IMPACT OF STUDENT-CENTERED LEARNING IN MATHEMATICS

By

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Abstract

Mathematics students in the United States appear to be underachieving when compared to other comparable countries as evident by global studies. Despite research that has linked student inadequacies to their lack of true understanding of mathematical concepts, many teachers continue to teach students through procedural, lecture-based methods. This mixed methods experimental study examined the impact of a student-centered learning environment on middle school students’ as evident by their ability to problem solve and communicate thinking on various summative assessments in mathematics. Additionally, the students’ perceptions of this type of learning was evaluated. It was found that the student-centered learning methods led to an increase in student understanding as evident through various assessment measures. Also, it was made clear that students enjoyed these problem-based tasks and appreciated the collaboration made available through this method of learning. This study affirmed that a student-centered environment is beneficial to student learning in mathematics and leads to an increase in students’ ability to problem solve and communicate their thinking.
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Chapter One

Introduction

According to recent research in the area of mathematics, instruction must provide an opportunity for students to develop a deep understanding of the content that includes the patterns and rationales behind these concepts (Carpenter & Lehrer, 1999; Darling-Hammond, 1997; Zemelman, Daniels, & Hyde, 2005). As students learn mathematics, they must construct meaning. When students are able to develop their own personal strategies to solve problems alongside instructional support that scaffolds learning, students perform significantly better than those students who simply memorize algorithms to solve problem (Kitchen, Depree, Celedon-Pattichis, & Brinkerhoff, 2007). According to Zemelman et al. (2005), many students and teachers alike fail to recognize math as a dynamic, coherent, interconnected set of ideas.

Current research surrounding curriculum and instruction suggests constructivism as an appropriate framework for understanding how one learns mathematics. The constructivist perspective of learning suggests that, “reality is viewed and interpreted by the individual… it is not objective and cannot be measured through experiment” (Egbert & Sanden, 2014, p.35). Similarly, Fosnot (2005) states that contrary to the beliefs of many educators, knowledge is acquired from personal experience and not forced upon from outside sources, such as teachers. Teachers cannot simply transfer the mathematical processes and theorems to the student through lectures or direct instruction methods (Fosnot, 2005). It is necessary that students develop this knowledge on their own through
their own meaning-making experiences. According to Clements and Battista (1990),
“Ideas are constructed or made meaningful when children integrate them into their
existing structures of knowledge” (p.6). Rather than demonstrate mathematical processes
to students with the intent of students reciprocating these processes independently,
teachers must create an environment where students uncover the knowledge for
themselves through meaningful experience.

For many decades, mathematics curriculum was viewed as “a mile wide and an
inch thick” (Protheroe, 2007, p. 51). With so many mathematical standards mandated by
state departments, content was presented at a very superficial level leaving little room for
rich mathematical problem solving. As discussed by Protheroe (2007), the curricula in
which students were exposed-did not allow for a deep understanding of the mathematical
concepts and expected students to learn at a more procedural level.

Since the publication by the National Council of Teachers of Mathematics
(NCTM) of the Curriculum and Standards for School Mathematics in 1989, implemented
mathematics curricula has become more student-centered and constructivist in nature.
According to researchers Zemelman, Daniels, and Hyde (2005), the NCTM’s 1989
publication offered a broad view of school mathematics curriculum and described
instructional practices that foster a deep level of understanding. These standards were
considered radical for those in the mathematics discipline as this was a paradigm shift in
instructional thinking.

Furthermore, in 2000, the NCTM published a revised set of standards titled
Principles and Standards for School Mathematics (NCTM, 2000). These standards were
created to help better transition educators towards this constructivist approach to learning and introduced five process standards: problem solving, reasoning and proof, communication, connections, and representation (Zemelman et al, 2005). The process standards provided a well-defined road map to beneficial, research-based mathematics instruction. Further, these standards suggested that students were required to problem solve, reason and communicate through creating connections and making representations. Thus, it was necessary that students learn in a way where they were not simply following procedures, but instead, truly constructing an understanding of the standards and how the ideas were inter-connected.

While the NCTM standards were created as recommendations to mathematics educators, they were not state law. Hess and McShane (2014) explain that under the No Child Left Behind Act passed by George Bush in 2001, it was federally mandated that all states determine some method of assessment for all students in grades 3-8 in addition to one high school assessment. States were able to select the standards as well as the assessments used to test proficiency. Though standards and curriculum were under the jurisdiction of the state, it was becoming evident that each state had different levels of expectations. Mississippi, Georgia, West Virginia, North Carolina, Oklahoma, and Tennessee appeared to have set low state proficiency levels as compared to other states (Hess & McShane, 2014). In order to encourage rigor in the classroom, the federal government decided to provide federal funding for those states that were willing to come together and make common standards that were rigorous in nature.

Nearly a decade later in 2010, the Common Core State Standards (CCSS) were
established independently of the NCTM standards to help promote a rich mathematics curriculum that prepared students to become college and career ready (National Governors Association, 2010). The Common Core State Standards, according to Hess & McShane (2014), are a set of standards ranging from grades K-12 that list delineate what students should know at each grade level in the areas of English Language Arts and Mathematics. As compared to the state standards previously established by states independent of one another, the new Common Core State Standards define less concepts but expect teachers to spend more time developing students’ understanding of the standards that are outlined (Hess & McShane, 2014).

In addition to the mathematical content standards that are provided for grades K-12, the Common Core State Standards also outline eight process standards (National Governors Association, 2010). These Standards for Mathematical Practice that are part of the Common Core State Standards could be achieved through the constructivist idea of knowledge acquisition (Hiebert, 2007; Fosnot, 2005). The Standards for Mathematical Practice - which include ideas such as modeling mathematics, reasoning abstractly, and constructing viable arguments in mathematical problems - ultimately encourage teachers to instruct in a way that promotes useful construction of knowledge.

Since research has shown that students learn mathematics best by constructing their own knowledge (Fosnot, 2005), it is essential that teachers provide opportunities other than lectures or demonstrations for students to learn. Mathematics researchers often refer to this type of instruction as student-centered as opposed to teacher-centered (Van de Walle & Lovin, 2006). Paying close attention to process standards found in the
Common Core State Standards, teachers can enable students to construct their own knowledge. Teachers must create an environment that allows for a rich curriculum where students uncover mathematics in problem solving approaches using intentional tasks with meaningful discussion (Smith & Stein, 2011).

“In reality, no one can teach mathematics. Effective teachers are those who can stimulate students to learn mathematics” (Clements and Battista, 1990, p.34). One may ask, then, why current mathematics instruction consists of a teacher-centered approach rather than student-centered?

The Statement of the Problem

Often, the current in-class tasks and daily homework assignments given to students in mathematics classrooms do not allow students to construct knowledge in a manner that cultivates a deep understanding of the concepts at hand (Clements & Battista, 1990; Hiebert, 2007). When students are given problem-solving tasks on summative assessments, it appears that students do not have a deep enough understanding of the concept to be successful. Clements and Battista (1990) write, “Most traditional mathematics instruction and curricula are based on the transmission, or absorption, view of teaching and learning… Teaching consists of transmitting sets of established facts, skills, and concepts to students.” (p. 6). This is not considered best practice for teaching mathematics.

According to international studies, the United States does not show a strong ability in mathematics when compared to other countries. According to the Trends in International Mathematics and Science Study (TIMSS) released in 2011, the United
States did rank above average, but scored below national competitors such as Japan and Germany (Mullis, Martin, Foy, & Arora, 2012). In the Program for International Student Assessment (PISA) completed in 2012, the United States scored in the middle of the rankings in mathematics, falling below countries like Singapore, Korea, and China (OECD, 2012). It appears that the education system in the United States is lacking something as compared to its global competitors. Through the research of these studies, it has been found that some of the countries exceeding the United States in mathematics are utilizing more student-centered instructional techniques (Stigler & Hiebert, 1999).

Additionally, according to Smith and Stein (2011), the instructional practices that are orchestrated in America’s classrooms are not preparing students for a successful transition into the twenty-first century workforce. This statement occurred as a result of Smith and Stein (2011) write, “Gone are the days when basic skills could be counted on to yield high-paying jobs and an acceptable standard of living. Especially needed are individuals who can think, reason, and engage effectively in quantitative problem solving” (p.1). In order to compete with a global workplace and produce individuals with problem solving abilities, students must learn how to navigate tasks which allow for the construction of knowledge within the confines of their prior understandings (Smith & Stein, 2011). Due to previous findings on the importance of the student-centered Constructivist approach, this study seeks to specially examine how implementing instructional problem-solving tasks in and out of the classroom can impact seventh grade students’ understanding on summative tasks.
Research Question

Specifically, this study sought to address the following questions:

1. How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high achieving seventh grade students’ ability to be successful on summative assessments?

2. How do the perceptions of high achieving seventh grade students change when their instruction changes from teacher-centered to student-centered?

Significance of the Study

This investigation seeks to examine in what ways the purposeful use of student-centered instruction may impact students’ abilities to be successful on summative assessments involving unfamiliar, problem-solving tasks. Notably, student-centered instruction will be utilized in both in-class tasks as well as homework assignments. First, this study will examine students’ abilities to develop both conceptual and procedural understanding as a result of implementing more rigorous student-centered instruction. Furthermore, this study aims to analyze students’ perceptions of student-centered instruction.

The results of this study could be used to enrich other mathematics classrooms at the middle school level. Perhaps more intentional tasks both in and outside of the classroom can be presented to gain a deeper understanding of mathematics. Through this investigation, the teacher researcher hopes that meaningful instruction can be implemented with the goal of developing students who can communicate their reasoning more effectively on summative tasks.
Limitations

There are various limitations that should be considered when forming conclusions from this study. The first limitation to note is the short, five-week duration of this research study. The intervention only lasted for one unit in the Connected Mathematics series (Lappan, Phillips, Fey, Friel, 2014). A longer intervention period would have allowed for further analysis of the intervention, examining the impact of implementation on various instructional concepts. The second limitation to this study was the teacher researcher’s lack of experience with teaching the Connect Mathematics curriculum. The first time that the teacher researcher had taught the Connected Mathematics curriculum was during this research study experience. It is possible that the teacher researcher would have had differing results if the student-centered instructional style had been professionally utilized prior to the study. The final limitation of this study is the differences in the time of day that the instruction occurred for the control group and experimental group.

Definition of Terms

The teacher researcher used the following terms continuously throughout the research study:

Constructivism. Constructivism is a learning theory that states that one learns from constructing knowledge from purposeful inquiry rather than form the transfer knowledge from someone else (Fosnot, 2005).

Student-centered Instruction. Student-centered instruction incorporates teaching strategies which allow for the student to construct knowledge through
meaningful experiences (Van de Walle & Lovin, 2006).

**Teacher-centered Instruction.** Teacher-centered instruction incorporates teaching strategies which include teachers transferring knowledge to students directly through lectures, drill and practice, or guided discovery (Van de Walle & Lovin, 2006).

**Problem-based Tasks.** Problem-based tasks are problems or investigations that require students to use problem solving techniques rather than prescriptions to arrive at a solution. These tasks are considered problematic when solving (Heinemann, 1997).

**Formative Assessment.** Formative assessment is the process teachers use to determine what students are currently understanding with the intent of changing instruction to better improve the students’ future learning. Teachers adapt instruction to meet student needs (Black, Harrison, Lee, Marshall, & William, 2003).

**Summative Assessment.** Summative assessment is the process used by educators to determine what students understand at the end of a definitive instructional period (Black, Harrison, Lee, Marshall, & William, 2003).

**Conclusion**

The teacher researcher’s experience with mathematics instruction has revealed a disconnect between classroom instruction and student understanding (Fosnot, 2005). A need for meaningful tasks in mathematics instruction that encourages the construction of mathematical knowledge has prompted this investigation (Heinemann, 1997). A review of related literature in the area of this study is outlined in the proceeding chapter.
Chapter Two

Literature Review

This thesis examines the use of student-centered instructional tasks and its impact on high-achieving students participating in a seventh grade mathematics classroom. Additionally, this thesis considers students’ perceptions of the transition from a traditional teacher-centered form of mathematics instruction to a more student-centered approach. Ideally, the results of this study can potentially influence educators to utilize more effective learning tasks both inside and outside of the mathematics classroom.

The following literature review closely examines topics related to student learning in mathematics. Topics discussed in this literature review provided the foundations for this study. First, a discussion of the theoretical framework will be presented. Proceeding this section will be a discussion of how students best learn mathematics. Next, effective learning tasks in mathematics both in and outside of the classroom will be reviewed. Finally, there will be a discussion on curriculum that supports student-centered learning.

Theoretical Framework

This study on instructional practices in mathematics is highly influenced by a social constructivist theoretical framework. Though the cognitive theory of Constructivism has only recently been defined, the foundations of Constructivism were originally inspired by the seminal work of Piaget, Dewey, and Vygotsky during the turn of the eighteenth-century.
First, it may be important to note that the idea of learning through the lens of prior knowledge was first documented by Piaget. He concluded that learners experience a cognitive progression called Equilibration (1977). According to Piaget, Equilibration is the process one goes through as they are constructing knowledge. Piaget further said that Equilibration is the process of "self-regulated behaviors balancing two intrinsic polar behaviors, assimilation and accommodation" (Fosnot, 2005, p.16). While assimilation is the process of taking something different and trying to understand it through the knowledge the learner already holds to be true, accommodation is when the learner has to change his or her internal understanding (Piaget, 1977). Alternatively, Piaget defines Disequilibrium as occurring when one is processing information that does not fit into his or her current internal understanding. While learning is taking place, incoming information regulates itself until the learner is able to understand the information by changing his or her schema through assimilation or accommodation.

Another educational reformer who contributed to the foundation of Constructivism was philosopher John Dewey. John Dewey (1938) expressed the importance of the learner having an active role in his or her level of understanding through the process of inquiry and discovery. Rather than rote methods of teaching, Dewey believed that students should be involved in activities that promote learning and the construction of knowledge (Dewey, 1938).

Building upon the idea of learning through experience was Vygotsky’s stance on social interactions and its role in knowledge acquisition. Similar to Dewey, Vygotsky placed deep emphasis on the social aspect of building understanding. According to
Vygotsky, one acquires knowledge through social interactions (Vygotsky, 1978). In his theory of Zone of Proximal Development, Vygotsky explained the importance of understanding what a learner currently knows and what he/she has the potential to understand with scaffolding. Taking a note from Vygotsky’s social learning theories, Social Constructivism also indicates the importance of providing learners with opportunities to construct knowledge from social interactions (Vygotsky, 1978).

Only during the last several decades has the term Constructivist Learning theory been introduced formally in education. Fosnot defined this learning perspective:

A constructivist view of learning suggests an approach to teaching that gives learners the opportunity for concrete, contextually meaningful experiences through which they can search for patterns; raise questions; and model, interpret, and defend their strategies and idea. (2005, p.xi).

According to a constructivist learning theory, the background experience and an individual’s understanding of mathematical concepts is imperative to his or her future knowledge (Carpenter & Fenemma, 1992; Cobb, 2005). Clements and Battista (1990) stated, “Ideas are constructed or made meaningful when children integrate them into their existing structures of knowledge” (p.6). Through social and cultural interactions, learners develop meaning that offers new truth making.

Assuming these constructivist foundations as truth, it is imperative that classroom teachers are providing students with appropriate settings for meaningful social interactions. This allows the learner to be challenged, allowing for intellectual growth from social experiences (Fosnot, 2005). Effective teaching strategies which take into
account this theoretical framework will be outlined in the following section.

**Effective Teaching Strategies in Mathematics**

A plethora of research has revealed America’s need for more improved schooling. This was especially true when taking into consideration the theoretical perspective that one learns through meaningful social interactions. Through an extensive review of the literature, two categories of essential instructional strategies in math were continuously recommended based upon how students learn mathematics: 1) teaching for understanding and 2) teaching for real world application.

**Teaching for understanding.** For most of the educational history of the United States, educators have tried to teach students mathematics by transferring knowledge from the teacher to the learner. This has been achieved through various methods of note taking, demonstrations, and lectures. It is crucial that the understanding of mathematical concepts is uncovered by the individual rather than be transferred from another source directly (Fosnot, 2005; Hiebert, 1997). Because students learn from developing meaning and constructing knowledge, teachers must teach for understanding. In other words, students who learn most effectively are not asked to memorize complex formulas or a set of procedures. Instead, students with a deep understanding of mathematical content are given opportunities to derive their own formulas and methods. When students are able to develop their own personal strategies to solve problems through the use of mathematical tools and meaningful discussion, they perform significantly better than those who simply memorize algorithms to solve problem (Kitchen et al., 2007). According to Darling-Hammond (1997), “Whatever our twentieth-century education system has produced, it is
increasingly clear that it has not developed a wide-spread pedagogy for understanding…” (p.96). Instead of providing students with the knowledge of reasoning, teachers teach instruct children through rote mechanisms that provide students with just enough information to pass achievement tests.

Though there is no single method of instruction that produces high achievement, high-achieving countries engage children in serious thinking about the concepts of math (Stigler & Hiebert, 1999; Vail, 2005). When students understand the process of math, they have the potential to learn more at a quicker rate. Hiebert (1997) has written, “Understanding is crucial because things learned with understanding can be used flexibly, adapted to new situations, and used to learn new things” (p.1). Depriving students of the right to understand why mathematics works proves detrimental to their learning and will suppress their future success in mathematics (Fosnot, 2005). With each day, new and improved formulas and methods for mathematics are changing. Furthermore, if students understand how and why math works, they will be able to adapt to this unpredictable world without the need to utilize one specific method.

Authors Clements and Battista (1990) have stated, “In reality, no one can teach mathematics. Effective teachers are those who can stimulate students to learn mathematics” (p.6). Teachers must create an environment that allows for a rich curriculum where students uncover mathematics in problem solving approaches.

**Teaching for real world interest and application.** In addition to teaching students a deep understanding of math content, teachers must also instruct for real world interest and application. According to Ziegler and Chapman (2004), teachers should
“attempt to make applied math relevant to the real-world and particularly to the students in the class” (p.2). Math must be relevant and geared to a child’s life experience. One way to accomplish is by planning guest speakers that discuss the importance of math in areas such as the car and logistics industry as well as financial planning (Ziegler & Chapman). According to Bobis and Handal (2004), providing students with purpose for mathematics education helps humanize learning and allows students to see and understand why they need to learn the information.

In addition to guest speakers, another way to teach students in a way that provides real world interest and application is to teach in themed units (Bobis & Handal, 2004). Themes are the organizers of the mathematical curriculum; Therefore, concepts, skills, and strategies are taught around a central theme that is intended to give meaning and direction to the learning process. When students find meaning in what they are learning, they are not only more excited to learn the information, but they will also have a better chance of retaining the information. As Bobis and Handal stated, “Thematic instruction in mathematics is an umbrella term for a wide range of educational experiences that relate mathematics to real life situations” (2004, p.4).

Haberman (1995) encouraged, however, that all instruction link back to what interests the child, not just what will be useful to them in the future. Many things are important for students to know in their later life, but only what seems interesting and linked to their current understanding will be retained. Students must be engaged to the mathematical instruction taking place. Teachers should also articulate to students what interests them and should explain to students what they are doing to further their
knowledge in that area, too (Haberman, 1995).

Though teaching for real world application is critical to the instruction of mathematics, it is important that teachers consider what “real life” constitutes for students (Pogrow, 2004). If a teacher tries to incorporate math and uses situations that students are not aware of due to a student’s cultural background, socioeconomic status, background knowledge or life experiences, the notion of real life application could be irrelevant and more confusing than helpful to students. As Pogrow (2004) pointed out, “The worst thing that you can do to students who think that math is a pointless extension of adult-imposed rules is to tell them that they will understand the need for math when they grow up or that learning math will make them more successful adults” (p.299).

As mentioned in current mathematical literature, teaching for understanding and teaching for real world application are two critical mathematics-teaching strategies that can be used by educators. These strategies allow for students to construct their own knowledge through engaging, meaningful experiences. Tasks that lead to effective understanding of mathematics are outlined in the next section.

**Effective Mathematics Tasks**

Harboring an understanding of how educators create opportunities for meaningful learning experiences is as equally important as understanding how students learn. Not only is the curriculum presented to students important, but so are the tasks assigned. Students often miss the reasoning behind various tasks assigned to them both in and outside of the classroom (Stigler & Hiebert, 1999). Students must be given assignments that are worthwhile and that prepare them for solving problems in other settings such as
school, work, and home. As stated by Maltese, Tai, and Fan (2012), the issue is less about the amount of time spent on mathematical tasks but how the mathematical tasks are used in the classroom.

**Tasks within the classroom.** Hiebert (1997) discussed how important the daily activities in the classroom really are to student performance in mathematics. Essentially the tasks that teachers ask students to partake in become the tasks that they become most comfortable in completing. For many classrooms in the United States, this centers around procedural based mathematics problems. These types of procedural tasks, however, are not as worthwhile as allowing students to construct new understandings and to build new relationships with mathematical concepts through problem-based learning. Furthermore, there are important guidelines for impactful tasks in mathematics that are offered. To begin, mathematical tasks must encourage students to reflect and communicate with one another. Students must be engaged and excited about finding the solution to the task at hand. Next, these worthwhile tasks must give students opportunities to use mathematic tools to construct meaning. These tools can be actual physical materials or symbols and must leave behind important mathematical residue. If a well-developed task does not present students with a mathematics premise or theory at the end, it has not been successful in fostering a deep, conceptual understanding for students (Hiebert, 1997).

Furthermore, the discussions surrounding assigned mathematics tasks can also serve as an important avenue for student-centered learning. Without meaningful discussion, mathematical tasks may lend themselves to little understanding for most
According to Smith and Stein (2011), there are several important components surrounding productive math discussions. These authors outline five practices that should be considered for the discussions that complement problematic mathematical tasks. The first part of a well-orchestrated discussion is the anticipation of the mathematical problem and its corresponding questions. Next, teachers must closely monitor students during the discussion. It is essential that teachers know and try to make sense of the students’ rationales and methods for problem solving. The third important component of a well-planned discussion in mathematics is the selecting of mathematical concepts. While all students have ideas and thoughts, perhaps only some should be brought to the discussion for fear of misleading students or presenting methods for solving that are too developmentally complex. Furthermore, the sequence of student responses to the task at hand is essential to building student understanding. It is best to start with simpler ideas and then move to the most complex and sophisticated strategies when sharing student work. Finally, connections must be made to ensure the mathematics behind the problem is evident (Smith & Stein, 2011).

Chapin, O’Connor, and Anderson (2009) also discussed the importance of classroom talk and discussion during mathematic tasks. Additionally, they emphasize the importance of creating an atmosphere that fosters a respect for the ideas of others. When students feel respected and trust that their teacher and peers are willing to hear their mathematical rationales, they are more willing to talk (Chapin et al., 2009). Furthermore, O’Conner and Anderson have presented various “talk moves” that are beneficial in all
classroom discussions. While one move includes simply asking students to repeat the response of another student, another move includes asking students to justify the reasoning of another student. These mathematical explanations encourage other students not only to listen carefully, but also to make sense of others’ reasoning. Another “talk move” even requires that the students apply their own reasoning to the reasoning of the other students. It may be beneficial to simply extend the wait-time given to students to ensure that students make sense of the problem before listening to the reasoning of other students. These simple talk moves can improve the quality of mathematical discussions. (Chapin et al., 2009)

**Tasks outside of the classroom.** The institution of public education has undergone many transformations over the last century, including the assignment of homework outside of the classroom. Homework, according to expert Harris Cooper (2007), is defined as tasks assigned by schools teachers to be completed out of the classroom setting.

The research on the assigning of homework begins in the early 1900s for the purposes of this literature review. According to Cooper (2007), it was culturally believed that homework was important for students to complete in order to discipline the minds of the students. Just like strengthening muscles for athletic-related activities, educators agreed that the brain needed to be stretched using tactics of memorization. Memorization, according to teachers of this time, was best completed outside of the classroom. Public views regarding homework began to change in 1940. Educators started to oppose the emphasis on memorization in student learning and
turned to problem-solving approaches in part to the findings of Piaget, Dewey, and Vygotsky. Rather than memorize facts, teachers determined that it was more important that students have the skill set to work through problems and find the answers. Additionally, the 1940s were seen as a time for children to explore extra-curricular activities such as music, athletics, and other disciplines that were non-academic in nature. Assigning of out of school tasks only hindered students from exploring diversified activities (Cooper, 2007).

By the mid-1950s, homework would again find relevance in the lives of schoolteachers and students alike. As the Russians advanced in math and sciences with their launching of the Sputnik (Cooper, 2007), Americans wondered if students from the United States were being comparatively challenged in the classroom. In order to compete with other nations, it was thought that the practice of homework should again be emphasized. This view held strong until about 1965 when, according to Cooper (2007), “Homework came to be seen as a symptom of too much pressure on students to achieve” (p.2). Again, the pendulum shifted away from teachers assigning homework.

A Nation at Risk (National Commission on Excellence in Education, 1983) was one of the first major documents that highly transformed America’s public education system in more ways than just the views on assigning out of classroom tasks. Homework, according to the report, was “…a defense against the rising tide of mediocrity in American education”. In order to save the nation, homework would be required to meet state-mandated academic standards (Cooper, 2007). According to the National Council for Teachers of Mathematics during this time period (1980), homework
was] meant to “extend productively the time students are engaged in the study of mathematics.”

By the turn of the twenty-first century, parents would begin to push for the reduction of homework as part of the student curriculum. According to parents, students were growing tired because of the excessive stress caused by homework (Cooper, 2007). Studies by Maltese, Tai, and Fan (2012) uncovered that while approximately 33-37 minutes were spent on high school math homework during the 1990s, 60 minutes were spent on homework in 2002.

Whether one views homework as positive or negative, its existence is undisputable. As the literature shows, assigning of out of classroom tasks can vary in popularity depending on factors such as the social practices of the time, current political publications and initiatives, and even the accomplishments of other countries. If out of classroom tasks are assigned, educators must use the homework as an extension to the problem-based tasks that were presented in class.

It is important that classroom tasks in and outside of the classroom support mathematical best practice of teaching for understanding (Fosnot, 2005; Hiebert, 1997). Students can reach a deeper understanding of content through social tasks that allow students to construct knowledge with scaffolding.

**Student-centered Mathematics Curriculum**

As discussed previously, students learn mathematics when they are able to adapt their previous learning to new information through their own meaning-making (Fosnot, 2005; Stigler & Hiebert, 1999). In order to offer students these opportunities to construct
knowledge, purposeful tasks must be assigned (Fosnot, 2005; Stigler & Hiebert, 1999). The curriculum standards implemented must be presented in a manner that allows concepts to build upon one another so that understanding is constructed. It is also beneficial to present curriculum in an order that allows certain concepts to be incorporated together through intentional tasks.

Curricular materials are similarly important to curriculum standards. Educators often use curriculum materials to guide their instruction. According to Remillard (2005), the educational system was faced with new curriculum standards supported by NTCM recommendations as well as new curriculum materials that aligned with these standards. The National Science Foundation provided funding to help develop curriculum materials that would assist educators in implementing a mathematics curriculum that emphasized mathematical thinking and reasoning, conceptual understanding, and problem solving in realistic contexts (Remillard, 2005).

One such curriculum developed as a result of the National Science Foundations funding was the Connected Mathematics series (Lappan, Phillips, Fey, Friel, 2014). The Connected Mathematics Project (CMP) began in 1991 with the intent of forming curriculum materials that provided students with opportunities to develop understanding in the areas of reasoning and number, geometry, measurement, algebra, probability, and statistics. The creators of this curriculum series focused on essential concepts, skills, procedures, and ways of thinking and reasoning in mathematics instruction. Furthermore, this curriculum series was revised in 2000 by the National Science Foundation and again in 2010 with aid from the University of Maryland and Michigan State University.
As stated by Lappan:

The overarching goal of CMP is to help students and teachers develop mathematical knowledge, understanding, and skill along with an awareness of and appreciation for the rich connections among mathematical strands and between mathematics and other disciplines. (2014, p.4)

The curriculum’s sole mathematical standard is that students are able to reason and communicate proficiently (Lappan et al., 2014). Lappan writes in regards to this single standard that students should be able to solve problems using reason and insight.

The Connect Mathematics Project supports the instructional tasks recommended by researchers such as Fosnot (2005) and Stigler and Hiebert (1999). The very first guiding principle from the CMP curriculum is a problem-centered curriculum (Lappan et al., 2014). Additional guiding principles include exploring big ideas in depth, intertwining conceptual and procedural knowledge, and promoting inquiry-based instruction (Lappan et al., 2014).

Lappan (2014) supported the argument for a problem-centered curriculum that promotes understanding and engagement. Students become comfortable in solving mathematics tasks in which they are familiar. When students are used to working with mathematical computations using rote methods, this is how they begin to define mathematics. However, the CMP curriculum materials give students opportunities to construct knowledge.

In addition to engaging, problem-solving tasks, Lappan, Phillips, Fey, and Friel (2014) explain the need for cooperative learning groups in the classroom. Cooperative
learning groups can be used to promote thinking and allow for students to communicate their thinking. Through classroom discourse of solution methods, students will develop a stronger sense of mathematics (Lappan et al., 2014; Smith & Stein, 2011).

Recent studies have analyzed the effectiveness of the Connected Mathematics series. Riordon and Noyce (2001) conducted a quasi experimental study out of Massachusetts and noted the positive impacts that the Connected Mathematics series had on student performance on state testing. These findings were consistent across subgroups which consisted of gender, race, and socioeconomic status. Additionally, the researchers analyzed questions types such as open response, short answer, and multiple choice. The Connected Mathematics curriculum resulted in higher achievement as compared to students using traditional mathematics curriculums in all areas.

Through the use of the Connected Mathematics Project, teachers can provide meaningful tasks to students which promote problem-solving techniques (Lappan et al., 2014). These engaging tasks can initiate social interactions which aid in the construction of mathematical knowledge (Lappan et al., 2014). It is important to note that, although these curriculum materials can be presented to educators, the way in which the materials are presented is crucial to the final effectiveness of the resources. Though curriculum materials are important, the teacher’s implementation of these resources is most essential to student success in mathematics.

Summary

Current research surrounding curriculum and instruction documents social constructivism as a framework for learning that is crucial to mathematics understanding.
In the idea of Constructivism, “reality is viewed and interpreted by the individual… it is not objective and cannot be measured through experiment” (Egbert & Sanden, 2014, p.35). Knowledge, according to Fosnot (2005) must be personally experienced and not forced upon from outside sources, such as teachers. Thus, students learn mathematics best when they truly understand the concepts and have developed their own meaning through the use of intentional tasks given in and outside of the classroom. The following chapter outlines the methods used to investigate the purposeful use of mathematics tasks in a seventh grade classroom and its impact on instruction and student perception.
Chapter Three

Methodology

The purpose of this study was to investigate the impact of a student-centered learning environment on the understanding of mathematics as evidenced on summative assessments. The students studied were considered high-achieving. Additionally, this research aimed to analyze students’ perceptions of student-centered instruction. In-class and out-of-class tasks were used in the analysis of this study. In this chapter, I will first describe the research design and the methods used to collect and analyze data in response to the following questions:

1. How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high-achieving seventh grade students’ ability to be successful on summative assessments?

2. How do the perceptions of high-achieving seventh grade students change when their instruction changes from teacher centered to student centered?

This chapter of research methodology includes the research design followed by a description of the participants and setting. Next, the data collection methods are included as well as a summary of how these instruments were analyzed. In total, five measures of data collection were used: pre-/post-assessment, pre-/post-survey, student journals, teacher notes, and student interviews.
Research Design

This study followed a mixed methods experimental design using both qualitative and quantitative data (Mertler, 2014) to explore in what ways students alter the way in which they communicate their thinking on various problem tasks when taught in a student-centered approach. Additionally, this study aimed to analyze how students perceived a student-centered teaching approach. A mixed methods research design is empirical research involving the collection and analysis of both quantitative and qualitative data (Punch & Oancea, 2014). While the quantitative data instruments (pre-/post-assessment, pre-/post-survey, and student journals) allowed statistical analysis of the mean values of the participants including tracing trends, this method alone was not sufficient enough to allow the teacher researcher to understand some of the thought processes and opinions of those studied. Qualitative instruments used (teacher notes, and interview questions) allowed for themes and contexts to be uncovered. According to Punch and Oancea (2014), a research study that asks questions that are open ended often requires a study where both numbers as well as words can be used can be used to describe observations so that any weaknesses that exist in one method can be compensated for in the other method.

A pre-/post-assessment design was used between a control and experimental group to examine any differences between the two groups analyzed in regards students’ ability to explain and justify their thinking on problem-based tasks. As mentioned by Mertler (2014), a pretest-posttest design allows the researcher with the opportunity to compare data between the intervention group and the control group to note possible
impacts with the given treatment. Weekly journals were also assessed using a rubric to provide insight into students’ ability to answer problem-based questions throughout the duration of the study. Through the use of teacher notes, the researcher was able to include narrative accounts of the intervention during the study (Mertler, 2014).

The mathematical attitudes of both the control and experimental group were measured before and after the intervention through the Attitudes Towards Mathematics Survey (Tapia & Marsh, 1996). Likert surveys are valuable ways to assess the opinions of study participants using a continuum (Mertler, 2014). Teacher notes from and student interviews were also analyzed providing qualitative statistical data on student perceptions of the student-centered teaching approach to learning (Mertler, 2014).

This research design included an experimental component so that it was possible to see if the use of a constructivist-based intervention had an impact on students’ ability to be successful on problem-based tasks. If there would not have been an experimental group and a control group, it would be difficult to note impacts of the intervention.

Participants. The classroom teacher was a full participant in this investigation, acting as both classroom teacher and the researcher. The teacher-researcher taught both classes and administered all assessments and problem-based tasks, as well as guided discussions on these tasks. This study also involved 46 students in two mathematics classes who were selected to participate because they were all mathematics students of the teacher-researcher. The teacher researcher selected the classes used in this study because when considering all the available class sections, these two classes were assigned the same amount of time for instruction each day and were also most similar when
comparing teacher to pupil ratio.

Moreover, the experimental group was Class A while the control group was Class B. Class A consisted of 21 students. Of these students, 11 students (52%) were female and 10 (48%) were male. Class B consisted of 25 students. Of these students, 19 (76%) were female and 6 (24%) were male. Both classes were enrolled in the same course, Mathematics 7 Accelerated. The standard curriculum for both classes consisted of all Common Core State Standards (CCSS) 7th grade standards and 30% of the CCSS 8th grade standards. There were no students on Individual Education Plans (IEPs) in either class. All students were designated as accelerated compared to their peers. This designation was determined by their sixth grade teachers coupled with their 2013-2014 Ohio Achievement Assessment at the mathematics level.

**Setting.** This study was conducted in a junior high school within a small rural district as designated by the Department of Education (2014). The school served approximately 350 students in seventh and eighth grade. Demographically, the composition of the student population was as follows: 94.8% Caucasian students, 10.2% students with disabilities, 27.1% economically disadvantaged students (Ohio Department of Education, 2014). The district is comprised of two elementary schools, one middle school, and junior high school, and one high school serving approximately 2,000 students in grade kindergarten to twelve.

It is important to note that the mathematics teacher did not use a textbook for instruction prior to this study. The school district requires the mathematics teachers at the middle school level to design instruction that is aligned with the Common Core State
Standards in mathematics from outside resources. The school also implemented a fixed bell-schedule. Some class periods varied in duration because of lunch and intervention periods.

Specifically, this study focused on two seventh grade classrooms. The first classroom in which this study took place was referred to as Class A. Class A was held during the first period of the day and was 42-minutes in length. This period began at 7:44AM and concluded at 8:26AM, Monday through Friday. Student desks were grouped together with five students in each collaborative work environment. Six groups were formed in sum. Though the desks were grouped together, the chairs faced towards the white board at the front of the room. The student groupings were new as typically the desks were isolated from one another. Technology used in this classroom consisted of an Epson BrightLink interactive white board, a document camera, and one classroom computer.

The second classroom in which this study took place was referred to as Class B. Class B was held during the last period of the day and was 42-minutes in length. This period began at 1:38 PM and concluded at 2:20 PM Monday through Friday. Each student sat at an individual desk that was isolated from other desks. The desks in the room formed a U-shape that opened towards the front of the room where instruction typically transpired at the white board. Technology used in this classroom was identical to that of Class A.

It is pertinent to note that the routine way of instruction in the teacher researcher’s classroom consisted of direct instruction teaching. This teaching model included a daily
warm up followed by a review of the homework assignment from the previous night. Then the teacher would transition into a lecture that introduced a new concept. After copying down notes from the white board, the class would try practice problems as a class. The students would then attempt various problems individually which would be reviewed later. The students’ homework assignment would be about five to ten procedural problems that closely resembled work completed in class.

This study began in the spring after the conclusion of statewide testing. The study continued without interruption for five weeks.

**Intervention.** In this study, the intervention was administered to Class A while the teacher maintained a routine way of instruction with Class B. The intended outcomes for both classes were aligned with the Common Core State Standards curriculum in mathematics; these goals were the same for both classes. With that said, more focus and emphasis was placed on the communicating and justifying of student thinking during the intervention instruction with Class A. Class B was instructed during this study in the way described in the previous section. Again, this type of instruction was lecture based and very teacher-centered. Though the classroom tasks as well as homework tasks looked different between Class A and Class B, all assessments and journal entries administered were the same for both classes.

Moreover, Class A was taught in a student-centered manner. During the intervention period following all initial data collecting, students in Class A were given a task that was the main focus of the lesson which was modeled after the Connected Mathematics 3 “It’s All in the Systems” curriculum (Lappan et al., 2014). These tasks
were intended to help students uncover the mathematical learning targets that particular day. The Connected Mathematics curriculum has been designed as a student-centered framework for instruction allowing students to construct knowledge for themselves through intentional tasks that encourage inquiry. These task-based teaching strategies were research based according to works by experts in the area (Fosnot, 2005; Hiebert, 1997; Stigler & Hiebert, 1999). The tasks required students to build upon existing knowledge to construct new knowledge through activities and investigations that required problem-solving techniques. While students completed the task, the teacher researcher used intentional questioning techniques with groups to help guide the meaning-making process. After the groups explored the tasks, the teacher helped orchestrate intentional discussions (Smith & Stein, 2011).

To investigate the effectiveness of out of classroom tasks which was an extension of the problem-based curriculum, the students from Class A were also given homework assignments that extended daily learning concepts that had been developed and discussed in class. These tasks reinforced the concepts that students developed in the lesson during class. Students were not asked to construct new ideas but were prompted to build on ideas from the in-class discussions.

When students from Class A returned to class the day after the assignment was assigned, class began with a discussion over the homework assignment from the night before. The teacher allowed students to share their answers to the assignment in their learning groups. The class then regrouped and through intentional questioning techniques (Smith and Stein, 2001), the teacher used student discussions to clear any
misconceptions. During the discussion the teacher encouraged students to model how to communicate the answer, represent the work, and justify the responses to the answers.

Table 3.1 below outlines the various Connected Mathematics 3 tasks used in this study as well as its alignment to Common Core State Standards in mathematics.

Table 3.1  

**Instructional Task Alignment to Common Core State Standards**

<table>
<thead>
<tr>
<th>Week</th>
<th>Instructional Task</th>
<th>Alignment with CCSS</th>
</tr>
</thead>
</table>
| 1    | Class A: CM 1.1 Shirts and Caps  
Solving Equations with Two Variables  
Class B: Solving Equations with Two Variables | 8.F.A.3 Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line. |
| 2    | Class A: CM 1.2 Connecting  
Ax + By = C  
CM 1.3 Booster Club Members  
Intersecting Lines  
Class B: Writing Linear Equations in Ax + By = C and $y = mx + b$ Forms  
Pairs of Linear Equations | 8.EE.C.8 Analyze and solve pairs of simultaneous linear equations.  
8.EE.C.8a Understand that solutions to a system of two linear equations in two variables correspond to points of intersection of their graphs, because pairs of intersection satisfy both equations simultaneously. |
| 3    | Class A: Caps Again  
Solving Systems with $y = mx + b$  
Class B: Solving Systems of Equations through Graphing & Substitution | 8.EE.C.8c Solve real-world and mathematical problems leading to two linear equations in two variables. |
| 4    | Class A: CM 2.1 Shirts and Caps Again  
Solving Systems with $y = mb + b$  
Class B: Solving story problems using Systems of Equations | 8.EE.C.8a Understand that solutions to a system of two linear equations in two variables correspond to points of intersection of their graphs, because pairs of intersection satisfy both equations simultaneously.  
8.EE.C.8c Solve real-world and mathematical problems leading to two linear equations in two variables. |

*Note.* Pre-assessment data and surveys were collected prior to week 1 while post-intervention data was collected in week 5 of the study.
The intervention lasted the duration of the unit on linear equations and systems of equations. This unit lasted approximately five weeks starting mid-April through mid May. All instruction took place after state standardized testing to allow for flexibility in instruction and assessment. Again, it is important to note that while Class A used the student-centered Connected Mathematics 3 instruction, Class B continued learning through teacher-centered approaches.

Data Collection

Pre-assessment/Post-assessment. The first instrument used was the pre-assessment (Appendix A) /post-assessment (Appendix B) adapted from the Connected Mathematics 3 “It’s All in the Systems” curriculum (Lappan, Phillips, Fey, Friel, 2014) and both the pre- and post-assessment contained a parallel structure and assessed the same learning targets. The assessment consisted of one-third procedural questions and two-thirds problem-based questions which were classified by the researcher according to the extent which the students had to apply the knowledge using their own strategies. The problem-based questions existed at two levels: a basic and advanced level. This instrument was used to distinguish possible differences in students’ ability to answer both procedural and problem-based questions before and after the intervention. The pre-/post-assessment from “The Shapes of Algebra” unit in Connected Mathematics 2 was used in this collection-method (Lappan, Fey, Fitzgerald, Friel, Phillips, 2006) as it correlated with the “It’s All in the Systems” unit from the updated Connected Mathematics 3 curriculum. Although the teacher researcher used the assessment material from an older Connected Mathematics series, the teacher researcher had access to a larger test bank as
the publisher had more materials available in this earlier series. The pre-/post-assessment was comprised of a compilation of various questions within the assessment bank that the teacher-research felt was appropriate for the unit. The assessments were not taken directly from the Connected Mathematics series as a pre-existing pre- and post-assessment because an appropriate assessment for this study using procedural and problem-based questions did not exist already at the desired length. Additionally, there was not a pre- and post-assessment that provided questions that were identical with the exception of different values. The teacher researcher wanted the pre- and post-assessment to align as closely as possible. Data was collected from both Class A and Class B. Students were given two class periods to complete this assessment (84 minutes).

**Pre- and post-survey.** Students in Class A and Class B were given a 40-question survey on their perceptions of mathematics adapted from the Attitudes Toward Mathematics Inventory (ATMI) by Assessment Tools in Informal Science (Tapia & Marsh, 1996). This survey (located in Appendix C) was given to students at the beginning and end of the study to track possible shifts in attitudes after learning in a student versus teacher-centered approach. This is a 4-factor survey that was specifically designed to measure students’ attitudes toward mathematics in the areas of self-confidence, value, motivation, and enjoyment as recommended by the creators of this survey. Students were given this survey on the first and last day of the study. Students had as long as they wanted to complete the survey.

**Student journals with samples of student communication.** Students in both classes were given a blank composition book to use as their student journal. The journal
prompts can be located in Appendix D. The teacher researcher would given the students a paper copy of the journal prompt which they would attach into their composition book. This journal, which was completed as a cold-read at the beginning of class on Monday of the second, third, and fourth week of the study, stayed in the investigator’s classroom and was completed in class only. No review was given before the journal entry. The journal prompt was task-based in nature and required students to use problem-solving techniques as well as communicate their thinking. These questions required higher-level thinking according to Smith and Stein (1998) and required students to problem solve using complex and non-algorithmic thinking. Additionally, these tasks required students to access relevant knowledge and experience and make use of them appropriately through the completion of the task (Smith & Stein, 1998). The journal prompts were selected by the teacher researcher but were derived directly from the Connected Mathematics 3 curriculum materials (Lappan, Phillips, Fey, Friel, 2014). In other words, problems that aligned with the understandings that were uncovered from the week’s tasks were selected from the Connected Mathematics 3 curriculum materials.

**Teacher notes.** The investigator maintained an electronic journal that was used on a frequent basis (approximately 13 of the 25 days of the study) to keep a record dialogue of the researcher’s thinking throughout the study. The teacher included things in his or her notes such as students’ in-class responses, student misconceptions of the mathematical concepts at hand, students’ abilities to work through journal entries, and any other revelations that came to mind during this time of reflection. Specifically, the teacher made note of how both classes were performing when asked to perform problem-
based tasks and also any observations about their attitudes when working through these daily tasks. There were no predetermined questions or categories selected that limited the teacher researcher in his or her note taking. This data collection tool was informal and open-ended.

These teacher notes were analyzed so that the teacher researcher could search for possible conclusions or major findings from the intervention that would aid in finding answers to the research questions. The teacher researcher hoped that this data collection tool could provide insight into the intervention that might not otherwise be exposed through out collection methods.

**Student-interview.** A four-question student-interview was given to four, randomly selected students at the conclusion of the intervention as shown in Table 3.2 below. During an interview with the teacher researcher, which concluded at the end of all intervention lessons, the students were asked questions regarding their experience with student-centered learning. The questions were selected because they focused on some of the main components of the interview. This interview was only given to Class A students because Class B students did not undergo the student-centered learning intervention.

Table 3.2

<table>
<thead>
<tr>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) How do you feel you best learn mathematics?</td>
</tr>
<tr>
<td>2) Explain the role you feel homework plays in your learning.</td>
</tr>
<tr>
<td>3) What types of mathematics tasks and homework assignments do you find most beneficial?</td>
</tr>
<tr>
<td>4) Have you noticed a difference in the way we have been learning mathematics this past unit? If so, explain your reaction to this new way of instruction.</td>
</tr>
</tbody>
</table>
Timeline and Relevance of Data-Collection Instruments

In Table 3.3 below, the reader will find a timeline of the various data-collection procedures that were followed by the teacher researcher. This table outlines when various data-collection tools were administered and collected by the teacher researcher. Data collection tools were used to collect data on both classes with the exception of the student interview which was used on the intervention group (Class A) only as the control group (Class B) did not undergo the student-centered learning tasks.

Table 3.3

Data Collection Timeline

<table>
<thead>
<tr>
<th>Data Collection Tool</th>
<th>Date(s)</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-assessment Part I</td>
<td>April 23, 2015</td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Pre-assessment Part II</td>
<td>April 24, 2015</td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Attitudes Toward Mathematics Inventory Survey</td>
<td></td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Student Journal Entries</td>
<td>May 4, 11, 18</td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Teacher Journal Entries</td>
<td>April 28, 30</td>
<td>Teacher researcher</td>
</tr>
<tr>
<td></td>
<td>May 1, 4, 5, 6, 7, 8, 11, 12, 18, 19, 20,</td>
<td></td>
</tr>
<tr>
<td>Post-assessment Part I</td>
<td>May 21, 2015</td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Post-assessment Part II</td>
<td>May 22, 2015</td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Attitudes Toward Mathematics Inventory Survey</td>
<td></td>
<td>Class A &amp; B</td>
</tr>
<tr>
<td>Student Interviews</td>
<td></td>
<td>Class A</td>
</tr>
</tbody>
</table>
In addition to the data-collection timeline above, the teacher researcher also created a venn diagram which shows the relationship between the data-collection instruments and the research questions they seek to answer. This resource can be found in Appendix E.

**Data Analysis**

The following section will describe the findings in the data analysis of the various data collection instruments. This analysis reports the quantitative and qualitative results.

**Pre-assessment /Post-assessment.** The pre- and post-assessment results were analyzed by assigning point values to each question. Student pre- and post-assessment mean scores from Class A and Class B were compared. This analysis used descriptive statistics to look at the mean scores for both classes before and after the intervention. Additionally, the questions on the assessment were classified into three different categories: procedural-based, problem-based (low), and problem-based (high) as displayed in Table 3.4 below.

Table 3.4

*Pre-/Post- Assessment Question Types*

<table>
<thead>
<tr>
<th>Category</th>
<th>Related Assessment Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedural</td>
<td>1.a., 1.b, 2.b, 4, 7.b.iii.</td>
</tr>
<tr>
<td>Problem-based (low)</td>
<td>2.a., 6, 7.a, 7.b.i, 7.b.ii</td>
</tr>
<tr>
<td>Problem-based (high)</td>
<td>2.b, 3, 5</td>
</tr>
</tbody>
</table>

*Note.* Question 2.b was evaluated as problem-based (high) for students’ ability to uncover possible solutions and evaluated as procedural in regards to students’ ability actually to graph the coordinates.
Two rubrics were used to evaluate the responses in pre- and post-assessment and were modeled by the Exemplars Standards Based Rubric (McNair, 2001). The rubric on ability to problem solve (Appendix F) was used to score the low-problem solving and high problem-solving questions. Additionally, a second rubric was used to assess each student’s ability to communicate and construct viable arguments of his or her mathematical thinking (Appendix F). The categories on the rubric were assigned a numerical value from one to four. Students receiving the lowest possible score received a score of one while students receiving the highest possible score received a four. The results of the rubric scores were then analyzed for themes across the two classes. The investigator looked for differences between the before and after intervention tests in the quality of responses and the students’ ability to communicate their thinking.

**Pre- and post-survey.** The responses from the 40-question Attitudes Toward Mathematics Inventory survey (Tapia & Marsh, 1996) were analyzed using descriptive statistics. Each of the four responses were given a numerical value. A score of 1 was awarded to responses marked as a “strongly disagree”, a score of 2 to responses marked as “disagree”, a score of 3 to responses marked as “agree”, and a score of 4 was awarded to responses marked as “strongly agree”. The teacher researcher looked for patterns in the student responses comparing before and after responses. The survey was grouped into four categories: self-confidence, value, motivation, and enjoyment as designed by the creators of this survey. Questions that had been asked to the participants in a negative manner were reverse-scored by assigning a numerical score of 4 to responses marked as a “strongly disagree”, a score of 3 to responses marked as “disagree”, a score of 2 to
responses marked as “agree”, and assigning a score of 1 to responses marked as “strongly agree” as these were purposefully worded in a way to ensure the survey-respondent was answering the survey consistently. The teacher researcher calculated the mean of the responses for each of the four categories for both the intervention group and the control group for before and after the study.

**Student journals with samples of student communication.** Using the communication rubric (Appendix F) modeled by the Exemplars Standards Based Rubric (McNair, 2001), the students’ ability to describe their thinking in the prompt was assessed for possible differences between the control and experimental group. The categories on the rubric were assigned a numerical value from one to four. Students receiving the lowest possible score received a score of one while students receiving the highest possible score received a four. The student journals provided the investigator the ability to assess the student responses for their ability to communicate their answers. The teacher used the rubric to determine a quantitative score for each category on the rubric. Using this data, the teacher found the class averages of the journal entries from both Class A and Class B and looked for any trends in the mean score in the area of communicating the answers.

**Teacher notes.** The teacher notes were analyzed to look for patterns in student thinking and attitudes during the study. The investigator coded the notes for emerging themes, or categories, to provide a descriptive analysis of students’ thinking during this unit.

**Student-interview.** The student-interview was coded qualitatively for themes.
The teacher looked for commonalities in responses in order to form generalizations about student attitudes towards the student-centered instructional approaches both in class and homework tasks.

**Summary**

The research study utilized a mixed methods experimental design. Four primary sources of data were used: pre-/post-assessment, pre-/post-survey, student journals, teacher notes, and student interviews. All data was analyzed in conjunction with one another so that possible themes and generalizations could be made.

Chapter four will discuss the results and findings from this study on a student-centered learning environment. The teacher researcher were investigate the impact this type of instruction has on students’ ability to be successful on summative tasks as well as student perception of this type of instruction.
Chapter Four

Findings

This mixed methods experimental study aimed to investigate the influence of a student-centered learning environment on mathematics understanding as demonstrated on summative assessments. Additionally, this study assessed student attitudes on student-centered learning. The participants were 46 students and the teacher-researcher in a mathematics classroom setting. The research questions analyzed were:

1. How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high achieving seventh grade students’ ability to be successful on summative assessments?

2. How do the perceptions of high achieving seventh grade students change when their instruction changes from teacher centered to student centered?

The results and findings of this study will be described in this chapter. First, the pre- and post-assessment results will be stated. Then, the pre-survey and post-survey will be addressed. Next, student journals and teacher journals will be reported. Finally, the student interview results will be summarized.

Pre-Assessment and Post-Assessment Results

The following section describes the pre-assessment scores as well as the post-assessment scores for both Class A and Class B. Furthermore, this section will discuss the overall scores for both classes as well as separate scores for the procedural tasks,
problem solving (high) tasks, and students’ ability to communicate their reasoning and make viable arguments. Table 4.1 below shows the overall results of the pre- and post-assessment scores of Class A and Class B.

Table 4.1

*Overall Mean Pre- and Post-Assessment Results*

<table>
<thead>
<tr>
<th>Class</th>
<th>Pre-Assessment Mean</th>
<th>Pre-Assessment Standard Deviation</th>
<th>Post-Assessment Mean</th>
<th>Post-Assessment Standard Deviation</th>
<th>Mean Gain</th>
<th>p (Mean Gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 21)</td>
<td>6.46</td>
<td>3.18</td>
<td>19.45</td>
<td>2.27</td>
<td>13.00</td>
<td>0.26</td>
</tr>
<tr>
<td>B (N = 25)</td>
<td>7.17</td>
<td>2.42</td>
<td>19.38</td>
<td>2.20</td>
<td>12.21</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p<0.05, one-tailed

While the pre-assessment scores describe student performance prior to the intervention, the post-assessment scores describe student performance after the intervention. According to Table 4.1, the intervention group, Class A, scored a 6.46 on the pre-assessment and a 19.45 on the post-assessment out of a total of 22 points. The mean gain of Class A was a 13.00. Moreover, the control group, Class B, scored a 7.17 on the pre-assessment and a 19.38 on the post-assessment. The mean gain of Class B was a 12.21. While Class B scored higher on the pre-assessment, Class A ended with a higher post-assessment mean score. The mean gain of Class A from the pre-assessment to the post-assessment was .79 points higher. This mean difference in gain had a p-value of 0.26 and therefore was not significantly significant when using a significant value of less than 0.05.
The teacher researcher also analyzed the standard deviations of Class A and Class B on the pre- and post-assessment. On the pre-assessment, Class A received a standard deviation of 3.18 while Class B had a standard deviation of 2.42. Moreover, on the post-assessment, Class A received a standard deviation of 2.27 and Class B had a standard deviation of 2.20. While the standard deviation of Class B stayed consistent between the start and end of the unit, the standard deviation of Class A decreased.

Table 4.2 below shows the pre- and post-assessment results of the questions categorized as procedural by the teacher-researcher (Table 3.4). According to the results Table 4.2

*Mean Pre- and Post-Assessment Results: Procedural Tasks*

<table>
<thead>
<tr>
<th>Class</th>
<th>Pre-Assessment Mean</th>
<th>Pre-Assessment Standard Deviation</th>
<th>Post-Assessment Mean</th>
<th>Post-Assessment Standard Deviation</th>
<th>Mean Gain</th>
<th>p (Mean Gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 21)</td>
<td>2.10</td>
<td>0.54</td>
<td>3.57</td>
<td>0.75</td>
<td>1.48</td>
<td>0.09</td>
</tr>
<tr>
<td>B (N = 25)</td>
<td>1.52</td>
<td>.51</td>
<td>3.36</td>
<td>.81</td>
<td>1.84</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p<0.05, one-tailed

above, Class A had a mean gain of 1.48 points while Class B had a mean gain of 1.84 points on a four-point scale. This data shows that the control group grew more throughout the study than the experimental group in the area of procedural question types. It is important to note, however, that the p-value found when running the paired-t-test was 0.09 which is not statistically significant when using a significance level of 0.05.

Table 4.3 looks at the pre- and post-assessment means of students’ ability to solve high-problem solving tasks on questions considered in this category (Table 3.4).
Table 4.3

*Mean Pre- and Post-Assessment Results: High-Problem Solving Tasks*

<table>
<thead>
<tr>
<th>Class</th>
<th>Pre-Assessment Mean</th>
<th>Pre-Assessment Standard Deviation</th>
<th>Post-Assessment Mean</th>
<th>Post-Assessment Standard Deviation</th>
<th>Mean Gain</th>
<th>p (Mean Gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 21)</td>
<td>1.04</td>
<td>0.22</td>
<td>3.29</td>
<td>0.85</td>
<td>2.24</td>
<td>0.22</td>
</tr>
<tr>
<td>B (N = 25)</td>
<td>1.0</td>
<td>0.0</td>
<td>3.01</td>
<td>.89</td>
<td>2.01</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p<0.05, one-tailed

Class A scored a mean of 1.04 on the pre-assessment using a four-point scale and scored a mean of 3.29 on the post-assessment. Class B scored a 1.0 mean on the pre-assessment and a 3.01 on the post-assessment. While Class A experienced a mean gain of 2.24, Class B ended with a 2.01 mean gain. Though Class A did hold the higher mean gain at the conclusion of the study, this was not statistically significant using a significance level of less than 0.05 as the p-value was 0.22 on the paired t-test.

The pre- and post-assessment results of students’ ability to communicate mathematical thinking are represented in Table 4.4 below. According to Table 4.4,

Table 4.4

*Mean Pre- and Post-Assessment Results: Ability to Communicate Mathematical Thinking*

<table>
<thead>
<tr>
<th>Class</th>
<th>Pre-Assessment Mean</th>
<th>Pre-Assessment Standard Deviation</th>
<th>Post-Assessment Mean</th>
<th>Post-Assessment Standard Deviation</th>
<th>Mean Gain</th>
<th>p (Mean Gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 21)</td>
<td>1.24</td>
<td>0.44</td>
<td>3.24</td>
<td>0.83</td>
<td>2.0</td>
<td>0.23</td>
</tr>
<tr>
<td>B (N = 25)</td>
<td>1.20</td>
<td>0.41</td>
<td>3.0</td>
<td>0.82</td>
<td>1.80</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* p<0.05, one-tailed
Class A earned a mean score on their pre-assessment of 1.24 and earned a mean score of 3.24 on their post-assessment. This assessment assessed their ability to communicate their mathematical thinking and was evaluated on a four-point scale. Class B earned a mean score of 1.20 on their pre-assessment and ended with a 3.0 on their post-assessment. Furthermore, Class A showed a mean gain of 2.0 points while Class B showed a mean gain of 1.80 points. This gain was not statistically significant when using a significance level of less than 0.05 as the calculated p-value was 0.23.

**Pre-Survey and Post-Survey Results**

Table 4.5 below shows the pre- and post-survey mean results from the Attitudes Towards Mathematics Inventory for Class A and Class B. Each category had a possible minimum value of 1 (negative attitude) to a possible maximum value of 4 (positive attitude).

**Table 4.5**

*Pre-Questionnaire and Post-Questionnaire Results*

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean Class A Rating Pre (N = 21)</th>
<th>Mean Class B Rating Pre (N = 25)</th>
<th>Mean Change Class A</th>
<th>Mean Class A Rating Post (N = 21)</th>
<th>Mean Class B Rating Post (N = 25)</th>
<th>Mean Change Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Confidence</td>
<td>2.74</td>
<td>2.82</td>
<td>0.08</td>
<td>2.81</td>
<td>2.90</td>
<td>0.07</td>
</tr>
<tr>
<td>Value</td>
<td>3.45</td>
<td>3.52</td>
<td>0.07</td>
<td>3.43</td>
<td>3.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>2.91</td>
<td>2.92</td>
<td>0.02</td>
<td>2.82</td>
<td>2.96</td>
<td>0.14</td>
</tr>
<tr>
<td>Motivation</td>
<td>2.95</td>
<td>3.11</td>
<td>0.16</td>
<td>2.85</td>
<td>3.04</td>
<td>0.19</td>
</tr>
</tbody>
</table>
attitude). In looking at the data, both classes increased in the category of self-confidence, enjoyment, and motivation between the start and end of the study. While Class A showed a gain of 0.07 in valuing mathematics, Class B did not change in this category.

**Student Journals with Samples of Student Communication**

The journal scores, which were assessed using the “Ability to Communicate and Construct Viable Arguments” Rubric (Appendix F), show that on Journal 1, Class A students earned a score of 2.67 on a four-point scale while Class B scored a 2.16 on the same prompt. For Journal 2, Class A scored a 3.05 out of 4 while Class B scored a 2.76. On Journal 3, Class A received a score of 3.10 while Class B scored a 2.50. According to the journal scores, Class A received the higher journal average each prompt.

Additionally, the Class A mean in ability to communicate mathematical thinking improved with each prompt while Class B actually worsened from Journal 2 to Journal 3. It is important to note that Journal 1 had a p-value of 0.05 and Journal 3 had a p-value of 0.02 which are both statistically significant when using a significance level of less than 0.05. The differences in mean score were not significant using a significance level of 0.05 on Journal 2 where the p-value calculated was 0.02. According to the data generated from the journal prompts, students in Class A demonstrated higher scores when communicating their mathematical reasoning. These scores can be viewed on Table 4.6. As evident on the mean rubric score from the student journals, Class A was able to communicate their mathematical thinking and make viable arguments better than Class B. Samples of student journal entries for Class A and for Class B can be viewed in Appendix G noting the various misconceptions of student thinking from Class B.
Table 4.6  

*Mean Journal Scores*

<table>
<thead>
<tr>
<th>Class</th>
<th>Journal 1 Mean Score</th>
<th>p of Mean Score</th>
<th>Journal 2 Mean Score</th>
<th>p of Mean Score</th>
<th>Journal 3 Mean Score</th>
<th>p of Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 21)</td>
<td>2.67</td>
<td>0.05</td>
<td>3.05</td>
<td>0.17</td>
<td>3.10</td>
<td>0.02</td>
</tr>
<tr>
<td>B (N = 25*)</td>
<td>2.16</td>
<td>2.76</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* For Journal 3 (Class B), three students did not complete the task due to absence. The N value for this was 22.

Teacher Notes

The first theme generated by the teacher-researcher was teacher’s ability to understand student thinking and is summarized in Table 4.7. The teacher-researcher was able to understand student thinking and address misconceptions in understanding more easily during the instructional time with the student-centered instructional methods as compared to the teacher-centered instructional methods. While the teacher-researcher noted that many students in Class A were communicating their thinking and justifying their work for the first time on May 7, 2015, she was unable to determine the students’ understanding in Class B because there were no opportunities to share answers as evident on April 30, 2015. When Class B was forced to communicate their mathematical thinking and justify their work on quizzes and journal entries, many fallacies were noticed (as evident on May 8, 2015). On May 8, the teacher researcher noted in Class B, “The students noticed the new equation looked different than the first and therefore stated that the given point must not be a solution to the equation 3x – 5y = 15. This is NOT why the point is not a solution.”
Table 4.7

**Theme One: Ability to Understand Student Thinking**

<table>
<thead>
<tr>
<th>Examples from Teacher Notes</th>
<th>Examples from Teacher Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intervention Group (Class A)</strong></td>
<td><strong>Control Group (Class B)</strong></td>
</tr>
<tr>
<td>“Because I was circling the room and conversing with students, I was able to hear who was understanding the content as intended and who was not.”</td>
<td>“Because the teaching was whole-group, it was more difficult for me to determine who was understanding the lesson objects and who was not.”</td>
</tr>
<tr>
<td>4/30/15</td>
<td>4/30/15</td>
</tr>
<tr>
<td>“I was able to hear more of students’ rational and thinking than I was used to hearing.”</td>
<td></td>
</tr>
<tr>
<td>5/1/15</td>
<td></td>
</tr>
<tr>
<td>“I was able to handle student misconceptions at a personal level almost immediately. For example, students were confused as to why the m-value in slope-intercept form should be written as a fraction rather than writing only the integer (for example, 2 as m was converted to 2/1.”</td>
<td>“When reviewing the quizzes from Friday with the kids, I saw the value of having them explain why ((-10,9)) was not a solution to (3x - 5y = 15). Many students did not plug the points into the equation but had just tried to convert the equation to slope-intercept form. The students then noticed the new equation looked different than the first and therefore stated that the given point must not be a solution to the equation (3x – 5y = 15). This is NOT why the point is not a solution. Obviously, the student’s rationale was incorrect as evident on their journal work.”</td>
</tr>
<tr>
<td>5/6/15</td>
<td>5/8/15</td>
</tr>
<tr>
<td>“Students were communicating their thinking and justifying their work who had never talked or asked questions before.”</td>
<td></td>
</tr>
<tr>
<td>5/7/15</td>
<td></td>
</tr>
<tr>
<td>“Students wanted to write (y = 3x + 0) to indicate the y-intercept was 0. They were not recognizing that if the 0 was not indicated, it was still technically in slope-intercept form. Because I was working with small groups, I was able to pick up on this confusion.”</td>
<td></td>
</tr>
<tr>
<td>5/8/15</td>
<td></td>
</tr>
</tbody>
</table>

The second theme uncovered by the teacher-researcher from the teacher notes is in Table 4.8: students’ understanding of in-class learning. Students who were instructed from a student-centered approach seemed to have a deeper understanding of the mathematical concepts and could articulate this thinking better than the students who were instructed from a teacher-centered approach. The teacher-researcher noted on May 12, 2015, that Class A showed evidence of a deep understanding of the solution in a
### Theme Two: Students’ Understanding of In-class Learning

<table>
<thead>
<tr>
<th>Examples from Teacher Notes (Class A)</th>
<th>Examples from Teacher Notes (Class B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The students who were confused seemed to understand better when listening to their peers describe their solution methods.” 5/5/15</td>
<td>“Today we had our first journal prompt. Students struggled with their journals knowing how to set up story problems.” 5/1/15</td>
</tr>
<tr>
<td>“…the students had a great discussion of how substitution could be used to solve equations instead of graphing. This discussion, initiated by student questions, was impactful.” 5/12/15</td>
<td>“When going over the procedural questions, I heard a lot of ‘Why are you doing that?’ and ‘I don’t understand why you subtract x that time and added it the other time.’” 5/5/15</td>
</tr>
<tr>
<td>“Today we learned about systems of equations. Students seemed to understand the common solution was the “break even point” of the equation.” 5/12/15</td>
<td>“The students struggled more in answering the journal prompt. Students attempted to ask me many questions.” 5/8/15</td>
</tr>
<tr>
<td>“When investigating story problems involving systems of equations, students seemed to understand how to approach these problems with little prompting from the teacher through questioning techniques.” 5/18/15</td>
<td>“Students had a hard time figuring out how to solve systems of equations when given two equations in slope-intercept form.” 5/19/15</td>
</tr>
<tr>
<td>“When constructing their own equations, students did not include x in the formula “y=mx+b” form. For example, if the slope was 7 and the y-intercept 2, one-fourth of the students would write ‘y = 7 + 2’ rather than ‘y = 7x + 2’. 5/20/15</td>
<td>“There were more questions during test. Need clarification of story problems.” 5/20/1</td>
</tr>
<tr>
<td>“Students had a hard time thinking through how to write an equation if given the slope and y-intercept. This is something that had never been done in class.” 5/20/15</td>
<td>“Students seemed to struggle with identifying the parts to slope-intercept form and what they represented.” 5/20/15</td>
</tr>
<tr>
<td>“When students were graphing a line for one of the assessment questions, many students failed to recognize that the line they created had a positive vs. negative slope.” 5/20/15</td>
<td></td>
</tr>
</tbody>
</table>
system of equations problem in a real-world context. Looking at the teacher notes from Class B, it is clear that various misconceptions of the content existed in the understanding of the students (May 5, May 19, May 20) that did not seem to present problems with Class A. Additionally, Class B had frequent struggles when going through various tasks as evident on May 1, May 8, and May 20 resulting on addition questions for the teacher during the lecture. Students had a difficult time adjusting to the in-class student-centered instructional methods as well as the homework tasks that extended these in-class tasks. A summary of these observations is noted in Table 4.9. The teacher-researcher noted

Table 4.9

<table>
<thead>
<tr>
<th>Examples from Teacher Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>“After I introduced the task and allowed the students to work in their groups together to discuss their thinking, the students were very quiet. It was almost as if they did not know how to work together.” 4/28/15</td>
</tr>
<tr>
<td>“Students seemed to be more focused on who was in their group than the mathematical discourse that was occurring in their group. Several students requested to work with new groups rather than their normal groups.” 5/1/15</td>
</tr>
<tr>
<td>“Higher achieving students seemed frustrated at times during the investigation of the tasks.” 5/1/15</td>
</tr>
<tr>
<td>“There was too much down time between parts of the tasks. Students seemed to struggle with maintaining discussions while waiting to communicate thinking to the teacher.” 5/4/15</td>
</tr>
<tr>
<td>“Students seemed frustrated that I would not provide the solution to the tasks.” 5/4/15</td>
</tr>
<tr>
<td>“Students seemed stumped when going over the homework. They wanted me to ‘give’ them the way to answer the problem.” 5/5/15</td>
</tr>
</tbody>
</table>
frustration on May 1, 2015, and May 4, 2015, in Class A regarding the in-class tasks as well as the homework. It also was evident that students were seeking teacher assistance in receiving the answers to the problem-tasks and were reluctant to work through the problems as a group. Through the course of the study, these negative feelings towards problem-based learning tasks seemed to lessen. By the end of the study, no feelings of frustration were noted regarding these tasks.

The forth theme generated by the teacher-researcher was on student engagement and can be noted in Table 4.10. Students seemed more engaged during the student-centered instruction (Class A) compared to the teacher-centered instruction (Class B).

The teacher notes revealed that students were excited and making real-world connections

<table>
<thead>
<tr>
<th>Examples from Teacher Notes Intervention Group (Class A)</th>
<th>Examples from Teacher Notes Control Group (Class B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The students seemed excited to go over the homework problems from the night previous. I allowed the students to go over their work before we went over the questions as a class. I listened to discussion as they talked about the answers.” 4/30/15</td>
<td>“Students seemed bored during the lesson. They are talkative and had to be redirected many times, almost seeming restless.” 4/28/15</td>
</tr>
<tr>
<td>“I noticed some students moving ahead of me before I was able to finish the lesson. Some students, on the other hand, were stuck and needed the concept re-explained which frustrated the rest of the class.” 4/28/15</td>
<td>“I had to quiet the class multiple times.” 4/30/15</td>
</tr>
<tr>
<td>“Students seemed to connect the real life context of graphing equations.” 5/12/15</td>
<td>“Kids seemed disengaged and could not understand how it was connected to real life.” 4/30/15</td>
</tr>
</tbody>
</table>
in Class A while in Class B, students seemed to lose focus and lack connections to life contexts. The teacher-researcher explains on April 30, 2015, that students were eager to discuss the night’s homework task. Class B, however, appeared bored and disengaged on April 28, 2015, and April 30, 2015.

The last theme from the teacher-notes was regarding students’ ability to solve procedural problems and can be viewed in Table 4.11. While Class B seemed to feel comfortable in the completion of procedural tasks, Class A seemed to ask more questions of procedural tasks and even requested more of these type problems as evident from the teacher notes on May 19, 2015.

Table 4.11

Theme Five: Students’ Ability to Solve Procedural Problems

<table>
<thead>
<tr>
<th>Examples from Teacher Notes</th>
<th>Examples from Teacher Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention Group</td>
<td>Control Group</td>
</tr>
<tr>
<td>(Class A)</td>
<td>(Class B)</td>
</tr>
<tr>
<td>“It seemed to help the kids when they practiced graphing just regular procedural problems that were not tied to story problems. While we went over the problems, the students were still engaged. I was sure to still ask intentional questions which allowed a discussion surrounding the meaning behind the graph’s intersection points.”</td>
<td>“Practicing multiple procedural problems seemed to be beneficial. By the last example problem, the kids were catching on to the task of converting to the correct form of the equation.”</td>
</tr>
<tr>
<td>5/11/15</td>
<td>4/30/15</td>
</tr>
</tbody>
</table>

“Students wanted more procedural problems to practice during our review. Though they seemed to understand the big ideas of solving equations and systems of equations, they seemed to lack the confidence to actually solve the more procedural questions.” 5/19/15
**Student Interviews**

Student interviews were used to gather qualitative data regarding student perceptions of the student-centered instructional methods used during the intervention. These questions were only asked to the intervention group (Class A).

The responses to the first interview question regarding how the students feel they learn math best are summarized in Table 4.12. When asked how students best learn mathematics, results from the student interviews show that students believed they learned mathematics best when working together and communicating their mathematical thinking during the student-centered instruction as mentioned by Student B and Student C. It also seemed that students appreciated the time to think about and reflect on mathematical ideas but expressed appreciating teaching confirmation of their thinking. Student A stated, “I learn best when I have time to work on my own…” while Student D mentioned,

<table>
<thead>
<tr>
<th>Examples From Interview Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I learn best when I have time to work on my own but then the teacher confirms what I thought.” –Student A</td>
</tr>
<tr>
<td>“I like to talk in groups with other people when I learn.” –Student B</td>
</tr>
<tr>
<td>“I like working with other people. If I got a problem wrong, someone else could show me how to understand it better right away.” –Student C</td>
</tr>
<tr>
<td>“I need time to think about math.” –Student D</td>
</tr>
</tbody>
</table>
“I need time to think about math.” These findings are consistent with Smith and Stein’s discussion of the importance of wait time when trying to help strengthen students’ mathematical thinking (2011).

The second student interview question dealt with student perception of homework and its impact on learning, and responses can be found in Table 4.13 below. Students

Table 4.13

*Question Two Theme: Student Perceptions on Homework*

<table>
<thead>
<tr>
<th>Examples From Interview Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I don’t really like math homework. It just seems like we are doing the same things from class. I either know it already or I’m confused and still am confused at home.” –Student A</td>
</tr>
<tr>
<td>“I think we need a little bit of homework to practice but not a whole bunch of problems.” –Student B</td>
</tr>
<tr>
<td>“If I understand the concept, homework is good practice. But if I was confused, I can’t really do it at home either.” –Student C</td>
</tr>
<tr>
<td>“It seems like if I don’t understand the concept taught the homework just confused me more and during this unit my group left with a lot of questions.” –Student D</td>
</tr>
</tbody>
</table>

reported that homework seemed to reinforce the same level of understanding that the learner left the classroom with that day. In other words, students are practicing either the right or the wrong mathematical beliefs when they complete homework. According to Student D, “It seems like if I don’t understand the concept taught the homework just confused me more and during this unit my group left with a lot of questions.” Student A also mentioned the fact that if confusions exist during class, they are continued at home during the completion of homework tasks.
Table 4.14 below shows student interview responses on question three. The theme generated from this interview question was students’ perceptions on in-class tasks.

Table 4.14

*Question Three Theme: Students’ Perceptions on In-class Tasks*

<table>
<thead>
<tr>
<th>Examples From Interview Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I liked the hands on activities we did together in our groups. I liked exploring with my group.” –Student A</td>
</tr>
<tr>
<td>“I didn’t like the story problems. I liked working through the problems with my group, but the story problems I didn’t like. They confused me because I didn’t know how to do the math yet.” –Student B</td>
</tr>
<tr>
<td>“The group activities were awesome! I liked working with other people to solve the problems. It was another way to learn math without you just telling us how to do the problem.” –Student C</td>
</tr>
<tr>
<td>“I liked working with groups to uncover problems instead of the teacher giving me notes. It was hard to solve some of the word problems though even with our group.” –Student D</td>
</tr>
</tbody>
</table>

This interview question asked students to explain the mathematics tasks that they felt were effective to their understanding of mathematics. The results to the student interviews revealed that all students interviewed mentioned their approval of group work when defining effective learning tasks. Students A and C mentioned the use of activities to uncover the mathematics and felt this was useful. Though students seemed to enjoy working in groups to learn, it seemed like they were still uncomfortable with the heavy use of story problems as Student B and Student D expressed.

Table 4.15 outlines the responses of the student interviews on the last
question regarding their reactions of this new type of student-centered instruction.

Table 4.15

*Question Four Theme: Students’ Reaction to Student-centered Instruction*

<table>
<thead>
<tr>
<th>Examples From Interview Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>“We worked in groups a lot. I’d rather work alone because math is easy to me, but it seemed to benefit other students in my group.” –Student A</td>
</tr>
<tr>
<td>“I liked exploring the ideas for myself with my group.” –Student B</td>
</tr>
<tr>
<td>“I liked being able to talk to my group and work together and not just sit at my desk and listen all the time.” –Student C</td>
</tr>
<tr>
<td>“I thought it was easier to learn with these tasks because I could actually think about the concepts and talk to my friends instead of take notes.” –Student D</td>
</tr>
</tbody>
</table>

During the interviews, students provided useful feedback on student-centered instruction. Specifically, students mentioned that student-centered tasks provided time for the students to collaborate and share thinking with their peers as opposed to having to listen to the teacher as mentioned with Student B and Student C. Though Student A mentioned that he or she preferred working alone, the student acknowledged that student-centered learning was beneficial to other students. Overall, it seems that the students enjoyed having an active role in the learning process.

**Summary**

This chapter reported the quantitative and qualitative findings from this mixed methods experimental study on the impacts of student-centered instructional methods in mathematics to student understanding and performance on summative assessments.
Additionally, this study examined student perception of this type of learning. The final chapter will discuss the conclusions made by the teacher researcher in regards to the research questions. Implications of these findings for future action research will be shared.
Chapter Five

Discussion

This chapter will discuss the findings of a study aimed to investigate the influence of a student-centered learning environment on mathematics understanding. It was the goal of the teacher researcher to provide students in the intervention group with in-class and out-of-class tasks that allowed the students to construct their own knowledge through meaning-making opportunities. Furthermore, the teacher researcher wanted to determine what impact this type of student-centered instruction had on students’ mathematics understanding and students’ ability to communicate this understanding on assessments. Additionally, this chapter will address the findings of student attitudes on this type of student-centered learning. The research design used for this study was an experimental mixed-methods design. In order to form conclusions on the impacts of the intervention on student understanding and student perceptions of learning, the following instruments were used in this analysis: pre- and post-assessment, pre- and post-survey, student journals, teacher notes, and student interviews. The research questions analyzed were:

1. How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high achieving seventh grade students’ ability to be successful on summative assessments?

2. How do the perceptions of high achieving seventh grade students change when their instruction changes from teacher centered to student centered?
**Discussion of Findings and Conclusions**

A discussion of the findings and conclusions of this study will be described in this section. These findings and conclusions were made in response to the results described in Chapter Four.

**Pre-assessment and post-assessment.** The teacher-research noted various trends in the pre- and post-assessment results. According to the overall mean gains from Class A and Class B, it appears that the intervention group using the student-centered instruction showed more growth throughout the unit than the control group that used a traditional, teacher-centered approach to learning. These findings support the research of mathematics experts who promote learning through a constructivist framework through student-centered instructional methods and worthwhile tasks (Fosnot, 2005; Hiebert, 1997; Stigler & Hiebert, 1999). Additionally, these results are consistent with the research study conducted by Riordon and Noyce (2001). Though these findings were not statistically significant, these findings do show that the students who were given the intervention were not hindered in being able to show growth from a pre- and post-assessment.

When looking at the pre- and post-assessment by task as categorized in Table 3.4, the control group actually demonstrated more growth than the intervention group in the area of procedural tasks. Researchers such as Stigler and Hiebert (1999) have mentioned that students become confident and successful in the tasks in which they spend time on in the classroom. Because the control group completed many procedural tasks over the course of the study, these findings make sense. With that said, it would be the hope of
researchers such as Fosnot (2005) and Hiebert (1997) that these student-centered instructional practices would lay a strong enough mathematical foundation in instructed concepts that students’ ability to perform procedural tasks would also be strengthened despite the decrease in procedural learning methods.

In the category of solving high-problem solving tasks, Students in Class A demonstrated a higher mean growth score as compared to Class B. The researcher concluded that the student-centered learning methods which encouraged students to problem-solve and communicate their thinking in groups and whole-class discussions allowed for a better understanding of the content making it easy for students to problem solve and communicate reasoning on assessments. These findings are aligned with researchers in the area of student-centered learning (Fosnot, 2005; Hiebert, 1997; Stigler & Hiebert, 1999). Although these findings were not statistically significant, the teacher-researcher believes that given a longer intervention period, these differences in mean gains would be greater. Additionally, it should be noted that because Class B was communicating their reasoning on the weekly journal entries which was apart of the study’s data collecting, the control group was also given opportunities to think about, reflect, and discuss their reasoning once a week. Had the control group not been given these journal entries, their mean growth might have lessened from the pre- to post-assessment.

Finally, looking at the students’ ability to communicate their reasoning and form viable arguments from the pre- to post-assessment, it is evident that the students in the intervention group showed a larger mean gain as compared to the control group. Again,
this supports the work of Fosnot (2005), Hiebert (1997), and Stigler and Hiebert (1999) who found that students have a better understanding of the content through student-centered approaches. Similar to the problem-solving conclusions above, the teacher-researcher feels that these findings would have been statistically significant had the study continued for longer than five weeks and had the control group not been asked to communicate their thinking once a week through the journal data-collection methods.

**Pre-survey and post survey.** The teacher researcher used a mathematics survey that was adapted from the Attitudes Toward Mathematics Inventory (Tapia & Marsh, 1996). It does not appear that the student-centered instructional strategies negatively impacted student perceptions of their self-confidence, value, enjoyment, or motivation towards mathematics. With that said, the intervention group (Class A) and control group (Class B) did not exhibit any major variations in mean scores for the four noted categories. In other words, the intervention group did not show that they held a greater view or lesser view of mathematics after undergoing the intervention according to this specific survey.

**Student journals with samples of student communication.** The weekly student journals showed compelling support for the use of student-centered learning strategies in the students’ ability to problem solve and then communicate their reasoning. These findings support research in the area (Fosnot, 2005; Hiebert, 1997; Stigler & Hiebert, 1999). The intervention group showed mean scores that were higher than the control group throughout the study, and these means were statistically significant. Throughout the prompts, Class A more clearly articulated the idea that points on a line represent...
solutions to an equation and furthermore, when two or more lines were present, the intersection point of these lines is a solution that satisfies both equations. Many students in Class B could not communicate this idea. For example, when the lines in a system of equations was parallel, the students believed that all solutions were possible as opposed to no solutions were possible. Furthermore, the students in Class A better understood the parts of slope-intercept form and could create equations better than Class B when not given the slope and y-intercept directly. Class A also seemed to show better understanding of Standard Form as opposed to Slope-Intercept Form and could explain when it was better to use one form over the other. The control group held more misconceptions in their thinking as compared to the intervention group. Additionally, it was harder for the control group to communicate their thinking during these weekly checkpoints.

**Teacher notes.** The teacher notes provided a powerful way for the teacher researcher to assess both the ability for students to be successful on summative tasks as well as student perceptions of these student-centered instructional tasks. These conclusions are described below.

First, the teacher researcher identified the theme: ability to understand student thinking. In reviewing the various teacher notes supporting this theme, the teacher researcher found that she was better able to understand student thinking with the intervention group than with the control group. Furthermore, the teacher researcher noticed that she had the opportunity to converse with more students when they were collaborating together in their group as well as sharing their thinking in class discussions.
This opportunity for dialogue was something that was not apart of the control group’s classroom. This theme is supported by the work of Smith and Stein (2011) and Chapin (2009) who have found the benefit of orchestrated discussions that accompany student-centered learning tasks.

The second theme uncovered by the researcher was on students’ understanding on in-class learning. It was concluded through the teacher notes that students undergoing the intervention had a better understanding of mathematics concepts promoted in-class learning tasks as compared to the control group. Through various entries, the teacher researcher commented on the misunderstandings held by the control group once students from this class were asked to solve problems or communicate their thinking on the various data collection instruments (post-assessment, journal entries, etc.). This is consistent with Smith and Stein (2011) who discuss the importance of meaningful discussions in the classroom to promote mathematical discourse that leads to the uncovering of mathematical principles. Because the students in the control group did not have the opportunity to have meaningful discussions and work through tasks together, they would be lacking understanding, according to Smith and Stein (2011).

The third theme found by the teacher researcher was in regards to students’ perceptions of student-centered instruction. As made evident to the researcher, students seemed uncomfortable with the problem-based tasks at the start of the intervention. Students seemed frustrated about the lack of teacher aid in the problem solving. According to Stigler and Fosnot (1999), students become acquainted with the tasks they are used to in the classroom. Because the intervention students were used to procedural
tasks, these are the tasks they are comfortable with when solving problems. These reactions, then, support the research.

Another theme identified by the teacher researcher was student engagement during the intervention. It was determined that the students seemed more engaged about the problem-based tasks as opposed to the normal lecture instructional strategies. As stated by Donovan and Bransford (2005), students must be engaged in the learning process and instructional tasks must activate prior learning. Because the students in the intervention class were taught using engaging tasks that connected to their prior learnings, they were more connected to the lesson and able to construct meaning more easily.

Finally, the last theme found in the teacher notes was students’ ability to solve procedural problems. The teacher researcher concluded that the control group seemed better able to solve the procedural problems than the intervention group. This supports Stigler and Hiebert (1999) who mentioned that students become comfortable in solving the tasks which they are asked to solve. Because the students in the control group were constantly solving procedural questions, they were comfortable in these types of tasks.

**Student Interviews.** It was noted through the responses to the first student interview question that students felt that mathematics is learned best through experiences where they can work together to solve problems. Students also mentioned needing time to think about the mathematics at hand. These findings are conclusive with Vygotsky (1978) who encouraged scaffolding through social interactions.

The teacher researcher concluded in the second interview question that students
did not seem to see the need for homework in the learning process. All students mentioned that homework either strengthens those who already understand the mathematics concepts or weakens those who are confused about the mathematical concepts.

Furthermore, in the third interview question, students expressed the fact that they appreciated working together on problem solving tasks. Students seemed eager to solve the problems or tasks at hand. These findings support the work of Hiebert (1997) who mentioned the need for tasks that are viewed problematic by students so that they feel eager to solve the task. Lecture type tasks do not give students problematic tasks and this leaves students disengaged.

Finally, in the last interview question, the teacher researcher reported that students had a positive view on the student-centered instructional methods. It was concluded by the teacher researcher that students liked communicating their thinking with their peers and enjoyed the opportunity to think about the mathematics rather than be told the mathematics by the teacher. The one student who mentioned she would have rather worked independently still noted that she was able to help others understand through her insight into the mathematical concepts. This shows that though the student did enjoy working alone, she saw the value of helping others understand through collaborative work. This confirms findings by Hiebert (1997) which state that mathematical tasks must be problematic while also encouraging reflection and communication.

The above findings have lead the teacher researcher to some final conclusions which address the original research questions and were the driving force behind this
study. These conclusions are described in the following sections.

**Discussion of Research Questions**

This study first addressed the following question:

1) How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high achieving seventh grade students’ ability to be successful on summative assessments?

Through the triangulation of data using a mixed methods experimental design, the teacher-researcher found that the student-centered learning environment led to a higher success rate on summative assessments as evident from the pre-/post-assessment, student journals, and teacher notes. The intervention group, which was conducted using student-centered instructional strategies, showed higher mean gains from the pre- to post-assessment in all areas except for procedural-based questions as compared to the control group. Through mean journal scores, it was found that a student-centered learning environment led to better understanding and increased ability to communicate mathematical reasoning on summative assessments; these trends were statistically significant. Finally, through the use of teacher notes, it was discovered that students exhibited a deeper understanding of the mathematical concepts when taught from a student-centered rather than teacher-centered environment.

This study also sought to answer the following question:

2) How do the perceptions of high achieving seventh grade students change when their instruction changes from teacher-centered to student-centered?

Using pre- and post-surveys, student interviews, and teacher notes, the teacher
researcher concluded that although the initial shift from a teacher- to student-centered environment was frustrating to students, they quickly showed signs of approval towards the intervention. As made evident from the teacher notes and student interviews, the students enjoyed the problem tasks and appreciated working together to communicate their mathematical thinking. The pre- and post-survey showed the students did not develop a lesser view of mathematics in any of the categorized areas of self-confidence, value, motivation, and enjoyment.

**Reflections**

Overall, the teacher researcher was pleased with the action research study as well as the conclusions that were drawn on student-centered learning in mathematics. Through the completion of this task, the teacher-researcher was able to experience the benefits of problem-based tasks. Using this experience, the teacher researcher has transformed her thinking on effective instructional tasks in the classroom and intends to alter her teaching methods. Furthermore, the teacher researcher hopes the results to this study lead other mathematics educators towards more student-centered practices.

The findings and conclusions of this research study on effective mathematics tasks have already impacted curricular decisions within the district of the teacher-researcher. Furthermore, the district has decided to pilot the Connected Mathematics 3 curriculum as a result of the compelling findings from this study.

The teacher researcher also concluded that perhaps more high-yield tasks such as warm up problems or exit slips should be utilized in problem-based classrooms to provide students opportunities to practice the understandings developed in the problem
based tasks. High yield tasks allow opportunities for students to utilize their developed understandings and become more effective at apply the knowledge at a more procedural level (Marzano, 2001). It is the belief of the teacher researcher that the control group grew more in their procedural abilities because the intervention group had little exposure to these high-yield tasks as the researcher used all of her time to go over problem-solving tasks.

**Significance.** This study is beneficial to mathematics teachers, and the findings could guide them towards more impactful instruction. Research has shown that students in the United States have a difficult time using their mathematics knowledge in new and unfamiliar situations on summative assessments compared to other comparable countries (NCES, 2012; Mullis, Martin, Foy, & Arora, 2012). Findings from this study support this evidence showing that students need to learn in an environment that promotes problem solving and mathematical discourse (Fosnot, 2005, Hiebert, 1997; Smith & Stein, 2011; Stigler & Hiebert, 1999).

**Implications for future research.** At the conclusion of this study, the teacher-researcher was left with three main questions for further review. Through the use of additional action-research, the teacher-researcher would like to investigate these uncertainties further.

First, the teacher-researcher would like to see the implications of the intervention when used for a longer duration. This study was approximately five weeks and only consisted of about five tasks. To note the impact of this intervention, a longer study
would be beneficial. After implementing a longer intervention period, the teacher-researcher would like to see how the students perform on the post-assessment as well as how their opinions change on this type of student-centered learning. It would also be interesting to see if the mathematics survey results differentiate themselves more from the control group when the intervention is administered for a longer time period.

Second, the teacher-researcher would like to explore additional student-centered curriculum materials in addition to the Connect Mathematics 3 series (Lappan, Phillips, Fey, Friel, 2014). Though this series is known for its ability to creating tasks that leave mathematical residue, provide multiple solution methods, and lend themselves to mathematical discussions, the teacher-researcher is curious to see how the other student-centered programs accomplish the goal of teaching for understanding. This could also include a teacher-created curriculum with various task-based resources the teacher has deemed relevant to curriculum standards.

Finally, the teacher-researcher would like to perform this study in a classroom where the lead teacher has a background in teaching problem-based tasks. Because the teacher-researcher had little experience with teaching in a student-centered environment, it is possible that this introduced an additional variable in the analysis.

**Summary**

This action research project sought to uncover the impacts of student-centered learning environments on the ability for students to be successful on summative assessments in mathematics. Additionally, the project hoped to uncover students’ perceptions of this type of learning. Overall, the teacher researcher determined that these
student-centered methods led to improved understanding of the mathematical concepts and an increase in students’ ability to communicate their understanding on summative assessments. Students showed a positive view of these student-centered instructional methods.
Appendix A

Pre-Assessment
Appendix A: Pre-Assessment

Name: __________________ Date: __________________ Period: ____________

Systems of Equations
Pre-Assessment

Directions: Use the information below to answer questions 1-2. Indicate your response to each question in the shaded box provided.

The Plano Texans are a youth drum and bugle corps that competes with music and precision marching against other groups all over the country. The corps rents instruments to members. Each bugle rents for $10 per month and each drum rents for $5 per month.

1. What is the corps’ monthly income from instrument rentals if members rent:
   a. 7 bugles and 9 drums?
   b. 9 bugles and 7 drums?

2. a. What equation relates the number of bugle rentals \( x \) and the number of drum rentals \( y \) to the business manager’s goal of $100 in monthly rental income?
   equation: ________________

b. Draw a graph showing solutions of the rental income equation you found in part (a) on the following grid and give coordinates of 3 points that represent solutions.

   point 1) ______
   point 2) ______
   point 3) ______
Directions: For questions 3-6, read each question carefully. Indicate your response to each question in the shaded boxes provided.

3. The map shows Hope Road and the construction site for the new library. Find the equation of a "street" that passes through the building site and is parallel to Hope Road. Then, explain how you determined that this equation is parallel to Hope Road and passes through the library.

   equation: ______________

   explanation: ______________________________________________________________

4. Use graphing methods to find solutions for these systems of linear equations.

   \[ y = 4x + 3 \]
   \[ y = -x - 2 \]

   x = __________
   y = ______

   Explain how graphing these equations can help uncover the solution to the system.
5. Identify the slope and y-intercept for each of the linear equations.

\[ 2x + 4y = 14 \]

\begin{align*}
\text{slope: } & \phantom{=} \\
\text{y-intercept: } & \phantom{=} 
\end{align*}

Then, explain the strategies you used to determine the slope and y-intercept of this equation.

6. Solve the systems of equations by substitution.

\[ \begin{aligned}
3x + 5y &= 33 \\
x &= 2y
\end{aligned} \]

\begin{align*}
\text{x} &= \phantom{=} \\
\text{y} &= \phantom{=}
\end{align*}
Directions: Use the information below to answer question 7 parts a and b. Indicate your response to each question in the shaded box provided.

7.

Sam is planning a ski trip and wants to figure out which mountain offers the best deal. Sam needs to rent skis and buy a lift ticket. He researched his options, and he found the following two packages which include ski rental and lift ticket:

<table>
<thead>
<tr>
<th>Zippity Ski Slopes Rental Package</th>
<th>Cruising Ski Slopes Rental Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5</td>
<td>$20</td>
</tr>
<tr>
<td>+ $5 per hour for rental</td>
<td>+ $2 per hour for rental</td>
</tr>
</tbody>
</table>

Sam wants to find the best deal for his ski trip. Use the information above to answer the following questions.

a. Write equations to represent each of the ski packages.

- Zippity Ski equation: ________________
- Cruising Ski equation: ________________

b. Graph each equation. Then use the graph to answer these questions.

i. Under what circumstances are the costs for the ski packages the same, and what will that cost be? Explain how you know if the cost will be the same.

ii. Under what circumstances is Zippity cheaper than Cruising Ski Slopes?

iii. What is the cost of a ski package for Cruising Ski Slopes if you rent the skis for 10 hours?

i.) hours: ________ cost: __________

explanation:

ii.) :

iii.) cost: __________
Appendix B

Post-Assessment
Appendix B: Post-Assessment

Name: __________________ Date: __________________ Period: ____________

Systems of Equations
Post-Assessment
Part I

Directions: Use the information below to answer questions 1-2. Indicate your response to each question in the shaded box provided.

*The Plano Texans are a youth drum and bugle corps that competes with music and precision marching against other groups all over the country. The corps rents instruments to members. Each bugle rents for $5 per month and each drum rents for $15 per month.*

1. What is the corps monthly income from instrument rentals if members rent:
   a. 7 bugles and 9 drums?
   b. 9 bugles and 7 drums?

   a) ____
   b) ____

2. a. What equation relates the number of bugle rents \( x \) and the number of drum rentals \( y \) to the business manager's goal of $120 in monthly rental income?

   equation: __________________

   b. Draw a graph showing solutions of the rental income equation you found and give coordinates of 3 points that represent solutions.

   point 1) ____
   point 2) ____
   point 3) ____
Directions: For questions 3-4, read each question carefully. Indicate your response to each question in the shaded boxes provided.

3. The map show Hope Road and the construction site for the new library. Find the equation of a “street” that passes through the building site and is NOT parallel to Hope Road.

   Then, explain how you determined that this equation is NOT parallel to hope road and passes through the library.

   equation: __________________
   explanation: __________________________________________
   __________________________________________
   __________________________________________

4. Use graphing methods to find solutions for these systems of linear equations.

   \[ y = -2x + 2 \]
   \[ y = -2x - 2 \]

   x = ____
   y = ____

   Explain how graphing these equations can help uncover the solution to the system.
5. Identify the slope and y-intercept for each of the linear equations.

\[-12x + 3y = -16\]

slope: ____________
y-intercept: ____________

Then, explain the strategies you used to determine the slope and y-intercept of this equation.

6. Solve the systems of equations by substitution.

\[
\begin{align*}
-3x + 51 &= 8y \\
y &= -6x
\end{align*}
\]

\[
\begin{align*}
x &= ____ \\
y &= ____
\end{align*}
\]
Directions: Use the information below to answer question 7 parts a and b. Indicate your response to each question in the shaded box provided.

7. Sam is planning a ski trip and wants to figure out which mountain offers the best deal. Sam needs to rent skis and buy a lift ticket. He researched his options, and he found the following two packages which include ski rental and lift ticket:

<table>
<thead>
<tr>
<th>Zippity Ski Slopes Rental Package</th>
<th>Cruising Ski Slopes Rental Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 + $2 per hour for rental</td>
<td>$4 + $4 per hour for rental</td>
</tr>
</tbody>
</table>

Sam wants to find the best deal for his ski trip. Use the information above to answer the following questions.

a. Write equations to represent each of the ski packages.

Zippity Ski equation: ________________

Cruising Ski equation: ________________

b. Graph each equation. Then use the graph to answer these questions.

i. Under what circumstances are the costs for the ski packages the same, and what will that cost be? Explain how you know if the costs will be the same.

ii. Under what circumstances is Zippity cheaper than Cruising Ski Slopes?

iii. What is the cost of a ski package for Cruising Ski Slopes if you rent the skis for 10 hours?

i.) hours: _______ cost: ___________

explanation:

ii.) : ______________________________________

iii.) cost: ___________
Appendix C

Attitudes Towards Mathematics Survey
Appendix C: Attitudes Towards Mathematics Survey

Homework Survey

**Directions:** This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Slightly Disagree</th>
<th>Slightly Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mathematics is a very worthwhile and necessary subject.</td>
<td></td>
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<tr>
<td>2. I want to develop my mathematical skills.</td>
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<tr>
<td>3. I get a great deal of satisfaction out of solving a mathematics problem.</td>
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<tr>
<td>4. Mathematics helps develop the mind and teaches a person to think.</td>
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<tr>
<td>5. Mathematics is important in everyday life.</td>
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<tr>
<td>6. Mathematics is one of the most important subjects for people to study.</td>
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<tr>
<td>7. High school math courses would be very helpful no matter what I decide to study.</td>
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<tr>
<td>8. I can think of many ways that I use math outside of school.</td>
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</table>

Adapted from the **Attitudes Toward Mathematics Inventory (ATMI)**
by Assessment Tools in Informal Science
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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>9. Mathematics is one of my most dreaded subjects.</td>
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<tr>
<td>10. My mind goes blank and I am unable to think clearly when working with mathematics.</td>
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<tr>
<td>11. Studying mathematics makes me feel nervous.</td>
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<tr>
<td>12. Mathematics makes me feel uncomfortable.</td>
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<tr>
<td>13. I am always under a terrible strain in a math class.</td>
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<td>14. When I hear the word mathematics, I have a feeling of dislike.</td>
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<tr>
<td>15. It makes me nervous to even think about having to do a mathematics problem.</td>
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<tr>
<td>16. Mathematics does not scare me at all.</td>
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<td>17. I have a lot of self-confidence when it comes to mathematics.</td>
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<tr>
<td>18. I am able to solve mathematics problems without too much difficulty.</td>
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</tbody>
</table>

Adapted from the *Attitudes Toward Mathematics Inventory (ATMI)* by Assessment Tools in Informal Science
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>19. I expect to do fairly well in any math class I take.</td>
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<td>20. I am always confused in my mathematics class.</td>
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<td>21. I feel a sense of insecurity when attempting mathematics.</td>
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<td>22. I learn mathematics easily.</td>
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<td>23. I am confident that I could learn advanced mathematics.</td>
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<td>24. I have usually enjoyed studying mathematics in school.</td>
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<tr>
<td>25. Mathematics is dull and boring.</td>
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<tr>
<td>26. I like to solve new problems in mathematics.</td>
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<tr>
<td>27. I would prefer to do an assignment in math than to write an essay.</td>
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<tr>
<td>28. I would like to avoid using mathematics in college.</td>
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</tbody>
</table>

Adapted from the Attitudes Toward Mathematics Inventory (ATMI) by Assessment Tools in Informal Science
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>29. I really like mathematics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. I am happier in a math class than in any other class.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Mathematics is a very interesting subject.</td>
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</tr>
<tr>
<td>32. I am willing to take more than the required amount of mathematics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. I plan to take as much mathematics as I can during my education.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34. The challenge of math appeals to me.</td>
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<td></td>
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<tr>
<td>35. I think studying advanced mathematics is useful.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36. I believe studying math helps me with problem solving in other areas.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>38. I am comfortable answering questions in math class.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Adapted from the *Attitudes Toward Mathematics Inventory (ATMI)*
by Assessment Tools in Informal Science

87
39. A strong math background could help me in my professional life.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Slightly Disagree</th>
<th>Slightly Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

40. I believe I am good at solving math problems.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Slightly Disagree</th>
<th>Slightly Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

*Adapted from the Attitudes Toward Mathematics Inventory (ATMI)*

by Assessment Tools in Informal Science
Appendix D:

Journal Prompts
Appendix D: Journal Prompts

| Name: ____________________ | Date: ____________________ | Period: _____ |

**Journal Prompt 1**

| Part A: How many coins does she need to make $10 if:
| all the coins are quarters? __________
| all the coins are dimes? __________ |

**Part B:** What equation relates the number of quarters $x$ and the number of dimes $y$ to the goal of $10? 

**Equation:** ____________________________

| Part C: Use the answers from part (A) to help you draw a graph showing all solutions to the equation. |
| Part D: Explain how you can use the graph to find two other combinations of dimes and quarters that will allow Katerina to reach her goal. |

| Name: ____________________ | Date: ____________________ | Period: _____ |

**Journal Prompt 2**

**Student council is selling cans of pop for $1 and pieces of pizza for $2. Their goal is $200.**

**Part I:** Write an equation in standard form or slope-intercept that represents the situation above showing the total income earned.

Let $x =$ cans of pop and $y =$ pieces of pizza

______________________________

**Part II:** Explain why you determined it was best to write your equation in this form over the other.

______________________________

______________________________

______________________________

**Part III:** Graph various solutions to your equation in Part I on the graph below.

**Part IV:** Explain your strategies for graphing the equation above. In other words, how did you go about graphing this equation?

______________________________

______________________________

______________________________

______________________________
Journal Prompt 3

Directions: Maria was given the following equations and asked to find the solution to the system of equations:

\[ y = 2x + 1 \quad y = -x - 1 \]

Maria tried the graphing method and substitution method to solve. Her responses were both marked wrong on her paper. Look at her work below and explain the error(s) Maria made in her work.
Appendix E:

Relationship Between Data-Collection Instruments and Research Questions
Appendix E:

Relationship Between Data-Collection Instruments and Research Questions

**Relationship Between Data-Collection Instruments and Research Questions**

<table>
<thead>
<tr>
<th>Research Question One</th>
<th>Both</th>
<th>Research Question Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-/Post-Assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Journals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher Notes</td>
<td></td>
<td>Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student Interviews</td>
</tr>
</tbody>
</table>

**Research Questions:**

1. How does a student-centered learning environment, which encompasses both problem-based and procedural homework tasks, impact high achieving seventh grade students’ ability to be successful on summative assessments?

2. How do the perceptions of high achieving seventh grade students change when their instruction changes from teacher centered to student centered?
Appendix F:

Ability to Problem Solve and Communicate Rubrics
<table>
<thead>
<tr>
<th>Ability to Problem-Solve (High/Low) Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Novice</strong> (1)</td>
</tr>
<tr>
<td>No strategy is chosen or a strategy is chosen that will not lead to a solution. Little or no evidence of engagement in the task present.</td>
</tr>
<tr>
<td><strong>Apprentice</strong> (2)</td>
</tr>
<tr>
<td>A partially correct strategy is chosen, or a correct strategy for only solving part of the task is chosen. Evidence of drawing on some relevant previous knowledge is present, showing some relevant engagement in the task.</td>
</tr>
<tr>
<td><strong>Practitioner</strong> (3)</td>
</tr>
<tr>
<td>A correct strategy is chosen based on the mathematical situation in the task. Planning or monitoring of strategy is evident. Evidence of solidifying prior knowledge and applying it to the problem-solving situation is present. Note: The Practitioner must achieve a correct answer.</td>
</tr>
<tr>
<td><strong>Expert</strong> (4)</td>
</tr>
<tr>
<td>An efficient strategy is chosen and progress towards a solution is evaluated. Adjustments in strategy, if necessary, are made along the way, and/or alternative strategies are considered. Evidence of analyzing the situation in mathematical terms and extending prior knowledge is present. Note: The Expert must achieve a correct answer.</td>
</tr>
</tbody>
</table>

Adapted from the Exemplars Standards-Based Math Rubric © 2001
Ability to Communicate Thinking and Construct Viable Arguments
Rubric

<table>
<thead>
<tr>
<th>Novice (1)</th>
<th>Apprentice (2)</th>
<th>Practitioner (3)</th>
<th>Expert (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arguments are made with no mathematical basis. No correct reasoning nor justification for reasoning is present.</td>
<td>Arguments are made with some mathematical basis. Some correct reasoning or justification for reasoning is present.</td>
<td>Arguments are constructed with adequate mathematical basis. A systematic approach and/or justification of correct reasoning is present.</td>
<td>Deductive arguments are used to justify decisions and may result in formal proofs. Evidence is used to justify and support decisions made and conclusions reached.</td>
</tr>
</tbody>
</table>

Adapted from the Exemplars Standards-Based Math Rubric © 2001
Appendix G:

Examples of Student Work on Journal Entries
Appendix G: Examples of Student Work on Journal Entries

Class A

The above responses are from Journal 1. These responses show an understanding of the fact that once two or more points are found on the graph, many more solutions are possible. These students were able to communicate this reasoning.

The sample to the left shows a response to Journal 2. This student is able to communicate why creating an equation in Standard Form might be more logical than Slope-Intercept Form.
These are student samples from Journal 3. In these examples, it is possible to see that these students understood both of the errors in Maria’s work. Additionally, these students were able to graph the equations correctly and fix the errors made by Maria.
These responses from Journal 1 show that even if the students were able to set up the equation (as evident in the first sample), the students had difficulties knowing how to graph these solutions. This made it impossible for the students to communicate their reasoning or construct viable arguments.
This is a student sample from Journal 2. Though this student has created an equation that is logical, the student was not able to communicate viable arguments as to why an equation in Standard Form made more sense than using an equation in Slope-Intercept Form.

The image to the left is a sample of a student response to Journal 3. This student was able to identify one of the two errors in Maria’s thinking. This student did not try to communicate the correct way to graph these equations as the graph is still blank.
The sample below is from Journal 3. This student is showing an understanding of both of the errors in Maria’s thinking.

**Explain her mistakes here. Feel free to use the graph to show the correct way to solve if necessary.**

On the first one she went over instead of down/up first. On the second one she didn’t add in the negative which made her line positive.
Appendix H:

Informed Consent
Appendix H: Informed Consent

INFORMED CONSENT

Background
Your child is being asked to participate in a research study being conducted by Brittany Garner, a graduate student at Wittenberg University, seeking a Master’s degree in Education. The focus of this study is to investigate how certain instructional strategies and homework assignments might contribute to improved ability to transfer existing knowledge to new mathematical tasks. Following this idea, my main research question is “How does a student-centered learning environment which encompasses both problem based and procedural homework tasks impact high achieving seventh grade students’ ability to be successful on summative assessments?” My secondary research question is “How do the perceptions of high achieving math students change when their instruction changes from teacher-centered to student-centered?” The purpose of my study is to investigate through teacher observations and collecting of student work which type of homework tasks are most effective to improving students’ ability to be successful on transferring knowledge to new tasks, and ultimately, how educators can use this knowledge to help students succeed in mathematics. Please read the following information carefully and ask questions about anything you do not understand.

Study Procedure
Research for this study will be conducted during spring semester, 2015 at Jonathan Alder Junior High School during the students’ normal mathematics instruction for four weeks in duration. Each class session will be forty minutes. The data collection will be concluded by May 2015. Analysis of the assessments and observations will take place after all the research information has been collected.

Risks
The risks involved in this study are considered to be minimal, as participants might feel discomfort in knowing that their mathematics understanding is being observed. Participants have the right to not participate in the study without repercussions. Student confidentiality will be maintained at all times, and the entire process will be done anonymously.

Benefits
Potential benefits of participating in this study include helping to shed light on effective math strategies and homework practices by mathematics teachers to students in middle childhood education. Another possible benefit from participating in this study includes contributing to results that will provide information to the researcher, as well as the faculty and administration in the research site school, that could be used in the development of future mathematics instruction. Since there has been little research in the area of effective homework tasks in mathematics, the results of this study will also inform the larger research community in middle school mathematics.
Alternative Procedures
The only alternative to participating in this study is not to participate.

Confidentiality
Every effort will be made to protect your child’s confidentiality, including:
1. Only the researcher will know that your child is participating in the study.
2. Pseudonyms will be used on all student work samples related to this study.
3. Pseudonyms will be used on all written material (e.g., reports, thesis) related to this study.
4. All data collected during this study will be placed in a locked file cabinet that is only accessible by the researcher.

Persons to Contact
For questions regarding this study or any related matters, you may contact the principal investigator, Brittany Garner, at (614) 216-4237, or the researcher’s thesis chair, Gina Post, at (937) 327-6404 or e-mail at rpost@wittenberg.edu.

If you have questions regarding your rights as a participant, please contact the Assistant Provost, Chair of Institutional Review Board, Dr. Ralph Lenz, at (937) 327-7305.

Voluntary Participation
Your child’s participation in this study is completely voluntary. If you decide to allow your child to take part in this study, you will be asked to sign this consent form. You are free to withdraw your child from this study at any time without penalty. Choosing to withdraw your child from this study will not affect the relationship you or your child has with the investigator.

Costs to Subjects
Your participation in this research study will not result in any additional costs.

Consent
By signing this consent form, I, ____________________________________________ (print your name), confirm that I have read and understood the information and have had the opportunity to ask questions.
I understand that my child’s participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I understand that I will be given a copy of this consent form. I voluntarily agree to allow my student to take part in this study.

Child’s Name: _______________________________________________________

________________________________________  Relationship to Child  Date

________________________________________  Date

Signature of researcher
Appendix I:

Institutional Review Board Approval
Appendix I: Institutional Review Board Approval

Notification of approval by the Institutional Review Board was received via email on March 21, 2015. The message was sent to the researcher, the thesis committee chair, and IRB members.

The text of the email appears below (identifying information redacted):

Hi Brittany,
I have looked over your materials, and on behalf of the ********** IRB I am communicating our approval of your petition. Good luck with your research.
********
****** IRB chair

Brittany Garner
References


http://dx.doi.org/10.1787/9789264201170-en


