, students are more likely to be engaged not only with their minds but with their whole self (Ferlazzo, 2017; Shaw, 2002). This type of engagement allows students to make connections between their daily lives and the mathematical world of abstract numbers and symbols. When students are engaged in hands-on activities, they usually play games or manipulate concrete objects, making math come alive for them.

According to research, students who participate in hands-on activities and games gain a deeper understanding of mathematical concepts being presented (McCarthy et al., 2018; Teachnology, 2018). Research also shows that students who manipulate objects consistently show an improvement in their scores compared to students who did not (Kablan et al., 2013). Manipulatives assist students in building a firm foundation of mathematical concepts because they help develop an understanding of the mathematical idea being represented (Uribe-Florez & Wilkins, 2017). Using manipulative materials in teaching can help students learn how to relate real-world situations to mathematics symbolism and work together cooperatively in solving problems (Heddens, 1997; Larbi & Mavis, 2016). Manipulatives allow students to discuss mathematical ideas, concepts and verbalize their mathematical thinking (Heddens, 1997; Larbi & Mavis, 2016). Using manipulatives can also help students retain information and increase their scores on tests (Kablan, 2016; Sowell, 1989). Therefore, a manipulative, when developmentally appropriate, bridges the gap between informal and formal mathematics (Jones & Tiller, 2017).

The average retention rate by lecture is 5% compared to 75% when learners are engaged in hands-on activities (Obanya, 2012). The retention rate continues to increase as learners are engaged in more interactive and action-oriented activities (Ekwueme et al., 2015). Ekwueme et al. (2015), explored this concept by designing a program where learners were actively involved at least 90% of the instructional time. The results of their study revealed a significant difference in performance between the experimental and control groups as learners within the experimental group demonstrated an increase of 9.07 on their mean score while the control group gained 0.21 on their mean score. Therefore, it was concluded that there was not a significant difference for the control group because they were not provided with the hands-on approach designed lessons.

Dennis (2011) cited that new teaching strategies need to be utilized to help students gain a better understanding of mathematical ideas (Slavin & Madden, 2005). Manipulatives have been designated as this new strategy (Dennis, 2011). They bring excitement to math lessons, capture a student’s attention, generate an understanding of concepts, and promote math communication (Dennis, 2011). Students are more likely to comprehend mathematical concepts at the abstract level when they have a concrete understanding of the skill (Agrawal & Morin, 2016; Buckley, 2005; Lafay et al., 2019).

Dennis put Buckley's theory into action by studying the effects manipulatives had on the comprehension of math concepts among fifth-grade students. The results of her study revealed significant differences in post-test volume and capacity scores between students who used manipulatives and those who did not.

Incorporating manipulatives in the mathematics curriculum can be an effective method of closing the achievement gap (Dennis, 2011). In studies conducted by Dillion (2009), the achievement gap decreases as research-based instructional strategies are implemented. Kelly (2006) found similar results when exploring the impact manipulatives had on student achievement when introducing math concepts. These results included higher overall test scores and increases in test means, medians, and modes (Dennis, 2011). Students who spend prolonged periods working with manipulatives score higher on standardized math assessments than those who do not (Gersten, 2008; Witzel & Little, 2016). Thus, manipulatives will increase student achievement, help students understand concepts, boost self-confidence, and help teachers feel more confident (Dennis, 2011; Larkin, 2016).

Domino (2010) explored the effects physical manipulatives have on mathematics achievement in grades K-6 through a meta-analysis of 31 studies. The effect sizes which resulted from the meta-analysis ranged from -0.22 to 1.52, indicating that any effect size over 0 supports the use of manipulatives within mathematics instruction. The weighted mean effect size of 0.50 and the 95% confidence interval between 0.34 and 0.65 reveal that students' mathematical achievement is greater when manipulatives are used. In other words, students who use manipulatives during mathematics instruction score half of standard deviation higher or 69 percent better than those students who do not (Domino, 2010).

While the incorporation of manipulatives can significantly impact student achievement, incorrect use could lead to negative results (Van de Walle et al., 2014). The most widespread misuse of manipulatives occurs when teachers select the manipulatives and inform the students to “do as I do” (Van de Walle et al., 2014). Teachers should create an environment where manipulatives are easily accessible for students to select and utilize as they are learning mathematical concepts (Van de Walle et al., 2014). Most importantly, students have to choose manipulatives that make sense to develop a proper understanding of the mathematical concepts.

Students who engage in hands-on activities are provided an opportunity to take ownership of their learning and explore mathematical concepts themselves. During the exploration period, students should experiment and question their findings in search of understanding. As students search for understanding, they develop and apply problem-solving and critical thinking skills to analyze the information. Educational research has proven that learning is most valuable through the use of manipulatives when students actively construct their mathematical understanding (Boggan et al., 2010). Thus, the time students spend engaging in manipulative exploration leads to sustained and long-term effects of deepening mathematics understanding (Shaw, 2002).

Small Group Instruction and Improving Mathematical Achievement

For this section of the literature review, the term cooperative learning will be utilized synonymously with small group instruction. Also, two forms of small group instruction, differentiated instruction and the math workshop model, will be explored. Small group instruction can be easily identified within the classroom as the teacher can be seen working with a group of 2-4 students (Meador, 2015). Through small group instruction, teachers are given the opportunity to provide targeted, differentiated instruction to students (Meador, 2015). As cited by Johnson (2010), differentiated instruction can be defined as a teaching philosophy based on the premise that teachers should adapt instruction to students' individual differences (Tomlinson, 1995). Cooperative learning can be defined as a form of active learning where students work together to perform specific tasks in a small group (Lewis, 2016).

Research studies dating back as far as 1985 have provided sufficient evidence that the implementation of small group instruction has positive effects on student learning and academic achievement. Students exposed to classes utilizing small groups significantly outscore students who are not provided with these opportunities (Grouws & Cebulla, 2000). Hattie (2009) found that cooperative learning is more effective than individualistic learning and direct instruction as conceptual understanding relies on the rich mathematical discussions that occur as students work together (Hattie, 2009). Through collaborative activities, students create their understanding of mathematical concepts as they connect personal knowledge and understanding with information gained from their peers.

Hattie (2009, 2012) explored 21 meta-analyses and 2,104 studies to assign effect sizes related to the impact cooperative learning has on student academic achievement. Hattie's research created three groups of meta-analyses: cooperative versus individualistic learning, cooperative versus competitive learning, and cooperative versus heterogeneous classes. When comparing cooperative learning to individualistic learning, an effect size of 0.59 standard deviation is achieved, meaning that students participating in the cooperative learning group will outscore approximately 73% of the students involved in individualistic learning. An effect size of 0.54 standard deviation yielded when comparing cooperative versus competitive learning; therefore, students learning cooperatively outscored peers in the competitive learning environment by approximately 71%. When Hattie (2009, 2012) analyzed cooperative learning versus heterogeneous class environments, an effect size of 0.41 standard deviation was found, indicating that students in cooperative learning environments would outperform students in heterogeneous classes by approximately 66%.

In addition to cooperative learning, Hattie also explored small group learning. Hattie (2012) defines small group learning as assigning a task to a small group of students and expecting them to complete the task. Two meta-analyses and 78 studies resulted in an effect size of 0.49 standard deviation. Students involved in small group learning perform better than approximately sixty-nine percent of the students who do not. The effects of small-group learning are enhanced if students have already had experience working in small groups or if the teacher provides explicit instruction on cooperative learning strategies (Hattie, 2012). Most importantly, small group learning reaches its maximum effectiveness when materials and instruction are varied to meet the diverse needs of each student (Hattie, 2009).

Small group instruction and cooperative learning have significant impacts on student mathematical achievement (Pellegrini et al., 2018; Slavin et al., 2010). Based on the meta-analysis conducted by Slavin et al. (2010), mathematical programs that encourage cooperative learning through student interaction have larger impacts on student achievement. Cooperative learning or small group instruction "fosters the application and practice of mathematics and collaborative skills within the natural setting." Students who work cooperatively tend to focus less on failure and instead concentrate on accomplishing the assigned task (Gamble, 2011).

Differentiated instruction is a small group instructional strategy designed to meet students at their current academic level and move them along as quickly as possible (Cannon, 2017; Johnson, 2010; Kaur & Gupta, 2019). Thus, each student receives a curriculum that is most appropriate to his or her learning needs. Recent research conducted on differentiated instruction yields varying results as it pertains to improving mathematical achievement. Johnson (2010) conducted a study to investigate if students taught through differentiated instruction would demonstrate greater achievement gains than students taught utilizing traditional teaching methods. The results of Johnson's study revealed that there were no significant differences between students who received differentiated instruction and those who do not.

Gamble (2011) explored the impact differentiated instruction and traditional instruction had on the mathematical achievement of fifth graders. Gamble's study utilized the Math Out of the Box (MOOTB) curriculum as the foundational piece for differentiated instruction. Students involved with the MOOTB curriculum were provided frequent opportunities to collaborate with others to discuss and explain their ideas (Gamble, 2011). Utilizing a one-way covariance analysis Measures of Academic Progress pretest and posttest scores were compared for fifth graders receiving differentiated instruction and traditional instruction. The results of the student data revealed there were no significant differences in the mean scores of students who received differentiated instruction and those who had not. However, both groups did show improvements from the pretest to posttest assessment.

Maxey (2013) studied the effects of differentiated instruction on primary students' mathematics achievement and found no statistically significant differences in students' scaled scores in the differentiated instruction group and students in the whole group instruction group, based on a one-way ANOVA. However, Maxey did find a statistically significant difference in the gain scores of the three ability groups (high, average, and low) within the differentiated instruction group. Students in the high group demonstrated more significant growth than students in both the average and low groups.

Math workshop model is another type of research-based small group instructional strategy that is implemented in the mathematics classroom to improve students' mathematical achievement. "A math workshop can be defined as an instructional model in which teachers create and facilitate learning experiences for individuals, partners, and small-groups to cultivate math learners' deep conceptual understanding, fluency with numbers, and problem-solving strategies" (Siena, 2009, p. 93). According to Hoffer (2012), the workshop model cultivates all learners' mathematical abilities by creating and facilitating learning experiences that provide opportunities for students to construct deep conceptual understanding and fluency with numbers. Supporting Vygotsky's zone of proximal development theory, students meet more challenging tasks as they complete these tasks working cooperatively within a community of learners (Vygotsky, 1978). The integration of the math workshop model actively engages all students in increasing their math achievement as they explore instructional activities that are designed to meet their diverse needs and ability levels (Ashley, 2016).

Ashley (2016) conducted a qualitative study exploring the implementation of the math workshop model in the elementary classroom. Math workshop was one of the three primary themes which emerged from the study. Within the math workshop theme, a sub-theme of the impact on students arose. Based on the interviews conducted with teachers and math specialists, it was found that students' mathematical achievement improved due to being able to engage students at their individual skill levels.

Students who experience small group instruction demonstrate improvement in their mathematical achievement. Through peer collaboration, students can explore mathematical concepts as they share and reshape their conceptual understanding. Mistakes that are made through small group instruction are seen as learning opportunities as students work together to solidify each other's understanding. Thus, small group instruction can provide opportunities for students to engage in challenging, mathematical problem-solving tasks as the community of learners build confidence and supports constructing one's understanding.

Problem-Solving Activities and Improving Mathematical Achievement

Another method that has proved effective in increasing the mathematical achievement of students is problem-solving activities. Problem-solving is a method that encourages students to make connections in math, draw upon their mathematical thinking, and apply mathematics to daily life (Laurens et al., 2018; Maxey, 2013). As a higher-order thinking skill, problem-solving requires students to draw upon their prior knowledge to solve authentic problems and explain their thinking both orally and in writing (Maxey, 2013). Due to the implementation of rigorous mathematical standards, problem-solving is the preferred method of instruction (Smith et al., 2011). Problem-solving is associated with greater conceptual understanding, improved reasoning and higher mathematical achievement (Cave, 2010; Lithner, 2017).

Hattie (2009, 2012) ranked problem-solving as the 20th most influential teaching strategy as it pertains to students' academic achievement. This ranking resulted from six meta-analyses encompassing 221 studies. Yielding a medium to high effect size with a standard deviation of 0.61, problem-solving has proven to have positive impacts on student achievement (Hattie, 2009, 2012). A significant direct correlation between problem-solving and the performance of basic skills in mathematics was found (Hembree, 1992). Furthermore, formatting problem-solving tasks that include diagrams, figures, or sketches positively enhances students' academic performance (Hattie, 2009, 2012).

The South Carolina Association of School Administrators Superintendent's Roundtable, the South Carolina Chamber of Commerce, and the South Carolina Council of Competitiveness adopted and approved The Profile of the South Carolina Graduate which outlines the world-class knowledge, skills, life and career characteristics every high school student should have upon graduation (South Carolina Education Oversight Committee, 2018). Problem-solving accompanied by critical thinking is one of the world-class skills identified in this document. Thus, it is the expectation that educators provide numerous opportunities in the classroom for students to engage in problem-solving activities to enhance their problem-solving skills.

The incorporation of problem-solving activities in the mathematics classroom requires the teaching of problem-solving methods. As with any mathematical standard, students must become proficient in mathematical problem-solving. The earlier students become proficient in problem-solving, the better prepared they will be for solving and engaging in more complex mathematics (Woodward et al., 2012). Throughout the mathematics curriculum, from kindergarten to higher-level math, students develop and enhance their problem-solving abilities, including reasoning and analysis, argument construction, and the creation of innovative strategies-skills that directly impact students' achievement scores on standardized assessments (Woodward et al., 2012).

Woodward et al. (2012) provided five recommendations for teachers to improve the incorporation of problem-solving tasks and activities in the classroom. These recommendations are: (a) prepare problems and use them in whole-class instruction, (b) assist students in monitoring and reflecting on the problem-solving process, (c) teach students how to use visual representations, (d) expose students to multiple problem-solving strategies, and (e) help students recognize and articulate mathematical concepts and notations (Woodward et al., 2012). Recommendations a and b address the vital role teachers' play when incorporating problem-solving tasks and activities in the classroom, while recommendations c, d, and e identify ways to teach problem-solving. Teachers should expose students to both routine and non-routine problem-solving tasks that address the unit's learning objectives and the learning needs and academic abilities of the students. Also, teachers should model how to monitor and reflect during the problem-solving process, provide students with a list of prompts that supports their monitoring and reflecting, and utilize students thinking to develop their ability to monitor and reflect (Woodward et al., 2012).

Engaging students in problem-solving activities in the classroom prepares students for the mathematical problems they will face upon entering the real world. As cited by Norford (2012), problem-solving provides the foundation necessary to learn new mathematical information, make connections, and assist in solving daily problems (Montague, 2003). Several factors can be attributed to enhancing students' mathematical achievement as it relates to mathematical problem-solving. Some of them include serving as active participants in class discussions where students are engaging in mathematical experiences that progress through the concrete, pictorial, and abstract learning progression; engaging in real-life and multiple methods of mathematical problem-solving activities; the ability to distinguish between relevant and irrelevant information when solving a mathematics problem; encouraging students to explain how they derived a solution utilizing diagrams as well as words; and collaborating with peers throughout the entire process of problem-solving (Norford, 2012).

Studies conducted by Sigurdson & Olson, 1992; and Verschaffel et al., 1999, revealed that students who are learning in classroom environments where problem-solving is incorporated daily, typically outperform their peers on mathematics achievement assessments who are not participants in this type of environment (Bostic, 2011). For example, scores from fourth-grade students in Singapore consistently earn them the highest ranking on the Trends in International Mathematics and Science Study assessment. This level of mathematical success can be attributed to Singapore's curriculum, which emphasizes problem-solving and learning strategies grounded in constructivist theory.

As evidenced by earlier research, engaging in problem-solving activities during mathematics instruction can increase students' mathematical achievement as they explore mathematical concepts on a deeper level. Problem-solving activities help students develop, enhance, and reshape their mathematical understanding as they apply what they already know to unfamiliar situations. It is through problem-solving that students make connections to the real world, thus understanding the importance of mathematics outside of the classroom. Most importantly, mathematical investigations grounded in problem-solving allow students to reflect upon their problem-solving process as they reason and communicate with peers.

Classroom Discussions and Improving Mathematical Achievement

Classroom discussions are a vital component of the mathematical learning environment as they deepen the understanding of students' mathematical ideas and their ability to solve problems proficiently (Lamberg, 2013). Communication has been identified as one of five process standards by The National Council of Teachers of Mathematics. From pre-kindergarten to twelfth grade every student should be engaged in mathematical communication that: (a) organizes and consolidates their mathematical thinking; (b) communicates their mathematical thinking coherently and clearly to peers, teachers, and others; (c) analyzes and evaluates the mathematical thinking strategies of others; and (d) uses the language of mathematics to express mathematical ideas precisely (The National Council of Teachers of Mathematics, 2017). In 2009, the National Governors Association Center for Best Practices and the Council of Chief State School Officers developed eight standards of mathematical practice. Standard three of the standards of mathematical practice's, construct viable arguments and critique the reasoning of others, addresses the importance of communication in the mathematics classroom. Mathematically proficient students demonstrate mastery of this standard by constructing viable, oral, and written arguments and listening to and critiquing the reasoning of others (O'Connell & SanGiovanni, 2013).

Vygotsky's (1978) research emphasizes that students internalize instruction more efficiently when good questioning and productive discussions are integrated into the curriculum. Thus, students should experience two phases of activity during classroom discussions, exploratory talk and elaborate talk. Exploratory talk occurs when students manipulate their ideas, and elaborate talk occurs as students express their refined ideas (Gavin et al., 2015). Engaging students in frequent classroom discussions surrounding mathematical concepts help students persevere when solving problems as they organize, consolidate, and clarify their thinking, and view problems from different perspectives as students share their diverse thinking and problem-solving techniques (Gavin et al., 2015).

Creating a mathematical learning environment that fosters collaboration through classroom discussions takes time (Bahr & Bahr, 2017). However, the conceptual understanding that is developed allows students to attain greater math skills (Lamberg, 2013). As students engage in classroom discussions, they develop number sense, making it easier for them to create mathematical connections and more efficiently solve problems (Lamberg, 2013). Classroom discussions engage all learners and emphasize cognitive development (Kilic et al., 2010; Setianingsih et al., 2017). The questions that arise during this time, such as “would you do it differently next time, which strategy made sense to them (and why), and what caused problems for them (and how they overcame them),” are essential in developing mathematically proficient students (Van de Walle et al., 2014).

Chapin et al. (2013) identify four goals that will assist in achieving productive mathematical discussions. These goals include helping students: (a) clarify and share their thoughts, (b) orient toward the thinking of others, (c) deepen their reasoning, and (d) engage the reasoning of others (Chapin et al., 2013). It is imperative students understand that discussions are more than sharing one’s thoughts, but it requires a level of listening and responding that makes mathematical discussions rich. To assist in creating a learning environment conducive to mathematical discussions, teachers can utilize the five talk moves of revoicing, repeat/rephrase, agree/disagree and why, adding on, and wait time (Chapin et al., 2013). Also, by asking students who, what, when, where, why, and how, students' mathematical thinking is initiated, and it deepens their understanding (Chapin et al., 2013).

Smith and Stein (2018) identify five key practices teachers can implement during their mathematics instructions to orchestrate productive mathematical discussions. These five practices are anticipating, monitoring, selecting, sequencing, and connecting. During mathematical discussions, teachers must anticipate student responses to challenging tasks and prepare questions for those students. They must monitor students' responses while they work in pairs or small groups. As teachers monitor, they should be selecting students to share their mathematical thinking with the class and sequencing the order in which student's work will be shared. Finally, connections should be made as students are presenting their mathematical thinking with the class. Thus, the purpose of these practices is to advance the mathematical understanding of all students. Therefore, intentional planning is required to ensure this occurs (Smith & Stein, 2018).

Mathematical classroom discussions are typically conducted through number talks (Parrish, 2010). A number talk is a tool used to help students develop computational fluency as they utilize number relationships and the structures of numbers to add, subtract, multiply and divide (Math Perspectives, 2011). Parrish (2010) identifies five benefits students attain when sharing and discussing computation strategies: (a) clarify their own thinking, (b) consider and test other strategies to see if they are mathematically logical, (c) investigate and apply mathematical relationships, (d) build a repertoire of efficient strategies, and (e) make a decision about choosing efficient strategies for specific problems. During number talks, the focus is not on the answer but the justification and reasoning that is provided as proof. Wrong answers are used to create new learning opportunities as students question and analyze thinking, bringing misconceptions to the forefront and solidify understanding (Parrish, 2010).

Highly engaging classrooms have been shown to increase students' mathematical achievement (Fung et al., 2018; William, 2018). One component of this type of classroom is classroom discussions. Classroom discussions allow students to actively explore mathematical concepts as they share their reasoning and refine their understanding (Richland et al., 2017). Students enhance their mathematical knowledge through classroom discussion as they describe, explain, defend, and justify their ideas about mathematics (Kosko, 2012). Earlier research found that mathematics deepens and develops through communication, thus positively impacting mathematical achievement (D'Ambrosio et al., 1995; Grouws, 2004; Hiebert & Wearne, 1993; Lee, 2006; Mercer & Sams, 2006; Silver et al., 1990; Wilburne et al., 2018). Teachers should encourage students to develop new strategies, share their ideas with the class, and lead class discussions to help them communicate their process of thinking (Sedova et al., 2019).

Engaging students in classroom discussions deepen their understanding of mathematical ideas and concepts and allows them to learn from each other (Alber, 2015; Ellis, 2018; Gresham & Shannon, 2017). As students' mathematical knowledge and understanding are deepened, their ability to improve their academic achievement is heightened (Fung et al., 2018; William, 2018). Classroom discussions allow students to solidify their understanding as it is shaped and reshaped because of information that is learned and processed from their peers. In addition, students who experience classroom discussions develop a greater number sense, making it easier for them to make connections and solve mathematical problems more efficiently (Lamberg, 2013).

Implications

This study may promote social change by providing insight on how teachers may effectively deliver mathematics instruction. Research has shown that facilitating mathematics instruction through highly engaging classrooms can improve the mathematical achievement of students (Fung et al., 2018; William, 2018). By incorporating hands-on instruction, small group investigations, problem-solving activities and classroom discussions, students can amplify their understanding of mathematical concepts and ideas. Having this deeper level of understanding assists students in making connections and solving unfamiliar mathematical problems more efficiently. Also, facilitating an environment where learner-centered, research-based instructional strategies serve as the framework of instruction makes students accountable for their learning. Most importantly, hands-on instruction, small group investigations, problem-solving activities, and classroom discussions assist in meeting the World Class Knowledge, World Class Skills and Life and Career Characteristics requirements outlined in the Profile of the South Carolina Graduate.

Several possible projects can be implemented after this study, given its nature. One possible project could be the development of a curriculum for teachers that fosters the incorporation of research-based instructional strategies. A second potential project could be the development of an acceptable measurable threshold for the implementation of research-based instructional strategies in the mathematics classroom. A third possible project could be the development of an implementation fidelity framework for teachers to follow when planning mathematics instruction. Also, the creation of a project-based learning camp or afterschool program could be developed. Project-based learning is a student-centered pedagogy that encompasses the research-based instructional strategies that were explored during this study. The results of the study determined the direction of the project.

Summary

An effective mathematics classroom encompasses three critical components: (a) teaching for conceptual understanding, (b) developing children's procedural literacy, and (c) promoting strategic competence through meaningful problem-solving investigations (Shellard & Moyer, 2002). Thus, students should be engaged in highly interactive tasks that encourage them to explore problems, formulate ideas, and check their mathematical ideas with others through discussions and collaborations (McREL, 2010). It is through these types of learning experiences that students construct their knowledge and understanding of the content. As cited by Ashley (2016), instructional strategies are a critical factor as it pertains to maximizing student achievement; thus, the mathematical achievement of students is directly aligned to the delivery of instruction (Black, 2007).Students who are exposed to more learner-centered activities, such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions, demonstrate higher levels of proficiency on standardized assessments and increased mathematical achievement (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013; Woodward et al., 2012).

The incorporation of hands-on activities, small group instruction, problem-solving tasks, and classroom discussions exemplify the characteristics of Bruner's constructivist theory. By exploring these instructional strategies, learners become active participants throughout the learning process as they engage in mathematical learning experiences that encourage social interaction (Powell & Kalina, 2009). Implementing hands-on activities grounded in the constructivist theory requires students to take a lead role in learning, taking ownership of the ideas they create and their conclusions (White, 2012). Through hands-on activities, opportunities become available for cooperative learning or small group instruction where students can explore and make connections between concepts and concrete representations (White, 2012). Mathematical classroom discussions give students an avenue to express their ideas (Peressini et al., 2004) as they engage in problem-solving activities (Boaler & Greeno, 2000; Langer-Osuna, 2017), which simultaneously structure or restructure their thinking (Hiebert & Wearne, 1993). The quantitative research question was informed by Weimer's (2013) learner-centered teaching, which tested whether implemented research-based instructional strategies, grounded in Bruner's (1966) constructivist theory, will improve the mathematical achievement of students who receive this type of instruction. The qualitative research question was informed by Weimer's (2013) learner-centered teaching and Bruner's (1966) constructivist theory, as this study sought to find to what extent research-based instructional strategies are being implemented. Section 2 will explore the methodology that was utilized to conduct this study.

Section 2: The Methodology

Introduction

The purpose of this study was to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group instruction, problem-solving tasks, and classroom discussions for district students in Grades 2-5. In investigating whether the implementation of research-based instructional strategies can be an effective intervention associated with an increase in mathematical proficiency, I focused on two central questions: (a) Is there a difference in mathematical achievement, as measured by Math Inventory (MI), between students at Elementary School A who have experienced research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) and those who have not at Elementary School B? and (b) To what extent were teachers implementing research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) at Elementary School A? In this section, I provide an overview of the research design, sampling procedures, participants, instrumentation tool, data collection procedures, and the quantitative and qualitative statistical analyses used to address the RQs.

Mixed-Method Design and Approach

I used a mixed-methods design featuring quantitative and qualitative research methods to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group instruction, problem-solving tasks, and classroom discourse for students in Grades 2-5 at Elementary School A. The MI assessment, administered during the 2019-2020 winter testing window, was used as the dependent variable to test the quantitative question. The MI assessment 2019-2020 fall scores were used as the covariate. The MI assessment measured students' readiness for math instruction by identifying the math concepts students already know as well as what concepts they are ready to learn (MetaMetrics, 2017). For the qualitative component of this study, I investigated the implementation of research-based instructional strategies through teacher interviews and analysis of teacher lesson plans.

A mixed-methods research design combines both quantitative and qualitative research creating a deeper understanding of the RQs being explored (Lodico et al., 2010). Using a mixed-methods approach for this project study provided an opportunity to investigate the local problem of teacher-centered learning environments through an in-depth investigation of the outcomes and implementation of research-based instructional strategies. Employing a mixed-methods research design gives an overall view of the local problem of teacher-centered learning environments as the outcomes and implementation of research-based instructional strategies are investigated (Lodico et al., 2010).

Different mixed-methods approaches could have been used for this study. Convergent parallel, embedded, exploratory and explanatory sequential are the four common types of mixed-methods research designs used today (Creswell, 2012). As Creswell (2012) noted, the convergent parallel design allows for simultaneous collection of both quantitative and qualitative data that are merged together to interpret or understand a research problem. The embedded research design allows for simultaneous or sequential quantitative and qualitative data collection with one form of data supporting the other. Exploratory sequential and explanatory sequential are two mixed methods designs that require two phases of data collection. Exploratory sequential is the initial collection of qualitative data to explore a phenomenon followed by the collection of quantitative data used to confirm the relationships found in the qualitative data. Conversely, the explanatory sequential design consists of collecting quantitative data followed by qualitative data which is used to explain or elaborate on the quantitative results. I used the explanatory sequential design in this study.

For the quantitative portion of this study, I sought to determine if there was a difference in mathematical achievement, as measured by MI, between students who have experienced research-based instructional strategies (Elementary School A) and those who have not (Elementary School B). For the qualitative portion of the study, I explored the extent to which teachers at Elementary School A were implementing research-based instructional strategies. The qualitative data collected from teacher lesson plans and interview responses were used to triangulate the quantitative data collected from two administrations of the MI Assessment. Data were collected at Elementary School A after the school day. Once IRB approval was received, an email was sent to the principal to inquire if there was still an interest to participate in this study. Upon agreement, I emailed consent forms to teachers. Teachers who consented to participate provided the qualitative data through interviews and lesson plan analysis. Information obtained from this study was shared with the school administrative team and participating teachers at its conclusion. The information shared included the study results and, most importantly, any policy or procedural documents developed as part of the project.

Quantitative Design

I used a causal-comparative nonexperimental quantitative research design. As a result of classroom rosters being in place prior to this study, random assignment of students was not possible. The students in Elementary School A received research-based instruction for 5 months during the 2019-2020 school year prior to COVID-19 disrupting the school year in the spring of the 2019-2020 school year. Quantitative data were collected from the fall and winter administrations of the MI assessment. I used the quantitative data to determine if there was a difference in means between students who experienced research-based instructional strategies and those who had not. MI was administered during the fall, which served as the covariate and then again during the winter testing window, allowing for an analysis of covariance (ANCOVA).

An ANCOVA analysis was the appropriate method for this study because the type of instructional strategies received served as the independent variable, scores on the MI assessments represented the dependent variable, and the preassessment given prior to mathematical instruction to adjust for mean differences served as the covariate. Teachers administered pre-and postassessments before and after instruction to measure individual student growth. The preassessments (i.e., the fall administration of the MI) were used as a covariate to adjust for mean differences between the groups. Using the fall administration as the covariate reduced the bias because the comparison was between intact or self-selected groups (see Cook et al., 2009).

School-based administrators encouraged classroom teachers at Elementary School A to implement four research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) within second- through fifth-grade classrooms. These grade levels consisted of four classes at the second-grade level (69 students), three classes at the third-grade level (74 students), four classes at the fourth-grade level (74 students) and three classes at the fifth-grade level (70 students). Elementary School B, which served as the control group, consisted of four classes at the second-grade level (85 students), four classes at the third-grade level (74 students), five classes at the fourth-grade level (80 students) and four classes at the fifth-grade level (72 students). The school-based administrators at Elementary School B did not encourage or require teachers to engage in instructional techniques resembling any of the four research-based instructional strategies.

There were some threats to the internal validity of this research study, such as instrumentation and regression toward the mean. I controlled the threat of instrumentation by giving the same type of assessment. The testing threat was controlled by utilizing valid assessments that are the same when administering pretest and posttest assessments. The regression toward the mean threat was eliminated or reduced as a result of a covariate. I used the covariate to adjust any initial ability differences between Elementary School A and Elementary School B in the measurement of the winter MI administration (see Tables 10, 15, 20 and 25).

Qualitative Design

Qualitative data consisted of teacher interviews and the collection of lesson plans. I collected teacher lesson plans as part of the interview process and reviewed them for analysis. Teacher interviews were conducted to determine the extent to which research-based instructional strategies were indeed implemented. For this study, a total of 12 teachers could be interviewed. However, only 25% (i.e., 3) of the teachers from Elementary School A agreed to participate in this portion of the study. A typological analysis of teacher lesson plans and teachers' perspectives through interviews occurred to explore the ways in which research-based instructional strategies were being implemented by the three teachers at Elementary School A. I used typological analysis as I already knew the broad categories of interest within the data (see Hatch, 2002). These broad categories were Weimer's learner-centered teaching practices. Once all data were collected, analyzed, and interpreted, quantitative and qualitative findings were triangulated to present the overall results.

Setting and Sample

I identified Elementary School A as the treatment school because it was evident in district learning walk data that research-based instructional strategies were being implemented. Elementary School B was identified as the control school because it was not evident throughout observations that research-based instructional strategies were taking place. Elementary School A and Elementary School B are in a suburban community located in a major city in South Carolina. Elementary School A had a population of 512 students in prekindergarten through fifth grade at the time of the study. Elementary School B had a population of 559 students in the same grade levels. The descriptive statistics in Tables 3-6 demonstrate that the two schools were congruent on important covariates such as gender and ethnicity.

I conducted an a-priori power analysis to calculate the minimum sample size to achieve a medium effect size. Cohen (1988) interpreted small, medium, and large effect sizes for partial eta-squared (η^2) values as .10, .25, and .40, respectively. G*Power 3.1 (Faul et al., 2009) was used to determine the minimum sample size for this study. The G*Power input values given were (a) medium effect size of .25, (b) $\alpha = .05$, (c) power specified was .80, (d) numerator degrees of freedom was 1, (e) number of groups was two, and (f) number of covariates was 1. Based on the values given, the total sample size (*N*) for each grade level was estimated to be 128.

I used eight second grade classes, seven third grade classes, nine fourth grade classes, and seven fifth grade classes for this study. There were no second through fifth grade math classes excluded. The student population for this study included 294 second through fifth graders at Elementary School A and 328 second through fifth graders at Elementary School B. The demographic makeup of the students was 86% African American, 4% White, 10% other, 52% female, and 48% male at Elementary School A; and 83% African American, 3% White, 14% other, 45% female, and 55% male at Elementary School B. The students in these classes were not considered participants as the emphasis of this study is placed on teacher implementation of research-based instructional strategies. The de-identified student data was used to measure the outcomes of the implemented research-based strategies. In Tables 3-6 the grade-level descriptive statistics are provided related to the treatment and control groups.

I used purposeful sampling as this study targets second through fifth grade teachers. The sample population selected for this study included 12 teachers. Of the second through fifth-grade teachers, 84% are African American, 8% are White, 8% are Other, 92% are female and 8% are male. According to Creswell (2012) if the number of participants is too small then there will be insufficient data to address the research questions, yet if the sample is too large, the depth of inquiry may not be sufficient. I used student data from four grade levels at two schools and the 12, second through fifth grade teachers from Elementary School A were asked to participate in order to ensure that there was an adequate representation.

Table 3

Grade 2 Sample Descriptive Statistics

	Treatment	Control
N	64	76
Gender		
Male *n*(%)	33 (52%)	35 (46%)
Female *n*(%)	31 (48%)	41 (54%)
Ethnicity		
Black *n*(%)	59 (92%)	65 (86%)
White *n*(%)	1 (2%)	2 (3%)
Hispanic *n*(%)	1 (2%)	3 (4%)
Asian *n*(%)	0 (0%)	2 (3%)
Native *n*(%)	0 (0%)	0 (0%)
Other *n*(%)	3 (5%)	4 (5%)

Note. Due to rounding, totals may not be 100%

Table 4

Grade 3 Sample Descriptive Statistics

	Treatment	Control
N	64	68
Gender		
Male *n*(%)	37 (58%)	29 (43%)
Female *n*(%)	27 (42%)	39 (57%)
Ethnicity		
Black *n*(%)	52 (81%)	60 (88%)
White *n*(%)	4 (6%)	0 (0%)
Hispanic *n*(%)	1 (2%)	2 (3%)
Asian *n*(%)	2 (3%)	2 (3%)
Native *n*(%)	0 (0%)	0 (0%)
Other *n*(%)	5 (8%)	4 (6%)

Note. Due to rounding, totals may not be 100%

Table 5

Grade 4 Sample Descriptive Statistics

	Treatment	Control
N	68	70
Gender		
Male *n*(%)	32 (47%)	32 (46%)
Female *n*(%)	36 (53%)	38 (54%)
Ethnicity		
Black *n*(%)	59 (87%)	54 (77%)
White *n*(%)	3 (4%)	0 (0%)
Hispanic *n*(%)	2 (3%)	5 (7%)
Asian *n*(%)	0 (0%)	5 (7%)
Native *n*(%)	1 (1%)	0 (0%)
Other *n*(%)	3 (4%)	6 (9%)

Note. Due to rounding totals may not be 100%

Table 6

Grade 5 Sample Descriptive Statistics

	Treatment	Control
N	62	66
Gender		
Male *n*(%)	33 (53%)	30 (45%)
Female *n*(%)	29 (47%)	36 (55%)
Ethnicity		
Black *n*(%)	54 (87%)	56 (85%)
White *n*(%)	2 (3%)	3 (5%)
Hispanic *n*(%)	2 (3%)	4 (6%)
Asian *n*(%)	2 (3%)	0 (0%)
Native *n*(%)	0 (0%)	0 (0%)
Other *n*(%)	2 (3%)	3 (5%)

Note. Due to rounding, totals may not be 100%

Gaining Access to Participants

I gained access to the teacher participants through the Principal at Elementary School A. The principal provided the names and emails of the second through fifth-grade teachers whom I contacted directly. Upon initial contact, teachers were asked if they would like to participate in the qualitative component of this study voluntarily. Teachers who voluntarily agreed to participate were required to fill out an informed consent form. The informed consent form included background information about the study, the voluntary nature of the study, the risks and benefits of being in the study, and the privacy measures that will be taken to protect participant identities.

I established a researcher-participant working relationship, which required building rapport with the teachers participating in this study. It was important that rapport was built with interview participants to increase the likelihood that teacher interview responses were truthful. As I established rapport, the teachers were provided information to know and understand that this study was not intended to evaluate them regarding their certification. Hence, teacher responses during the interviews remained anonymous. Participating teachers signed consent forms that were sealed in an envelope and kept in a locked desk. It was necessary to ensure confidentiality; therefore, each teacher was assigned a pseudonym (Teacher D, Teacher E, and Teacher F). This pseudonym was used to de-identify all qualitative data collected from the teachers. The teacher participants are protected from harm as their identifying information will remain confidential.

Instrumentation and Materials

The Houghton Mifflin Harcourt MI Assessment was the instrument used for the quantitative portion of this study. MI is a computerized adaptive research-based assessment that reliably measures students' math ability and progress from Kindergarten to Algebra II (MetaMetrics, 2017). MI was developed during 2008–2010, launched during the Summer of 2010 and has been purchased by the district for district-wide administration. MI allows educators to track student performance throughout a given school year while providing a detailed list of skills students have mastered and where to go next. MI will measure students' mathematical understanding of algebra and algebraic thinking, number sense, numerical operations, measurement, geometry, and data analysis statistics and probability.

A quantile measure is provided after each test administration, indicating the performance level of the student. This quantile measure identifies which skills and concepts students are ready to learn; the level of success students are expected to have with an upcoming skill or concept; and how students are growing in mathematics on a single scale across grade levels (MetaMetrics, 2017). Students' quantile measures are calculated based on the level at which he/she answers questions within the content strands assessed. Quantile measures served as the dependent variable and were used to measure the outcomes of the implementation of research-based instructional strategies, the independent variable. The mean quantile measure for the group receiving (Elementary School A) mathematics instruction through research-based instructional strategies was compared to the group not receiving (Elementary School B) research-based instructional strategies. To complete the MI assessment, students needed access to a computer and a secure testing browser. Students logged into the system and the test proctor administered the assessment. The students answered questions at their own pace and received a quantile measure at the conclusion of the assessment.

Second through fifth-grade participants took the MI assessment during the fall and winter test administration windows. Thus, it was appropriate for this study as individual student growth was measured at multiple points during the school year. Raw data is housed on the Scholastic Achievement Management database as well as the district's Enrich database. The district's research specialist provided access to the raw data. The materials needed for this assessment instrument included a computer and a secure testing browser.

In 2012, MI received the highest rating for validity and reliability by the Center on Response to Intervention at the American Institutes for Research (Math Solutions, 2018). Both MI and the quantile framework underwent extensive reliability research to ensure accurate test results and alignment to instruction (Math Solutions, 2018). Questions for the MI assessment are pulled from a bank of questions that have been developed by math teachers and item-development specialists who have experiences with mathematics instruction at various levels (Scholastic Inc., 2012). Test bank items were developed utilizing the same protocol that was used to develop items for the quantile scale (Scholastic Inc., 2012). With reliability of 0.97 it is most appropriate for a computer-adaptive assessment (Scholastic Inc., 2012). In addition, through test-retest reliability, a reliability coefficient of 0.78 was established, satisfactory meeting the expectation of the educational measurement community (Scholastic Inc., 2012). Both the content-description validity and construct-identification validity indicate explicit connections to concepts and skills (based on national and state mathematics standards) and age-related differences in performance levels are to be expected (Scholastic Inc., 2012).

I created an interview protocol form to help prepare for the interviews (see Appendix C). On this form, the purpose of the interview is stated along with the interview questions. This form ensured that what is asked of one participant is asked of all. In addition, it informed the participant that participating in the interview is on a voluntary basis, all responses shared will remain confidential as the researcher will be the only one analyzing the information and the participant has the right at any time to end the interview if they felt it was needed. I took notes during the interview and the conversation was audio-taped and then transcribed for analysis. In accordance with Walden’s IRB policy, the recording will be deleted within five years of the published study.

I created a lesson plan analysis protocol to highlight research-based instructional strategies (see Appendix D). The protocol was adapted from South Carolina's Department of Elementary Mathematics Education. This protocol identified the research-based instructional strategies implemented in the lesson and the connection between the activity and the instructional strategy. Weimer's learner-centered teaching practices served as the framework for the lesson plan analysis protocol as the five principles were the "look fors" when determining the implementation of learner-centered instructional strategies. This protocol determined if teachers planned learner-centered activities demonstrating the characteristics of Weimer's learner-centered teaching theory.

The qualitative research question explored for this study addressed the extent to which teachers implemented research-based instructional strategies within their mathematics lessons. Data collected from teacher lesson plans and teacher interviews sufficiently answered the research question as what was shared by the teachers during the interviews was triangulated with the data obtained from the lesson plans. The triangulation of data helps validate information retrieved from all three sources as each method of data collection can be cross-referenced, increasing the credibility and validity of the findings (Creswell, 2012). Triangulating the qualitative data generated from teacher interviews and lesson plan analysis helped support the quantitative data obtained from the MI assessments as the instructional strategies implemented in the classroom can be cross-referenced with student quantile scores.

With three teachers participating in this study, a maximum of three interviews were conducted, lasting no longer than 30 minutes. For the purposes of the interview, I gained access to the teachers via the principal of the school site. Once the principal provided me with permission to talk with teachers, I emailed the teachers individually, inviting them to participate in the interview phase of the study. Teachers who responded were assigned an interview time and asked to sign a consent form prior to the interview beginning. Data collected from all three sources is kept in a research log, and the emerging understandings that arose were kept in a reflective journal.

I am currently employed by the school district as the gifted and talented elementary consultant and have no direct role at the schools. As a consultant, I serve as a support personnel, not an evaluator. I am an additional instructional resource as teachers come to me for advice and suggestions as it pertains to gifted instruction. My role as the gifted elementary consultant may affect the data collected from the interviews as teachers may be prone to say what they believe I want to hear. This was minimized by explaining to the teacher the purpose of the research and ensuring them that their honest answers are important and will remain confidential. As a former math coach, math lead teacher, and district math facilitator, my experiences with incorporating research-based instructional strategies span nine years. Thus, my interest in seeing teachers implement research-based instructional strategies with fidelity is high. I ensured that my bias pertaining to implementing research-based instructional strategies is not forced upon the participants in this study. This was through the avoidance of asking follow-up questions and summarizing teacher responses during the interviews.

Data Collection and Analysis

Quantitative

Quantitative data was collected from the Scholastic Achievement Manager database of second through fifth graders' MI scores. MI assessment data was collected following the fall and winter test administrations. Access to second through fifth grade MI data was provided via the district research specialist. Once data was received it was recorded in an EXCEL spreadsheet. The spreadsheet included the following data fields:

- Unique student number (i.e., Student A4, Student B3, etc.)
- Student grade level
- Teacher name (i.e., Teacher A, Teacher B, etc.)
- Fall quantile score
- Winter quantile score

The assessment results collected were uploaded into an inferential statistical software program for analysis to determine various statistics. Data collected from the MI assessment was from the fall and winter 2019-2020 testing administrations. A comparison between groups occurred to identify the outcomes of implementing research-based instructional strategies. This comparison provided the evidence needed to support either the null or alternative hypothesis.

The statistical analysis for the quantitative data was analyzed by using SPSS Statistics for Windows, Version 22.0 (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). A comparison of differences between groups was performed by using a one-way between-subjects ANCOVA inferential test to determine if there is a significant difference between the treatment and control groups. The ANCOVA was conducted separately for each grade level at the significant level of ($\alpha = .05$). The null hypothesis states there is no significant difference in mathematical achievement between students who have experienced research-based instructional strategies and those who have not. Finally, all of the relevant assumptions for the ANCOVA were conducted and assessed. If there were any assumptions not tenable, non-parametric statistics would have been considered. The assumptions conducted for each grade-level were (a) normality, (b) independence of observations, (c) homogeneity of variance, (d) the covariate variable must be correlated with the dependent variable, (e) the within-group relationship between the dependent variable and covariate should be linearly related, and (f) the homogeneity of regression slope.

The Math Big 3 Observational Tool (see Appendix B) was used to classify a school as research-based strategies or not by district personnel during biannual *Learning Walks*. There are three categories within this rubric to assess research-based teaching strategies. The categories are Number Sense, Daily Problem Solving, and Manipulatives. There are seven Likert-scale questions for Number Sense, eight Likert-scale questions for Daily Problem Solving, and six Likert-scale questions for Manipulatives. In addition, there is an open-ended question within each category for the rater to add observational notes. The Likert scale is a 1-point scale, where not observed is coded 0, not evident is coded 0, and evident is coded 1. Based on this coding with a total of 21 Likert-scale questions, the scale for The Math Big Observational Tool to assess whether or not a school falls into the category of research-based strategies is 0–21 points.

In addition, a rating of above average is 18 or more points, average is between 12 and 17 points, and below-average is less than 12 points. Based on the rubric used, Elementary School A was above average overall as a school in assessing Grades 2-5. Conversely, Elementary School B was below average overall as a school in assessing Grades 2-5. Furthermore, the observational notes for each of the open-ended questions strongly demonstrated that Elementary School A was attempting to implement research-based strategies in the classrooms throughout the building. The observational notes were not favorable for Elementary School B. There was no evidence from the leadership or that the teachers supported the research-based teaching strategies concepts**,** the director, noted.

Qualitative

I collected qualitative data from teacher lesson plans and interview responses. The frequency in which research-based instructional strategies were integrated into the sixty-minute mathematics block was determined from teacher lesson plans and interview responses. Teacher interview responses allowed data to be collected on the following interview questions: (a) how would you define learner-centered activities in mathematics? would you consider (hands-on activities, small group investigations, problem-solving tasks, classroom discourse, etc.) to be a learner-centered activity?; (b) please describe the learner-centered activities you are currently or have in the past implemented during your mathematics instruction?; (c) in what ways have these activities been successful?; (d) how often would you say your students engage in learner-centered activities?; (e) describe a typical math lesson in your classroom.; (f) in what ways do you think that incorporating learner-centered instructional strategies can impact student mathematical achievement?; (g) tell me your opinion about learner-centered activities in mathematics.; and (h) in your opinion, is it possible to have an effective mathematics classroom without the implementation of research-based instructional strategies?

The qualitative data I collected from teacher interviews was transcribed for a typological analysis and teacher lesson plans were analyzed utilizing the Lesson Plan Analysis Protocol (see Appendix D), which looked for Weimer's Learner-centered teaching practices. A typological analysis was used as I already knew the broad categories of interest within the data (Hatch, 2002). These broad categories were Weimer's learner-centered teaching principles: (a) engages students in the hard, messy work of learning; (b) includes explicit skill instruction; (c) encourages students to reflect on what they are learning and how they are learning it; (d) motivates students by giving them some control over learning processes; and (e) encourages collaboration. After identifying the typologies, participants' interview responses were reviewed and annotated as it related to the typologies. Next, entries by typology were read and main ideas were recorded on a summary sheet. Then, patterns and themes were looked for within typologies. Data coding entries were read according to the patterns and themes identified, and a record was kept of what entries go with which elements of the pattern. Next, a decision was made to determine if the patterns identified were supported by data and non-examples were searched. Relationships were looked for among the patterns. Then, one sentence generalizations of patterns were written. Finally, data excerpts were selected to support the generalizations.

Using the Lesson Plan Analysis Protocol (see Appendix D), I analyzed 5 weeks of teacher lesson plans to determine the frequency of Weimer's Learner-centered teaching practices. During the analysis, activities that exhibited students engaging in the hard, messy work of learning, participating in explicit skill instruction, reflecting about learning and the learning process, taking ownership of their learning, and collaborating with peers were looked for and recorded. Based on the frequency of implementation, the five learner-centered teaching practices would be identified as strengths or weaknesses. In addition, evidence from these plans would be used to support the themes developed from the interviews.

The validity and trustworthiness of both the quantitative data and the qualitative findings are sufficient as the questions used for the MI assessment have been studied over a period of several years and the qualitative themes found were triangulated across the three data sources. The integration of quantitative data and qualitative findings will enhance the results of the study as the qualitative findings will be used to support the quantitative results.

Assumptions

I made three assumptions for this study. First, I assumed that all second through fifth graders understood how to take the computerized MI assessment. The second assumption I made is that students will receive core mathematics instruction through research-based instructional strategies as indicated by teacher responses and lesson plans from teachers at Elementary School A. Lastly, I assumed that teachers would answer truthfully when interviews were conducted, and lessons plans submitted served as a truthful representation of what occurs in the classroom.

Limitations

One limitation of this study is attributed to the location. When making generalizations, results for this study are limited to suburban elementary students. A second limitation of this study is the selected sample. Student participants will be selected for this study according to their grade level (2^{nd}–5^{th}) and teacher participants will be selected based on the grade level (2^{nd}-5^{th}) they teach. The setting serves as a limitation as all data will be collected from only two school sites. A third limitation was the inability to collect MI data during the spring 2019-2020 school year due to COVID-19 mandatory school closures. If spring data were collected, a repeated-measures ANOVA could have been used, which would have provided additional statistical power and another three months of the treatment. Finally, researcher bias could arise as a potential limitation as personal interest could result in inaccurate quantitative and qualitative data interpretations.

Data Analysis Results

I used an explanatory sequential design mixed-methods approach to conduct this study. I collected quantitative data from the fall and winter administrations of the MI Assessment. I collected qualitative results from teacher interviews and lesson plans. The following subsections will identify and discuss both the quantitative and qualitative data results with a summary triangulating the data from all three sources.

Quantitative Results

I conducted a one-way between-subjects (treatment versus control) ANCOVA to investigate differences between groups, where the winter MI scores served as posttest scores for the dependent variable, and the fall MI scores served as pretest scores for the covariate variable. The quantitative results will be presented by grade level. There were four grade levels investigated within the treatment school and within the control school, grades 2-5. Given there were more than one statistical analysis conducted for the same research question, the Bonferroni method was used to determine the alpha level to avoid a type I error, falsely flagging a significant result (Armstrong, 2014). Because there were four analyses of covariance conducted, an alpha level of .01 was used to determine significance for each ANCOVA.

ANCOVA is a powerful inferential statistic to use only when the underlying assumptions are tenable. The following assumptions were conducted, and all were tenable for each of the grade levels investigated, (a) normality, (b) the covariate variable must be correlated with the dependent variable, (c) the within-group relationship between the dependent variable and covariate should be linearly related, and (d) the homogeneity of regression slope assumption is met. In addition to these four assumptions, independence of observations was met, and the homogeneity of variance was investigated and found to be tenable for each grade level. Prior to presenting the main ANCOVA findings, the statistical results for each of these assumptions will be presented in order. Finally, post-hoc procedures were unnecessary because the groups only had two levels, treatment and control.

Grade 2 Findings

In testing the normality assumption, the Kolmogorov-Smirnov (KS) test and P-P plots were used. The outcome variable was normally distributed ($p > .05$), also in reviewing the P-P plots, the normality assumption being tenable is supported (see Appendix E). The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .83$. Furthermore, the covariate, pretest math inventory scores, was significantly related to students' posttest math inventory scores, $F(1,136) = 306.37$, $p = .00$. Table 7 presents the ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,138) = 1.64$, $p = .20$. Table 8 shows the within-group regression slopes are equal, $F(1,136) = .00$, $p = .99$. Table 9 Levene's test showed that the assumption of equal variances was also met, $F(1,138) = .69$, $p = .42$. All of the assumptions were tenable, no violations were identified. Table 10 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. Table 11 presents the ANCOVA summary. The ANCOVA yielded a nonsignificant difference between group means, $F(1,137) = .43$, $p = .51$.

Table 7

Grade 2 Covariate Tests of Between-Subject Effects, One-Way ANOVA

Source	Sum of Squares	*df*	Mean Square	*F*	*P*
Group	24921.87	1	24921.87	1.64	.20
Error	2095680.11	138	15186.09		

Table 8

Grade 2 Within-Group Regression Slope

Source	Sum of Squares	*df*	Mean Square	*F*	*P*
Group	1603.28	1	1603.28	.30	.58
Pretest	1627292.32	1	1627292.32	306.37	.00
Group*Pretest	1.96	1	1.96	.00	.99
Error	722376.91	136	5311.60		

Table 9

Grade 2 Test of Homogeneity of Variance

Levene's Statistic	*df*1	*df*2	*p*
.69	1	138	.42

Table 10

Grade 2 Mean Pretest and Mean and Adjusted Mean Posttest Scores for Math Inventory Scores

				Posttest		
		Pretest		Obtained		Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	64	99.13	129.64	213.00	132.49	200.19
Control	76	72.34	117.58	181.25	128.79	192.04

Table 11

Grade 2 Analysis of Covariance Summary

Source	Sum of Squares	*DF*	Mean Square	*F*	*P*
Pretest	1627433.38	1	1627433.38	308.65	.00
Group	2279.53	1	2279.53	0.43	.51
Error	722378.88	137	5272.84		

Grade 3 Findings

In testing the normality assumption, the Kolmogorov-Smirnov (KS) test and P-P plots were used. The outcome variable was normally distributed ($p > .05$), also in reviewing the P-P plots, the normality assumption being tenable is supported (see Appendix E). The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .78$. Furthermore, the covariate, pretest math inventory scores, was significantly related to students' posttest math inventory scores, $F(1,128) = 204.31$, $p = .00$. Table 12 presents the ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,130) = 1.38$, $p = .24$. Table 13 shows the within-group regression slopes are equal, $F(1,128) = .05$, $p = .82$. Table 14 Levene's test showed that the assumption of equal variances was also met, $F(1,130) = .19$, $p = .67$. All of the assumptions were tenable, no violations were identified. Table 15 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. Table 16 presents the ANCOVA summary. The ANCOVA yielded a nonsignificant difference between group means, $F(1,129) = .24$, $p = .63$.

Table 12

Grade 3 Covariate Tests of Between-Subjects Effects, One-Way ANOVA

Source	Sum of Squares	*df*	Mean Square	*F*	*P*
Group	24821.79	1	24821.79	1.38	0.24
Error	2333597.85	130	17950.75		

Table 13

Grade 3 Within-Group Regression Slope

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Group	17.35	1	17.35	0.00	0.97
Pretest	1840236.97	1	1840236.97	204.31	0.00
Group*Pretest	462.17	1	462.17	0.05	0.82
Error	1152920.71	128	9007.19		

Table 14

Grade 3 Test of Homogeneity of Variance

Levene's Statistic	*df*1	*df*2	*p*
.19	1	130	.67

Table 15

Grade 3 Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

				Posttest		
		Pretest		Obtained		Adjusted
Group	*N*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	64	249.95	141.75	335.64	154.81	323.06
Control	68	222.51	126.24	319.34	149.23	331.18

Table 16

Grade 3 Analysis of Covariance Summary

Source	Sum of Squares	*DF*	Mean Square	*F*	*p*
Pretest	1848619.08	1	1848619.08	206.76	0.00
Group	2150.41	1	2150.41	0.24	0.63
Error	1153382.88	129	8940.95		

Grade 4 Findings

In testing the normality assumption, the Kolmogorov-Smirnov (KS) test and P-P plots were used. The outcome variable was normally distributed ($p > .05$), also in reviewing the P-P plots, the normality assumption being tenable is supported (see Appendix E). The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .79$. Furthermore, the covariate, pretest math inventory scores, was significantly related to students' posttest math inventory scores, $F(1,134) = 215.68$, $p = .00$. Table 17 presents the ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,136) = 2.80$, $p = .10$. Table 18 shows the within-group regression slopes are equal, $F(1,134) = .11$, $p = .74$. Table 19 Levene's test showed that the assumption of equal variances was also met, $F(1,136) = .28$, $p = .60$. All of the assumptions were tenable, no violations were identified. Table 20 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. Table 21 presents the ANCOVA summary. The ANCOVA yielded a nonsignificant difference between group means, $F(1,135) = 1.27$, $p = .26$.

Table 17

Grade 4 Covariate Tests of Between-Subjects Effects, One-Way ANOVA

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Group	68721.53	1	68721.53	2.80	0.10
Error	3337757.34	136	24542.33		

Table 18

Grade 4 Within-Group Regression Slope

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Group	6625.08	1	6625.08	0.57	0.45
Pretest	2507289.36	1	2507289.36	215.68	0.00
Group*Pretest	1270.50	1	1270.50	0.11	0.74
Error	1557729.81	134	11624.85		

Table 19

Grade 4 Test of Homogeneity of Variance

Levene's Statistic	*df*1	*df*2	*p*
.28	1	136	.60

Table 20

Grade 4 Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

				Posttest		
		Pretest		Obtained		Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	68	370.25	143.58	441.21	172.61	421.36
Control	70	325.61	168.39	422.91	175.57	442.19

Table 21

Grade 4 Analysis of Covariance Summary

Source	Sum of Squares	*DF*	Mean Square	*F*	*p*
Pretest	2564048.30	1	2564048.30	222.03	0.00
Group	14664.31	1	14664.31	1.27	0.26
Error	1559000.30	135	11548.15		

Grade 5 Findings

In testing the normality assumption, the Kolmogorov-Smirnov (KS) test and P-P plots were used. The outcome variable was normally distributed ($p > .05$), also in reviewing the P-P plots, the normality assumption being tenable is supported (see

Appendix E). The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .72$. Furthermore, the covariate, pretest math inventory scores, was significantly related to students' posttest math inventory scores, $F(1,124) = 144.94$, $p = .00$. Table 22 presents the ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,126) = .17$, $p = .68$. Table 23 shows the within-group regression slopes are equal, $F(1,124) = 3.23$, $p = .08$. Table 24 Levene's test showed that the assumption of equal variances was also met, $F(1,126) = .03$, $p = .86$. All of the assumptions were tenable, no violations were identified. Table 25 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. Table 26 presents the ANCOVA summary. The ANCOVA yielded a non-significant difference between group means when using the Bonferroni alpha adjustment, $F(1,125) = 4.76$, $p = .03$.

Table 22

Grade 5 Covariate Tests of Between-Subjects Effects, One-Way ANOVA

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Group	3049.86	1	3049.86	0.17	0.68
Error	2297580.15	126	18234.76		

Table 23

Grade 5 Within-Group Regression Slope

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Group	12757.62	1	12757.62	1.24	0.27
Pretest	1487694.79	1	1487694.79	144.94	0.00
Group*Pretest	33169.85	1	33169.85	3.23	0.08
Error	1272748.02	124	10264.10		

Table 24

Grade 5 Test of Homogeneity of Variance

Levene's Statistic	*df*1	*df*2	*p*
.03	1	126	.86

Table 25

Grade 5 Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

		Pretest		Posttest Obtained		Posttest Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	62	468.16	135.41	528.60	137.61	524.53
Control	66	458.39	134.69	560.18	159.39	564.01

Table 26

Grade 5 Analysis of Covariance Summary

Source	Sum of Squares	*DF*	Mean Square	*F*	*p*
Pretest	1500510.87	1	1500510.87	143.63	0.00
Group	49758.63	1	49758.63	4.76	0.03
Error	1305917.87	125	10447.34		

Qualitative Results

I collected qualitative data from two sources, teacher interview responses and lesson plans. A total of three teachers participated in the interview phase of the study. During the interviews, teachers were asked to respond to the following questions: (a) how would you define learner-centered activities in mathematics? would you consider (hands-on activities, small group investigations, problem-solving tasks, classroom discourse, etc.) to be a learner-centered activity?; (b) please describe the learner-centered activities you are currently or have in the past implemented during your mathematics instruction?; (c) in what ways have these activities been successful?; (d) how often would you say your students engage in learner-centered activities?; (e) describe a typical math lesson in your classroom.; (f) in what ways do you think that incorporating learner-centered instructional strategies can impact student mathematical achievement?, (g) tell me your opinion about learner-centered activities in mathematics.; and (h) in your opinion, is it possible to have an effective mathematics classroom without the implementation of research-based instructional strategies?

In addition, I collected lesson plans from the three teachers who participated in the interviews for five weeks. A typological analysis of teacher lesson plans and teachers' perspectives through interviews occurred to explore the ways in which teachers were implementing research-based instructional strategies at Elementary School A. This type of analysis was used as I already knew the broad categories of interest within the data (Hatch, 2002). These broad categories were Weimer's learner-centered teaching principles: (a) engages students in the hard, messy work of learning; (b) includes explicit skill instruction; (c) encourages students to reflect on what they are learning and how they are learning it; (d) motivates students by giving them some control over learning processes; and (e) encourages collaboration. See the previous section, *Qualitative Data Collection and Analysis* to understand the process used to analyze the data.

As a result of the analysis, several patterns emerged. Patterns recorded during the interview analysis included: (a) students being hands-on in their learning, (b) students engaging in learner-centered activities, (c) students thinking through problems, (d) students participating in math centers to delve deeper into learning, (e) students learning to be responsible for their learning process, (f) students engaging in collaborative learning to work together and solve problems, (g) students improved mathematical achievement through the implementation of learner-centered instructional strategies, and (h) the inability to have an effective mathematics classroom without the implementation of these strategies. Table 27 displays the frequency in which the interview responses supported the patterns identified. Patterns recorded during the analysis of lesson plans when looking for the frequency in which Weimer's Learner-Centered Teaching practices were evident resulted in these practices being categorized as either strengths or weaknesses.

I categorized the data based on the teaching practice being evident across the lesson plans at least 80% of the time. The strengths were engaging students in the hard messy work of learning, motivating students by giving them some control over the learning process, and encouraging collaboration. The weaknesses were explicit skill instruction and encouraged students to reflect on what they are learning and how they are learning it. Table 28 displays the frequency of Weimer's learner-centered teaching practices across the 15 weeks of lesson plans (5 weeks of lesson plans per teacher).

Based on the patterns I recorded during the analysis of teacher interviews and lesson plans the following themes were established: (a) student ownership of learning, (b) students engaging in learner-centered activities, (c) students engaging in collaborative learning and (d) lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interview responses, however, there was a lack of evidence to support this theme utilizing teacher lesson plans. The subsections that follow will explore the themes through the lens of the data.

Table 27

Pattern Frequency in Teacher Interview Responses

Pattern	Frequency
Hands-on in their learning	5
Engaging in learner-centered activities	9
Thinking through problems	4
Participating in math centers to delve deeper into learning	3
Learning to be responsible for their learning process	5
Engaging in collaborative learning to work together and solve problems	5
Improved mathematical achievement through the implementation of learner-centered instructional strategies	5
Inability to have an effective mathematics classroom without the implementation of learner-centered activities	3

Table 28

Frequency of Weimer's Learner-Centered Teaching Principles in Teacher Lesson Plans

Teaching Principle	Frequency	Percentage
Engages students in the hard, messy work of learning	13 out of 15	86.67%
Includes explicit skill instruction	10 out of 15	66.67%
Encourages students to reflect on what they are learning and how they are learning it	8 out of 15	53.33%
Motivated students by giving them some control over the learning processes	15 out of 15	100%
Encourages collaboration	14 out of 15	93.33%

Student Ownership of Learning

Motivating students by giving them some control over the learning process is the fourth learner-centered principle identified by Weimer, and one of the recurring themes found during the qualitative analysis. During the interview analysis, there were ten instances where participants indicated that learner-centered activities allowed the learner to be responsible for his/her learning as well as the learning process and were hands-on in their learning. Five of these instances will be provided in the sentences that follow. As a response to Interview Question 1 (IQ1), Teacher D stated, "Learner-centered activities enable a student to be in control of their learning." In addition to Teacher D's response to IQ1, Teacher F stated, "I would define learner-center activities as activities that make the learner responsible for his/her own learning." In response to Interview Question 7 (IQ7), Teacher E stated, "learner-centered activities are essential in the classroom, so every student has the opportunity to grow their weakness." Teacher F's response to IQ7 stated, "learner-centered activities are a means to help students succeed without the teacher having to prompt and give answer." Finally in response to Interview Question 2 (IQ2), Teacher D stated, "Students were … asked to show representation of their thinking while solving a problem. They could use a drawing, equal groups, or an array to show their answer."

During the analysis of lesson plans, I determined that 15 out of 15 weeks of teacher lesson plans demonstrated Weimer's learner-centered teaching practice of motivating students by giving them some control over the learning process. This determination was based on the experiences/activities teachers outlined for their students to engage in during the learning process. Underlined sections in Figures 1–6 show the activities that teachers planned for students to take ownership of their learning.

Figure 1

Teacher D Lesson Plan, Example 1

Learning Experience	**Warm-Up Activity:** **Problem of the Day / Number Talk** **Initiate:** • Explain to students what Fermi problems are and how they never have exact answers. • Share an example of a Fermi problem: "How many raisins will fit into a one-liter bottle?" • Generate questions that need to be answered before they can tackle the main Fermi problem. • Ask students to decide on the size of the raisin. Also have them investigate the number of cubic centimeters in a liter. (may include some research on the internet) • Discuss students' solutions to the problem. **Investigate:** • Have students turn to **Student Activity: "Fermi Problems" pp. 38 –Student Mathematician's Journal** • Students will pair up and discuss how they might proceed with answering the Fermi problem. • Teacher: remind the students of the four steps to solving a Fermi problem: 1. make an initial estimate, 2. generate a list of questions that they need to answer first, 3. investigate some of these new questions by gathering data and experimenting, and 4. use calculations to come up with an approximate answer.

Figure 2

Teacher D Lesson Plan, Example 2

Learning Experience	**Student Activity:** *Refer to the TE, pgs. 67-82.* **Initiate**: • "SARAHSARAHSA" –Write this on the board. • Ask the students the following questions: ~What are the next five letters that Sarah would write? Explain your answer ~What would the 18th letter be if Sarah continues this pattern? Explain your answer **Investigate :** Students will explore repeating patterns and learn to generalize a rule for determining the element in any given position of the pattern. Students will engage in "The Name Game" –pg.5 of the Student Mathematician's Journal. Students will work independently and then the teacher will split them into pairs to discuss their answers ("Conga line"). **Mathematical Communication:-Part 1** Discuss the Think Deeply question as a class.
Differentiation	Pair students, this will encourage them to think and act as practicing mathematicians and take responsibility for their own learning.

Figure 3

Teacher E Lesson Plan, Example 1

Learning Experience	**Problem of the Day** **Initiate:** • **Mini-lesson:** Gridlock: locate and plot ordered pairs on a graph • Discuss Graph 1 (journal page 21) to Graph C (page 13) *comparisons: same variables, line moves upwards from left to right, distance from starting point increases *differences: starting point • What is the x-coordinate of Graph 1? • How do the y-coordinates compare? (Graph 1 is greater) • What does the graph show? (person's a given distance from starting point; cheating) • Y-intercept: point where graph intersects/crosses y-axis • Discuss Graph 2: line one is steep and increasing distance over time; line two is horizontal indicating no change in distance over time (break); line three is increasing distance over time but gradually (person slowing down) *How does the first line segment differ from the third one? *What might this indicate in the situation? *What do you notice about the second line segment? *What might this indicate in the situation? • Discuss Graph 3: opposite of Graph C; person is far from finish line; greater y-intercept; person moves closer to finish line so distance is 0 *What graph is the opposite? *What are the variables on Graph 3? *What might this indicate in the situation? **Investigate:** • Analyze the graphs on journal pages 23-25 with a partner *name the variables and interpret the relationships between them (describe the change) **Mathematical Communication:** • Think Deeply pages 27 and 29

Figure 4

Teacher E Lesson Plan, Example 2

Learning Experience	**The Teacher Will:** Introduce "Problem of the Day: (Whole Group). Elicit a student to read the problem aloud. Ask 1-2 volunteers to retell the problem in their own words. Have student to think about how they will solve the problem. Then have students solve the problem independently, with a partner, or in small group. TW: Monitor the group, asking guided questions, and look for examples to share. Invite students to share what they think the answer is, how they got their answer, and how they know their answer is correct. • Explain goals and objectives for the day • Review Small Group Center Procedures for **Math Workshop** • Have students turn in their Student Mathematical Journal to "A Penny Saved: Comparing Records and Rates of Change." Introduce "Predicting Penny Records." p. 217 Teacher's manual. **Student Journal page 61** • Then give students a scenario to solve. **Tell student to think like mathematicians and predict what the graph for this scenario would look like. (Activity only for students who already reached 100% mastery on grade-level district benchmark assessments.) Other students will be working on assigned tasks in various centers.** • **Send students out to their assigned rotating centers to complete assignments.** • **Early Finishers: p. 61 and 62 Student Journal** Questions students are to respond to: • What are the dependent and independent variable? • Which variable will be graphed on the x-axis? • Which variable will be graphed on the y-axis? • Will the graph start at the origin? • Will the points on the graph lie on the same line? • Did we break a record? Explain **Investigate:** Have students turn in their Student Mathematician's Journals to review assignment "A Penny Saved." Have students work individually, with a partner, or small group to complete the task Provide Hint Cards, Think Beyond as need by students

Figure 5

Teacher F Lesson Plan, Example 1

Learning Experience	**Warm-up Review:** **Target Practice:** In the target below, 10 is the bulls eye sum. You need to add two numbers to equal 10. The numbers in the outside of the target have been filled in for you. You need to write the number that must be added to each other number in order to make it equal 10.  *Dreambox: 15 minutes **Teacher**: 1. Students will observe multiplication patterns. 2. List the multiplication table for the 9's times table. 3. Have students Turn/Talk and discuss the pattern they notice. 4. Write the 10 times table on the board and do the same thing 5. Investigate multiplication patterns in the Student Math Journal, pp 35-37. 6. Ask students to turn to "Multiplication Patterns" in their Student Mathematician's Journals on pp. 35–37. These pages introduce students to two interesting multiplication patterns. They will practice applying the multiplication algorithm and they will read and write "big" numbers. 7. In an expression where no parentheses are present, multiplications and divisions are performed before additions and subtractions. The multiplications and divisions are performed in the order they occur, and then the additions and subtractions are performed in the order they occur. Thus, in solving 1,234 × 8 + 4 or 4 + 1,234 × 8, you multiply 1,234 by 8 **before** adding 4. So, the answer is 9,876 to both problems. **Students:** 8. Once students have completed the calculations, bring the group together to discuss how to read these numbers. **Investigate:** 9. T. E, p.165 to model two problems. Before having students work independently on "Multiplication Puzzles" on pp. 39–40 in their Student Mathematician's Journal, it is recommended that you work through the first two puzzles as a class or in small groups.

Figure 6

Teacher F Lesson Plan, Example 2

Learning Experience	**A. Number Talk: Review the Hand Signals** • Students will refer to The Student Math Journal Book, located in TEAMS. • They will read the word problem on p. 11. (Janet's little brother thinks 99,999 is bigger than 100,000. He says it has five 9's and 100,000 only has 1 and some zeros which are a lot smaller than 9. How should Janet respond to him?) • The students will solve the problem individually and then present their responses to the group. The teacher will emphasize hand signals as students provide responses. Math Lesson: Big Idea: Students are introduced to big numbers up to 1 million by learning periods, place value, and expanded notation. Teacher: 1. Teacher asks do you ever wonder about big numbers. What do you think about? 2. Tell students that we are going to begin our study of big numbers by thinking about the size of one million. We often talk about a million as being really large, but we never think about how many objects are represented by the number 1,000,000. 3. Next, have students turn to "Starry, Starry Night" on p. 5 in their Student Mathematician's Journal. Each student first makes a prediction of how many stars are shown in this photo taken by the Hubble telescope. Refer to SMJ in TEAMS, show students how to get there. 4. Have students think of a plan to estimate how many stars in the picture. 5. Ask how many groups think there will be more than 100 stars in the photo? More than 1,000? More than 10,000? Have students compare the approximate count to their prediction. 6. The Teacher will then model how to read and write large numbers using a Document Camera. 7. Write 342,681 on the board. This number is read "three hundred forty-two thousand, six hundred eighty-one. 8. Tell students that to help us read large numbers, we separate the number into periods. This is a new vocabulary word. Discuss the term periods and provide an example of this in a chart for students to copy to their notebooks. (Use Anchor Charts that will be created as we go along.) 9. Show various problems using display board (model how to write the word name, standard form and expanded notation). Use sticky notes to display problems as well. Independent Practice 1. Student Math Journal, Practice p. 7 will be independent practice. 2. Check for understanding. Students are to write their answers in their Math Notebooks. Follow-up: Homework will be SMJ p. 8.

Students Engaging in Learner-Centered Activities

Students engaging in learner-centered activities is the second recurring theme that emerged from analyzing the qualitative data. This recurring theme correlated with Weimer's learner-centered teaching practice of engaging students in the hard, messy learning process. Several patterns presented in Table 27 fall under this category. These patterns included students being hands-on in their learning, students engaging in learner-centered activities, students thinking through problems, and students participating in math centers to delve deeper into learning. Each of these patterns received the following frequencies respectively, 5, 9, 4, and 3.

Several of the teacher interview responses are shared in the sentences that follow. In response to IQ2, Teacher D states, "They were also asked to turn their division equation into a multiplication equation to check their work." In response to IQ7, Teacher D states, "In my opinion, learner-centered activities are needed and important to students obtaining the full understanding of the concept." Two instances where Teacher E's responses supported this theme are, "After the mini-lesson, students engage in learner-centered activities (Interview Question 5)," and "Learner-centered activities take place at least three-four days out of the week (Interview Question 4)." There were two responses from Teacher F as stated, "I use Math Centers in my classroom that guides students through different approaches to the topic that we are working on in class (IQ2);" and "These activities have been successful at helping students learn to persevere and think through problems (Interview Question 3). These were all statements supporting the theme of students engaging in learner-centered activities

During the lesson plan analysis, I determined that 13 out of 15 weeks of teacher lesson plans demonstrated Weimer's Learner-Centered Teaching practice of engages students in the hard, messy work of learning. This determination was based on the experiences/activities teachers outlined for their students to engage in during the learning process. Underlined sections in Figures 7–12 show the activities that teachers planned for students to engage in the hard, messy work of learning.

Figure 7

Teacher D Lesson Plan, Example 1

Learning Experience	**Warm-Up Activity:** **Online Resource: Points on a number line for about 10 minutes. (Focus on Whole Numbers and Big Numbers Activity Menu).** **Investigate: T.E. p.166** Students will work to solve multiplication puzzles that will require them to make use of their understanding of facts, place value, and the structure of the multiplication algorithm. ~The teacher will work through the first two puzzles as a class. ("Multiplication Puzzles" pp. 39-40 –Student Mathematician's Journal). ~Refer to the teacher guide for questions that will help students to focus in on the mathematical relationships of the puzzles. **Student Activity: "Multiplication Puzzles" pp. 39-40 –Student Mathematician's Journal** ~After modeling and when the teacher feels the students have a good grasp of how to approach these problems, have them work on the other problems on the "Multiplication Puzzles: worksheet in their student journals. **Lesson Discussion:** 1. Have students share strategies for solving the multiplication puzzles, which should include their thinking about the relationship of the numbers in the puzzles. **Mathematical Communication, T.E, p. 168** 1. Guide students through Think Deeply in their Student Math Journal, p. 41.
Differentiation	• Math Messaging Board, Think Beyond Cards
Closure	Using strategies based on place value, rounding, and the properties of operations helps develop computational fluency. Creating and ordering numbers on a number line helps students understand the size of numbers and make comparisons.
Reflections	I have extended my understanding of place value to 100,000 and I can create and order larger numbers on a number line. (Numbers to 100,000).

Figure 8

Teacher D Lesson Plan, Example 2

Learning Experience	**Problem of the Day** **Number Talk:** How many triangles do you see? **Investigate:** • What digits might go in the squares in #2? How might we start? • What digit could go in the square in the ones place so the product will have a "4" in the ones place? *list multiples of 6 (6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72) *could be 9 or 4 • Multiply with the 9 in the square first. *What digit might go in the tens place + 5 that ends in zero? (impossible) • Multiply with the 4 in the square. *What digit might go in the tens place + 2 that ends in zero? (3 and 8) *Which digit gives 2304 as the answer? *Why start solving these problems by first considering the digit(s) in the ones place(s) instead of jumping to the tens or hundreds place? *What strategies do you use to narrow down possible digits? • Complete #4 and #6 journal pages 39-40 with a partner. **Mathematical Communication:** • Think Deeply journal pages 41-44

Figure 9

Teacher E Lesson Plan, Example 1

Learning Experience	**Problem of the Day** **Teacher:** • Introduce Problem of the Day. Allow time for students to solve individually or with a partner. Review problem in whole group • Review Learning Targets **Mini Lesson: Whole Group –Community Rug Area** • Mathematicians make sense of problems and persevere in solving them. They never give up! • After mini lesson is taught, give students a problem to solve while on the run in group time. • Give students an opportunity to persevere through the problem. • Allow them to "Turn and Talk" to a partner and explain how they got they **"persevered"** during the problem. • Review math **Vocabulary** –"Getting Into Shapes" **Parallel lines, Parallelogram, perpendicular lines, polygon, quadrilateral, rectangle, rhombus, right angle, simple shape** Student will represent each shape in their math journal and share everything they know about each of the shapes during partner talk. • **Lesson One: You Either Have It---Or You Don't** Mathematician's Journal Worksheet will be completed as Whole Class. List characteristics on Anchor Chart as students discuss them. After students have finished, have them turn to **"Our Class Definition"** their Mathematician's Journal and write a sentence definition for the first shape. Then compare their definition with the one listed in the glossary. Repeat each example on the Worksheet. Assign, discuss and reflect the two Think Deeply questions. These questions will be used to assess students' understanding of the concepts presented in the lesson

Figure 10

Teacher E Lesson Plan, Example 2

Problem of the Day

Initiate:

- **Mini Lesson: (How Multiplication and division are related to division)** Using the Smartboard, easel, or Chart Paper, the teacher will invite a student to demonstrate model for the class. The teacher will model for students as well
- In whole group, review basic multiplication and division facts by writing the following on the board and asking students to group them. (Example), 4x6, 36 divided by 9, 5x9, 24 divided by 6, 45 divided by 9, 9x4). **(Students may categorize, or group these by putting multiplication expressions in one group and the division expressions into another group)**
- Invite students to explain a method of grouping, and discuss what multiplication basic facts are, as well as division basic facts.
- Explain: **Multiplication some basic facts**
  Division basic facts are the inverse of the multiplication basic facts that are formed using the digits 0-9 as factors. Example: **6x7=42** is a **multiplication basic fact, and 42 divided by 6= 7, and 42:7=6 –These are all corresponding division facts**
- Review with students the largest division basic fact: **(81 divided by 9 =9)**
- **Invite students to generate examples of some other division facts: (32 divided by 4= 8) (27 divided by 3= 9), (64 divided by 8 =8), (27 divided by 3=9), (64 divided by 8= 8) (28 divided 7=) , 35 divided by 5=7), 63 divided by 9= 7) (48 divided by 6 = 8)**
- Guide the discussion to helps students realize that the basic division facts are the inverse of the multiplication basic facts that are formed using digits 0 through 9 as factors
- Review with students the largest division basic facts (81 divided by 9= 9)
- Invite students to share different ways fact families are grouped. Then create fact family for **8, 9, 72**

Investigate:

- Students will work as partners and/or small groups to complete the following pages in their Mathematician's Journal (page 49, 51, 53) "**Factors, Multiples and Leftovers"**

Mathematical Communication:

- Think Deeply page 55 Student Mathematician's Journal "**Factors, Multiples and Leftovers"**

Figure 11

Teacher F Lesson Plan, Example 1

Learning Experience	**Warm Up Review: 3.NSBT.5 SC Ready Practice** Amir is filling a garden with dirt using a bucket. 1 One bucket of dirt fills of the garden. 10 8 So far, he has filled of the garden with dirt. 10 How many buckets of dirt has Amir put into the garden so far? A. 1 10 B. 8 10 C. 1 D. 8 **Teacher**: 1. Review for the Unit Check-up 1. T.E., pp.137-138. 2. Administer Unit I Check Up (See Answer Key, T.E., p.139). **Investigate: Palindromes T.E, p.143-146.** 1. Start lesson by introducing the term palindrome, and ask if anyone knows the meaning. 2. Provide the following examples: "Have students turn and Talk to discuss the following problems. (dad and 19,391) 3. Have students work with a partner to generate three words or phrases that are palindromes. 4. Create an Anchor Chart with students and have them come up and list their findings on the chart paper. 5. Explore Numerical palindromes, T.E, p. 145. Discuss examples. **Student Activity:** **6.** Have the students create their own two-digit number and see how many steps it takes to form their palindromes. **7.** Display student palindromes.
Differentiation	Partner modeling of palindrome.
Closure	Math Journal, students record the meaning of a palindrome and provide 1 word and 1 mathematical palindrome.

Figure 12

Teacher F Lesson Plan, Example 2

Learning Experience	**Warm-up:** **Number Talk: Number Talk Removal or Counting Backwards: 21-6 21-1+5, 20-5=15 and 65-32= 65-30=35 35-2=33** ***Dreambox: 15 minutes** Teacher: 1. Introduce new vocabulary to students, T.E, p. 126. 2. Have students create Two Column Notes for the vocabulary terms which are located in the back of their Student Math Journal Books. Student Activity: 1. Lead students into investigating arrays. T.E.,p.126, in order to understand the associative, commutative and distributive properties of multiplication. 2. Have students use square tiles to model the array 4X6. 3. Direct students to break the array into two 2 × 6 arrays, and ask them how they might use the new arrays to find the product for 4 × 6. 4. Next, direct students to break the 4 × 6 array into a 4 × 5 array and a 4 × 1 array. Have them compare the sum of these products to the original. 5. Ask students to find several other combinations of arrays that also can be combined to make the 4 × 6 array. Ask them, "What do all of these arrays have in common?" and "How do these combined arrays compare to the 6 × 4 array? 6. Repeat this for other multiplication fact arrays and encourage students to break these down in a variety of ways. Students should compare their different strategies with a partner and with others in small groups. Next, students should share answers as a whole group. 7. Ask students to talk about tips for learning basic combinations and to write these down on the "Multiplying Magician" worksheet. Student Math Journal, p. 43. 8. After students have discussed a number of patterns and have created a number of arrays, ask them to complete "The Arrays Have It," "The Arrays Have It Part II," and "The Arrays Have It Part III" worksheets in the Student Mathematician's Journal to apply what they have learned. Student Math Journal, p. 37 and 39.
Differentiation	Have students use multiplication charts if they struggle with their basic facts.
Closure	Have students solve problems using manipulatives to review basic division facts

Students Engaging in Collaborative Learning

The third recurring theme that resulted from the qualitative analysis of teacher interviews and lesson plans was students engaging in collaborative learning. Students engaging in collaborative learning correlated with encourages collaboration, Weimer's fifth learner-centered teaching practice. During the interview analysis, there were eight instances where participants indicated that learner-centered activities allowed the students to engage in collaborative learning to work together and solve problems and participate in math centers to delve deeper into learning. The frequency of teacher interview responses relating to this theme were 5 and 3, respectively. Examples of these instances will be provided in the sentences that follow. In response to IQs 2, 3, and 4, Teacher D stated, "Students were split into groups of 4 and asked to show representation of their thinking while solving the problem;" "Students were able to become teachers for not only themselves, but others; They had to collaborate with one another and correct each other's errors;" and "We then solve problems together in groups." In response to IQ2, Teacher E stated, "Students are divided into groups in order to work on skills learned in the classroom." In response to IQ2, Teacher F stated, "I use Math Centers in my classroom that guides students through different approaches to the topic that we are working on in class."

During the lesson plan analysis, I determined that 14 out of 15 weeks of teacher lesson plans demonstrated Weimer's learner-centered teaching practice of encourages collaboration. This determination was based on the experiences/activities teachers outlined for their students to engage in during the learning process. Underlined sections in Figures 13–18 show the activities that teachers planned for students to engage in collaborative learning.

Figure 13

Teacher D Lesson Plan, Example 1

Learning Experience	**Warm-Up Activity:** **Online Resource: Points on a number line for about 10 minutes. (Focus on Whole Numbers and Big Numbers Activity Menu).** **Investigate: T.E. p.166** Students will work to solve multiplication puzzles that will require them to make use of their understanding of facts, place value, and the structure of the multiplication algorithm. ~The teacher will work through the first two puzzles as a class. ("Multiplication Puzzles" pp. 39-40 –Student Mathematician's Journal). ~Refer to the teacher guide for questions that will help students to focus in on the mathematical relationships of the puzzles. **Student Activity: "Multiplication Puzzles" pp. 39-40 –Student Mathematician's Journal** ~After modeling and when the teacher feels the students have a good grasp of how to approach these problems, have them work on the other problems on the "Multiplication Puzzles: worksheet in their student journals. **Lesson Discussion:** **1.** Have students share strategies for solving the multiplication puzzles, which should include their thinking about the relationship of the numbers in the puzzles. **Mathematical Communication, T.E, p. 168** 1. Guide students through Think Deeply in their Student Math Journal, p. 41.

Figure 14

Teacher D Lesson Plan, Example 2

Learning Experience	**Warm-Up Activity:** **Problem of the Day / Number Talk** **Initiate:** • Explain to students what Fermi problems are and how they never have exact answers. • Share an example of a Fermi problem: "How many raisins will fit into a one-liter bottle?" • Generate questions that need to be answered before they can tackle the main Fermi problem. • Ask students to decide on the size of the raisin. Also have them investigate the number of cubic centimeters in a liter. (may include some research on the internet) • Discuss students' solutions to the problem. **Investigate:** • Have students turn to **Student Activity: "Fermi Problems" pp. 38 –Student Mathematician's Journal** • Students will pair up and discuss how they might proceed with answering the Fermi problem. • Teacher: remind the students of the four steps to solving a Fermi problem: 1. make an initial estimate, 2. generate a list of questions that they need to answer first, 3. investigate some of these new questions by gathering data and experimenting, and 4. use calculations to come up with an approximate answer.
Differentiation	Think Beyond Cards, Hint Cards, Grouping
Closure	Have students discuss their problems and thinking and/or solutions with the whole class.

Figure 15

Teacher E Lesson Plan, Example 1

Learning Experience

Mini Lesson: Whole Group –Community Rug Area

- Mathematicians make sense of problems and persevere in solving them. They never give up!
- After mini lesson is taught, give students a problem to solve while on the run in group time.
- Give students an opportunity to persevere through the problem.
- Allow them to "Turn and Talk" to a partner and explain how they got they **"persevered"** during the problem.
- Review math **Vocabulary** –"Getting Into Shapes" **Parallel lines, Parallelogram, perpendicular lines, polygon, quadrilateral, rectangle, rhombus, right angle, simple shape** Student will represent each shape in their math journal and share everything they know about each of the shapes during partner talk.
- **Lesson One: You Either Have It---Or You Don't** Mathematician's Journal Worksheet will be completed as Whole Class. List characteristics on Anchor Chart as students discuss them. After students have finished, have them turn to **"Our Class Definition"** their Mathematician's Journal and write a sentence definition for the first shape. Then compare their definition with the one listed in the glossary. Repeat each example on the Worksheet.

Assign, discuss and reflect the two Think Deeply questions. These questions will be used to assess students' understanding of the concepts presented in the lesson

Collaborative Math Work Stations

Center 1	Center 2
Technology- Math Practice	**Study .com Math Review**
Center 3	**Center 4**
Math Games: **Logics** **"Getting Into Shapes" M3 Math Project –F**	**Teacher conference/ Small Group**

Figure 16

Teacher E Lesson Plan, Example 2

Learning Experience	The Teacher Will: • Review basic order of operation: Review with whole group that in an expression where no parentheses are present, the multiplication and division problems are performed before the addition and subtraction. The multiplications and divisions are performed in the order they occur. For example, in solving 1,234 X 8+4 or 4+ 1,234 X 8, you multiply 1,234 X 8 **BEFORE ADDIDING** 4. **The answer to 1,234 X 8+4 is 9,876**. Also, in the problem: 4+ 1,234 X 8- **The answer is still The answer to 1,234 X 8+4 is 9,876** • Have students turn to "Multiplication Patterns" in their Student Mathematician's Journal on pap. 35-37. Have students work in small group or with pa partner on determining the products of the first multiplication pattern using hand calculators. **Page 35-7 Student textbook** • Once students have completed the calculations, bring the group together to discuss how to read these numbers • Review Place Values from **Chapter 1, Lesson 1**. **Review Lesson**: Essential Question: Is **99,999** bigger that **1000,000**? Explain how you know. Students may use their white boards to help explain their thinking. **Answer**: 100,000 is bigger. It has **6 digits**. 99, 000 only has **5 digits. The 1 in 100,000 means One Hundred Thousand.** There are **No Hundred Thousand** in 99,999. There are One Hundred Thousands 1's in 1000,000 and One Less I's in 99,999 Use Base ten blocks • Have students explain what they know to others in the group. If time permits, we will go to **Investigate 1: Multiplication Puzzles Page 39-40 Student Mathematician's Journal** The main part of this investigation lesson focuses on solving multiplication puzzles. These puzzles require students to reason deeply about the effects of multiplying by specific digits on the partial product (partial answer), 2 5 X 7☐ 2 00 175 **Teacher:** Before asking students to find the value of the square, ask the follow questions: 1. What do you know must be true about the square? ☐ **Possible Responses**: • Must be a single digit (**0-9**) • The digit that multiplies by 5 must have a product that ends in zero 2. Ask students to work with a partner or small group to find the value of the ☐ as well as find the answer to the multiplication problem **3.** After students have worked on the problem, teacher will ask: ***What is the product? How did you determine the value of*** ☐ **4.** Teacher will review answers ***5. Students will try Problems 2***

Figure 17

Teacher F Lesson Plan, Example 1

Learning Experience	**Warm Up Review: 3.NSBT.5 SC Ready Practice** Amir is filling a garden with dirt using a bucket. 1 One bucket of dirt fills of the garden. 10 8 So far, he has filled of the garden with dirt. 10 How many buckets of dirt has Amir put into the garden so far? A. 1 10 B. 8 10 C. 1 D. 8 **Teacher**: 1. Review for the Unit Check-up 1. T.E., pp.137-138. 2. Administer Unit I Check Up (See Answer Key, T.E., p.139). **Investigate: Palindromes T.E, p.143-146.** 1. Start lesson by introducing the term palindrome, and ask if anyone knows the meaning. 2. Provide the following examples: "Have students turn and Talk to discuss the following problems. (dad and 19,391) 3. Have students work with a partner to generate three words or phrases that are palindromes. 4. Create an Anchor Chart with students and have them come up and list their findings on the chart paper. 5. Explore Numerical palindromes, T.E, p. 145. Discuss examples. **Student Activity:** **6.** Have the students create their own two-digit number and see how many steps it takes to form their palindromes. **7.** Display student palindromes.
Differentiation	Partner modeling of palindrome.

Figure 18

Teacher F Lesson Plan, Example 2

Learning Experience	**Warm-Up Problem of the Day: SC Ready Practice** Richard and Sebastian each make a number pattern. The table shows the first four numbers in Richard's and Sebastian's number patterns. Two Number Patterns Term Richard's Pattern Sebastian's Pattern 17 1 2 10 6 3 13 11 4 16 16. Which two sets of ordered pairs correctly show Richard's and Sebastian's number patterns? A. Richard's number pattern: (1, 7) (2, 10) (3, 13) (4, 16) Sebastian's number pattern: (1, 1) (2, 6) (3, 11) (4, 16) B. Richard's number pattern: (7, 1) (10, 6) (13, 11) (16, 16) Sebastian's number pattern: (1, 7) (6, 10) (11, 13) (16, 16) C. Richard's number pattern: (7, 3) (10, 3) (13, 3) (16, 3) Sebastian's number pattern: (1, 5) (6, 5) (11, 5) (16, 5) D. Richard's number pattern: (1, 7) (2, 17) (3, 30) (4, 46) Sebastian's number pattern: (1, 1) (2, 7) (3, 18) (4, 34) **Teacher:** 1. Word Study: Students will create 2 Column Notes to familiarize them with the following terms: **(dependent variable, independent variable, proportion, rate, rate of change, ratio, unit rate, and variable**). **2. Initiate, Day 1 T.E., p.137.** **3.** Tell students that today they will look at another way to analyze the change between variables in a situation. Tables are useful tools to do this. **4.** Have students turn to "Olive Oyl Makes the Record Books" in their Student Mathematician's Journals and discuss the situation with students. **Student Activity:** **5.** Ask students what the independent and dependent variables would be in this situation. After their explorations in Lesson 1, they should be able to state the two variables, time as the independent variable and number of jumps as the dependent variable. **6. Jump Rope demonstration**: To get a sense for this, do a demonstration in class. Ask one student to volunteer to jump rope for 1 minute while you act as timekeeper. Another student will call out the number of jumps as you signal every 10-second interval. The count should be cumulative, so students need to continue on from the last count after you call out each 10-second mark. Make sure to point out that this is what is meant by a "running total." Write a table like the one below on the board, document camera, or on chart paper and have another student record the number. See T.E, p.138.

Lack of Implementation Fidelity

The fourth recurring theme that resulted from the qualitative analysis of teacher interviews and lesson plans was the lack of implementation fidelity. For this study, as mentioned previously, implementation fidelity occurs when students are engaged in research-based instructional strategies daily, 50% of the mathematics instructional block for an entire academic school year. Fidelity is measured across five components, adherence, exposure, quality of delivery, participant responsiveness, and program differentiation (Favre & Knight, 2016). Adherence measures whether a program service or intervention is delivered as designed or written (Mihalic, 2004). The amount of time students receives the intervention is measured by exposure (Dunesbury et al., 2003). Quality of delivery measures how well the individual delivers the intervention in accordance with the program/curriculum (Mihalic, 2004). Participant responsiveness measures the level of engagement displayed by the participants during the period of intervention (Kirkpatrick, 1967). The final component, program differentiation, identifies the essential elements of the program (Dunesbury et al., 2003).

During the analysis of teacher interviews, IQ4 specifically addressed the concept of implementation fidelity. The following three sentences are Teacher D, E, and F's responses to IQ4. Teacher D stated, "My students engage in learner-centered activities daily." Teacher E stated, "Learner-centered activities take place at least three to four days out of the week." Teacher F said, "I try to do at least one learner-centered rotation per week during center time." Based on teacher interview responses, it is evident that teachers are not implementing the research-based instructional strategies with fidelity. The amount of time (exposure or dosage) students engage in the instructional strategy is not explicitly stated as it pertains to the number of minutes exposed during the 60-minute instructional block. In addition, when teachers are asked to describe a typical math lesson in their classroom, IQ5, teachers failed to mention how the research-based instructional strategies would be incorporated within the lesson (adherence). The following teacher responses demonstrate these points:

> A typical math lesson in my class involves the I do, we do, you do model. I start by asking students what they know already about the subject. I then show a video on the subject to give the students an introduction. We discuss what we learned in that video. I solve an example problem and do a walk through. We then solve problems together in groups. Several students may come to the board to solve.

> The students are then engaged in independent or collaborative learning (Teacher D).
>
> We start math with the “Problem of the Day” so students are engaged in real-world problems. Then students learn new skills during the mini-lesson. After the mini-lesson, students engage in learner-centered activities. When time is up for learner-centered activities, the class comes back together for a review (Teacher E).
>
> A typical math lesson begins with the “Problem of the Day.” We then move to the mini-lesson and proceed to math centers. Math centers is when students are able to delve deeper into the topic from the mini-lesson. We close with a closure, and I have then to do a fluency activity before we line up for lunch (Teacher F).

During the analysis of teacher lesson plans, implementation fidelity is lacking due to the missing fidelity components of adherence and exposure. Of the fifteen lesson plans analyzed, none of them explicitly stated how the research-based instructional strategies would be delivered (adherence) or indicated the amount of time the students would be engaged with the research-based instructional strategies within the instructional block (exposure). The fidelity components of quality of delivery, participant responsiveness, and program differentiation could not be analyzed based on the data obtained from teacher interview responses and lesson plans.

Improved Mathematical Achievement

The fifth recurring theme that resulted from the qualitative analysis of teacher interviews was improved mathematical achievement by implementing learner-centered activities. Improved mathematical achievement through learner-centered activities correlates with all Weimer's learner-centered teaching practices. During the interview analysis, there were five instances where participants confirmed that students' mathematical achievement improved through the implementation of learner-centered strategies. Examples of these instances will be provided in the sentences that follow. In response to Interview Questions 6 and 8, Teacher D stated, "By incorporating learner-centered instructional strategies, students' grades will increase tremendously;" and "…teaching mathematics without research-based instructional strategies would be ineffective for students' learning." Teacher E's response to IQ3, "Students have shown growth since the beginning of the school year on multiple skills in mathematics based on Math Inventory data." In response to Interview Question 6, Teacher F stated, "I think by including learner-centered strategies, students' scores will improve." Finally, during the analysis of teacher lesson plans, there was no evidence within the plans that supported improved mathematical achievement.

Summary of Quantitative and Qualitative Results

I presented the quantitative findings for RQ1 in four phases representing each grade level (second through fifth) participating in this study. Based on the findings, the null hypothesis was accepted as there was no statistically significant difference in mathematical achievement between students who experienced research-based instructional strategies and those who had not. The qualitative findings for RQ2 resulted in the emergence of the following recurring themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, and lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interviews.

There are two propositions that can be made as it pertains to why there was no statistically significant difference in mathematical achievement between students at Elementary School A and Elementary School B. First, the inability for a more prolonged dosage of the treatment due to COVID-19 and implementation fidelity concerns. As a result of mandatory school closures in March 2020, students from Elementary School A could not continue receiving the research-based instructional strategies they received. Secondly, implementation fidelity arose as a concern, as the analyses of teacher lesson plans and teacher interview responses revealed that teachers were not implementing research-based instructional strategies with complete fidelity. For implementation fidelity to occur, students had to be engaged in research-based instructional strategies daily, 50% of the mathematics instructional block for an entire academic school year. Based on the qualitative data analysis, this was not evident, as the fidelity components of adherence (research-based instructional strategy delivered as designed) and dosage (frequency and amount of time exposed) were missing.

Section 3: The Project

Introduction

An effective mathematics classroom encompasses three critical components: (a) teaching for conceptual understanding, (b) developing children's procedural literacy, and (c) promoting strategic competence through meaningful problem-solving investigations (Shellard & Moyer, 2002). Thus, students should be engaged in highly interactive tasks that encourage them to explore problems, formulate ideas, and check their mathematical ideas with others through discussions and collaboration (McREL, 2010). It is through these types of learning experiences that students construct their knowledge and understanding of the content. As Ashley (2016) observed, instructional strategies are a critical factor in maximizing student achievement; thus, the mathematical achievement of students is directly aligned to the delivery of instruction (Black, 2007). Students who are exposed to more learner-centered activities, such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions, demonstrate higher levels of proficiency on standardized assessments and increased mathematical achievement (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013; Woodward et al., 2012).

However, it is unknown the frequency at which students should be exposed to the implemented instructional strategies. Using the data obtained from teacher interviews, lesson plans, and student MI scores, I sought to establish a fidelity framework to assist teachers with the implementation of research-based instructional strategies and increase implementation fidelity. The resulting fidelity framework is a resource for teachers to use as they plan for future mathematics instruction, maximizing opportunities for students to engage in research-based instructional strategies that improve the mathematical achievement of students. In this section, I will provide the project's description, goals, and rationale; summarize literature on implementation fidelity, measurable threshold, and visible learning; describe the protocol for implementation and evaluation; and discuss the project's implications, including for social change.

Description and Goals

The problem at Elementary School A was that the mathematics learning environments for the student population exemplified a one-way instructional setting where the content was delivered and very limited learner-centered practices were employed. To transition the mathematics learning environments from teacher-centered to learner-centered and improve student outcomes, leadership focused district- and school-based mathematics professional development on implementing research-based instructional strategies during the 2018–2019 academic school year. Although Elementary School A appeared to be implementing research-based instructional strategies, it was unknown if these changes have improved mathematics achievement. In addition, the level of implementation fidelity as it pertains to the research-based instructional strategies was unknown. In this study, I sought to answer the following questions: (a) Is there a difference in mathematical achievement, as measured by Math Inventory (MI), between students at Elementary School A who have experienced research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discourse) and those who have not at

Elementary School B, and (b) In what ways are teachers implementing research-based instructional strategies at Elementary School A?

The quantitative analysis revealed no statistically significant difference in mathematical achievement between students who experienced research-based instructional strategies and those who had not. The qualitative analysis of interview responses and lesson plans revealed the following themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, and lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interviews. As a result of there being no statistically significant difference between the treatment and control groups despite the implementation of research-based instructional strategies, implementation fidelity arose as a concern. This lack of implementation fidelity was evident as the analyses of teacher lesson plans and teacher interview responses revealed that teachers were not implementing research-based instructional strategies with complete fidelity. I developed a policy recommendation paper to address implementation fidelity as it pertains to implementing research-based instructional strategies. In the policy recommendation paper, I created an implementation fidelity framework to assist teachers with the level of implementation fidelity that is needed to increase students' mathematical achievement when implementing hands-on activities, small group investigations, problem-solving tasks, and classroom discussions. Thus, the policy recommendation paper aims to assist teachers with the implementation fidelity of research-based instructional strategies that positively impact students' mathematical achievement.

Rationale

I chose to create a policy recommendation paper to provide a framework when implementing research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse) in the mathematics classroom because teachers often are not aware of the level of fidelity or frequency of implementation that is required to positively impact student achievement. The purpose of a policy recommendation paper is to provide a comprehensive and persuasive argument justifying the policy recommendations presented in the paper and therefore to act as a decision-making tool and a call to action for the target audience (Overseas Development Institute, 2009). Based on the data, it is evident that participating teachers understand what learner-centered activities are and their importance of implementation during the mathematics block. In their interviews, participants shared that without learner-centered activities mathematics instruction would be ineffective. Also, they provided evidence about how students' mathematical achievement increased as a result of implementing these practices. Thus, it is through the policy recommendation paper that teachers can enhance the level of fidelity as it pertains to implementing these research-based instructional strategies during their daily mathematics instruction, promoting learner-centered instructional environments. Students who are exposed to more learner-centered activities, such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions, demonstrate higher levels of proficiency on standardized assessments and increased mathematical achievement (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013; Woodward et al., 2012). The policy recommendation paper serves as a solution to the problem because it encourages teachers to implement research-based instructional strategies at an enhanced level of fidelity by outlining what is required to improve students' mathematical achievement.

Review of the Literature

Several studies have been conducted to determine the types of instructional strategies that are linked to improving the mathematical achievement of students. I explored four of these strategies: hands-on activities, small group investigations, problem-solving tasks, and classroom discussions. My analysis of these student-centered instructional strategies was grounded in the theoretical framework of Bruner's (1977) constructivist theory and the conceptual framework of Weimer's learner-centered teaching. Both frameworks emphasize learning as an active process where students are responsible for accessing their prior knowledge to reconstruct new meaning as they manipulate tasks and engage in academic discourse (Diaz, 2017). To ensure that this occurs, teachers must create a learning environment where student activities are guided, the behavior is modeled, and examples are provided to transform student discussions into meaningful communication (Flynn, 2005; Sammons, 2018). Classrooms must evolve into ones where problem-solving, concept development, and the construction of learner-generated solutions are the primary components (Liljedahl et al., 2016; Lunenburg, 2011). It is still unknown whether the instructional practices implemented are reaching the level of fidelity needed to impact student achievement. In the review of the literature that follows, I will synthesize research on the development of a policy recommendation paper, implementation fidelity, measurable threshold, and visible learning after establishing the theoretical framework. Educational research databases from Walden University Library and other resources such as ERIC, SAGE, and Google Scholar were used to find research addressing the topics/key words stated in the previous sentence.

Theoretical Framework

Changes made within the realm of the educational setting can be viewed as both simple and complex. The complexity of the change arises as it is introduced into the social setting. This occurs because change challenges the current ways of thinking, involves new ways of doing things, includes the assumption that outcomes are unpredictable, and impacts a large number of people/groups; in addition, the success of the change is dependent upon influence and motivation (National College for Teaching and Leadership, 2018). Fullan (2007) argued that deep change will not occur unless new knowledge and solutions are created or discovered and people interact, maintain their commitment and excitement level about pursuing new solutions, and persistently question and critique ideas as they pursue better ones. Thus, change can be considered a messy process. Fullan’s model of change, with an emphasis on implementation, served as the theoretical framework.

Fullan’s (2007) model of change is comprised of four phases: initiation, implementation, continuation, and outcome. Initiation occurs when an individual or group of people begins or promotes a particular program or direction of change.

Existence and quality of innovations, access to innovations, advocacy from central administration, teacher advocacy, and external change agents are five factors that affect the initiation phase (Fullan, 2007). The implementation phase is the "process of putting into practice an idea, program, or set of activities and structures new to the people attempting or expected to change" (Fullan, 2007, p. 84). The process of implementing change can be impacted by the characteristics of change (need, clarity, complexity, and quality/practicality), local factors (school board, community board, principal, teacher), and external factors (government and other agencies). Continuation is the third phase of Fullan's model of change. Continuation involves making a decision regarding the innovation's longevity within the educational setting based upon the positive or negative reaction to the change (Fullan, 2007). The fourth and final phase of Fullan's change model, outcome, focuses on the following four perspectives as it pertains to the change process: active initiation and participation; pressure, support, and negotiation; changes in skills, thinking, and committed actions; and overriding of the problem of ownership (Fullan, 2007).

Policy Recommendation

An important resource when impacting change in the educational system is a framework (Viennet & Pont, 2017). A framework is designed to provide a basic structure or set of ideas that provides support for something ("Framework", n.d.). Through the project, an implementation fidelity framework was created to assist teachers with the implementation of research-based instructional strategies in the mathematics classroom. Based on the results of this study, Elementary School A would benefit from the implementation of the fidelity framework as there was no statistically significant difference between students who received research-based instructional strategies and those who had not. To ensure the implementation of the fidelity framework will add value, Elementary School A's instructional team should devise a systematic approach or plan to implement and monitor the implementation of the fidelity framework. The creation of an implementation plan or systematic approach will assist Elementary School A as they put their plan into action (Eby, 2017).

A policy recommendation paper, also referred to as a white paper, is a concise document used to provide a research-based solution to a problem or issue being presented (Environmental Studies Library Guide, 2021; "Policy Briefs", 2021; & "Policy paper", 2017). The purpose of the policy recommendation paper is to persuade the audience that the solution being presented is viable. This is accomplished by supporting the solution presented with research. A policy recommendation paper contains three primary parts (issue, analysis, and recommendation) and follows a problem-solving sequence (identify and clarify the policy issue; research relevant background and context; identify the alternatives; carry out required consultations; select the best policy option; and prepare policy recommendation document for approval) (Doyle, 2013). The basic structure of a policy recommendation paper is the Executive Summary, Introduction (and Background), Methodology, Literature Review, Policy Options or Policy Contexts, Analysis of Findings or Evidence, Case Studies and Best Practices, Policy Options and Recommendations, Implementation and Next Steps, Conclusion, Appendices, and Bibliography (Herman, 2013).

Implementation Fidelity

Implementation fidelity can be defined as the degree to which an intervention or program is delivered as intended (Carroll et al., 2007; Harn et al., 2017; McKenna & Parenti, 2017; Roberts, 2017, p.1). It can also be defined “as the similarity between enacted practice and the benchmark of program designers’ specifications”, (Anderson, 2017). Implementation fidelity can serve as a liaison between the intervention and the intended outcomes as the relationship is being evaluated (Carroll et al., 2007). To effectively measure implementation fidelity, one must first understand and evaluate the fidelity itself (Hill & Erickson, 2019). Without this assessment, one will not know if the success level of the outcomes is attributed to the intervention or the level of implementation. Thus, making it harder to transition findings from the research settings to real-world settings (James Bell Associates, 2007).

Fidelity is measured across five components: adherence, exposure, quality of delivery, participant responsiveness, and program differentiation (Favre & Knight, 2016). Adherence measures whether a program service or intervention is delivered as designed or written (Mihalic, 2004). The amount of time students receives the intervention is measured by exposure (Dunesbury et al., 2003). Quality of delivery measures how well the individual delivers the intervention in accordance with the program/curriculum (Mihalic, 2004). This component may require additional evaluation as benchmarks should be in place to measure and define quality. Participant responsiveness measures the level of engagement displayed by the participants during the period of intervention

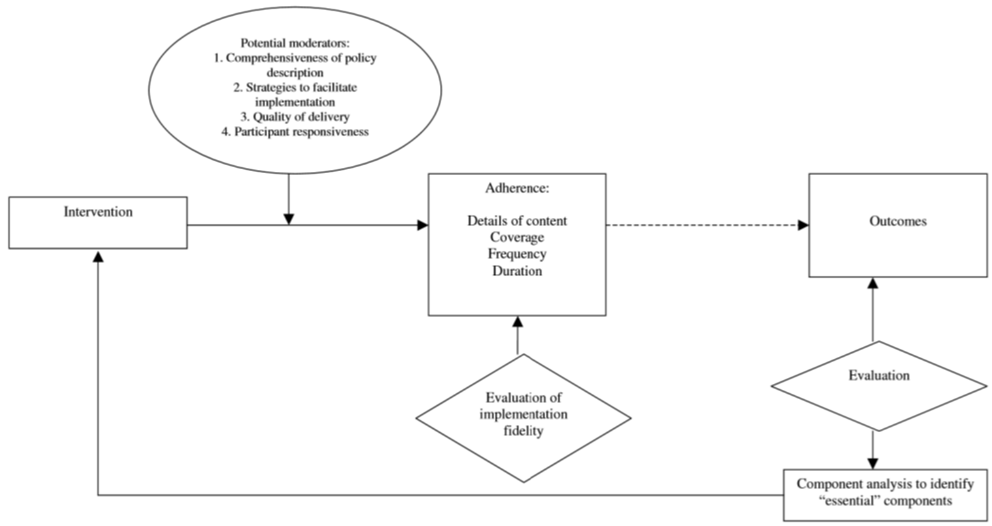
(Kirkpatrick, 1967). The final component, program differentiation, identifies the essential components of the program (Dunesbury et al., 2003).

When measuring implementation fidelity, the literature reveals the two most common ways this can be done (Carroll et al., 2007). A way fidelity can be evaluated is by measuring any one of the components in isolation. The one-way fidelity measure often utilized in the area of mathematics is adherence (Nelson et al., 2019). The second way is to evaluate all five components. Carroll et al. (2007) created a third framework that uses the process of measuring all five components, including their functions and relationships to each other and the introduction of two additional components, intervention complexity and facilitation strategies. The purpose of intervention complexity is to explore the barriers that present themselves when implementing a new idea that is foreseen as complex. Facilitation strategies are strategies that are put in place to achieve the maximum level of fidelity. These strategies include but are not limited to manuals, guidelines, training, monitoring and feedback, capacity building, and incentives (Bellg et al., 2004; Walton et al., 2017).

The process of measuring implementation fidelity is parallel to the process of measuring adherence. Adherence, as stated previously, evaluates how well the individual delivers the intervention as formatted by the program designers. Through the lens of adherence, one can measure the content covered, frequency, and duration of the intervention. In addition, the level to which adherence is achieved can be affected by the quality of delivery, participant responsiveness, intervention complexity, and facilitation strategies (Brigandi, 2019). This parallel relationship is visually outlined in Figure 19.

Figure 19

Conceptual Framework for Implementation Fidelity



Note. The conceptual framework for implementation fidelity shows the parallel process between measuring implementation fidelity and measuring adherence. From "A conceptual framework for implementation fidelity," by C. Carroll et al., 2007, *Implementation Science*, *2*(40), 407. Copyright 2007 by Creative Commons Attribution License.

Feely et al. (2018), developed a Field Guide describing a five-step process to fidelity measurement. This sequential process is as follows:

1. Define the purpose and scope of the fidelity assessment used for evaluation of the intervention.
2. Identify the essential components of the fidelity monitoring system.
3. Develop the fidelity tool.
4. Monitor fidelity during the study.

5. Use the fidelity ratings in analyses (Feely et al., 2018).

The five-step process to fidelity measurement assists with the measuring and monitoring of the level of fidelity when establishing research-based interventions (Feely et al., 2018). In addition, it seeks to identify the type of environment that deems an intervention to be effective (Feely et al., 2018).

Durlak and DuPre (2008) identified fidelity and dosage as two factors that impact the implementation of any program or activity. Programs and activities implemented on a consistent and frequent basis are more likely to yield positive outcomes as determined by Durlak and DuPre (2008). The level of implementation fidelity of any program or activity is directly aligned to its overall success (Reeves, 2009; Schecter et al., 2017). A program or activity that is implemented with only very little frequency is comparable to a program or activity that has never been implemented at all. Thus, the higher the frequency, the higher the level of success (Reeves, 2009).

When it comes to implementation fidelity, several factors can impact the level to which fidelity occurs (Stirman et al., 2019). In a case study conducted by Roman (2016), implementation fidelity was explored through the implementation of a new elementary mathematics program. The research questions guiding this study were: (a) what do teachers think gets in the way of fidelity of implementation of the standards-based program, (b) do teachers feel committed to the concept of fidelity of implementation of the standards-based program, and (c) what concerns do teachers have about the standards-based program, its components, and district expectations for implementation? District and site factors associated with implementing the goals of the Common Core

State Standards of Mathematics; the impact of the implementation on teachers, classrooms, and schools; roles of the central office in the implementation; and the outcomes related to student achievement and teaching practices were the focal points of this study (Roman, 2016).

Teachers' perspectives from interviews were utilized as the data points to determine if their perspectives influenced the level of fidelity. The data collected was analyzed through an interpretative phenomenological analysis revealing the following three themes: (a) teachers are committed to meeting their professional responsibilities, meeting students' needs, and providing the benefits of the program; (b) teachers need support from the district and at the building level to be adequately prepared to implement the program with fidelity in their classrooms; and (c) teachers are concerned with the expectations for pacing, checking for understanding, and testing (Roman, 2016). Based on the emerging themes, Roman (2016) found that the teachers participating in the study did not implement the program with fidelity because they failed to change their beliefs and teaching styles as it related to the implementation of the new mathematics program.

In a study conducted by Duplessis et al. (2014), implementation fidelity was explored as it pertains to Professional Learning Communities (PLCs) and its impact on student achievement and growth in Rutherford County Schools. This study involved six schools (two elementary, two middle, and two high) within a suburban school district in Tennessee. Data from these six schools were analyzed to determine if there was a difference in student achievement and growth scores between schools that implemented PLCs with higher fidelity and those that implemented PLCs with lower fidelity. For the purpose of this study, the following four aspects were used to evaluate the school's level of fidelity: (a) adherence to PLC norms, (b) regular team meetings, (c) active participation by team members, and (d) and administrative support. Utilizing a mixed-methods approach, responses from questionnaires, direct observations, and results from the 2013–2014 Tennessee Comprehensive Assessment Program and End of Course tests were analyzed to determine the level of implementation fidelity and measure student achievement and growth. As a result of the research, the study revealed that higher achievement scores were achieved within schools where PLCs were implemented with higher fidelity. These findings were more prevalent within the two participating middle schools. Based on the findings, Duplessis et al. (2014) recommended that student achievement can be improved if the fidelity level of PLCs is increased through frequent, focused, and data-driven meetings, common assessments, common planning time, and active involvement of school and district leadership.

Measurable Threshold

The term measurable can be defined as a quantifiable identifier that is used to monitor the progress of a program, project, or an implemented instructional strategy towards an established target or goal. The term threshold is defined as a magnitude or intensity that must be exceeded for a certain reaction, phenomenon, result, or condition to occur or be manifested ("Threshold", n.d.). Thus, a measurable threshold can be defined as a point at which a program, project, or implemented instructional strategy has met and/or exceeded the desired level needed to effect change. For the purpose of this study, a measurable threshold is defined as the point where an implemented mathematical instructional strategy meets or exceeds the intended level to increase student mathematical achievement (Ayadat et al., 2020). This portion of the literature review will explore the process of establishing performance measures to create measurable thresholds.

Before establishing measurable thresholds, one must operationalize the program, innovation, or instructional strategy that is to be implemented (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). During this process, an instructional strategy is defined in a way that can be measured when conducting observations. This derived definition should include the following components: what practitioners need to do, how should they do it; and how to determine if they are doing it as intended by the innovation developers (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). To assist in the development of such a specific definition, a Practice Profile can be created. According to Permanency Innovations Initiative Training and Technical Assistance Project (2016), a Practice Profile is a document that describes how innovation works in everyday practice.

The Practice Profile serves as a framework by identifying the supports that will be needed during the implementation process (Hitt & Tucker, 2016). The essential functions, operationalized definition, core activities, behaviorally based practice indicators, and practice criteria are the five elements that make up the Practice Profile. Essential functions are the strategies that a practitioner engages in to address an identified problem (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). The operationalized definition is based on the researched change theory and should be connected to the values, principles, and philosophy of the strategy (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). The actions performed by the practitioner during an observation are considered the core activities (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). Behaviorally based practice indicators describe the observable actions and indicate what behaviors are warranted to ensure successful implementation (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). Expected, developmental, and unacceptable are the three levels of practice criteria. These levels are categorized based on the following criteria:

- Expected–"Includes activities that exemplify practitioners who are able to apply required skills and abilities to a wide range of settings and contexts; use these skills consistently and independently; and sustain skills over time while continuing to grow and improve their positions."
- Developmental–"Includes activities that exemplify practitioners who are able to implement required skills and abilities but in a more limited range of contexts and settings; use these skills inconsistently or need supervisor/coach consultation to complete or successfully apply skills; and benefit from a coaching agenda that targets particular skills for improvement to move practitioners into the "expected/proficient" category."
- Unacceptable–"Includes activities that exemplify practitioners who are not yet able to implement required skills or abilities to any context." (Permanency Innovations Initiative Training and Technical Assistance Project, 2016, p. 7)

Based on the level of performance demonstrated by the practitioner, one can begin to provide the support he or she needs to be successful.

After operationalizing instructional strategies and developing the Practice Profile, one can begin to develop measurable thresholds. When establishing measurable thresholds, one must consider the fidelity of implementation. Fidelity of implementation analyzes whether an intervention or program was delivered or implemented as outlined by the developer (Corcoran, 2017). Through the analysis, the following components are examined: adherence, exposure, quality of delivery, participant responsiveness, and program differentiation. After the analysis, the components (individually or collaboratively) should yield a point where improved academic achievement is demonstrated, thus establishing a measurable threshold.

Visible Learning

In 2009, John Hattie published *Visible Learning*, a text that ranked 138 influences and effect sizes as it relates to student achievement. To do this, Hattie studied over 800 meta-analyses. In 2011, Hattie updated the effects to 150 in *Visible Learning for Teachers* and 195 effects in 2015 in *The Applicability of Visible Learning to Higher Education*. Since then, Hattie's research has evolved with over 1200 meta-analyses synthesized. This synthesis has resulted in the identification of 252 influences and effect sizes related to student achievement. Also, Hattie's research found that the average effect size related to student achievement is 0.40, meaning that students should attain at least a year's growth. Hattie's effect sizes for hands-on activities, small group investigations, problem-solving tasks, and classroom discussions will be used to establish the measurable thresholds needed to develop the implementation fidelity framework.

Hands-on activities, small group investigations, problem-solving tasks, and classroom discussions were influences studied by Hattie (2009) and Hattie et al., (2017) to determine their effect size on student achievement. Hands-on activities with an emphasis on manipulative materials during mathematics instruction yielded an effect size of 0.3 and has a ranking of 150. An effect size of 0.47 was yielded when studying small group investigations with an emphasis on the learning process and has a ranking of 92. The implementation of problem-solving tasks through problem-solving teaching yielded an effect size of 0.68 with a ranking of 37. Last but not least, classroom discussions yielded an effect size of 0.82 with a ranking of 15.

Implementing hands-on activities emphasizing the effects of manipulative materials on mathematics allows students to make connections between mathematical representations (Khalid & Embong, 2020; O'Connell, 2016). Students should be engaged in connecting mathematical representations for two purposes: (a) provide concrete representations that lead students to develop conceptual understanding and later connect that understanding to procedural skills, and (b) provide a variety of representations that range from using physical models to using abstract notations (Hattie et al., 2017). To encourage the use of manipulatives during mathematical concept exploration, teachers should implement tasks that allow students to use a variety of representations and encourage students to represent a mathematical situation in different ways (concrete models, pictures, words, numbers, etc.) to justify their mathematical thinking and reasoning (Hattie et al., 2017). Through the incorporation of manipulatives, teachers can facilitate and scaffold students through the C-R-A (concrete, representational, abstract) process helping students shape and solidify their understanding of mathematical concepts (Gibbs et al., 2018).

To ensure the implementation fidelity of incorporating hands-on activities in the mathematics classroom, teachers should plan lessons where manipulatives are introduced and incorporated to explore concepts (Van de Walle et al., 2019). As students explore mathematical concepts with manipulatives, all five of the implementation fidelity components are met. The adherence component is met as the manipulatives are used to assist students in building their conceptual understanding of the mathematical concept (Kwon & Capraro, 2018). Through daily hands-on exploration, the components of exposure and quality of delivery are met as manipulatives are designed to assist students in solidifying conceptual understanding to make connections to procedural skills. The participant responsiveness component is met as students engage with the materials to make sense of problem situations and make connections between concrete, pictorials, and abstract representations (Flores et al., 2020). Last but not least, the component of program differentiation is met as manipulative integration is deemed an essential component of an effective mathematics classroom.

The implementation of small group learning through the lens of the learning process provides opportunities for teachers to meet the needs of all students as instruction is explored. The process of learning is deemed a social one, thus individuals learn better when they are able to interact with others (Hattie et al., 2017; Masika & Jones, 2016).

Through small group instruction, teachers can differentiate learning, ensuring that students are challenged at their appropriate instructional levels. Thus, small groups should be flexible and designed strategically as student's proficiencies and deficiencies vary depending on the mathematical skill being addressed. In addition, small group instruction allows teachers to informally assess student understanding and provide immediate feedback as they engage in the learning process (Lomibao et al., 2016).

The level of implementation fidelity as it pertains to small group learning is met as teachers create instructional learning environments that support collaborative learning (van Leeuwen & Janssen, 2019). Teachers should ensure that students are exposed to small group learning at least 50% of their instructional time (Hattie et al., 2017), meeting the exposure component of implementation fidelity. Participant responsiveness is achieved as students engage in small group learning activities that require active participation, complex thinking, and intellectual discourse. Small group learning is designed to meet the needs of all students and should be strategically planned and implemented to meet the adherence and quality of delivery components of implementation fidelity (Benders & Craft, 2016; Dixon et al., 2018). The program differentiation component of implementation fidelity is met when the essential components of small group learning (positive interdependence, individual and group accountability, interpersonal and small group skills, face-to-face promotive interaction, and group processing) are addressed.

According to Hattie (2009), "problem-solving teaching involves the act of defining or determining the cause of the problem; identifying, prioritizing and selecting alternatives for a solution; or using multiple perspectives to uncover the issues related to a particular problem, designing an intervention plan, and then evaluating the outcome" (p. 210). Teachers that expose students to problem-solving investigations allows students to build their cognitive flexibility while at the same time increasing mathematical achievement (Mrayyan, 2016). Problem-solving processes and methods have been developed as far back as Polya's (1957) four-phase method (understand the problem, obtain a plan of solution, carry out the plan, and examine the solution obtained). The implementation of problem-solving teaching through investigations allows students to explore and obtain knowledge themselves (Sumirattana et al., 2017). Hattie et al. (2017), identifies two purposes of implementing tasks to promote reasoning and problem solving: (a) provide opportunities for students to engage in exploration and make sense of important mathematics, and (b) encourage students to use procedures in ways that are connected to understanding. Therefore, teachers should integrate tasks that are built on students' understanding, have multiple solutions, and are interesting to students (Hattie et al., 2017).

To ensure fidelity of implementation, students should be exposed to real-world problem-solving tasks increasing the meaningfulness and relevancy of their learning. This would assist in meeting the participant responsiveness component of implementation fidelity as the students' level of engagement should be higher due to an interest in the task being explored (Kanter & Leinwand, 2018). The fidelity component of adherence could be met by ensuring that teachers engage students in problem-solving tasks that build students' understanding, have multiple solutions, and are interesting to students

(Hattie et al., 2017). In addition, the quality of delivery component of fidelity can be met by ensuring that a protocol for exploring problem-solving tasks such as Polya's (1957) four-phase method (understand the problem, obtain a plan of solution, carry out the plan, and examine the solution obtained) is taught and used by students during the problem-solving portion of the mathematics lesson.

Of the research-based instructional strategies explored in this study, classroom discourse is the highest-ranked with an effect size of 0.82, which means that students who experience classroom discourse can attain academic growth of more than two school terms. Two purposes of facilitating classroom discourse are to provide students with opportunities to share ideas, clarify their understanding, and develop convincing arguments; and advance the mathematical thinking of the whole class by taking and sharing aloud (Hattie et al., 2017). Through the implementation of classroom discourse, teachers can assess students to gauge their level of understanding, thus allowing them to determine who needs intervention, who is on track, and who may need an additional challenge (Russell, 2019). This immediate assessment can only be attained if the students are engaging in deep thinking and discussion about the concept and not the teacher (Russell, 2019).

To increase the fidelity of implementation for classroom discourse, the teacher must first understand the purpose and process of facilitating meaningful mathematical discourse, addressing the adherence component (Matsumura et al., 2019). Prior to implementation, teachers should establish norms with their students. Sociomathematical norms should be established to promote true mathematical discourse (Cobb & Yackel, 1996b). Some examples of these norms are as follows:

- *Explanations* are mathematical arguments, not procedural summaries of the steps that were used to arrive at an answer. Explanations include justifications.
- *Errors* are opportunities to reconsider a problem from a different point of departure. Even when the answer is correct, there is further discussion about more efficient and more sophisticated pathways.
- *Mathematical thinking* requires that teachers cultivate a sense of intellectual autonomy that prizes participation in the discussion of possible solutions. (Hattie et al., 2017, pgs. 150-151)

To address the fidelity component of quality of delivery the teacher should engage students in explaining their mathematical reasoning in both small group and whole group situations; facilitate discussions among students supporting their ability to make sense of a variety of strategies and approaches; and scaffold classroom discussions so students can make connections between representations and mathematical ideas (Hattie et al., 2017; Webb et al., 2019). The level of engagement or participant responsiveness component will be met as students are engaging in discussions with their peers. Finally, the fidelity component of exposure will be met as students should be engaged in mathematical discourse daily as they explore and apply mathematical concepts.

Project Description

Potential Resources and Existing Supports

While working on this project study, several resources and existing supports came to mind. Fortunately, the schools within the district have access to a variety of mathematical resources that can be used to assist with mathematics instruction. One of the most valuable resources are the curriculum units which compiles all resources on a particular topic in one place. Existing supports for instruction can be found at two levels, district and building/school. On the district level, there is an elementary math consultant who provides professional learning opportunities to teachers and administrators throughout the school year. In addition, the district may contract external math consultants who provide additional professional learning opportunities at the schools during the year. At the building level, there is an instructional team comprised of the principal, assistant principal, curriculum resource teacher, and possibly a math coach who can assist with the implementation and follow-up of research-based instructional strategies.

Potential Barriers

Some potential barriers can arise with the implementation of a policy recommendation paper. One potential barrier could be the lack of buy-in from teachers. Without buy-in, teachers will be less likely to change their instructional practices. Another barrier could be teachers not knowing how to effectively implement the research-based instructional strategies due to lack of knowledge or unfamiliarity. A final barrier could be the lack of follow-up conducted by the instructional team to ensure research-based instructional strategies are implemented and implemented effectively.

Proposal for Implementation and Timetable

A policy recommendation paper has been developed to provide a framework when implementing research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse) in the mathematics classroom. This document will provide a comprehensive and persuasive argument justifying the policy recommendations presented in the paper, and therefore act as a decision-making tool and a call to action for the target audience (Overseas Development Institute, 2009). The target audience being stakeholders of elementary schools.

The policy recommendation paper will be presented to the schools' instructional teams participating in this study as well as the district's math consultant. The instructional teams can then decide to create an implementation plan that they can then share with their staff.

Roles and Responsibilities of Student and Others

A policy recommendation paper was created to provide a framework for implementing research-based instructional strategies in the mathematics classroom. After presenting the findings of the study, and the policy recommendation paper to the instructional teams of both schools, it will be their responsibility to create an implementation plan. Once the plan is created, they should share it will their respective staff and follow up as needed to ensure implementation. The district's math consultant and external consultants contracted to provide professional learning opportunities could also assist the instructional teams with implementation.

Project Evaluation Plan

A policy recommendation paper was created to assists schools in the implementation of research-based instructional strategies in their mathematics classrooms. The evaluation of the project will focus on the policy paper itself, instead of the implementation of the instructional strategies. A formative evaluation will be used to evaluate the policy paper to assist in making revisions and modifications.

Project Implications

This study may promote social change by potentially altering how teachers deliver mathematics instruction. Research has shown that facilitating mathematics instruction through highly engaging classrooms can improve the mathematical achievement of students (Fung et al., 2018). Through the incorporation of hands-on instruction, small group investigations, problem-solving activities, and classroom discussions, students can amplify their understanding of mathematical concepts and ideas. In having this deeper level of understanding, this will assist students in making connections and solving unfamiliar mathematical problems more efficiently. Also, facilitating an environment where learner-centered, research-based instructional strategies serve as the framework of instruction makes students accountable for their learning. Most importantly, hands-on instruction, small group investigations, problem-solving activities, and classroom discussions assist in meeting the World Class Knowledge, World Class

Skills, and Life and Career Characteristics requirements outlined in the Profile of the South Carolina Graduate.

Local Community

This project addresses the needs of my local community because as a district 43.5% of third grade, 33.1% of fourth grade, and 36.5% of fifth grade students demonstrated proficiency on the 2018 administration of SC Ready. With over half of the student population scoring in the nonproficient categories, a shift in the instructional delivery of mathematics is warranted. Through the implementation of learner-centered activities, such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions, students will demonstrate higher levels of proficiency on standardized assessments and increased mathematical achievement, while teachers will experience a shift in instructional delivery (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013; Woodward et al., 2012). Thus, all stakeholders will benefit from the implementation of the recommendations found in the policy paper.

Far-Reaching

The completed policy recommendation paper could be used as a model for other elementary schools located within the school district as well as neighboring districts. Building level instructional teams could use the policy paper to create an action plan for implementation within their buildings. Through the implementation of these research-based instructional strategies, the mathematical learning environment will shift from one solely focused on the teacher to one that holds students accountable for their learning, making math meaningful and relevant. In addition, exposure to more learner-centered learning environments could increase the percentage of struggling students who are deemed proficient on state standardized assessments, district benchmarks, and nationally normed assessments. Thus, increasing students' academic achievement can empower them to excel in everyday tasks and future career endeavors (Waller, 2012).

Conclusion

The purpose of this project was to create a policy recommendation paper that assists teachers with the fidelity of implementation when implementing research-based instructional strategies that positively impacts students’ mathematical achievement. Fullan’s change theory served as the theoretical framework that guided the development of the policy paper, along with the review of literature on policy recommendation, implementation fidelity, measurable threshold, and visible learning. District and school-level support and curriculum resources were identified as potential resources and supports during the process of implementation. Potential barriers such as teacher buy-in, teacher lack of knowledge, and lack of follow-thru from the instructional team were identified and discussed. A proposal for project implementation and an evaluation plan has been described and included. The project’s relevance to today’s academic challenges and needs has the potential to impact social change on both the local and far-reaching levels. The next section of this paper will focus on my reflections as it pertains to my doctoral journey and final product.

Section 4: Reflections and Conclusions

Introduction

In this project study, I sought to determine whether implementing research-based instructional strategies in the mathematics classroom had improved the math achievement of second through fifth graders at Elementary School A. An analysis of the quantitative data provided inconclusive results due to the limitations discussed in Section 2, mostly related to dosage and frequency. The qualitative data revealed that math achievement could be improved when research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse are implemented within the mathematics classroom with fidelity. Based on the data findings, I created a policy recommendation paper to provide a framework to assist instructional teams and, most importantly, teachers with implementing research-based instructional strategies in the mathematics classroom with fidelity. In this section, I will discuss the project's strengths and limitations, offer recommendations for alternative approaches, and consider the implications and applications for future research. In addition, I will reflect on the research process through the lens of scholarship, project development and evaluation, and leadership and change, as well as reflect upon the importance of this work.

Project Strengths and Limitations

The problem at Elementary School A was that the mathematical learning environment for the student population exemplified a one-way instructional setting where the content was delivered and very limited learner-centered practices were employed. To transition the mathematics learning environment from teacher-centered to learner-centered and improve student outcomes, leadership focused district- and school-based mathematics professional development on the implementation of research-based instructional strategies during the 2018–2019 academic school year. Although teachers at Elementary School A appeared to be implementing research-based instructional strategies, it was not known if these changes have resulted in improved mathematics achievement. In addition, the level of implementation fidelity as it pertains to the research-based instructional strategies was unknown. I used a mixed-methods study to address the local problem by selecting two schools with approval and direction from the district to participate in this study. Based on the study findings, I created a policy recommendation paper to support instructional teams and teachers with implementing research-based instructional strategies with fidelity.

The policy recommendation paper introduces an implementation fidelity framework that assists teachers with implementing research-based instructional strategies and outlines the steps instructional teams should take to begin the implementation process. Thus, one strength of this policy recommendation paper is the guidance provided for instructional teams to develop their implementation plan. In addition, instructional teams are provided the opportunity to create or select a tool to systematically measure the fidelity of implementation as it pertains to research-based instructional strategies. Another strength of this recommendation is the professional learning opportunities that instructional teams are encouraged to provide their teachers to ensure that they understand how and when to implement each strategy, building teacher capacity and enhancing their level of buy-in.

One limitation of the policy recommendation paper is that the instructional team of the school will devise a plan to support the implementation of the fidelity framework. I assume that if a plan is devised and implemented that the instructional team will monitor the implementation process using the monitoring tool. Another assumption can be made regarding the teachers' ability to take the knowledge gained during the professional learning opportunities and apply it to the instructional needs of the students within their classes. Most importantly, I am assuming that the instructional team will have ample time to devise a plan, select a monitoring tool, outline a schedule for classroom observations, and identify the professional learning opportunities needed to address the instructional needs of their staff.

Recommendations for Alternative Approaches

Based on the limitations shared in the previous section, I would recommend that once school leaders have developed an instructional plan to address implementation fidelity, they share it with district-level leadership and support personnel. The sharing of the instructional plan would hold school leaders accountable by inviting district stakeholders to assist in the monitoring process to ensure implementation is occurring. It would also provide an opportunity for the school's instructional team to receive feedback.

Another way to address the implementation fidelity of research-based instructional strategies is to identify a mathematics curriculum that already outlines or integrates these strategies in the mathematics classroom. Once the mathematics curriculum is adopted, intense professional learning opportunities should be provided to ensure that teachers implement the program with fidelity. This implementation process can be enhanced by requiring teachers to immediately implement what they learned during the professional learning opportunity within an outlined period of time. They should then be required to bring evidence of implementation to the next scheduled professional learning opportunity for discussion purposes. In addition to teachers' expectations, the school's instructional team should conduct classroom observations to monitor implementation. The results of these observations should be discussed as a team and then a consensus determined to share with the facilitators in preparation for the next professional learning opportunity.

Scholarship, Project Development and Evaluation, and Leadership and Change

This doctoral journey has been one filled with many trials and tribulations. Through this process, I have learned that it is not for the weak and faint at heart. At times, I even wanted to quit, but I remembered my philosophy of always going after what I wanted. I believe that what is worth having is worth working for to attain the goal.

Throughout this research process, I have learned so much about myself and the amount of work it takes to attain a doctorate. Although this was not my first encounter with formulating a RQ, identifying the hypotheses, and conducting a literature review, I must say that this process was more extensive than my other experiences. However, I value my initial experiences because they provided me with the foundation I needed to be successful during my doctoral program.

Conducting a mixed-methods study has allowed me to grow as a researcher. In my previous research experiences, I only conducted quantitative research because I enjoy working with numbers. This research experience took me out of my comfort zone by exposing me to the process of creating and implementing protocols for conducting teacher interviews and analyzing teacher lesson plans. In addition, I was able to transcribe and analyze participating teachers' interviews and lesson plan data.

The process of triangulating data was a very rewarding experience. Not only was I able to gain a vast amount of knowledge, but I was also able to enhance my research study as the qualitative data explained and elaborated on the quantitative findings. I used these data for the policy recommendation paper. The development of the policy recommendation paper allowed me to immediately apply what I had learned from my research, producing a product (implementation fidelity framework) that could be used by instructional teams at various elementary schools who wish to improve students' mathematics achievement.

As I reflect on my growth as a leader and my ability to effect change, I have learned that one does not become better at what one does unless they experience times of discomfort. It is during these times that I demonstrated the most growth as I had to find solutions to problems that arose during this process. Many of these solutions required me to be flexible and adapt to the situation at hand. In addition, there were times where I had to think on my feet and make decisions fairly quickly to meet deadlines set forth by both the local school district and Walden University. Most importantly, this doctoral journey has allowed me to grow as a leader and effect change by identifying a problem, proposing and implementing a study to address the local problem, and finally devising a recommendation paper based on the results of the study.

Reflection on Importance of the Work

The purpose of this study was to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions for district students in Grades 2-5. The goal of the project, based on the results of the study, was to develop a policy recommendation paper to assist teachers with the level of implementation fidelity that is needed to positively impact students' mathematical achievement when implementing hands-on activities, small group investigations, problem-solving tasks, and classroom discussions. It was evident that an implementation fidelity framework was needed based on the analysis of teacher interviews and lesson plans, which revealed that participants did not fully implement Weimer's learner-centered teaching strategies. To ensure that research-based instructional strategies are implemented with fidelity, a systematic process for measuring fidelity of implementation is needed for continual implementation improvement and the improvement of student academic achievement (DeFouw et al., 2019; Gresham, 2017; Harn et al., 2017; King-Sears et al., 2018; McKenna & Parenti, 2017). If leaders of Elementary School A implement the recommendations presented in the policy recommendation paper, the fidelity of implementation as it pertains to the research-based instructional strategies studied should improve, thus increasing the mathematical achievement of second- through fifth-grade students.

Implications, Applications, and Directions for Future Research

There are local and national implications, applications, and directions for future research as it pertains to improving the mathematical achievement of students through the implementation of research-based instructional strategies when implemented with fidelity. If they implement the recommendations presented in the policy recommendation paper, leaders of Elementary School A should continuously collect and analyze fidelity and mathematical achievement data to inform instruction and guide the next steps. Furthermore, leaders of other elementary schools within the local school district may want to consider adopting the implementation fidelity framework presented in the policy recommendation paper to begin devising an implementation plan. Additionally, school leaders should develop a systematic process that continuously measures implementation fidelity through the collection of both quantitative (student mathematics assessment results) and qualitative (classroom observations) data.

Conclusion

In this project study, I sought to determine if implementing research-based instructional strategies in the mathematics classroom improved the mathematical achievement of second- through fifth graders at Elementary School A. Based on the results of this study, I developed a policy recommendation paper in which I introduced an implementation fidelity framework that assists teachers with the implementation of research-based instructional strategies through enhanced fidelity. The guidance provided by the policy recommendation paper was identified as one of the strengths, as building-level instructional teams can use it to develop their implementation plan. The creation of this plan was also identified as a limitation because it is assumed that the instructional teams will develop a plan to support the implementation of the fidelity framework. Thus, instructional teams should invite other stakeholders to assist in the creation and monitoring process of the implementation plan. Additionally, the school's instructional team should develop a systematic process that continuously measures implementation fidelity through the collection of both quantitative (student mathematics assessment results) and qualitative (classroom observations) data.

During my doctoral journey, I have experienced various trials and tribulations. It was during these times that I found myself growing the most. The growth I have experienced has affected me in all aspects of my life. I have learned that things worth accomplishing are worth fighting for. Most importantly, this process has allowed me to potentially impact the academic world through the development of a fidelity framework that may assist teachers with the implementation of research-based instructional strategies.

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Appendix A: The Project

A Fidelity Framework and the Implementation of Research-based Instructional Strategies

A Policy Recommendation White Paper

Keisha Knight Scott

Table of Contents for Project

List of Tables

Executive Summary

Introduction

The problem at Elementary School A was that the mathematical learning environment for the student population exemplified a one-way instructional setting where the content was delivered, and very limited learner-centered practices were employed. To transition the mathematics learning environments from teacher-centered to learner-centered and improve student outcomes, district and school-based mathematics professional development has focused on implementing research-based instructional strategies during the 2018 2019 academic school year. Although Elementary School A appeared to be implementing research-based instructional strategies, it is unknown if these changes have improved mathematics achievement. In addition, the level of implementation fidelity as it pertains to the research-based instructional strategies was unknown. A mixed-methods research design was conducted to determine if there is a significant difference in the mathematical achievement of students who experienced research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse) and those who had not. The quantitative analysis of Math Inventory (MI) data revealed no statistically significant difference between students who received (Elementary School A) research-based instructional strategies and those who had not (Elementary School B). The qualitative analysis of teacher interviews and teacher lessons revealed four reoccurring themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, and lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interviews. After triangulating the quantitative and qualitative data, it was determined that the focus of the policy recommendation paper should be implementing research-based instructional strategies with fidelity. The policy recommendation paper provides a framework for implementing research-based instructional strategies through enhanced fidelity that has the potential to improve student mathematical achievement. Thus, this executive summary will focus on developing the implementation fidelity framework, recommendations for implementation, and policy implementation.

Implementation Fidelity Framework

The implementation fidelity framework found in Appendix A, was developed utilizing the components of creating a framework. These components include: (a) describe the intended use of your framework, (b) outline your initiative or program’s vision and mission, (c) State the objectives of your initiative or effort, (d) describe the appropriate scope or level of your framework, (e) identify ALL components to include, (f) draft a picture of the framework, (g) check for the completeness, (h) implement the framework, and (i) revise framework as needed (The Community Tool Box, 2020). The purpose of the implementation fidelity framework is to assist teachers with implementation fidelity as it pertains to incorporating research-based instructional strategies in the mathematics classroom. The objectives of this framework are as follows: enhance mathematics learning environments to foster a more student-centered approach, ensure mathematical concepts are presented utilizing the C-R-A (concrete–

representational–abstract) process, and encourage teachers to purposefully plan mathematics instruction, through the incorporation of research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse). As seen in Appendix A, the following components were included in the implementation fidelity framework: purpose and mission, inputs, activities/interventions, and outputs/effects.

Recommendation for Implementation

The following recommendations of how to improve the fidelity of implementation as it pertains to the research-based instructional strategies explored during this study were formalized after analyzing the study's findings and reviewing current research. I recommend that the instructional team at Elementary School A review the implementation fidelity framework and devise a plan for school-wide implementation to enhance and improve the mathematics instruction, respectively. This plan should address the weaknesses discovered during the study, specifically targeting the components (adherence, exposure, quality of delivery, participant responsiveness, and program differentiation) of implementation fidelity. To ensure the implementation of the school-wide plan, a mathematical philosophy that supports the implementation of research-based instructional strategies should be developed, and capacity building for implementation along with observations of mathematics instruction should occur. To build capacity, a shared vision, teacher buy-in, effective professional learning opportunities, and a schoolwide systematic approach to implementation fidelity are needed. Most importantly, a tool for systematically measuring implementation fidelity should be developed and implemented.

Monitoring Policy Implementation

As instructional teams create their plans, they must consider how they will monitor the implementation of the implementation fidelity framework and the frequency at which this will occur. Once this happens, the team should identify individuals responsible for monitoring and providing feedback and those who will provide instructional support to teachers. During the periods of monitoring, designated individuals should observe instructional planning and mathematics instruction. In addition, all stakeholders should monitor student progress who have an impact on students' mathematical achievement. This should occur weekly as teachers and members of the instructional team engage in professional learning communities.

An observation protocol should be created to ensure a systematic approach when conducting observations, and all observers should utilize this same protocol. A sample observation protocol, observation tool, and fidelity checklists can be found in Appendix A. It's the responsibility of the instructional team to select which observational tool and fidelity measure to utilize. Once chosen, the observation tool and fidelity measure should be provided to the teachers, and professional learning opportunities planned and implemented to ensure teachers are aware of the expectations when observed. In addition, a classroom observation and fidelity checklist feedback form is provided in Appendix A.

Conclusion

Implementation fidelity is not at the level it needs to impact student achievement at Elementary School A. Therefore, an implementation fidelity framework was developed. The purpose of the implementation fidelity framework is to assist teachers with implementation fidelity as it pertains to incorporating research-based instructional strategies in the mathematics classroom. It is recommended that the instructional team at Elementary School A, review the implementation fidelity framework, devise a plan for school-wide implementation, develop a mathematical philosophy that supports these strategies, and create and implement a tool for systematically measuring implementation fidelity.

Introduction of the Local Problem

The implementation of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions was not the norm in the school district. The mathematics learning environment for the majority of the student population exemplified a one-way instructional setting where content is delivered and very limited learner-centered practices are employed. Forty-five minutes of the sixty-minute mathematics block is spent with students focusing solely on the teacher without any form of collaboration and self-directed learning, as evidenced by the school and district-based administrator's teacher observations, according to the district's elementary mathematics consultant. Although not required, the administrative staff encouraged teachers in the district to implement research-based instructional strategies with the help of the curriculum resource teacher and the district elementary math consultant.

During the spring of 2018-2019 school year, an analysis of teachers' lesson plans and classroom observations conducted by school-based administrators and the district's math consultant, revealed continued teacher-centered learning environments at Elementary School B. Based on observations, an average of 45- of the 60-minute math block is spent with teachers lecturing in a traditional manner (i.e., standing in front of the classroom providing instruction). Teacher-centered learning environments result in limited opportunities for students to engage in hands-on activities, small group investigations, problem-solving tasks, and classroom discourse (Van de Walle et al., 2014). Furthermore, the same analysis revealed that Elementary School A appeared to be implementing research-based instructional strategies, but the level of implementation fidelity could not be assessed. In Elementary School A classrooms, students can be seen exploring mathematics using manipulatives and engaging in group discussions. Also, teachers can be observed assisting small groups of students and facilitating whole group discussions as students shape their learning. The Math Big 3 Observational Tool was primarily used to determine whether or not a school was implementing research-based strategies (see Appendix B).

The problem at Elementary School A was that the mathematical learning environment for the student population exemplified a one-way instructional setting where the content was delivered, and very limited learner-centered practices were employed. To transition the mathematics learning environments from teacher-centered to learner-centered and improve student outcomes, district and school-based mathematics professional development has focused on the implementation of research-based instructional strategies during the 2018–2019 academic school year. Although Elementary School A appeared to be implementing research-based instructional strategies, it is unknown if these changes have improved mathematics achievement. In addition, the level of implementation fidelity as it pertains to the research-based instructional strategies was unknown.

A mixed-methods research design was conducted to determine if there is a significant difference in the mathematical achievement of students who experienced research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse) and those who had not. The quantitative analysis of MI data revealed that there was no statistically significant difference between students who received (Elementary School A) research-based instructional strategies and those who had not (Elementary School B). Three teachers from Elementary School A were voluntarily interviewed and their lesson plans analyzed to obtain their knowledge and beliefs on learner-centered instructional strategies. The analysis of interview results revealed four recurring themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, and lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interviews. Based on the findings from this study, the limitations highlighted, and implementation fidelity improved, more research is needed in the school district to determine if implementing research-based instructional strategies positively impacts students' mathematical achievement. This policy recommendation paper provides a framework for implementing research-based instructional strategies through enhanced fidelity that has the potential to improve student mathematical achievement.

Method

Research Questions

Three of the most recent administrations of the SC Ready statewide assessments revealed proficiency percentages of 32.9% in 2016, 29.8% in 2017 and 32.5% in 2018 at the district level, according to annual report cards issued by the state. Resulting in over 65% of the district's third- through fifth grade student population scoring in non-proficient categories. As a district, 43.5% of third grade, 33.1% of fourth grade, and 36.5% of fifth grade students demonstrated proficiency on the 2018 administration of SC Ready. When analyzing the proficiency percentages for each grade level at the district level, instructional changes are warranted as a low percentage of third- through fifth graders perform proficiently. As a result of both administrative and teacher buy-in, research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, classroom discourse) were implemented at Elementary School A. The effectiveness of the implementation was not known. The following RQs and hypotheses underpinned this study:

RQ1 (Quantitative): Is there a difference ($\alpha = .05$) in mathematical achievement, as measured by Math Inventory (MI), between students at Elementary School A who have experienced research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) and those who have not at Elementary School B?

> $H_0$1: There is no statistically significant difference in mathematical achievement between students who have experienced research-based instructional strategies and those who have not.
>
> H_A1: There is a statistically significant difference in mathematical achievement between students who have experienced research-based instructional strategies and those who have not.

RQ2 (Qualitative): In what ways are teachers implementing research-based instructional strategies (hands-on activities, small group instruction, problem-solving activities, and classroom discussions) at Elementary School A?

A mixed-methods approach was utilized to address the research questions. Quantitative data from the MI assessment were collected and analyzed along with data from teacher interviews and teacher lesson plans. The purpose was to investigate the outcomes and implementation of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discussions for students in Grades 2–5. The policy recommendation found in this document was formed based on the findings from the research questions referenced above.

Data Collection

Quantitative data from students' MI fall and winter assessment results and qualitative data from teacher interviews and lesson plans were used to create this policy recommendation paper. Based on these findings, the purpose of this policy recommendation is to provide a framework to assist teachers with the implementation fidelity of research-based instructional strategies. The quantitative data used for this study was obtained from the district's Enrich database. Interview and teacher lesson plan data were collected from three teachers at Elementary School A. Both sets of data apply to the 2019–2020 academic school year.

Analysis and Results

A one-way between-subjects (treatment versus control) ANCOVA was conducted to investigate differences between groups, where the winter MI scores served as posttest scores for the dependent variable, and the fall MI scores served as pretest scores for the covariate variable. Qualitative data collected from teacher interviews and lesson plans were coded and analyzed for themes. The validity and trustworthiness of both the quantitative data and the qualitative findings are sufficient as the questions used for the MI assessment have been studied over a period of several years and the qualitative themes found were triangulated across the data sources used. Thus, the integration of quantitative data and qualitative findings enhanced the results of the study as the qualitative findings were used to support the quantitative results.

RQ1/Quantitative Results. Quantitative data was collected from the Math Inventory scores of 294 students at Elementary School A and 328 students at Elementary School B. The quantitative results were presented by grade level. There were four grade levels investigated within the treatment school and within the control school, Grades 2-5. Given there was more than one statistical analysis conducted for the same research question, the Bonferroni method was used to determine the alpha level to avoid a type I error, falsely flagging a significant result (Armstrong, 2014). Because there were four analyses of covariance conducted, an alpha level of .01 was used to determine significance for each ANCOVA.

***Grade 2 Findings*.** The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .83$. The ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables is $F(1,138) = 1.64$, $p = .20$. The within-group regression slopes are equal, $F(1,136) = .00$, $p = .99$. Levene's test showed that the assumption of equal variances was also met, $F(1,138) = .69$, $p = .42$. All of the assumptions were tenable, no violations were identified. Table 1 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. The ANCOVA yielded a non-significant difference between group means, $F(1,137) = .43$, $p = .51$.

Table 1

Grade 2- Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

		Pretest		Posttest		
				Obtained		Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	64	99.13	129.64	213.00	132.49	200.19
Control	76	72.34	117.58	181.25	128.79	192.04

***Grade 3 Findings*.** The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was $r = .78$. The ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,130) = 1.38$, $p = .24$. The within-group regression slopes are equal, $F(1,128) = .05$, $p = .82$. Levene's test showed that the assumption of equal variances was also met, $F(1,130) = .19$, $p = .67$. All of the assumptions were tenable, no violations were identified. Table 2 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. The ANCOVA yielded a non-significant difference between group means, $F(1,129) = .24$, $p = .63$.

Table 2

Grade 3- Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

		Pretest		Posttest		
				Obtained		Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	64	249.95	141.75	335.64	154.81	323.06
Control	68	222.51	126.24	319.34	149.23	331.18

***Grade 4 Findings*.** The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was r = .79. The ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,136) = 2.80$, $p = .10$. The within-group regression slopes are equal, $F(1,134) = .11$, $p = .74$. Levene's test showed that the assumption of equal variances was also met, $F(1,136) = .28$, $p = .60$. All of the assumptions were tenable, no violations were identified. Table 3 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. The ANCOVA yielded a non-significant difference between group means, $F(1,135) = 1.27$, $p = .26$.

Table 3

Grade 4- Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

		Pretest		Posttest Obtained		Posttest Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	68	370.25	143.58	441.21	172.61	421.36
Control	70	325.61	168.39	422.91	175.57	442.19

***Grade 5 Findings*.** The covariate was strongly related to the dependent variable. The relationship between the pretest scores and the posttest scores was r = .72. The ANOVA results for checking the linearity assumption of the within-group relationship between the dependent and covariate variables, $F(1,126) = .17$, $p = .68$. The within-group regression slopes are equal, $F(1,124) = 3.23$, $p = .08$. Levene's test showed that the assumption of equal variances was also met, $F(1,126) = .03$, $p = .86$. All of the assumptions were tenable, no violations were identified. Table 4 presents the pretest, posttest obtained, and posttest adjusted means and standard deviations measured from each group of participants. The ANCOVA yielded a non-significant difference between group means when using the Bonferroni alpha adjustment, $F(1,125) = 4.76$, $p = .03$.

Table 4

Grade 5- Mean Pretest and Mean and Adjusted Mean Posttest Scores for the Math Inventory Scores

		Pretest		Posttest: Obtained		Posttest: Adjusted
Group	*n*	$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$
Treatment	62	468.16	135.41	528.60	137.61	524.53
Control	66	458.39	134.69	560.18	159.39	564.01

RQ2/Qualitative Results. Three teachers from Elementary School A, voluntarily participated in the interview phase of this study as well as provided five weeks of lesson plans. During the interview, teachers appeared to be highly engaged, and their passion and beliefs as it pertains to the instructional delivery of mathematics exuded through their responses. Teachers justified responses and supported opinions with evidence from the classroom. Thus, the interviews were considered reliable, and all information obtained was included. In addition, each teacher provided five weeks of lesson plans between the months of October and December. An overall analysis of teacher interview responses and lesson plans revealed four recurring themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, and lack of implementation fidelity. An additional recurring theme of improving mathematical achievement through the implementation of learner-centered activities was prevalent in the analysis of teacher interviews. When triangulating the data obtained from the interviews and teacher lesson plans it appears that teachers at Elementary School A have the knowledge and skill to implement research-based instructional strategies into their daily mathematics instruction. Thus, the emphasis of this policy recommendation paper will be creating a framework that assists teachers with implementing research-based instructional strategies with fidelity that positively impacts students' mathematical achievement.

Explanation of the Results

Based on the quantitative and qualitative analysis, research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse resulted in no statistically significant difference between students who have experienced research-based instructional strategies and those who have not. In assessing the qualitative themes: student ownership of learning, students engaging in learner-centered activities, students engaging in collaborative learning, lack of implementation fidelity and improving mathematical achievement through the implementation of learner-centered activities, implementing research-based instructional strategies with fidelity to improve students' mathematical achievement was not evident. The strengths and weaknesses of both sets of data were identified and compared to create the framework that can be used to implement research-based instructional strategies with fidelity, in the mathematics classroom. Further explanation of the results is found in the next two subsections.

RQ1/Quantitative Results. Based on the quantitative results, the implementation of research-based instructional strategies in the mathematical classroom did not have a statistically significant difference between students who learned mathematical content through these strategies than those who did not.

RQ2/Qualitative Results. Throughout the qualitative analysis, strengths and weaknesses emerged. Of the five emerged themes, implementing research-based instructional strategies deemed beneficial when improving the math achievement of students. Teachers shared that they knew the implemented activities were successful based on the academic growth exhibited by the students as demonstrated on various assessments, students' ability to apply their learning to new situations, and students' ability to select and apply strategies learned to solve problems. In addition, implementing research-based instructional strategies builds student confidence, provides opportunities for collaboration and critical thinking and holds students accountable for their learning. Most importantly, teachers unanimously agreed that it is impossible to have an effective mathematics classroom without implementing research-based instructional strategies. Thus, teachers understood the who, what, and why of implementing research-based instructional strategies.

The weaknesses as it pertains to the implementation of research-based instructional strategies emerged in the when, where, and how of the process. During the interviews, teachers stated that students are engaged in learner-centered activities on a daily or weekly basis; and outlined the components (problem of the day, mini-lesson, math centers/small group instruction, and closure) of the district's math instructional framework as they described a typical mathematics lesson in their classroom. However, the analysis of teacher lesson plans lacked two of Weimer's learner-centered practices. To improve upon the teaching practices of including explicit skill instruction and encouraging students to reflect on what and how they are learning, teachers need to be more intentional when creating their lesson plans.

Review of Literature

Several studies have been conducted to determine the types of instructional strategies linked to improving students' mathematical achievement. For this study, hands-on activities, small group investigations, problem-solving tasks, and classroom discussions are the four strategies that were explored. These student-centered instructional strategies were grounded in the theoretical framework of Bruner’s (1977) constructivist theory and the conceptual framework of Weimer’s learner-centered teaching. Both frameworks emphasize learning as an active process where students are responsible for accessing their prior knowledge to reconstruct new meaning as they manipulate tasks and engage in academic discourse. To ensure this occurs, teachers must create a learning environment where student activities are guided, the behavior is modeled, and examples are provided to transform student discussions into meaningful communication (Flynn, 2005). Classrooms must evolve where problem-solving, concept development, and the construction of learner-generated solutions are the primary components (Lunenburg, 2011). A synopsis of literature on Fullan’s change theory, implementation fidelity, measurable threshold, and visible learning will be explored in the subsections that follow.

Fullan’s Change Theory

Fullan’s model of change is comprised of four phases: initiation, implementation, continuation, and outcome. Initiation occurs when an individual or group of people, begins or promotes a particular program or direction of change (Fullan, 2007). Existence and quality of innovations, access to innovations, advocacy from central administration, teacher advocacy, and external change agents are five factors that affect the initiation phase (Fullan, 2007). The implementation phase is the “process of putting into practice an idea, program, or set of activities and structures new to the people attempting or expected to change” (Fullan, 2007, p.84). The process of implementing change can be impacted by the characteristics of change (need, clarity, complexity, and quality/practicality), local factors (school board, community board, principal, teacher), and external factors (government and other agencies). Continuation is the third phase of Fullan’s model of change. Continuation involves making a decision regarding the innovation’s longevity within the educational setting, based upon the positive or negative reaction to the change (Fullan, 2007). Outcome is the fourth and final phase of Fullan’s change model focusing on the following four perspectives as it pertains to the change process: (a) active initiation and participation; (b) pressure, support, and negotiation; (c) changes in skills, thinking, and committed actions; and (d) overriding problem of ownership (Fullan, 2007). For this policy recommendation paper, Fullan’s model of change, emphasizing implementation and outcome, will serve as the theoretical framework.

Implementation Fidelity

Implementation fidelity can be defined as the degree to which an intervention or program is delivered as intended (Carroll et al., 2007). It can serve as a liaison between the intervention and the intended outcomes as the relationship is being evaluated (Carroll et al., 2007). To effectively measure implementation fidelity, one must first understand and evaluate the fidelity itself. Without this assessment, one will not know if the success level of the outcomes is attributed to the intervention or the level of implementation. Thus, making it harder to transition findings from the research settings to real-world settings (James Bell Associates, 2007).

Adherence, exposure, quality of delivery, participant responsiveness, and program differentiation are the five components that must be measured when establishing fidelity. Adherence measures whether a program service or intervention is delivered as designed or written (Mihalic, 2004). The amount of time students received the intervention is measured by exposure (Dunesbury et al., 2003). Quality of delivery measures how well the individual delivers the intervention in accordance with the program/curriculum (Mihalic, 2004). Participant responsiveness measures the level of engagement displayed by the participants during the period of intervention (Kirkpatrick, 1967). The final component, program differentiation, identifies the essential components of the program (Dunesbury et al., 2003).

According to Carroll et al. (2007), implementation fidelity can be measured in isolation (individual components) or across all five components. A third process of measuring implementation fidelity was created and used the process of measuring all five components, including their functions and relationships, and the introduction of two additional components, intervention complexity and facilitation strategies. The purpose of intervention complexity is to explore the barriers that present themselves when implementing a new idea that is foreseen as complex. Facilitation strategies are strategies that are put in place to achieve the maximum level of fidelity. These strategies include but are not limited to manuals, guidelines, training, monitoring and feedback, capacity building, and incentives (Bellg et al., 2004; Walton et al., 2017).

The process of measuring implementation fidelity is parallel to the process of measuring adherence. Through the lens of adherence, one can measure the content covered, frequency, and duration of the intervention. In addition, the level to which adherence is achieved can be affected by the quality of delivery, participant responsiveness, intervention complexity, and facilitation strategies.

Measurable Threshold

Measurable can be defined as a quantifiable identifier that is used to monitor the progress of a program, project, or an implemented instructional strategy towards an established target or goal. The term threshold is defined as a magnitude or intensity that must be exceeded for a certain reaction, phenomenon, result, or condition to occur or be manifested (“Threshold”, n.d.). Thus, measurable threshold can be defined as a point at which a program, project, or implemented instructional strategy has met and/or exceeded the desired level needed to effect change. For the purpose of this study, measurable threshold is defined as the point where an implemented mathematical instructional strategy meets or exceeds the intended level to increase student mathematical achievement.

A practice profile is created to assist with the implementation process. The practice profile serves as a framework. The practice profile will be used to identify the supports that will be needed throughout the implementation process. According to Permanency Innovations Initiative Training and Technical Assistance Project (2016), a practice profile is a document that describes how innovation works in everyday practice. The essential functions, operationalized definition, core activities, behaviorally based practice indicators, and practice criteria are the five elements that make up the practice profile. Essential functions are the strategies that a practitioner engages in to address an identified problem (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). The operationalized definition is based on the research, change theory and should be connected to the values, principles, and philosophy of the strategy (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). The actions performed by the practitioner during an observation are considered the core activities (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). Behaviorally based practice indicators describe the observable actions and indicate what behaviors are warranted to ensure successful implementation (Permanency Innovations Initiative Training and Technical Assistance Project, 2016). Expected, developmental, and unacceptable are the three levels of practice criteria. These levels are categorized based on the following criteria:

- Expected – “Includes activities that exemplify practitioners who are able to apply required skills and abilities to a wide range of settings and contexts; use these skills consistently and independently; and sustain skills over time while continuing to grow and improve their positions.”
- Developmental – “Includes activities that exemplify practitioners who are able to implement required skills and abilities but in a more limited range of contexts and settings; use these skills inconsistently or need supervisor/coach consultation to complete or successfully apply skills; and benefit from a coaching agenda that targets particular skills for improvement to move practitioners into the “expected/proficient” category.”
- Unacceptable – “Includes activities that exemplify practitioners who are not yet able to implement required skills or abilities to any context.” (Permanency Innovations Initiative Training and Technical Assistance Project, 2016, p.7)

Based on the level of performance demonstrated by the practitioner, one can begin to provide the support he/she needs to be successful.

After the development of the practice profile, measurable thresholds can be established. Fidelity of implementation should be considered when developing measurable thresholds. Fidelity of implementation analyzes whether an intervention or program was delivered or implemented as outlined by the developer (Corcoran, 2017). Through the analysis, the following components are examined: adherence, exposure, quality of delivery, participant responsiveness, and program differentiation. After the analysis, each component should yield a point where improved academic achievement is demonstrated, thus establishing a measurable threshold.

Visible Learning

In 2009, John Hattie published *Visible Learning*, a text that ranked 138 influences and effect sizes as it relates to student achievement. To do this, Hattie studied over 800 meta-analyses. In 2011, Hattie updated the effects to 150 in *Visible Learning for Teachers* and 195 effects in 2015 in *The Applicability of Visible Learning to Higher Education*. Since then, Hattie's research has evolved with over 1200 meta-analyses synthesized. This synthesis has resulted in the identification of 252 influences and effect sizes related to student achievement. In addition, Hattie's research found that the average effect size related to student achievement is 0.40, meaning that students should attain at least a year's growth within an academic school year. Hattie's effect sizes for hands-on activities, small group investigations, problem-solving tasks, and classroom discussions will be used as the measurable thresholds needed to develop the implementation fidelity framework.

Hands-on activities, small group investigations, problem-solving tasks, and classroom discussions were influences studied by Hattie (2009) and Hattie et al. (2017) to determine their effect size on student achievement. Hands-on activities with an emphasis on manipulative materials during mathematics instruction yielded an effect size of 0.3 and has a ranking of 150. An effect size of 0.47 was yielded when studying small group investigations with an emphasis on the learning process and has a ranking of 92. The implementation of problem-solving tasks through problem-solving teaching yielded an effect size of 0.68 with a ranking of 37. Last but not least, classroom discussions yielded an effect size of 0.82 with a ranking of 15.

Implementing hands-on activities with an emphasis on the effects of manipulative materials on mathematics allows students to make connections between mathematical representations. Students should be engaged in connecting mathematical representations for two purposes: (a) provide concrete representations that lead students to develop conceptual understanding and later connect that understanding to procedural skills, and (b) provide a variety of representations that range from using physical models to using abstract notations (Hattie et al., 2017). To encourage the use of manipulatives during mathematical concept exploration, teachers should implement tasks that allow students to use a variety of representations and encourage students to represent a mathematical situation in different ways (concrete models, pictures, words, numbers, etc.) to justify their mathematical thinking and reasoning (Hattie et al., 2017). Through the incorporation of manipulatives, teachers can facilitate and scaffold students through the C-R-A (concrete, representational, abstract) process helping students shape and solidify their understanding of mathematical concepts (Agrawal & Morin, 2016).

The implementation of small group learning through the lens of the learning process provides opportunities for teachers to meet the needs of all students as instruction is explored. The process of learning is deemed a social one, thus individuals learn better when they are able to interact with others (Hattie et al., 2017). Through small group instruction, teachers can differentiate learning, ensuring that students are challenged at their appropriate instructional levels. Thus, small groups should be flexible and designed strategically as student's proficiencies and deficiencies vary depending on the mathematical skill being addressed. In addition, small group instruction allows teachers to informally assess student understanding and provide immediate feedback as they engage in the learning process.

According to Hattie (2009), "problem-solving teaching involves the act of defining or determining the cause of the problem; identifying, prioritizing and selecting alternatives for a solution; or using multiple perspectives to uncover the issues related to a particular problem, designing an intervention plan, and then evaluating the outcome" (p.210). Teachers that expose students to problem-solving investigations allow students to build their cognitive flexibility while at the same time increasing mathematical achievement. Problem-solving processes and methods have been developed as far back as Polya's (1957) four-phase method (understand the problem, obtain a plan of solution, carry out the plan, and examine the solution obtained). The implementation of problem-solving teaching through investigations allows students to explore and obtain knowledge themselves. Hattie et al. (2017), identifies two purposes of implementing tasks to promote reasoning and problem solving: (a) provide opportunities for students to engage in exploration and make sense of important mathematics, and (b) encourage students to use procedures in ways that are connected to understanding. Therefore, teachers should integrate tasks that are built on students' understanding, have multiple solutions, and are interesting to students (Hattie et al., 2017).

Of the research-based instructional strategies explored in this study, classroom discourse is the highest-ranked with an effect size of 0.82, which means that students who experience classroom discourse can attain academic growth of more than two school terms. Two purposes of facilitating classroom discourse are to provide students with opportunities to share ideas, clarify their understanding, and develop convincing arguments; and advance the mathematical thinking of the whole class by talking and sharing aloud (Hattie et al., 2017). Through the implementation of classroom discourse, teachers can assess students to gauge their level of understanding, thus allowing them to determine who needs intervention, who is on track, and who may need an additional challenge (Russell, 2019). This immediate assessment can only be attained if the students are engaging in deep thinking and talking about the concept and not the teacher (Russell, 2019).

Developing a Framework

A framework can be defined as a basic structure or set of ideas that provides support for something ("Framework", n.d.). For this policy recommendation paper, an implementation fidelity framework was created. When creating a framework, one must ensure the following components are explored:

1. Describe the intended use of your framework.
2. Outline your initiative or program's vision and mission.
3. State the objectives of your initiative or effort.
4. Describe the appropriate scope or level of your framework.
5. Identify ALL components to include.
6. Draft a picture of the framework.
7. Check for the completeness.

8. Implement the framework.
9. Revise framework as needed. (The Community Tool Box, 2020)

A synopsis of each component will be provided in the paragraphs that follow.

When describing the intended use of the framework, one should convey the purpose and direction of the initiative, show how multiple factors interact to influence the problem or goal, and identify actions and interventions more likely to lead to the desired result (The Community Tool Box, 2020). Outlining the program's vision involves the creation of an easy to communicate, uplifting statement that identifies the future aspirations of the program. The mission statement should identify what the program will do and through what lens it will be accomplished. The objectives of the initiative should specifically summarize the anticipated measurable results (The Community Tool Box, 2020). The overall initiative (includes all strategies to affect change and bring about improvement), a particular initiative (includes only the component or element of a specific aspect of the overall effort), and a specific work plan (an action or model for cooperation among stakeholders) are three types of descriptions that can be utilized when describing the appropriate scope or level of your framework.

Purpose/mission (what the group is going to do and why), context and conditions under which the problem or goal exists (may affect the outcome), inputs (resources and supports available as well as barriers), activities/interventions (what the initiative or program does to bring about change), outputs (direct results of the group's activities), and effects (results) are six components that should be included when creating the framework (The Community Tool Box, 2020). Drafting a picture of the framework requires an anticipated time sequence and directional arrows that communicate influence and sequence (The Community Tool Box, 2020). The drafted framework should then be taken through a real or hypothetical situation to obtain feedback that identifies its usefulness and completeness. This feedback should then be used to revise the framework as needed. The newly revised framework should then be utilized to affect change. Utilization of the framework can occur in one of the following five ways:

> a. orienting those doing and supporting the work - use to explain how the elements of the initiative or program work together, where contributors fit in, and what they need to be able to make it work;
> b. planning - used to clarify your initiative or program's strategies, identify targets and outcomes, prepare a grant proposal, identify necessary partnerships, and estimate timelines and needed resources for the effort;
> c. implementation – use to determine what elements you have and don't have in your initiative or program, develop a management plan, and make mid-course adjustments;
> d. communication and advocacy – use to justify to others why the initiative/program will work and to explain how investments will be used; and
> e. evaluation – use to document accomplishments, identify differences between the ideal program and the currently operating one, determine which indicators will be used to measure success and frame questions about attribution (of cause and effect) and contribution of the program/initiative to the mission. (The Community Tool Box, 2020, para. 8)

As the framework is continuously implemented to carry out the initiatives of various programs, it should be revised as needed to include emerging elements and components (The Community Tool Box, 2020).

Implementation Fidelity Framework

The components explored in the previous section when developing a framework were used to create the framework found in Appendix A. The purpose of the implementation fidelity framework is to assist teachers with implementation fidelity as it pertains to incorporating research-based instructional strategies in the mathematics classroom. Through the implementation of the framework, students will be allowed to engage in student-centered activities as teachers incorporate research-based instructional strategies within their mathematics instruction, promoting improved mathematical achievement. The objectives of this framework are as follows: (a) enhance mathematics learning environments to foster a more student-centered approach; (b) ensure mathematical concepts are presented utilizing the C-R-A (concrete–representational–abstract) process; and (c) encourage teachers to purposefully plan mathematics instruction, through the incorporation of research-based instructional strategies (hands-on activities, small group investigations, problem-solving tasks, and classroom discourse). A specific work plan for action or model for cooperation among stakeholders or participating agencies will serve as the scope of this framework as it focuses on the implementation of research-based instructional strategies in the mathematics classroom. As seen in Appendix A, the following components were included in the implementation fidelity framework: purpose and mission, inputs, activities/interventions, and outputs/effects.

Recommendations for Implementation

The following recommendations of how to improve the fidelity of implementation as it pertains to the research-based instructional strategies explored during this study were formalized after analyzing the study's findings and reviewing current research. I recommend that the instructional team at Elementary School A review the implementation fidelity framework and devise a plan for school-wide implementation to enhance and improve the mathematics instruction, respectively. This plan should address the weaknesses discovered during the study, specifically targeting the components (adherence, exposure, quality of delivery, participant responsiveness, and program differentiation) of implementation fidelity. To ensure implementation of the school-wide plan, several things would have to occur, from school-wide professional learning to observations of mathematics instruction. Most importantly, a tool for systematically measuring implementation fidelity should be developed and implemented. The paragraphs that follow will expound upon the recommendation presented.

The instructional team at Elementary School A is dedicated to improving the academic achievement of its students. For this study, the emphasis has been placed on mathematics achievement. Research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse have been proven to increase the mathematical achievement of students (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013;

Woodward et al., 2012). Thus, the school's instructional team should develop a mathematical philosophy that supports the implementation of these strategies. By developing said philosophy, the instructional team can focus on a high level of implementation fidelity as they build capacity for implementation (Sugai et al., 2016). Building capacity requires a shared vision, teacher buy-in, effective professional learning opportunities, and a schoolwide systematic approach to implementation fidelity (Harn et al., 2017; Sugai et al., 2016). Therefore, the instructional team would be responsible for developing a plan that addresses the components needed to build capacity.

Shared Vision

The purpose of a shared vision is to establish consistency in the curriculum utilized and the delivery of instruction (Victoria State Government, 2019). Student success is inevitable with a shared vision as every teacher throughout the school building enforces the exact expectations and instructional practices (Victoria State Government, 2019). A shared vision establishes the foundational beliefs that commence the path toward student achievement. Hence, I would recommend that the shared vision be established by the instructional team, with the assistance of grade-level chairs, includes the implementation fidelity framework developed from this study and fosters student mathematical achievement through the implementation of research-based instructional strategies.

Teacher Buy-In

Adherence and quality of delivery are two components that are essential when it comes to implementation fidelity. To ensure that a program or instructional strategy is implemented with the highest fidelity, one must adhere to the program's design and deliver it as intended. For this to occur, teachers must buy-in to what they are being asked to implement. Therefore, teachers need to receive adequate training (discussed in the next subsection), support from district and school-level instructional staff, and have a voice (Greene, 2016). In addition, teachers should know that the administrative staff is buying in as well. Administrative buy-in is essential because teachers practice what they see. If the administrative team does not buy into the research-based instructional strategies they are asking teachers to implement, then teachers are more likely not to adopt and support the initiative.

Allowing teachers to have a voice increases the level of buy-in as initiatives are implemented. Teachers must first understand why the initiative is necessary and how it supports the shared vision. Therefore, the instructional team is responsible for sharing data over a period of time that supports the rationale for improving mathematical academic achievement. In addition to the data shared by the administrative team, teachers should bring any data they have collected regarding the students in their respective classrooms. This data should provide teachers with students' strengths and weaknesses that guide them to make informed instructional decisions. As a grade-level team, teachers should collectively analyze and reflect upon the data to plan instruction that supports improved student achievement (Greene, 2016). During this process, teachers should develop SMART goals to simultaneously measure student growth and the effectiveness of the created instructional plan. As teachers develop growth goals that impact not only the students within their classrooms but the student body as a whole, the ability to secure teacher buy-in as it pertains to implemented initiatives are enhanced (Greene, 2016).

Professional Learning Opportunities

To increase the level of implementation fidelity as it pertains to implementing research-based instructional strategies, teachers must know what they are, when to implement, how to implement, and the impact they will have on student achievement. For this to occur, teachers should be provided with multiple opportunities for professional learning. The purpose of professional learning is to improve learning for both educators and students (Mizell, 2010; Pharis et al., 2019). Through effective professional learning opportunities, educators are allowed to develop and enhance their knowledge and skills to meet the diverse learning needs of their students (Mizell, 2010; Pharis, et al., 2019). The training should be carefully planned and executed with the learner in mind to ensure the effectiveness of the training being provided. Thus, the presenter should be prepared to adjust the direction of his/her presentation based on the feedback provided by the participants. During these sessions, teachers should be engaged in activities that allow them to explore the research-based instructional strategies. Situational examples of when and how to implement the research-based instructional strategies (hands-on activities, small group instruction, problem-solving tasks, and classroom discourse) should be demonstrated and opportunities for teachers to execute through simulations are encouraged. In addition, teachers should be required to apply what they have learned in their classrooms within a specified period of time and the school's instructional team should conduct observations to ensure the initiative is being implemented as intended.

Policy Implementation

The Instructional Team at Elementary School A is responsible for devising a plan to increase the level of implementation fidelity as it pertains to the implementation of research-based instructional strategies in the mathematics classroom. This plan should identify the roles and responsibilities of the instructional team and mathematics teachers. It should provide stakeholders with the necessary resources to effectively carry out the plan as written. A timeline should be included which outlines dates of implementation, observational and coaching feedback times, ongoing professional learning opportunities, and evaluation periods. Most importantly, the implementation fidelity framework, located in Appendix A, should serve as the foundational structure that guides the instructional teams as they create and implement their respective plans.

Monitoring Implementation Fidelity

As instructional teams create their plans, they must consider how they will monitor the implementation of the implementation fidelity framework and the frequency at which this will occur. Once this occurs, the team should identify individuals responsible for monitoring and providing feedback and those who will provide instructional support to teachers. During the periods of monitoring, designated individuals should observe instructional planning and mathematics instruction. In addition, all stakeholders should monitor student progress who have an impact on students' mathematical achievement. This should occur weekly as teachers and instructional team members engage in professional learning communities.

An observation protocol should be created, and the same tool used by all observers to ensure a systematic approach when conducting observations. A sample observation protocol, observation tool, and fidelity checklists can be found in Appendix A. It is the responsibility of the instructional team to select which observational tool and fidelity measure to use. Once chosen, the observation tool and fidelity measure should be provided to the teachers and professional learning opportunities planned and implemented to ensure teachers are aware of the expectations when observed. In addition, a classroom observation and fidelity checklist feedback form is provided in Appendix A.

Conclusion

The implementation of research-based instructional strategies (hands-on activities, small group instruction, problem-solving tasks, and classroom discourse) in the mathematics classroom has been shown to increase the mathematical achievement of students (Ashley, 2016; Hattie, 2012; Kablan et al., 2013; National Center for Education Statistics, 2013; Woodward et al., 2012). Thus, district and school-based mathematics professional learning opportunities focused on the implementation of these strategies during the 2018–2019, and 2019–2020 academic school year. However, implementation fidelity is not at the level it needs to be to impact student achievement. Two elementary schools (Elementary School A (treatment) and Elementary School B (control)) participated in this study and their results were used to guide and develop this policy recommendation paper. The quantitative results from this mixed-methods study revealed that there was no statistically significant difference between students who received research-based instructional strategies and those who did not, while lack of implementation fidelity emerged as the salient recurring theme prompting the development of an implementation fidelity framework. This policy recommendation paper recommends that the instructional team at Elementary School A, review the implementation fidelity framework, devise a plan for school-wide implementation to enhance and improve the mathematics instruction, develop a mathematical philosophy that supports these strategies, and create and implement a tool for systematically measuring implementation fidelity.

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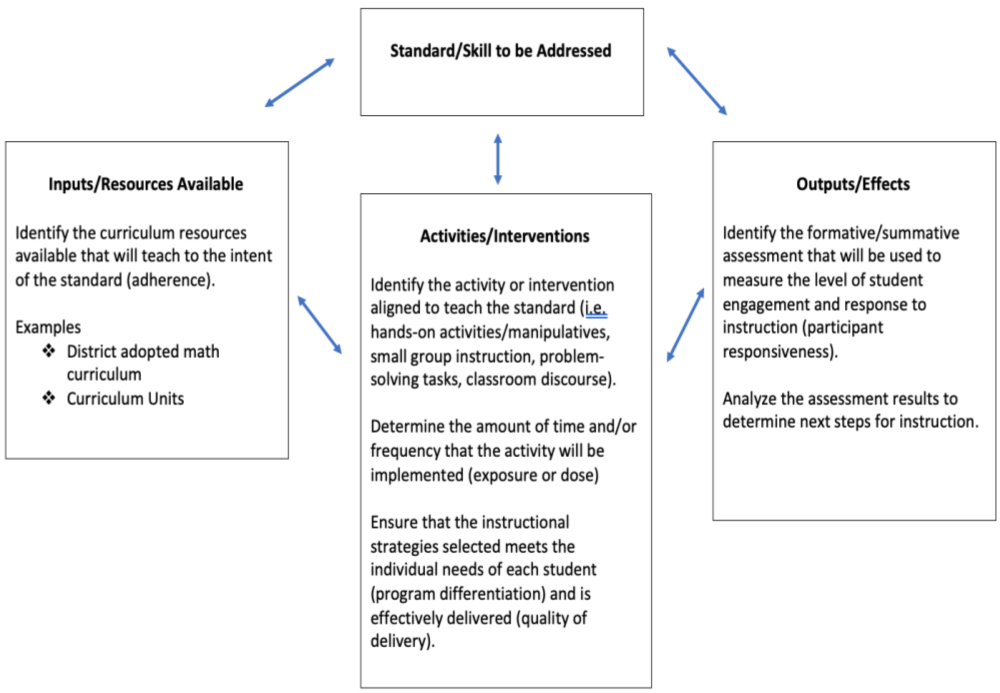
Appendix A-1: Implementation Fidelity Framework

Purpose
To assist teachers with implementation fidelity as it pertains to incorporating research based instructional strategies in the mathematics classroom.

Mission
To improve the mathematical achievement of students through enhanced learner-centered instructional strategies.



Appendix A-2: Observation Protocol

Before the Observation (Building Level Principal or Assigned Facilitator)

1. Inform teachers to set the tone for the observation (provide copies of the Observation Tool and Fidelity Checklist).
2. Send observers a copy of the observation protocol, observation tool, and fidelity checklist.

Before the Observation (Observers)

1. Review the Observation Tool and Fidelity Checklist.

During the Observations

1. Visit each assigned class for 15 minutes and record information using the Fifteen Minute Direct Observation Tool.
2. Address each area of the observation tool. You may review lesson plans, student work, or even speak with a student. Remember that comments can be written for each component of the observation tool.
3. Complete the Fidelity Checklist.
4. Due to the specified time for the observation, please report back to the meeting area by the established time.

After the Observations

1. The observation team will review findings from all observations, which may lead to brief discussions to include questions and comments.
2. The facilitator will assign a recorder to complete an Observation Feedback Form to share with each grade level.
3. As a group, the team should consider all that has been shared, paying close attention to commonalities to determine the overall commendations and recommendations for each grade level.
4. The team will identify commendations and recommendations, which the recorder will place on the Observation Feedback Form. After all commendations and recommendations have been shared, the entire group will reach a consensus on commendation and recommendations.
5. The last item on the Observation Feedback Form will require the team to reach consensus on one priority area of focus. This form will be shared with each grade level during their upcoming collaborative planning session.

Appendix A-3: 15-Minute Direct Observation Tool

Instructor:____________________________ Date/Time __________________________
Observed by:_________________________
Standard/Skill:______________________________ Number of students:________

WHAT TO LOOK FOR	NOTES
Active engagement of all students	
Modeling of instructional tasks	
Multiple chance to practice tasks	
Explicit instruction	
Corrective feedback	
Materials organized and readily available	
Engagement of students in independent activities	
Encouragement/direct praise	
Needed intervention provided	
Intervention began and ended on time	

Positive #1	
Positive #2	
Suggested Changes	
Next Steps	

I certify that everything reported on this form is accurate and correct and that interventions are being implemented with integrity at least 80% of the time.

____ signature

Appendix A-4: Fidelity Checklist

Instructor:______________________ Date/Time: ____________________

Observed by:______________________ Number of students:______________

Start and Stop Time:________________ Total Time of Observation:__________

High level of implementation=2
Inconsistent level of implementation=1
Low level of implementation=0

AREA	Level of Implementation	Comments
Materials and Time		
Teacher and student materials ready	**2 1 0**	
Teacher organized and familiar with lesson	**2 1 0**	
Instruction/Presentation		
Follows steps and wording in lessons	**2 1 0**	
Uses clear signals	**2 1 0**	
Provides students many opportunities to respond	**2 1 0**	
Models skills/strategies appropriately and with ease	**2 1 0**	
Corrects all errors using correct technique	**2 1 0**	
Provides students with adequate think time	**2 1 0**	
Presents individual turns	**2 1 0**	
Moves quickly from one exercise to the next	**2 1 0**	
Maintains good pacing	**2 1 0**	
Ensures students are firm on content prior to moving forward	**2 1 0**	

Completes all parts of teacher-directed lesson	**2 1 0**	
General Observation of the Group		
Student engagement in lesson	**2 1 0**	
Student success at completing activities	**2 1 0**	
Teacher familiarity with lesson formats and progression through activities	**2 1 0**	
Teacher encouragement of student effort	**2 1 0**	
Transitions between activities were smooth	**2 1 0**	

Notes:____

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I certify that everything reported on this form is accurate and correct and that interventions are being implemented with integrity at least 80% of the time.

____ signature

Appendix A-5: Classroom Observation & Fidelity Checklist Feedback Form

Date: ________________________ Grade Level: ____________________

Observers: ____

Student Engagement
Commendations: Recommendations:
Instructional Delivery
Commendations: Recommendations:
Instructional Framework
Commendations: Recommendations:
Intervention (if observed)
Commendations: Recommendations:

Overall
Commendations: Recommendations:

Area of Focus

Appendix B: The Math Big 3 Observational Tool

School: ____ Date: _____________
Teacher Name: __________________________________ Grade Level: _______

Number Sense			
Structures and Behaviors	Evident	Not Evident	Not Observed
Math Talks, Number Talks, Dot Talks, Number Strings, etc. are being used.			
Students use mathematical language to discuss math strategies.			
Students are encouraged to use problem-solving, reasoning, and communication skills to make conjectures, explore their own ideas and approaches, and/or identifies the relationships between numbers.			
Teacher establishes a learning environment that welcomes and expects student discourse.			
Students are flexible with numbers.			
Students can explain his/her thinking about numbers.			
Number tools are available (hundreds chart, number lines, number ladders, number cards, etc.)			
Notes:			
Daily Problem Solving			
Structures and Behaviors	Evident	Not Evident	Not Observed
Teachers presents students with real-world problems to activate math thinking.			
Teacher and students have multiple opportunities to discuss and share their mathematical thinking.			
Students and teachers frequently discuss problems.			
Teacher asks open-ended question to extend learning, provide clarification, or redirect misconception.			
Students consistently use manipulatives and mathematical tools appropriate to the task to help build conceptual understanding.			
Teacher consistently checks for understanding, using "How" and "Why" questions.			

Students justify "All" answers orally and/or in writing.			
Teacher provides explicit feedback. (Nice work! I like how you…)			
Notes:			
Manipulatives			
Structures and Behaviors	Evident	Not Evident	Not Observed
Teachers use manipulatives to model concepts.			
Manipulatives are organized, labeled, and easily accessible.			
A variety of manipulative are available.			
Students are aware of the purpose for the manipulatives used.			
Students independently access manipulatives at a point of struggle.			
Students are able to transfer from using the manipulatives to the pictorial representation to the abstract (C-R-A).			
Notes:			

Appendix C: Interview Protocol

(Adapted from Creswell, 2012)

Project: Effect of Student-Centered Instructional Strategies on Mathematics Achievement of Elementary Students

Time of Interview:

Date:

Place:

Interviewer:

Interviewee:

Position of Interviewee:
The purpose of this study is to investigate the implementation and outcomes of research-based instructional strategies such as hands-on activities, small group investigations, problem-solving tasks, and classroom discourse for district students in Grades 2-5. Data for the project study will stem from student MAP assessment results, teacher interviews, and teacher lesson plans. The goal of this interview is to gain a deeper understanding of how teachers view and understand learner-centered instructional strategies and how they are implemented in the mathematics classroom. All data collected will be confidential, and your names will not be used throughout the whole data analysis. The researcher will use coded names (Teacher A, Teacher B, Teacher C) while coding, triangulating, and reporting any data for my project study. This interview should take around twenty minutes.
(Turn on voice memo app)

Questions:

1. How would you define learner-centered activities in mathematics? Prompt if not discussed: Would you consider (hands-on activities, small group investigations, problem-solving tasks, classroom discourse, etc.) to be a learner-centered activity?
2. Please describe the learner-centered activities you are currently or have in the past implemented during your mathematics instruction?
3. In what ways have these activities been successful?
4. How often would you say your students engage in learner-centered activities?
5. Describe a typical math lesson in your classroom.
6. In what ways do you think that incorporating learner-centered instructional strategies can impact student mathematical achievement?

7. Tell me your opinion about learner-centered activities in mathematics.
8. In your opinion, is it possible to have an effective mathematics classroom without the implementation of research-based instructional strategies?

Appendix D: Lesson Plan Analysis Protocol

Project: Effect of Student-Centered Instructional Strategies on Mathematics Achievement of Elementary Students

Teacher Name: ______________________________ **Grade Level:** __________

Week of: ______________

Look fors: Weimer's Learner-Centered Teaching

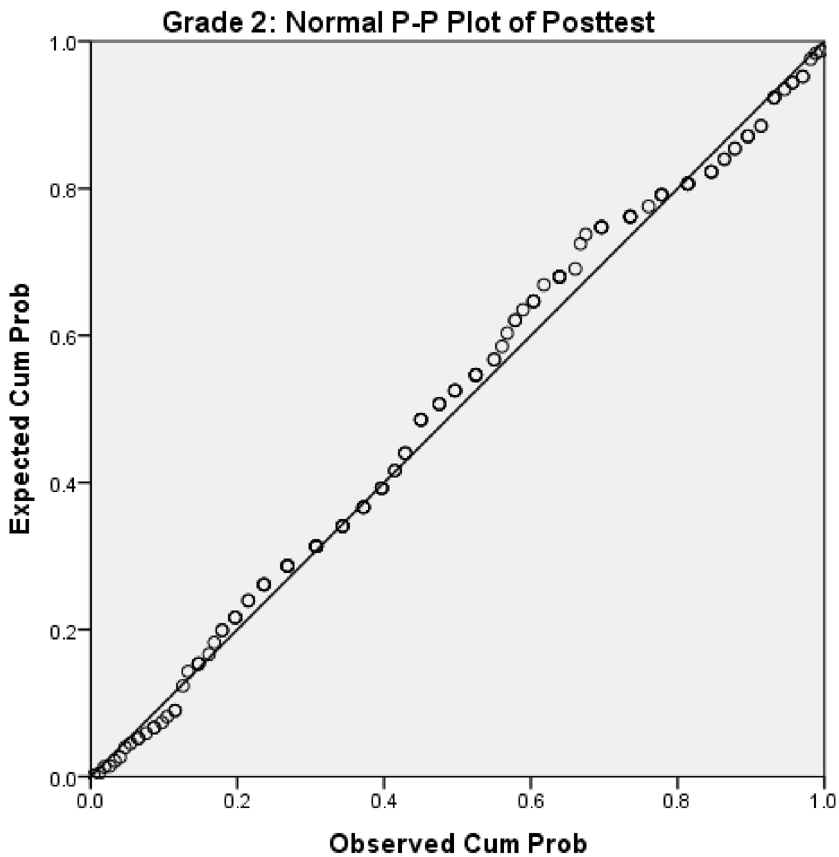
Learner-centered teaching…

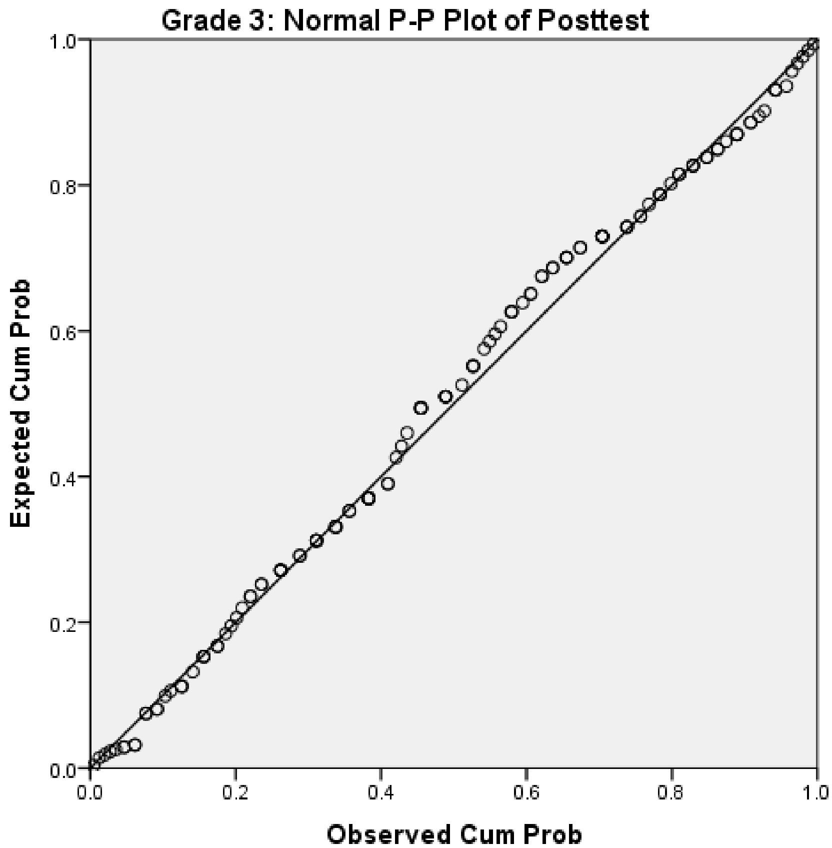
- engages students in that hard, messy work of learning.
- includes explicit skill instruction.
- encourages students to reflect on what they are learning and how they are learning it.
- motivates students by giving them some control over learning processes.
- encourages collaboration.

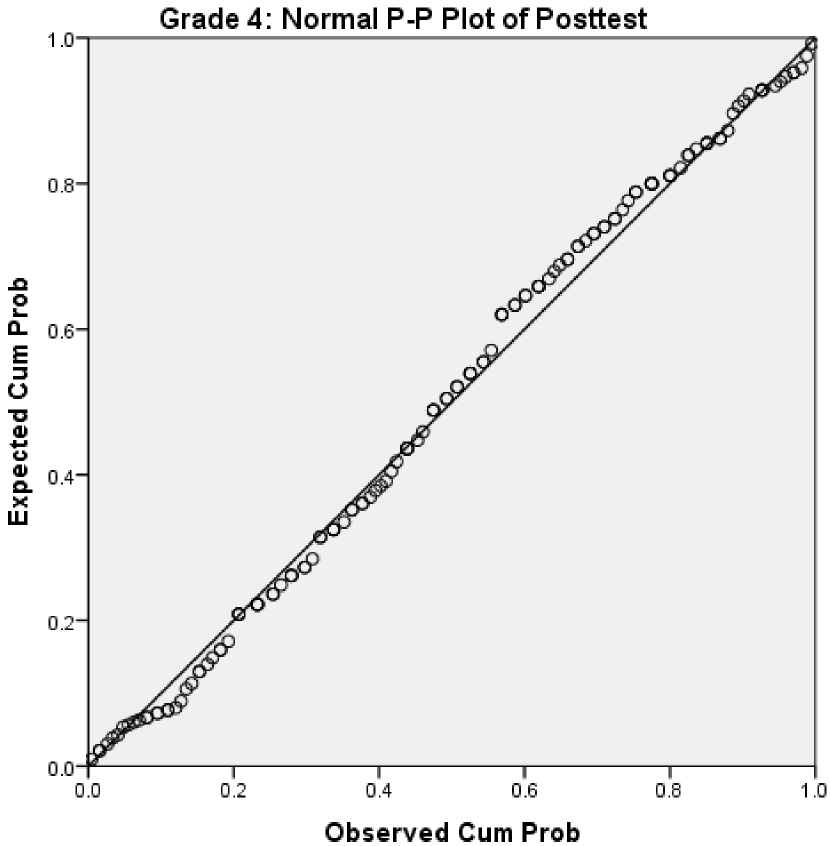
Minutes	Components	Literacy Connections	Materials	What should be seen/heard
Standard(s) Addressed				
Opening **5 Minutes ❑Whole Group ❑Small Groups	"We do…" (Activating Activity) ☐Fluency Games ☐ Individualized fluency activities ☐ Number strings ☐ Number talks	*Active Literacy* ❑Reading/Problem Solving ❑Justifying/Illustrating ❑Discourse/Listening ❑Communicating using precise vocabulary ❑Evaluating Mathematical thinking	☐ Book ☐ Computer ☐ Smart Board ☐ Manipulatives ☐Math Journal ☐ Whiteboards/markers ☐ Other	☐ Provide a hook ☐ Stimulate prior knowledge ☐ Review content addressed in activity ☐Teacher pre-planned purposeful questioning ☐Students questioning and sharing strategies ☐Fluency Activities
Whole Group Lesson **25 Minutes ❑Small Groups ❑Individual	"You do…" (Problem Solving Task/Direct Instruction) ❑Problem of the Day ❑Deliberate questioning ❑Modeling/Demonstrating ❑Discourse ❑Incorporate various Representations ❑Use of manipulatives when applicable	*Active Literacy* ❑Reading/Problem Solving ❑Justifying/Illustrating ❑Discourse/Listening ❑Communicating using precise vocabulary ❑Evaluating Mathematical thinking	☐ Problem of the Day/Task ☐ Computer ☐ Smart Board ☐ Designated work areas ☐ Math Journal ☐ Book ☐ Manipulatives ☐ Whiteboards/markers ☐ Other	☐ Cooperative problem solving ☐ Relevant experiences **Student:** ❑Solving problem in math journal ❑Justify reasoning and critique the reasoning of others ❑Connect mathematical ideas and real-world situations through modeling ❑Identify and utilize structure and patterns ❑Communicate with precise vocabulary ❑Use math tools effectively and strategically **Teacher:** ❑Anticipate student responses and difficulty ❑Observe students' strategies/representations ❑Facilitate and manage student-led discourse ❑ Model use of precise mathematics vocabulary ❑ Model efficient strategies ❑ Use intentional questioning ❑ Checking for understanding
Flexible Group Instruction **25 Minutes (*Combined with Centers*) ❑Small Flexible Groups ❑Individual	Occurs Simultaneously "I do…" (focused Independent Tasks) ❑Activate prior knowledge ❑Building Background ❑Problem Solving Task ❑Numerical Fluency ❑Math Center	*Active Literacy* ❑Reading/Problem Solving ❑Justifying/Illustrating ❑Discourse/Listening ❑Communicating using precise vocabulary ❑Evaluating Mathematical thinking	❑Easy access work space ❑Tubs with required materials to complete task ❑Accountability sheet/journal ❑Sticky notes for questions and solutions	❑Purposeful centers ❑Engages in independent practice ❑Participates in small group instruction ❑Evaluating mathematical thinking ❑Actively listening to explanations and questions ❑Practicing skills in supported context ❑Applying math skills to real world situations
Flexible Group Instruction **25 Minutes (Combined with Centers)	Occurs Simultaneously "I do…"Tiered tasks to address specific needs (Intervention) ❑Compliment Approach ❑Comprehension Approach ❑Skill Approach ❑Problem-Solving Approach ❑Student Self-Assessment and Goal Setting Approach ❑Recheck Approach	*Active Literacy* ❑Reading/Problem Solving ❑Justifying/Illustrating ❑Discourse/Listening ❑Communicating using precise vocabulary ❑Evaluating Mathematical thinking	☐ Pacing Guide ☐ Teacher Planning Guide ☐ Math Journal ☐ Sticky Notes ☐ Student record keeping method	☐ Conferring with students ☐ Implements tired tasks ☐ Facilitates instruction based on students' needs and standards ☐ Demonstrates skills or algorithms ☐ Monitoring of student responses and provides specific descriptive feedback ☐ Anecdotal note-taking ☐ Checking for understanding, questioning
Closing **5 Minutes ❑Whole Group	"We do…" (Whole group debriefing) ❑Whole group discussion	*Active Literacy* ❑Reading/Problem Solving ❑Justifying/Illustrating ❑Discourse/Listening ❑Communicating using precise vocabulary ❑Evaluating Mathematical thinking	❑Whole group meeting area ❑Representations or strategies being shared ❑Notes from content exploration	☐ Sharing solutions to problem solving tasks ☐ Highlighting sequenced representations and strategies strategically ☐ Summarize big ideas and define key vocabulary ☐ Highlight objective for the day ("we can…statement) ☐ Reflect on new learning ☐ Exit ticket

The Department of Elementary Mathematics Education, 2017

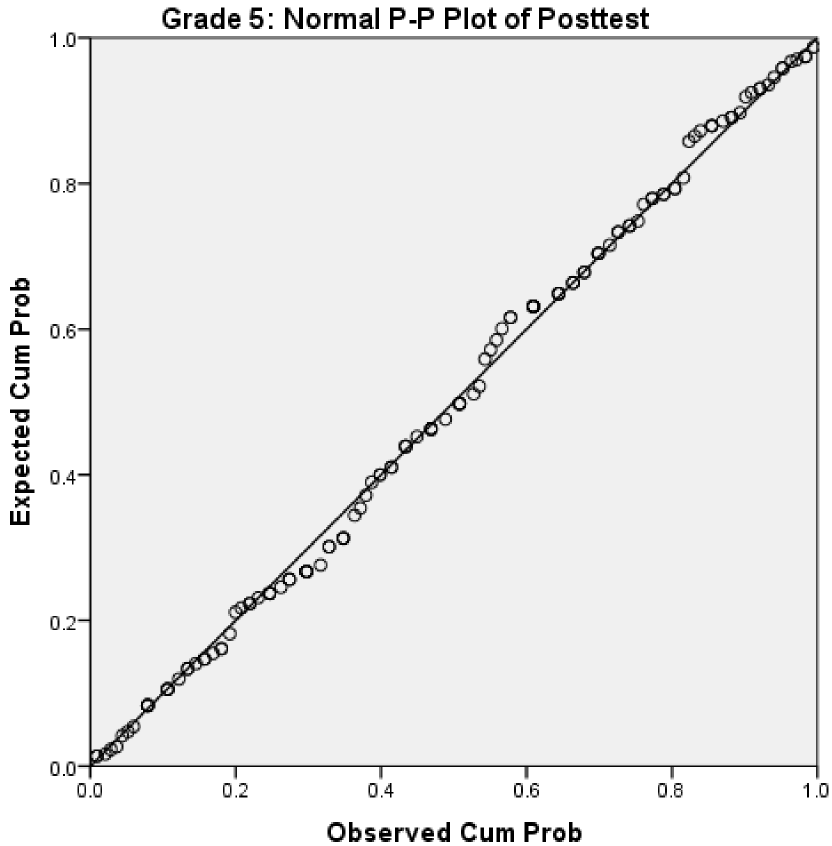
Appendix E: Normality Assumption Charts by Grade Level




Grade 3: Normal P-P Plot of Posttest
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0



Grade 4: Normal P-P Plot of Posttest
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0



Grade 5: Normal P-P Plot of Posttest
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob