Mathematical Learning Centers and Their Impact on Students' Mathematical Learning and Understanding

by

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May 1, 2008

A thesis submitted to the

Department of Education and Human Development of the

State University of New York College at Brockport

in partial fulfillment of the requirements for the degree of

Master of Science in Education

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Chapter 1: Introduction

"As we learn more about how children learn and what they need to support their learning, teachers are expected to change. The numerous responsibilities that face teachers in the 21st century can be overwhelming as they seek to meet the individual needs of the many different children in their classrooms." (Johnson, 2003, p.3)

Background

Many students have difficulty solving mathematical word problems because they often cannot decide what to do to solve the problem. Students' lack of problem solving strategies greatly concerns educators, researchers, and even students (NCTM, 2000). Oftentimes, students do not have the skills to solve complex, real life mathematical problems.

As a fourth grade teacher, I struggle to meet the needs of all learners in my classroom for mathematics instruction. Some students struggle with mathematical understandings, others perform well beyond grade-level expectations, and the rest fit somewhere in between. Within each of these categories of students, individuals also learn in a variety of ways and have a variety of learning styles. However, all students struggle to some degree with problem solving. Problem solving is an important skill needed to be successful in mathematics, successful on the New York State mathematics test and successful in everyday life. The new New York State mathematics standards (New York State Standards, 2005) as well as the NCTM standards (NCTM, 2000) stress the importance of problem solving. However, problem solving is not formally built into our *Investigations* program (Scott Foresman, 2003) that the X school district follows. Problem solving is embedded in *Investigations*, however, specific word problem solving strategies are not part of our everyday or weekly instruction. The majority of my students struggle to make meaning out of word problems. Some students struggle with unpacking the question and figuring out what the question is asking them to do. Others do not understand the language or vocabulary used in the word problem. Some students do not know which strategy to use to help them solve the problem. Some are not even aware of problem solving strategies. There are also students who need assistance in selecting proper manipulatives to aid in their problem solving. Yet overall, most students seem to struggle with understanding mathematical problem solving processes.

Rationale

My purpose for conducting research is to learn about learning centers, how to implement problem solving learning centers, and to determine if these centers really benefit my students and meet their individual needs. Learning centers offer the possibility of individualizing instruction and provide additional support for students to construct and practice problem solving strategies.

Centers encourage student ownership and empowerment, instill a natural discussion and decision making processes, and transport the students successfully along learning levels from knowledge/comprehension to application/evaluation through student-chosen activities and projects. In addition, learning centers have the potential to build connections beyond the classroom. They build transitions to the workplace/university/college or community. They develop students' skills in communication and organization. Centers also help students to maintain interactive relationships and encourage them to be convergent and divergent thinkers (Elam & Duckenfield, 2000). Given the possibilities of learning centers, the question arises, "how can problem solving centers be incorporated into my classroom to support students' understanding and development as problem solvers, while also challenging all students at their own individual levels?"

Research Questions

1. How might learning centers support the learning of diverse students in my classroom?
2. How might learning centers support students' problem solving capabilities?
3. How might learning centers create an opportunity for students to collaborate?

Definitions

Differentiation: Differentiation consists of the efforts of teachers to respond to variance among learners in their classroom. As a teacher reaches out to an individual or small group to vary his or her teaching in order to create the best learning experience possible for that student, the teacher is differentiating instruction. (Tomlinson, 2003)

Learning Centers: Learning centers are designated areas of the classroom that contain materials designed to teach, reinforce, or extend particular skills. In these designated areas, students have the opportunities to be actively engaged in simple to complex tasks on an independent or cooperative level. Learning centers allow for students to practice decision making, following directions, social interaction, learning new skills, and using resources and materials to gather information. (Johnson, 2003)

Problem Solving: Problem solving means engaging in a task for which the solution method is not known in advance. In order to find a solution, students must draw on their knowledge, and through this process they will often devélop new mathematical understandings. (NCTM, 2000)

Zone of Proximal Development: The gap between the learner's current or actual level of development determined by independent problem solving and the learners emerging or potential level of development. (Vygotsky, 1978)

Study Approach

My thesis was a qualitative research project because of the focus on individual students and because of the data collection/analysis process. It was also qualitative research because qualitative methods made it possible for me to look closely at students' learning processes and problem solving strategies over time at the centers. For my study, I guided my students to mathematical problem solving understanding through math centers. I worked with students in small groups as well as one on one. I took daily observation notes and reflected on student understanding. I kept copies of student work from a focus group of three students. Through consistent reflection on my students' understanding and learning, I better understood what my students need in order to be successful mathematicians.

Chapter 2: Literature Review

Introduction

The skills and strategies needed for successful mathematical problem solving start developing in the preschool years, when children acquire a basic conceptual understanding of the base ten number system. During these early years, they typically develop number sense needed to process and manipulate numerical information. In primary school, children continue to acquire mathematical concepts and are exposed to a variety of mathematical problems requiring addition and subtraction operations. Students in grades three, four, and five continue to apply and refine the skills and strategies necessary to solve real life mathematics problems. By middle school, students should be able to apply these skills and strategies effectively and efficiently in school, at home, and in the community (NCTM, 2000).

However, many students, especially students with learning disabilities, have difficulty solving mathematical word problems because they often cannot decide what to do to solve the problem. The lack of problem solving strategies greatly concerns educators, researchers, and even students. Oftentimes, students do not have the skills to solve complex, real life mathematical problems. Therefore, students need ample opportunities throughout the day to be immersed in problem solving. The strategies necessary for the solution to complex, real life mathematical problems can be addressed in learning centers. Learning centers offer the possibility of individualized instruction, create opportunities for students to collaborate and supports students' problem solving capabilities.

Constructivist Theory

Constructivism is a theory about learning and knowledge that began with researchers such as Jean Piaget and Lev Vygotsky. Constructivist learning environments are student-centered where students take charge of their learning, utilizing the teacher as a guide. Students construct their own meaning of concepts by building from their existing knowledge. Constructivism requires students to be actively involved in their learning by using higher-ordered thinking skills. This theory moves away from the idea that children learn through rote memorization where teachers provide all the necessary knowledge to students. Children can demonstrate their own knowledge and meaning through exploring and demonstrating their new knowledge by a variety of tasks and assessments. This theory supports my research and plan of implementing learning centers to create a student centered classroom.

According to various researchers, constructivist classrooms are student centered where students take charge of their learning. It views each learner as a unique individual with different needs and backgrounds. Constructivism encourages students' uniqueness and rewards it as part of the learning process. The teacher is the mentor or coach in helping students to process information while they are using the discovery approach to learning.

Students construct their own understanding of concepts in a constructivist classroom. The primary role of the teacher is not to lecture, explain, or otherwise attempt to 'transfer' knowledge, but to create situations for students that will foster their making the necessary mental connections. With constructivism as a framework, teachers encourage students to make (mathematical) meaning. Furthermore, constructivist theory requires that the learning environment stimulates student interest in order to enable the learners to develop or construct their own meaning. The constructivist theory as well as learning centers builds a foundation of skills and information. Students are best able to construct their own meanings be assuming responsibility and using teachers as guides who only intervene occasionally (Brooks & Brooks, 1993).

Mathematical constructivist learning environments will encourage students to make meaning for math and develop deeper understandings. Higher-ordered thinking enables students to develop a conceptualized learning of math (Brooks & Brooks, 1993). When students are challenged to think at higher levels in a constructivist classroom, they are encouraged to become better problem solvers. Thinking in more sophisticated ways at the elementary level results in a deeper understanding and thus problem solving will flourish.

Constructivism is not a method of teaching, nor is it a strategy (Brooks & Brooks, 1993). Constructivist theory requires that learning environments stimulate student interest in order to enable the learners to develop or construct their own meaning. Students are able to construct their own meanings by taking charge of their learning and using teachers as facilitators to their learning process (Brooks & Brooks, 1993).

Vygotsky (1978) states that students learn best through interaction with peers, teachers, and manipulative tools. Constructivism supports and requires peer, teacher and manipulative collaboration. Students collaborate with the teacher who functions as guide to learning, not the main contributor. In addition, Vygotsky states that students need to be guided by adults and that it is very important for students to be influenced by their peers as well as to enhance their own learning. The interaction with peers may expose students to a variety of prior experiences and spark cognitive conflict that would lead to the construction of knowledge. Interactions with teachers also foster the construction of knowledge when they act as a guide to learning within the zone of proximal development. Manipulative tools enable students to explore and discover concepts that can lead to understanding and construction of knowledge (Jaramillo, 1996).

Vygotsky states that the zone of proximal development (ZPD) is the gap between the learner's current or actual level of development determined by independent problem solving and the learners emerging or potential level of development. This supports the idea that learning pushes or leads to development. With the ZPD construct, students need to be pushed beyond what they can handle independently under guidance (Palincsar, 1998). As teachers we need to be aware of the difference between what a child can do with help and what they can do without help. Furthermore, the ZPD construct allows for teachers to scaffold instruction resulting in learners becoming more independent with the new learning. Vygotsky also believes students need to be guided by adults or a more knowledgeable peer as well as discover things on their own. Therefore, according Vygotsky's theory of how students learn best, learning centers support and allow teachers to challenge their students while also remaining under the guidance of an adult or peer. "Development occurs as children learn general concepts and principles that can be applied to new tasks and problems" (Palincsar, 1998, p.353).

Problem Solving

Problem solving is a mathematical skill that found in state and national standards at all grade levels. Problem solving means engaging in a task for which the solution method is not known in advance. In order to find a solution, students must draw on their knowledge, and through this process they will often develop new mathematical understandings (NCTM, 2000).

Importance of Problem Solving

Principles and Standards for School Mathematics (NCTM, 2000) states that "problem solving is an integral part of all mathematics learning, and as such it should not be an isolated part of the mathematics program" (pg. 52). When problem solving is integrated into all aspects of the mathematics curriculum, teachers and students can experience the energy and excitement of learning mathematics.

Problem solving is an important life-long skill for students to learn. Principles and Standards (2000) states that knowing mathematics can be personally satisfying and empowering. The underpinnings of everyday life are increasingly mathematical and technological. For instance, making purchasing decisions, choosing insurance or health plans, and voting knowledgeably all call for quantitative sophistication.

Problem solving is also an essential skill because mathematics is commonly found in the workplace. Although all careers require a foundation of mathematical knowledge, some are mathematics intensive. More students must pursue an educational path that will prepare them for lifelong work as mathematicians, statisticians, engineers, and scientists (NCTM, 2000).

Lastly, problem solving is an important skill for students to learn because in this changing world, those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures. Problem solving skills help to assist peer problems, deal with stress and manage life's challenges (NCTM, 2000).

Engaging Children in Problem Solving

Creating a classroom climate for problem solving is of the utmost importance as it fosters children's ability to think and understand complex problems. Effective teaching requires a positive classroom environment conducive to problem solving. Teachers need to encourage students to share successes and failures and to explore a variety of solutions. Organizing classrooms so that students think and talk about their work, share ideas, and question other students can contribute to problem solving success (Wakefield, 1997).

According to Stupiansky (1998), problem solving can be incorporated into all aspects of the school day. "Attendance and lunch count are ripe with problems to solve and data to be graphed" (Stupiansky, p.1). The number of seats needed for open house, how many pots of coffee to brew for parents, amount of money needed for field trips and many more are just some of the ideas suggested by Stupiansky. School is filled with mathematical problems that adults have to solve. When children are included as problem solvers, they can take ownership for everyday activities at school (Stupiansky, 1998). Problem solving can also become a part of Social Studies with students calculating distances on a map or a part of Science with students solving problems about the solar system.

The incorporation of problem solving across the school day has many benefits. For example, students are given ample opportunities to be immersed in the problem solving process. In addition, it gives students multiple opportunities to practice their mathematical skills. Thirdly, problem solving should not be thought of as an isolated skill but encouraged within all areas of education. This allows students to understand the importance of problem solving because it is embedded throughout all academic areas. Furthermore, the incorporation of problem solving across the school day supports students overall mathematical learning and understanding. They will naturally become more apt at problem solving the more they are immersed in the process (Wakefield, 1997).

Stupiansky (1998) also suggests some tips for successful problem solving. First of all, problems should be solved by the students as opposed to teachers modeling the process. Second of all, problems should really challenge thinking. They might even take several days to solve. Teachers should allow students time to collect data, brainstorm answers, compare results and arrive at a consensus. Thirdly, one should never underestimate students' problem solving ability. Given time and space, students can amaze us. And lastly, the article suggests that some of the best problems come from the students. Questions from the children that teachers normally answered effortlessly can become great problems. All in all, Stupiansky suggests that as a classroom climate is created, teachers must remember to lay fertile ground for problem solving. (Stupiansky, 1998) Problem solving can become a part of every day.

Problem solving is also a vital skill as it supports mathematical thinking. As "children solve their own problems and are accountable for the consequences, they become more confident about their problem solving" (Wakefield, 1997, p. 234). Simply put, this means that children learn much more when they become responsible for their own learning. Sometimes parents and teachers think that they are teaching children only when they are telling them directly how to do something (Wakefield, 1997). However, students become most empowered when they are held accountable for their learning and understanding.

Wakefield (1997) states that children become engaged in mathematical thinking and problem solving at early ages. They can develop their number sense by thinking about numbers, making intelligent guesses, playing simple board games, card games, matching, adding & subtracting, using counters, playing with dice, and other various activities which can all involve math. These activities stress the importance of students being immersed in problem solving. This can be accomplished through mathematical learning centers.

According to Wakefield, Piaget said that children cannot see, hear or remember that which they cannot understand (Wakefield, 1997). If the mental structures are not in place to support what is seen or heard, there will be no mental connection, and consequently it will not be remembered. Therefore, child initiated learning has an important role in mathematical understanding and problem solving. When children have opportunities to choose their activities they become more invested in the activity because they have chosen it. It is driven by interest.

Wakefield also points out the importance of student choice activities leading to success within mathematical learning centers. "Because children rarely choose to do what they can't, giving them a choice almost always ensures success" (Wakefield, 1997, p. 233). When children are successful, they feel confident about what they can do. They see themselves as being "smart" and their confidence rises. This sense of success helps create an optimal environment for further learning.

To sum up, Wakefield (1997) and Stupiansky (1998) stress the importance of embedding problem solving and number sense activities into everyday practice. These activities should be driven by student interest and student initiated choice. In addition, Wakefield (1997) stresses the importance of encouraging students to solve their own problems. This will foster a more supportive environment for thinking and learning.

In a similar study, McGatha and Sheffield (2006) conducted research over the course of a year long professional development program by using problem solving to develop mathematical thinking. Their goal was to empower both teachers and students to become problem solving thinkers. McGatha and Sheffield support the idea that problem solving is pertinent to all mathematical understandings.

A summer camp for kids was used to collect the data. Data were collected by observations and student interviews. Elementary school teachers and students entering second, third or fourth grade participated in the study. Each day of the one week camp focused on investigating one problem and delving deeply into one mathematical content strand. Each problem had a specific strand it related to, as well as children's literature that could accompany the problem and websites that would assist the students (McGatha & Sheffield, 2006).

During the camp, teachers were placed with small groups of children to observe them and gain a deeper understanding of the students' thinking. The teachers were able to observe the students' interaction with the original problem and then monitor their problem solving processes. Teachers also had the opportunity to model questioning strategies and probe students' thinking (McGatha & Sheffield, 2006).

At the conclusion of the camp, both teachers and students had a deeper understanding of problem solving. Discussions about successes, struggles, observations and questioning helped both the teachers and students to dig deeper into a problem. The authors' research supports the idea that students and teachers can develop positive, powerful, and persistent habits of mind through posing and solving problems (McGatha & Sheffield, 2006).

Improving Students' Problem Solving Skills

The deficiency of students' problem solving skills and strategies is often the focus of concern in education. However, many teachers do not feel comfortable or have the knowledge themselves to teach mathematical problem solving. According to Burns (2000), it is important for the teacher "to convey, through actions and words, that mathematics is essential in today's world" (Burns, p.1). Teacher preparation to teach problem solving can have an impact on student achievement. It is not fair to expect teachers to teach what they do not understand themselves. NCTM suggests teachers taking courses and attending workshops, conferences, and other professional development activities, along with self-reflection to increase their knowledge of mathematics (NCTM, 2000). The increased knowledge of teachers' would enhance students' overall mathematical learning and understanding.

Teachers and pre-service teachers should be capable and feel comfortable teaching problem solving to elementary students. Principles and Standards for School Mathematics (NCTM, 2000) states that universities have a significant influence on whether teachers enter the profession with a strong knowledge of mathematics, student learning, and mathematics teaching. Therefore, pre-service teachers should be taught through their preservice experience strategies for the teaching of problem solving.

Wilburne (2006) helps current and future teachers develop their problem solving abilities and build their confidence with problem solving at the university level. First of all, she states that problem solving should be part of the weekly routine.

The problems should pose questions that require pre-service teachers to use various strategies that spark students' interest in engaging in the problem solving process. Wilburne also states that teachers should be taught to go over the elements of a problem. What is the problem asking them to find? What information is needed? What information is given? What information is assumed? In order to help students solve problems, Wilburne gives a problem solving guide sheet. The guide sheet breaks down the process of solving a problem. Finally, Wilburne suggests using a problem solving rubric to help students in their problem solving analysis. The analysis helps students to be able to communicate their mathematical problem solving thought process.

While teachers need improvement in their own problem solving skills and teaching strategies, students are the main focus of improvement. One strategy for improving students' problem solving abilities is through the use of tools or manipulatives. In Principles and Standards for School Mathematics, the National Council of Teachers of Mathematics highlights the importance of giving students opportunities to use and discuss multiple representations during problem solving. Research has shown that the use of mathematics tools – a form of representation – can help make abstract concepts concrete and understandable so that children can solve problems that would be out of reach otherwise (NCTM, 2000).

Jacob and Kusiak (2006) used sixteen first graders to conduct research and better understand children's tool use during problem solving. Data were collected through problem solving interviews over the course of a year. During the interviews, the children were asked to solve addition story problems. The researches observed which strategies and tools were being used. According to the authors, tools are any objects that the children used to help them solve mathematical problems. Some common tools used during the investigation were fingers, counters, base-ten blocks, calculators, pictures, tally marks, and paper and pencil.

After the three interviews were conducted, Jacob and Kusiak (2006) came to some conclusions. In all three interviews, students used both mental strategies and tool-based strategies. The overall performance of the class improved over the year according Jacob and Kusiak. Sixty three percent answered the questions correctly in October and eighty-eight percent answered the questions correctly in May. The researchers also noticed steady progression toward more efficient strategies. However, the researchers also concluded that children needed more opportunities to be engaged in discussions about the relationship between tools and strategies. This was evident based on the interviews. Finally, they concluded that drawing attention to the use of tools not only encouraged students to solve the problems more accurately, but it also helped children to realize that multiple tools can be used to solve a problem.

At the conclusion of the research, authors Jacob and Kusiak (2006) found that tools should be an inherent part of problem solving. They concluded that an essential part of developing problem solving skills and number and operation sense is for children not only to use tools but also to discuss the how and why of tool use. Furthermore, they concluded that children needed ample opportunities to explore and discuss the use of multiple tools.

Similarly, Thomas (2006) supports the idea that the ability to think about, and reflect on, the problem solving process is an important component of learning mathematics. Therefore, she uses the THINK framework for improving problem solving skills. THINK stands for Talk about the problem, How can the problem be solved, Identify a strategy for solving the problem, Notice how your strategy helped you, and Keep thinking about the problem. Does it make sense? THINK provides a structure to support listening to and examining others' ideas.

THINK was used in a first, second and sixth grade classroom that had a pre-service teacher working in the room. There were a total of one hundred and twelve students participating in the study. The two main focal points while teaching problem solving were to focus on metacognitive thinking, in which students monitor their own thinking while using appropriate information and strategies during problem solving (Thomas, 2006) and a focus on cooperative learning. Instruction under the THINK model lasted for five weeks. Students used the framework to guide their discussions. To determine growth in problem solving skills, students solved four problems before and after the five weeks of instruction as well as responded to five interview questions. The teachers evaluated students' problem solving skills by using a rubric that measured each students' ability to understand, to plan, to solve and to check each problem (Thomas, 2006). The data from the pretest and posttest scores demonstrated that across grade levels the students showed greater overall growth in problem solving abilities. After the five weeks were up, students continued to use the THINK framework and were more likely to find errors in their reasoning and calculations and to correct their incorrect solutions.

The results of this research highlight several benefits of teaching students strategies such as the THINK model. First of all, working with a group of peers to solve mathematics problems gives students opportunities to develop problem solving skills. Second of all, it enhances students' mathematical reasoning behaviors. Lastly, strategies such as THINK enhance students' abilities to internalize and communicate their problem solving processes (Thomas, 2006). The THINK model was used a shared mental tool. This is yet another example of the social constructivist theory in action.

Mathematics Standards

Teachers are required to meet state and national mathematics standards. These standards include problem solving skills. Problem solving is the cornerstone of school mathematics according to the National Council of Teachers of Mathematics (NCTM, 2000). Thus, considering the importance of problem solving, it is puzzling that it has been taught as a separate and isolated component and frequently overlooked as an integral part of math curriculums. This contrasts with the recommendations of NCTM. When problem solving is taught in isolation, students learn isolated steps and strategies that are typically difficult to connect to prior knowledge. Therefore, teaching problem solving strategies, while making the process and problems meaningful to students, is critical to student success as problem solvers. The National Council of Teachers of Mathematics (2000) found the following:

> By learning problem solving and mathematics, students should acquire ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that will serve them well outside the mathematics classroom. In everyday life and in the workplace, being a good problem solver can lead to great advantages. (p.52)

The New York State Department of Education has recently changed and revised the mathematics standards (2005) to meet national standards. In response to the No Child Left Behind Act (NCLB, 2001), all students in grades three through eight are required to be tested in mathematics. Due to the changes in the New York State mathematics standards, instructional practices need to become more inquiry based. For example, the new standards focus on process. They are designed to foster a deep understanding for mathematical ideas and concepts where students are encouraged to problem solve and think critically. The new New York State Mathematics Standards do not call for the memorization of facts and procedures but rather developing a thorough understanding of mathematical concepts.

Therefore, due to the changes in the state standards, students at all grade levels will be seeking to find information, using manipulatives to answer problems, and expressing their mathematical thinking through various representations. Students will also need to now realize that math is more than just computation through the new math standards. Students will be required to start writing about their conjectures and discover various strategies for solving problems. Writing about their understandings will allow them to process the information.

In addition, there will be changes due to the fact that teachers will need to relinquish their role as the sole instructor. Responsibility will be placed on students to develop their own understandings. Students will be interpreting, representing, exploring, comparing, formulating, describing, discussing, and collecting data related to real world situations that will develop their mathematical skills. The New York State Department of Education states that students will only become successful in mathematics if they see mathematics as a whole, not isolated skills and facts (2005).

Finally, the new standards will impact student engagement within mathematical instruction and problem solving. The standards allow teachers to create numerous opportunities for students to build new knowledge, solve problems, use manipulatives, represent data through models, reflect and communicate their thinking, investigate conjectures, and apply their knowledge to new methods, procedures or real world applications. Using both conceptual understanding and skills students will make connections and apply their skills to real life situations (2005).

As a result of the changes in national and state standards, teachers will be reorganizing their instructional practices. The new standards can be supported through the use of learning centers. Learning centers can provide the inquiry based learning, the building of new knowledge, solving problems, using manipulatives, representing data, reflecting and communicating their thinking, investigating conjectures, and applying their knowledge to new methods, procedures or real world applications at the centers.

Learning Center Benefits

In most elementary classrooms, some students struggle with learning, others perform well beyond grade-level expectations, and the rest fit somewhere in between according to Johnson (2003). Within each of these categories of students, individuals also learn in a variety of ways and have different interests. Current research on best practice indicates that one of the best ways to meet the needs of all learners in a classroom is to provide classroom learning centers.

Learning centers are designated areas of the classroom that contain materials designed to teach, reinforce, or extend particular skills. In these designated areas, students have the opportunities to be actively engaged in simple to complex tasks on an independent or cooperative level. Learning centers allow students to practice decision making, following directions, social interaction, learning new skills, and using resources and materials to gather information (Johnson, 2003).

Research suggests that learning centers benefit teachers and students at every grade level. In learning centers, teachers "function as the students' guide, coaches, mentors, and advisors. Students under the teachers nurturing care master their curriculum, apply instruction in productive ways that affect their future, and develop into intelligent leaders and teammates who make sensible choices" (Elam & Duckenfield, 2000, p.7). According to Elam and Duckenfield, learning centers provide students an opportunity to become empowered with their own learning. The teachers set up an environment that allows students to learn how to develop their understandings while the teacher guides the students through the process.

Elam and Duckenfield (2000), authors of *Creating a Community of Learners,* provide a list of learning center benefits that go beyond the typical classroom experience. Their research is based on the impact of learning centers on student learning and achievement. For example, "it changes the instructional day to a balanced environment that is rewarding and satisfying" (p.8).

Learning centers encourage student ownership and empowerment. Students are responsible for their own learning at the centers. This allows students the opportunity to make their own meaning with the teacher acting as a guide. Learning centers support the constructivist theory as they are environments that are student-centered and encourage students to make meaning of concepts by building from their existing knowledge. Centers also encourage a natural discussion during the decision making process. This too supports the constructivist theory that students learn best through peer collaboration. In addition, centers transport the students successfully along learning levels from knowledge/comprehension to application/evaluation through student-chosen activities and projects. Again, this supports the constructivist theory that students need to be actively involved in their learning by using high-ordered thinking skills.

Furthermore, learning centers build connections beyond the classroom. They create opportunities to build transitions to the workplace/university/college or community by encouraging students to work with one another. Centers encourage students to work with other students that they may not typically choose to work with. Centers also help to maintain interactive relationships and encourage students to be convergent and divergent thinkers while also providing opportunities to develop students' skills in communication and organization (Johnson, 2003).

Finally, learning centers promote a positive classroom environment. Students develop problem solving skills, are willing to volunteer and take more risks, and they develop a sense of family within the classroom. Learning centers encourage students to take more risks as they are not working in whole group environments. Students are more apt to take a risk with fewer students involved. In addition, students are more apt to volunteer during a small group lesson or at the centers because there are fewer numbers of students involved in the center at one time. Students become more comfortable working with their peers through collaboration at the centers. They build better relationships which in turn creates a more positive classroom learning environment (Elam & Duckenfield, 2000).

While Elam and Duckenfield (2000) provided benefits of learning centers, they also provided an abundance of information in how to successfully run learning centers to scaffold student learning. Teachers become involved in the learning centers to structure and scaffold each individual student's learning to ensure success at the centers. In the beginning students may need a great deal of support, but eventually teachers lead them to independence. Therefore, due to the fact that researchers have examined learning centers as an effective means for teaching in today's society, Elam and Duckenfield (2000) have found that many classrooms have structured their instruction around the idea of learning centers.

Bottini and Grossman (2005) were interested in learning how centers affect children's growth and development in all domains. Their study took place in one kindergarten and one first grade classroom located in a public school in Michigan. The kindergarten classroom was organized in learning centers while the first grade classroom was organized in a more traditional setting without learning centers. Data were collected through observations of students in the two settings and through student surveys.

The kindergarten classroom (Bottini & Grossman, 2005) was organized into many different learning centers located around the room. The children were free to make choices and explore materials at their own pace. The centers focused on science, art, writing, reading, mathematics and computers. The teaching method in this classroom was not direct instruction. Instruction was accomplished through student learning at the centers. The centers allowed children to construct their own knowledge through exploration and experimentation while the teacher offered assistance.

The first grade classroom (Bottini & Grossman, 2005) was organized in a more traditional manner and the children were taught mostly by direct instruction from the teacher. The children remained at their seats and worked independently. They followed the teacher's directions and had little or no choice. The main role of the children was to pay attention, keep up with the instructions and work independently.

The structure of the two classrooms affected the children's behavior. Children in the kindergarten classroom were free to move about the room and to socialize with one another while they explored and experimented. On the other hand, the children in the first grade classroom were expected to sit still and work silently. While this could be conducive to learning it is not realistic for children. Hence, according to Bottini and Grossman, the students became restless, disruptive, didn't follow the rules and ending up getting reprimanded (Bottini & Grossman, 2005). Therefore, socializing and movement was a plus in the kindergarten room and would have benefited the learning environment in the first grade classroom. Students in the first grade classroom would not have become restless and ended up being reprimanded. The learning environment could have been enhanced allowing students to actually make more meaning through socialization. Hence, the centers positively affected the students' behavior in the kindergarten classroom.

The research also explored other avenues and benefits of implementing learning centers in the classrooms (Bottini & Grossman, 2005). For example, the efficient use of the teacher's and children's time, children's interdependence, support of playful learning, inclusion of art, music and physical movement, and academic learning were all avenues explored while implementing learning centers. The authors concluded that both educational settings were safe places that children could learn and grow. However, Bottini and Grossman (2005) felt that the kindergarten classroom was organized and managed in a more appropriate and beneficial way. Learning centers of all types would provide students with opportunities to explore, experiment, and construct their own knowledge. In addition, learning centers provide opportunities for movement, socialization, choice making, responsibility and problem solving. Lastly, the research found that students who were involved in the learning centers had more realistic and authentic experiences.

In a similar study, teachers researched the structure of learning centers that would be beneficial and appropriate for students' in an ever changing world. Researchers Johnson, Templeton, Thomas, Diamond, Miller and Triplett (2003) understood the benefits of implementing learning centers to ensure a differentiated classroom. However, as the world changes, classroom needs change and need to become more student-centered. It is essential to provide opportunities to engage for students to be engaged in learning centers.

Johnson et al., (2003) wanted to study and assess the quality of learning centers since our educational system is becoming more student centered. The subjects of the research were third grade students located in the Midwest. Data were collected through observations, teacher journals, and student surveys. During the investigation, nine learning centers were used for both regular education and special education students. The learning centers were all varied in style and focus, however, each center had the same ultimate goal of having students complete work independently once they understood the expectations. Some of the centers were focused around measurement and geometry, United States Presidents, adverbs, astronomy and space, and money and change.

The third grade children's learning center experience was assessed through a student survey/questionnaire. Students were asked specific questions about each center. Most questionnaires indicated that students enjoyed the centers, reinforced their skills, and motivated students to want to learn more about the topics (Johnson et al., 2003).

Johnson et al., (2003) and Bottini and Grossman (2005), found very similar results. The benefits of implementing learning centers were evident for both teachers and students. Students were engaged and excited to be participating in the learning centers. The centers provided students with hands on experiences, a chance to move and socialize and most importantly motivated the students to learn. The data collected caused the teachers to re-evaluate their classroom setting, classroom structure and time spent on activities.

Learning Center Possibilities

A number of writers address strategies for implementing learning centers. According to Cornell, author of *I Hate Math! I Couldn't Learn It, and I Can't Teach It* (1999), a correlation exists between student attitude and success. Students who did poor in math disliked math. Those who did well in math enjoyed math. The article states that there are five sources of frustration within math which lead to failure – mathematical vocabulary, incomplete instruction, skill and drill and exercises, rote memory, and isolation. These areas of frustration could be minimized through mathematical learning centers.

One possible learning center could be a math vocabulary learning center. Students could be using flashcards, visual aids or matching games to learn important math vocabulary for the year. This would allow students to be interacting with the vocabulary by manipulating the words and pictures (Elam & Duckenfield, 2000).

In addition, another learning center could be additional practice, remedial learning or enrichment of basic math facts. The skill and drill learning center would help students to strengthen their quick recall of facts. Students who are already successful at quick recall could be challenged at the learning center to move on to higher or more advanced math facts. For example of possible activities, students could be involved in math games such as bingo or Quizmo at this station. Students could also be on the computer playing different fact games and activities (Stupiansky, 1998).

Another learning center could give students the chance to use manipulatives to make meaning for themselves. They could use the learning center as a discovery approach to mathematics. For instance, students could be using various shapes and pieces to develop an understanding of fractions. They would be examining parts of a whole (Wakefield 1997).

Finally, another learning center could be projects that relate to real life instances. For example, fourth grade students who are learning to add money or decimals could practice ordering from a menu, adding up their meal, figuring out the tax and determining how much change they should get back. This learning center would be a real world learning experience (Wakefield, 1997).

Summary

In conclusion, the theory of constructivism calls for higher-order thinking skills so that students can think more deeply and critically about mathematics. New York State and national programs have made a move toward more sophisticated math standards that expect students to think at higher levels. As a result, students need to have a deeper mathematical understanding through more authentic learning experiences. Learning centers offer the possibility of individualized instruction while also creating opportunities for students to be engaged in higher level thinking. Learning centers can provide students the tools to be successful mathematical learners and problem solvers.

Chapter 3: Methods and Procedures

Introduction

The following methodology and data analysis is an examination of the impact of mathematical learning centers on students' mathematical learning and understanding. The objective of this study was to learn about how learning centers might improve students' mathematical learning and understanding as well as to learn about the implementation of centers in a fourth grade classroom. The study helped to examine these objectives.

Assumptions

As both the researcher and teacher of the classroom that had learning centers implemented into the daily routine, I needed to learn quite a bit about best practices for implementing learning centers before beginning the study.

During the research process and data collection process, I was in my fifth year of teaching. I had spent two years at the middle school level before moving to the elementary level where I have taught three years. Learning centers are not a new idea in education, but are new to me and my practice. As a middle school teacher, I was not accustomed to using centers. Centers are typically used at the elementary level, but are not common at the intermediate elementary level in my school. Therefore, I needed to conduct extensive research about learning centers before the process even began.

Research Questions

1. How might learning centers support the learning of diverse students in my classroom?

2. How might learning centers support students' problem solving capabilities?

3. How might learning centers create an opportunity for students to collaborate?

Participants

The participants were three fourth grade students from one suburban public school system in Western New York. All three students willingly volunteered to participate in the study by returning their assent forms as well as the parent consent forms.

All fourth grade students in my classroom were encouraged to attend the learning centers. However, I focused data collection and analysis on the three case study students. Students were selected for the research based on their previous classroom mathematics assessments, grades, and based on the students who had a more flexible schedule to participate in the centers. I chose students who represented the higher end of my class, the middle and lower end. I chose to focus on a small sample of students instead of all students in my classroom so that I could more accurately collect data and analyze students' progress.

Student A is a strong math student who prides himself in being successful. He enjoys solving challenging problems and thrives on enrichment work. Student A works hard to improve his overall understanding of math both at home and school. In addition, student A is a successful student across all academic areas. His strong fluency and reading comprehension skills help his ability to understand and solve complex problem solving tasks.

The second student, Student B, is an energetic nine year old. She is an average math student who depending on the unit seems to enjoy Math. She likes to memorize math facts and use various manipulatives to help her overall understanding of math concepts. However, student B lacks the confidence she needs to be an independent thinker and problem solver. In addition, student B struggles with reading comprehension. This does impact her overall understanding of a problem.

The third student, Student C, is a typical fourth grader who enjoys school and the social aspects of school. This student is well liked by her peers and gives 100% effort in all she does. However, student C is a below average math student who thoroughly dislikes math. In general, she is below average in all academic areas. She struggles with memorizing math facts, following multi-step processes and accurately reading a problem. Student C also struggles with reading comprehension.

The classroom was set up with a mathematical learning center located in the room to be accessible for all students. The center was not a stationary center in the classroom. Students could attend the center, gather their materials and head to any location in the room. Although, the center did allow for students to work it if they chose to stay put. All materials needed for the center were available at the center. Student problem solving worksheets were organized by color coded binders. The binders represented varying degrees of difficulty. Students were encouraged to work from a particular binder, however, they were allowed to choose the binder from which they selected their problems. Also, found at the center was a wide variety of mathematical manipulatives to assist students in their learning. For instance, students found math cubes, money, arrays, measuring tools, and various other manipulatives to be used during their problem solving center time. Students were not guided as to what manipulative to use. They were allowed to choose what manipulative they wanted to use or whether or not they even wanted to use any manipulatives.

Throughout the research process, students were ethically protected. First, I did not use real student names, but identified students by pseudonyms. Second, all interviews, surveys, observations, records, student samples, and other various forms of data collected were highly confidential. The data was not shared with the class and was only used to further students' problem solving understanding. Third, I sought permission from the parents of the students involved in the study, permission from the building principal, and assent from the students themselves. (See Appendices A and B.)

Demographics

The participants in this study are part of a very large school district. The district's student population of approximately 9,000 students, is the county's fastest growing and second largest school district. The elementary school houses grades K-5. Kindergarten is a half day program with two teachers each teaching two sections. First through fifth grades have four sections with about an average of one-hundred students per grade level. Therefore, the school is home to approximately six-hundred students and about fifty employees.

The three fourth-grade participants attend X Elementary School. They represent the majority of the school population. The majority of the school (92%) is of the white/non-Hispanic population. Ninety-five percent of the fourth grade class is white while two percent are Asian, and two percent are African American. In addition, this school is part of a middle class suburban town. Only three percent of the student population receives free or reduced lunch.

Instruments of Study

I set up learning centers in my fourth grade classroom at X Road Elementary School. The centers were set up and used for approximately eight weeks.

I created learning centers where students were able to work throughout the day, during math blocks, during activity period, and during free choice time. The learning centers were available based on student needs and interests. However, as time went on the centers were changed to continue meeting students' needs and to differentiate instruction.

The learning centers were set up in the room as a designated problem solving station. Students were able to participate at the center or move throughout the room with their materials. The center was organized by color coded binders. There were three different colored binders. One binder (red) represented a less challenging compilation of problem solving tasks. The other two binders represented medium (blue) and challenging (green) problem solving tasks. Students were allowed to choose the binder from which they worked. The binders were filled with a variety of problem solving activities centered on student interest. For example, there were different types of problems centered on baseball or shopping.

I led the students in a mini-lesson before they attended the learning center. There were multiple mini-lessons based on the problem solving strategies. For instance, one lesson was on learning how to guess and check while problem solving. Students then attended the center and applied their skills to the problems. After the completion of a center, students were expected to turn in samples of their work. Each student had a folder in the classroom to gather and collect his or her work samples.

Students attended the mathematical learning center as an additional learning opportunity within the school day. The center was set up to be used in coordination with a mathematical mini-lesson or to be used in isolation as enrichment or practice of problem solving skills. The center was designed to enhance students overall mathematical problem solving skills whether it was the focus of the math lesson for the day or not.

Students attended the center at various times throughout the school day. First of all, students attended the center after participating in a mathematical lesson. For example, students were taught a mini-lesson on adding and subtracting decimals. Then, they attended the learning center where they were able to apply their skills. Students also attended the learning center during free choice time. Students who had finished their work were able to go to the centers. In addition, students were able to attend the centers during activity period which is similar to a study hall. During activity period, students attend intramurals, chorus or art club. If they do not participate in one of those areas then they stay in the classroom and use their time as a study hall. Students attended the mathematical learning centers during that time. Finally, students attended the learning centers as part of a center rotation while I was working with small groups during the math block. The centers allowed me to not only differentiate my small group lessons, but to also differentiate the tasks at the center.

Data were collected through a variety of means during the research process. I first administered a survey (Appendix C) to students before the learning centers even began to assess their knowledge, understandings, and thoughts and feelings toward math. The survey asked the students ten simple questions about math and learning centers. The students not only selected yes or no for each question, but were also expected to elaborate on why they think or feel a particular way.

I also administered a pre-test (Appendix D) to assess students' problem solving understandings and capabilities at the beginning of the study. Students were given one at grade level problem solving task. All students completed the surveys and assessments, however, I only used data from the three case study students for research purposes.

As the learning centers began, I continually collected data through teacher observations. During the observations, I documented how students solved problems, collaborated together, used the strategies taught to them during mini-lessons, selected and appropriately used manipulatives, and their overall problem solving understandings and capabilities over time. While observing the students I was took field notes to document my observations as well as record student discussions. I wrote field notes throughout the day during regular teaching interactions with the students while they are involved in the centers.

I also conducted semi-structured interviews throughout the six week process. I used prompts (Appendix E) to initiate conversations with the problem solvers as well as to ask follow up questions. The interview took place after a couple of weeks of students being engaged in the learning centers. Student responses were documented through note taking during the interviews. I completed two rounds of interviews. The first interview took place after two or three weeks and the last interview took place during the last week of the data collection process.

Lastly, I collected data through student work samples. Students were expected to complete some type of product at each problem solving center they attended. The work students produced was collected for analysis. The student work samples were used to analyze student progress in mathematical understandings, to recognize students' trouble spots, and to identify connections. The work samples were dated as they were collected to keep track of student progress.

These collections of data will help to improve student's mathematical skills while also monitoring growth and progress (Gau, Hermanson, Logar, & Smerek, 2003). The data collected is evidence for students' progress within mathematical problem solving.

Limitations

There are many limitations which will play a factor in the impact of the learning center. Possible issues could lead to unanticipated results. Some of these limitations are the abilities and disabilities of students. For example, the purpose of the centers is to meet the needs of all learners, however, the center may not be appropriate for each learner. Some students may not understand how to solve a problem or they may not understand the problem solving strategies, others may not be able to complete the problems, and some might not be able to apply higher level thinking skills to answer comprehension questions. Limitations might also center on absent students, teacher aids, state testing, speech and music lessons, pull outs and especially student behaviors. Students who are not present in class to participate in the learning center will limit the findings of the study. Furthermore, students who might not do as well on a task or miss a mini-lesson may not have the chance to experience the enrichment opportunity of the center. In addition, the learning centers are independent work and therefore, behavior problems would result in a loss of the learning center for the student who behaves inappropriately. Students would be expected to work quietly and independently at the centers and if this was not able to occur than that student would lose the privilege of participating.

Data Analysis

I used constant comparison method in order to identify patterns, themes and connections. For example, I analyzed individual students' progress over time through analysis of student work samples, pre and post-work results, interview responses, student surveys, and student connections. This allowed me to understand students' thinking, problem solving capabilities and to determine if the learning centers met my goals of creating a differentiated classroom through the support of problem solving learning centers.

I used this initial analysis to categorize data according to the themes I uncovered. According to Stringer (2004), categorizing involves organizing data to make connections between events or ideas and identity commonalities, regularities, or patterns. I used the data collected to find common themes among students knowledge prior to using the centers, student's progress at the centers, and students' work from the centers.

A case study was constructed for each of the three fourth grade students participating in the centers. I used constant comparison to uncover patterns in students' use of strategies, patterns in collaboration, patterns in problems missed or correct, patterns in manipulatives used, time of day, and students' frequency at the centers. By constructing a case for each student, I was able to uncover evidence of each student's problem solving development.

In addition to patterns, I looked for evidence of student connections. I was looking for connections students made to real world problem solving strategies, connections to their peers, connections to their background knowledge, and connections to previous problems. For example, students who were trying to solve decimal problems could easily connect decimals to money. They associated the problem with shopping. One student in particular did not understand how to solve a decimal problem but after hearing how her classmate solved the problem, she was able to relate the problem to her own background knowledge of money and shopping and thus she solved the problem. Uncovering student connections allowed me to make sense of their mathematical understanding. NCTM (2000) states that the development of number sense should be connected with real life situations. If children learn to apply and connect numbers and problem solving within real contexts, numbers will have more significant meaning for them.

Besides examining each individual student's development, I looked across all three cases to compare students' capabilities while also uncovering common patterns, themes and anomalies. I was again looking for patterns in strategies, patterns in collaboration, patterns in knowledge, patterns in problems missed or correct, patterns in manipulatives used, time of day, and students' frequency at the centers. A comparison across the case studies was also evidence of the diverse learners in my classroom, the development of their problem solving capabilities compared to one another, choices at the centers, and their collaboration efforts with each other or other classmates.

After the data were collected and analyzed, the analysis helped to further the development of differentiated learning centers in our classroom. The data analysis was used to help me to make changes to the centers, implement new tasks, new manipulatives or to create a new structure to the centers. Furthermore, these data was used to help me as a teacher to develop and support students' mathematical problem solving capabilities.

Time Schedule

The learning center was used at various times throughout the school day. On average a student worked at the center for approximately 20 minutes. I began collecting data in May 2007 and stopped collecting data in July 2007. That gave me about 8 weeks of solid data collection.

Summary

To sum up, staying organized and maintaining a schedule of reflection time enabled me to answer my study sub-questions while also learning how to best implement a mathematical problem solving center. I used student surveys, interviews, worksheets, and observation notes as my main sources of data. I also relied on my observation notes to further analyze my students thinking and problem solving strategies. I focused on three students for particular data, yet still reflected on the class to help me answer my main research question: how can problem solving centers be incorporated into my classroom to support students' understanding and development as problem solvers, while also challenging all students at their own individual levels?

Chapter 4: Results

The objective of this project was to examine the impact of mathematical learning centers on students' mathematical learning and understanding. The research was conducted at a suburban public school in Western New York. The entire study took place in my own classroom. The participants in the study were three fourth grade students. This project was intended for me to reflect and modify my classroom learning centers so that I may better scaffold students' mathematical understanding. Furthermore, through personal reflection on my mini-lesson teaching and my students' engagement and learning, I wanted to know in what ways I could change my teaching practices to have learning centers benefit students' understanding.

Participants

Many students have difficulty solving mathematical word problems because they often cannot decide what to do to solve the problem. Students' lack of problem solving strategies greatly concerns me. Therefore, I chose three students from my class based on their classroom availability and their current math level. The selection decision was based on one student who is below grade level expectations, one student who is at grade level and one student who is above grade level expectations. These determinations were made based on previous classroom mathematics assessments. The following are case studies for each of the three students in my focus group.

Student A was selected to be a part of this research study because of her below grade level progress. I felt that student A could benefit from attending these stations by being immersed not only in mathematical problem solving but also mathematical literacy. Student A struggles with comprehension and determining importance not only in mathematics but across all curricular areas as well. She is often confused as to how to unpack the question and what she is being asked to do. Student A was also selected to be a part of this research because I wanted to examine the effects of learning centers on students' growth and progress. Since, Student A had little knowledge of problem solving, the centers would help me to determine if they were beneficial.

Student B was selected to be a part of this research study because she represents an average fourth grade student in my classroom. Student B requires less intervention than student A, however; student B still requires some support and is not completely independent when it comes to a task. Student B knows her math facts very well and enjoys learning about mathematics. Student B likes to be involved with hands on tasks such as using manipluatives. Student B's most difficult aspect of mathematical problem solving is determining what she is being asked to do, deciding which strategy to use and then implementing the strategy correctly.

Student C was selected to be a part of this research study because he is a student who is above average and above grade level expectations. I choose this student for a few reasons. First of all, he enjoys a challenging task and is always looking for ways to increase his mathematical knowledge. I also choose this student because I wanted to understand the impact of learning centers on students who were not struggling with problem solving. I was curious to learn if centers would still be beneficial for an above average student or if it would just be busy work for them.

When analyzing data across the three case studies, I looked at problem solving skills and strategies for solving a problem. I looked at the strategies students relied on more readily as well as the strategies they needed support in carrying out. I also looked at the patterns generated in my observation notes. I analyzed misconceptions the students had and varied my level of support in order to move the students through their ZPDs. I looked at the extent of prior knowledge and the ability to make real world connections for each student. Finally, I analyzed in comparison how mathematical learning centers impact students' understanding of mathematical concepts and the degree of student's engagement through hands on activities as well as student collaboration.

Research Questions

1. How might learning centers support the learning of diverse students in my classroom?
2. How might learning centers support students' problem solving capabilities?
3. How might learning centers create an opportunity for students to collaborate?

Instruments of Study

The learning centers in my fourth grade classroom were set up and used for approximately eight weeks. The centers were set up in the room as a designated problem solving station. Students were able to participate at the center or move throughout the room with their materials. The center was organized by color coded binders. There were three different binders representing a less challenging compilation of problem solving tasks, as well as medium and challenging problem solving tasks. Students were allowed to select the binder they choose to work from. The binders were filled with a variety of problem solving activities centered on student interest. Students then attended the center and applied their skills to the problems. After the completion of a center, students were expected to turn in samples of their work. Each student had a folder in the classroom to gather and collect his or her work samples.

As I analyzed the data there were very clear themes that surfaced. Students were very enthusiastic about attending the centers, however, they were not always sure how to attempt a problem solving task. As students began to solve the problem, they struggled at times with discriminating relevant and irrelevant information within the problem. In addition, students' understanding of mathematical vocabulary was not always accurate and there were obvious misconceptions. Furthermore, the learning centers determined that although students do have some problem solving strategies, they were not consistently using the strategies to solve a problem.

Theme # 1 – Not all students are confident when it comes to problem solving

Students' confidence plays a major role in their academic success. Confidence is needed to take risks and to reach new levels of their independent zpds. Confidence also allows the students to work through difficult problems. Throughout the data analysis process, I found that students were unpredictable with their confidence levels. Students' confidence levels varied from day to day and activity to activity.

Students A and B both lacked confidence with the mathematical learning centers. They were very unsure of themselves and seemed hesitant about the problem solving process. This theme did not apply to Student C. Student C is a very confident student especially when it comes to mathematical concepts. He is confident in his abilities and seemed always willing to take risks.

The student survey prior to the learning centers demonstrated that student A was not confident with her ability in mathematics. She wrote that she does not enjoy math because she always gets the answers wrong. In addition, student A stated that she does not do well in math because she gets easily confused. This theme was also apparent for student A through various interviews. Student A is aware of her trouble spots and this does impact her effort and willingness to try problems independently. For example, during an interview that took place half way through the learning centers, student A demonstrated her lack of confidence due to her trouble spots. "I can't solve problems that ask me to do a lot of things. I don't know how to do that kind of math. I get confused with all the words and forget what I am supposed to be doing. I look at my peers to see how they are solving the problem and then I get even more confused. I just can not do math."

I found it interesting that student A is well aware of the differentiation that takes place during math class. She realizes the tasks that are presented to her are different than tasks presented to the other students. This obviously decreases her confidence towards mathematics. In addition, her awareness of this has worked against increasing her overall confidence. For instance, after the students completed a problem they were expected to fill out a problem solving process sheet. Student A reflected that one particular problem was extremely easy. She rated it a two out of ten with one being the easiest a problem could be. However, as she reflected as to why the problem was a two she stated, "this problem was a two because it came from the red binder which is the easier binder." Student A knew she was working from the least challenging binder and she therefore thought the problem should be easy. She also seemed to be aware that the other students were not working from the red binder. Furthermore, on the same problem solving process sheet, student A stated that on a scale of one to ten, with one being did not solve problem so well and ten being solved the problem well, she was a three. This tells me that student A did not think she did a very good job on the problem. This is particularly interesting and demonstrates her lack of confidence because she stated that the problem was extremely easy but did not think she did well on the problem. If student A was confident in her problem solving skills, she would have stated that the problem was easy and she was successful with the problem. However, this was not the case. Obviously, student A is aware of the differentiated problems and thinks she should be working at a different level but struggles with the problems presented to her.

I observed student A working with minimal confidence at the learning centers. First of all, student A almost always looked for guidance and modeling from me before beginning a problem. One of the earliest problems student A chose to solve was from the red binder (less challenging). The problem was similar to problems found in third grade and student A was very capable of solving the problem on her own based on problems she had solved in the past.

> The student council held a fundraiser. They sold candy bars for $1.00 each, making a profit of 50 cents on each bar. The students sold 350 bars. How much money was collected? How much of the money was profit?

Figure 4.1. Student A's Student Council Fundraiser Problem

However, she looked to me to help her get started. Even with a great deal of encouragement and praise, student A continued to look for guidance throughout the eight week time period.

Second of all, student A demonstrated her lack of confidence by her facial expressions. She was allowed to choose the problem to solve, however, she was still very concerned with getting started and solving the problem correctly. Student A would seem a little shaky, put her head down, have a worried look on her face, seem embarrassed, or sometimes even cry if the problem seemed too difficult. Student A was obviously worried about failing or embarrassing herself in front of others. For example, student A selected to solve problem 4.1. As she read the problem aloud, her facial expressions showed that she did not seem to understand. Her eyes opened wide and seemed to bug out of her as if she was completely shocked or confused. She also placed her hands on her face which showed she was thinking about the problem but not quite sure what she was expected to be do. Student A also re-read the problem a few times and as she did her voice intonations changed. By the changes of her tone, it was apparent she was not confident with her abilities to solve the problem.

Thirdly, student A demonstrated her lack of confidence by constantly looking to her peers for either collaboration or self-assurance. The purpose of the learning centers was to create an environment where students were allowed to collaborate with one another. However, student A was often looking for her peers to show her how to do the problem or to do the unpacking of the problem for her. She wanted them to tell her what she needed to solve rather than figuring that out for herself or in collaboration. This was demonstrated numerous times. For instance, in problem 4.1, student A asked her peer (student B) to read the problem. She then said "this problem is confusing. What do you think I should do to solve it?" Student A was attempting to collaborate with her peers, however, she was looking to another student to unpack the problem and tell her how to solve it. Student A was also looking for reassurance by continuously looking at her peers papers if they were working on the same problem. Student A did not have the confidence to solve the problem independently and would check to see what her peers were doing. This often led to frustration as student A would erase her work and not properly show her work on the problem.

Finally, student A demonstrated a lack of confidence by seeking teacher or peer approval. The majority of the time student A would be looking for someone to tell her she was on the right path, solving the problem correctly or that she had solved the problem correctly. She lacked the confidence to solve the problem without having it checked by a teacher or peer. Again, while working on problem 4.1 student A demonstrated her lack of confidence by having her peer (student B) as well as me check the problem. I was surprised she asked student B to check her work after she had already asked student B how to solve the problem. Student B did help her with the problem and told her to draw pictures until she found a pattern.

The student council held a fundraiser. They sold candy bars for $1.00 each, making a profit of 50 cents on each bar. The students sold 350 bars. How much money was collected? How much of the money was profit?

1 bar = .50	128 bars = 64.00	
2 bars = 1.00	256 bars = 128.00	326 bars = 163.00
3 bars = 1.50	266 bars = 133.00	336 bars = 168.00
4 bars = 2.00	276 bars = 138.00	346 bars = 173.00
8 bars = 4.00	286 bars = 143.00	347 bars = 173.50
16 bars = 8.00	296 bars = 148.00	348 bars = 174.00
32 bars = 16.00	316 bars = 158.00	350 bars = 175.00

Figure 4.2. Student A's Student Council Fundraiser Problem Work

Student B did eventually check the work of student A and told her it would have been faster to just find half of three hundred and fifty dollars. Student A was then quick to start erasing her work. She was not confident that the way she chose to solve her problem was correct. I stopped student A from erasing her work and tried to talk about why it was right and why this strategy worked for her. However, student A was only interested in whether or not the problem was correct and/or needed to be solved again. "I drew pictures to solve the problem and I started to notice a pattern. The numbers were all doubling. So is it right? Do I need to solve it again? Should I just try and find half of three hundred and fifty like student B said?" I had hoped that by the end of the eight weeks, student A would be finding ways to check her own work or to just be proud of her own work without having to get approval from myself or a peer. However, this never happened. Student A was always searching for approval.

Similarly, student B also lacks confidence when it comes to mathematics. She did not demonstrate her lack of confidence through the student survey or teacher interview though. Rather I observed her behaviors during the learning centers that indicated a lack of confidence. I observed student B lacking confidence 80% of the time she was working at the centers. First of all, student B demonstrated her lack of confidence by wanting to read the problem aloud to me. Student B struggles with reading comprehension and is well aware of her weaknesses. She receives academic intervention services at school and also receives additional at home tutoring to develop her reading comprehension. Although, reading the problem aloud could seem like a strength of student B's to make sure she clearly read and understood the problem, it was interfering with her ability to solve a problem independently. Student B was unsure of herself in reading the problem alone or silently as she usually stated "did I read it correctly? Here's what I think I need to do." As I observed, I would not say anything to student B. I would just allow her to read aloud. I was hoping this would eventually increase her confidence so that she would not have to always check in with me. However, due to her self awareness of her weaknesses in comprehension, student B was hesitant to read on her own without some clarity or approval from others.

Second of all, student B demonstrated her lack of confidence by asking at least two or more questions before beginning a problem. Again, asking questions is a great way to seek clarity in understanding a problem. However, student B was looking to make sure she was solving the problem right the first time rather than experimenting or through trial and error. Student B usually chose problems that she was capable of solving. Although, before attempting to solve the problem she wanted to unpack the task and double check her thinking. Student B would sometimes check in with a peer (twenty percent of the time), however, she would usually seek the teacher.

Student council members want to buy playground equipment. The can buy a complete basketball set for $300 or they can buy the items separately.

Complete Basketball Set
includes: Pole, Backstop,
Net and 4 balls.
Only $300.

Basketball Equipment
Pole: $125
Backstop: $45
Net: $15
Basketballs $30 each

Which is the better deal? Explain why.

Figure 4.3. Student B's Basketball Equipment Problem

For example, before beginning the problem (Fig. 4.2) student B asked the following questions, "I need to figure out which is a better deal, right? Should I start by finding out how much the equipment costs? I will add these numbers together and then compare it with the cost of the basketball set, right? The lower price would be the better deal?" Student B was using talk as a way to understand the problem and to think out loud about how to approach it. However, she does not use self talk while working independently away from me. I noticed that my presence initiates more conversation from student B. Student B wants to check in about the problem to see if she read it correctly, to see if she understands it, how to solve it, and did she solve it correctly if I am near. This tells me she is not confident in solving the problem independently or on the other hand she is seeking teacher approval.

Furthermore, student B demonstrated her lack of confidence by wanting her answer and work to be checked by a teacher. I encouraged student B to collaborate with a peer, however, she wanted to seek teacher approval. When conferencing with her about this, she responded, “I want to make sure my answer is right. The other kids might not solve it correctly and then I wouldn’t know what I need to fix.” I commended student B on striving for accuracy, however, this interferes with her ability to collaborate with a peer as well as boost her own confidence that she is capable of solving the problems without teacher support. I was also trying to emphasize the importance of the problem solving process rather than just the answer or outcome. Student B’s desire to have a teacher check her work was also demonstrated in problem 4.2. “I think I finished the problem. Can you check over it? I added the numbers up and I got $305 for the individual equipment. Then, I compared the $300 and $305. $300 is less so the student council should buy the complete basketball set right?” It is evident that student B is more than capable of solving grade level word problems. She also seems to be using appropriate strategies. However, her confidence does impact her ability to solve the problems independently at the learning centers. Student B does not want to work alone for fear of solving the problem incorrectly. Student B wants to be constantly checking in and talking about the problem with a peer or teacher.

Theme # 2 – Students struggle to discriminate relevant and irrelevant information within the problem

Problem solving is the cornerstone of mathematics with students expected to solve problems at all grade levels. Problems are presented in different ways at each grade level as well as different ways within the same grade level. Therefore, the job of the student is to determine what is important information in the problem. However, there is often information in the problem not needed to solve the problem which creates confusion for students with weaker mathematical skills as well as for students who struggle with reading comprehension. The irrelevant information often leads to incorrect answers or increased time needed to solve a problem. This difficulty in choosing or creating a workable strategy for solving the problem was the case for the case study students.

The three case study students all struggled to varying degrees with discriminating relevant and irrelevant information within the problem. Students were expected to unpack the problem and determine which information was actually needed to solve the problem and which information could be considered a distracter. This struggle became a common theme as it was observed throughout the weeks of data collection. I observed students struggling with the relevant and irrelevant information. Students also shared their own frustration in an interview as well as a problem solving survey about discriminating the information.

The student survey prior to the learning centers demonstrated that the students did not have a problem with understanding the task or pulling out the important information needed to solve the problem. The students were asked in the survey "do you like to solve word problems" and all three students answered yes. Therefore, I took this question for the student interviews and had the students elaborate on why they like to solve word problems to better understand their thinking. Each student answer was different and unique to the individual's learning style.

Student A answered the interview question with "yes, I enjoy solving word problems because all the information I need is right there. I don't need to know anything else but what the problem says." I found student A's answer particularly interesting because she does exactly what she stated. She uses the information she has in front of her and that is all. She does not stop to think if the problem makes sense, has too much information, not enough information, or if her work relates to the problem and if her answer makes sense.

On the other hand, during student B's interview she stated "yes, I enjoy solving word problems because it is not something I have to memorize. I can read the problem and try to figure out what I am being asked to do. Sometimes I can solve the problem on my own and sometimes I need a little help. I also like to use math materials to help me solve problems." Again, I was intrigued by student B's answer because she too does exactly what she stated during the interview. Student B attempts to solve the problems independently but does require some help or assistance in pulling out the important information and checking in to see that she is solving the problem correctly. Student B does not seem to have a problem with the computational part o the problem but more so the actual understanding of the problem.

Lastly, student C stated during his interview "yes, I enjoy solving word problems because I like the challenge. Word problems can be a simple math problem but they seem more difficult because of the wording and language used. I also like word problems because I know that I am being enriched. I can use my math skills like multiplication and division at a higher level while trying to solve a problem." Student C is a very capable math student as he stated. However, it is interesting that he is aware that the language of the problem is what can make the overall task seem more challenging.

The directions were the same for all three students in the following problem. Students were expected to solve the problem and write their answers on the line. In addition, students were expected to fill out a problem solving worksheet that explained their process for data collection purposes. The following problem was used by all three case study students and all three were challenged with determining importance and sorting out the information.

> Mr. Harrington bought some oranges at the market. There were 25 boxes to be sold. He bought a total of 72 oranges. There were 6 oranges in each box. How many boxes of oranges did Mr. Harrington buy?

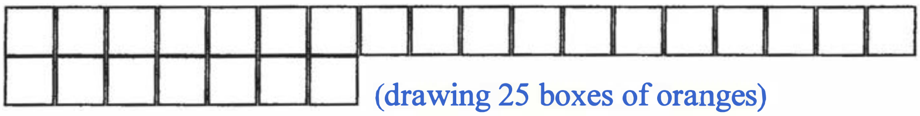
Figure 4.4. Oranges at the Market Problem

Student A struggled with solving problem 4.4 correctly. From this particular sample of her work, I can see that the irrelevant information was overwhelming for A. First of all, student A did not have prior knowledge of problem solving strategies. She understood that there was a problem she needed to solve and she immediately began to pull the numbers out of the problem. A wrote the numbers down and began to count on her fingers to solve the problem (72 – 25 = 47). She would appear to be thinking about the problem, however, she would be checking to see if she was on the right path by looking at her peers' papers. Student A was not confident in her abilities to solve this problem independently. As the teacher, I stepped in to guide student A. After about five minutes of working with her without any other distractions, student

A understood what the problem was asking her to do. “I need to find how many boxes of oranges he bought to solve this problem correctly.” As student A began to draw pictures of the problem, she was obviously still distracted by the irrelevant information. “I am drawing twenty five boxes of oranges because the store has twenty five boxes.” She drew the twenty-five boxes of oranges and then began to place six oranges in each box (25 X 6 = 150). “I am placing six oranges in each box because there are six oranges sold in a box.

Mr. Harrington bought some oranges at the market. There were 25 boxes to be sold. He bought a total of 72 oranges. There were 6 oranges in each box. How many *boxes of oranges* did Mr. Harrington buy?

72-25 = 47 boxes



(drawing 25 boxes of oranges)

6 X 25 = 150 boxes

Figure 4.5. Student A’s Oranges at the Market Work

As I reflected on this situation, I thought that perhaps having little circles to represent the oranges and/or little squares to represent the orange boxes would have been beneficial for my lower-end achieving students. Manipulatives would have most likely benefited student A to help her make better sense of the problem. The irrelevant information became overwhelming for her. A physical manipulative is a more concrete representation than pictures or numerals. Figure 4.2 is student A’s work on the Oranges at the Market problem.

Student B solved this problem correctly, however, was very unsure of herself and her answer. Typically, student B is very unsure of her abilities across all academic areas as well as social situations. Similar to student A, student B read the problem without fully understanding the task. She too began to pull out the numbers within the problem (25, 72 and 6). However, she was immediately confused as to what to do with the numbers. Student B tried different approaches and would quickly begin to erase her work. She attempted to subtract (72-25), add (6 + 6) and multiply (25 X 6). Although she is capable of performing division operations, she seemed to shy away from it. I encouraged student B to leave her work on the paper so we could see her progress and mathematical understanding. Student B responded with, "I know that my work should be left on the paper, but I am not sure what is the best way to solve this problem. The work just gets me more confused." Evidently, student B did not completely comprehend the problem. This was quite typical for student B while working at the learning centers. Based on my analysis of observational data, student B rushes to begin a problem. With her limited skills, she often misinterprets information or does not read to truly understand the problem. As the teacher and guide, I stepped in to slowly and carefully redirect student B by reading the problem to her. After listening to the problem being read, the light seemed to come on and she had an idea. Student B began to draw pictures on her paper to represent the oranges. She drew groups of six oranges. After drawing six oranges, she circled the group to represent one box. Eventually, student B had twelve groups of six oranges on her paper. She concluded that Mr. Harrington must have bought twelve boxes of oranges.

Student B's work proved to me that she is capable of solving the problems at the learning centers however she does need some teacher or peer support. Student B did not understand what the problem was asking her to do and therefore the additional (irrelevant) information got in the way of her solving the problem. In one of her first attempts to solve the problem, student B began to count by sixes. However she decided this strategy was not correct and erased her work. After she completed the problem, I asked student B why she stopped counting by sixes. She responded, " I thought that counting by sixes was not going to work because I knew that I would not land on twenty-five. I thought I had to use all the numbers in the problem." This was an important revelation. It showed me that student B sees numbers in a problem and infers that all numbers should be used. However, she does have the mathematical skills to correct her incorrect thinking. For example, she obviously has a strong sense of skip counting and multiples to know that she would not land on twenty five when counting by six. In addition, student B is not confident when it comes to choosing a problem solving strategy. She was instantly prepared to choose an operation to solve the problem without thinking about other ways to solve the problem After having the problem read to her, she seemed to understand that pictures of the oranges and boxes would help her to solve the problem.

Student B's mathematical thinking and understanding demonstrated that she can solve a problem based on her prior knowledge. However, irrelevant information and numbers causes student B to become confused. She could not separate what is needed to solve the problem and what is just additional information. Physical manipulatives may have benefited student B as it might have student A. Student B would probably have grouped the oranges (manipluatives) by sixes. The physical movement of the oranges would have allowed her to see much sooner that twenty five was not even part of the problem. She would have counted the oranges and realized that six is not a multiple of twenty five.

Student C clearly solved the problem correctly. From this particular sample of his work, I can visibly see how he understands the math concepts.

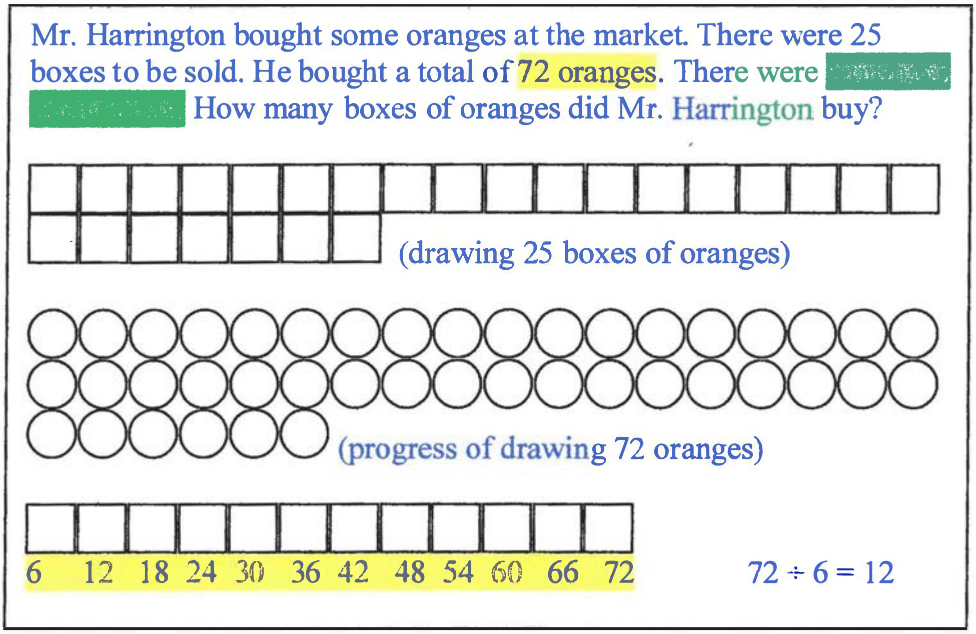


Figure 4.6. Student C's Oranges at the Market Work

I guided student C to a deeper understanding of this problem when I asked him to explain why he solved the problem this way. Student C responded, "I started to draw a picture of the oranges in boxes at the market because that was the first information I was given. I then began to draw the seventy-two oranges. That was taking too long though. Then, I realized there has to be a faster way. I also realized that there was too much information once I got started on my drawings. My drawings helped me to understand the problem better, but if I had read the problem more carefully I would have realized I did not need the twenty-five boxes of oranges. I could have just done a division problem."

Student C's work showed me that he was originally confused and distracted with the irrelevant information in the problem. However, after applying a mathematical problem solving strategy he had been previously taught student C realized that there was too much information and he needed to re-evaluate the problem. Student C used colored highlighters to highlight the relevant information in the problem. This obviously helped him to focus more on what the problem was asking him to do rather than all the information that composed the problem. Student C's work also showed me that he used his prior knowledge of problem solving strategies to solve this problem. He chose to draw pictures of the problem to represent the information given. Lastly, as I was guiding C to a deeper understanding of the problem and as I looked back at his work I noticed that he used an additional problem solving strategy. He chose an operation to solve this problem. When I asked C why he did this he responded, "I solved the problem and was fairly confident that the answer was twelve. It then dawned on me that I could have divided to solve the problem. So I doubled checked my work by using long division." The additional problem solving strategy was apparently purposeful which indicates to me that he was checking his work to see if his original answer from drawing pictures matched his answer from long division.

Student C's mathematical thinking and understanding demonstrated some key components of constructivist theory. He has a solid base of prior knowledge and experience from which he can easily draw on and apply to new mathematical problem solving tasks. He used a variety of strategies to solve a problem. In addition, student C can usually explain his process for solving a problem. However, the irrelevant information in a word problem can confuse him in solving the problem. Fortunately for Student C, he has a deep understanding of mathematical concepts as well as sound comprehension skills. Although, the irrelevant information distracted Student C from solving the problem he was able to eventually solve the problem correctly.

Theme # 3 – Students do not consistently apply strategies at centers

Before the learning centers began, students were asked in the student survey if they used strategies to help them solve word problems. Student A responded, "No I don't use any strategies. I just solve the problem." On the other hand, student B responded, "Yes, I use some strategies. I check with my teacher and peers. I use math operations. I draw pictures and I check my work before putting my pencil down." Also, student C responded with, "Yes, I use strategies to solve the problems. I draw pictures, choose an operation, and check my work." The survey was somewhat of a good indication to me that students have not been taught specific problem solving strategies or they have been taught in isolation and not applied to units or problems within mathematics.

As part of the mathematical learning centers, I taught mini-lessons on the problem solving strategies to the three case study students. The small group instruction was incorporated into the learning centers in order to build students' mathematical understandings. Students A and B required more frequent small group or individual instruction to further develop their problem solving strategy toolbox. Students were also given a checklist at the stations to remind themselves of various strategies they could use to solve a problem.

As the learning centers were well underway, it was apparent that the students were not consistently using or applying the problem solving strategies at the center. It was evident through student work samples, student surveys, the student problem solving worksheet, and teacher interviews. In general, all three students stated in the problem solving worksheet that they would forget to use the strategies. Student A stated, "I read the problem and know I have to use the numbers so I just focus on the numbers." Student B also stated that, "I want to solve the problem correctly so I use the numbers to either add, subtract, multiply or divide. I forget I could draw pictures or try and find patterns." Additionally, student C stated that, "I don't usually need to use a specific strategy like drawing pictures. I can look at the numbers and know what I need to do. I just use the numbers to solve the problem." Hence, it was evident that the students would read the problem and immediately pull out the numbers and begin solving.

Student A would have benefited from trying various strategies to help her solve a problem. Her lack of mathematical understanding could have been increased with applying the strategies. For example, student A seems to learn best at the centers by drawing pictures, however, she does not rely on this strategy. In figure 4.7, student

Oliver has 15 baseball cards. Adam has 3 times as many cards as Oliver. Dana has 2 times as many as Oliver. Bo has 4 times as many as Oliver. Cam has 7 times as many as Oliver. How many cards does each person have?

Oliver = 15 baseball cards
Adam = 3 + 15 = 18 baseball cards
Dana = 2 + 15 = 17 baseball cards
Bo = 4 + 15 = 19 baseball cards
Cam = 7 + 15 = 22 baseball cards

Figure 4.7. Student A's Baseball Card Comparison Problem

A immediately pulled all the numbers out of the problem without truly understanding the problem. After redirecting her to use pictures, she still solved the problem incorrectly.

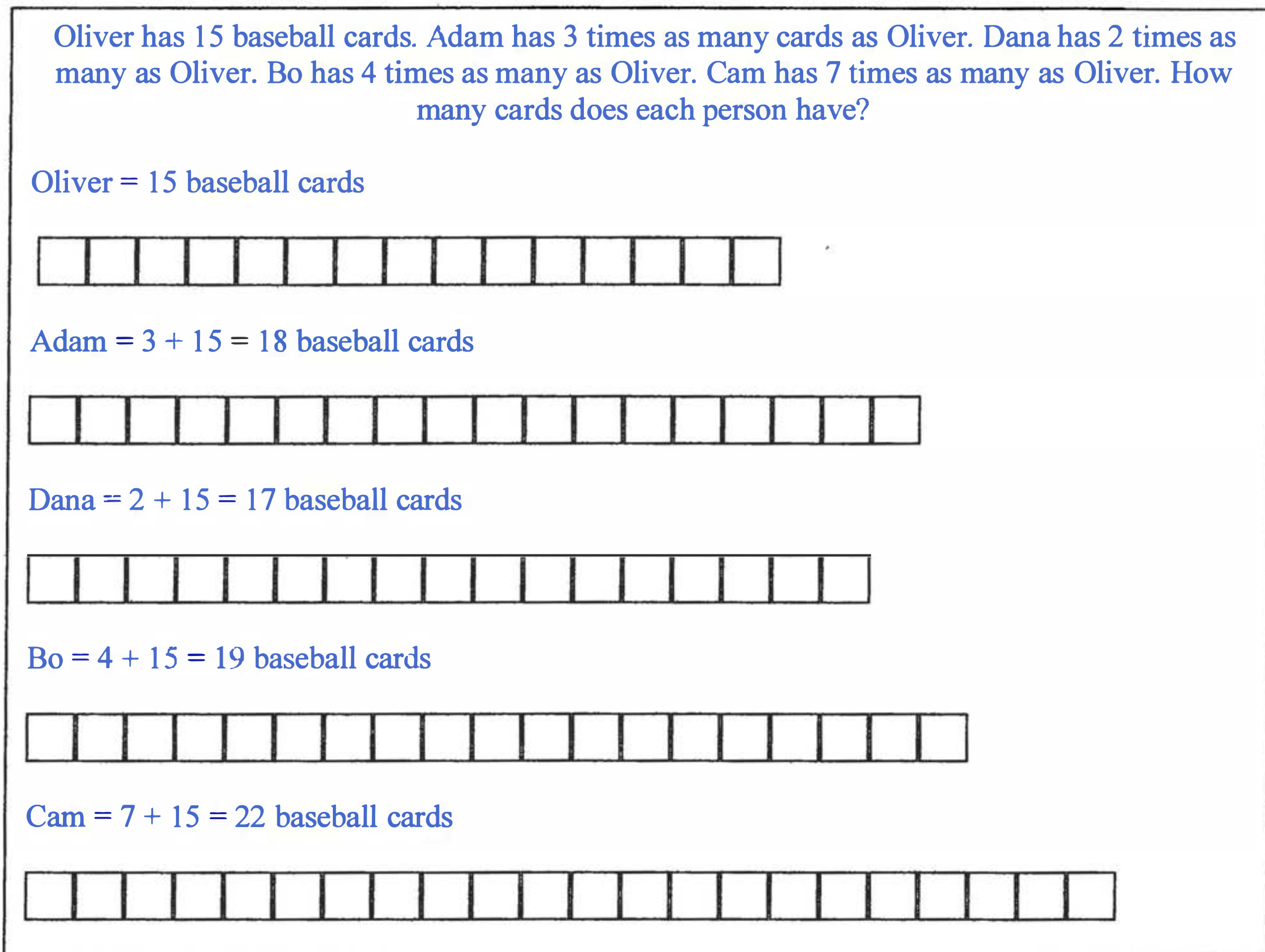


Figure 4.8. Student A's Baseball Card Comparison Problem With Pictures

Student A did clearly not understand the problem. She drew the pictures to represent what she had already stated. Therefore, she was not consistently or accurately using the strategy to help her solve the problem. I took the pictures to another level and had student B use little squares to present the baseball cards. We sorted out how many cards Oliver had. We then re-read the problem to find out how many cards Adam had. Student B responded, "Adam has three times as many cards as Oliver. That means Adam has more cards." I then prompted Student A to count out three groups of fifteen squares to represent the number of cards Adam had. Student B was able to determine that Adam had forty-five baseball cards. This then became an "ahh" moment both for student A and myself. She realized that she needed to make groups or she needed to multiply. The pictures and manipulatives allowed student A to clearly understand the problem. However, this was also an "ahh" moment for myself because it was not only the strategies that could have improved student A's understanding but also better clarification of mathematical vocabulary. Student A was not aware that "as many times" meant to multiply. She did know the numbers were going to increase however she did not seem to understand the language of the problem. Student A's original pictures clearly pointed out her misunderstanding.

The strategies also could have led to less frustration for student A if she had chosen a specific strategy rather than feeling overwhelmed by the problem. Again, looking at problem 4.7, student A was immediately frustrated when I tried to process the problem with her and encouraged her to use a specific strategy like drawing a picture to help her solve the problem. She was frustrated because she "used the numbers to solve the problem but did not use the numbers correctly and would now have to solve the problem again." Therefore, student A would likely have required less teacher intervention and support if she had been able to consistently use and apply the problem solving strategies.

In addition, student B was usually focused on finding the correct answer and seemed to think she had to use the numbers or clues and an operation to get the answer correct. She was not attempting to find a strategy to solve the problem as much as she was focused on getting the correct answer in the quickest amount of time.

The Happy Quilters Club is having a show to display the quilts made by club members this year. Use the clues below to determine the quilt made by each quilter.

Quilters = Rodney, Nicole, Sarah, Lena, Fred and Martha

Quilts = 5 star, Flower, Crazy Quilt, Circle in Circles, Red, White and Blue, and Swirly

Clues:
1. A woman did not make the crazy quilt
2. Martha patterned her quilt after bouquets from her garden
3. Fred's interest in astronomy influenced his design
4. Nicole's quilt used patriotic colors
5. Sarah used a compass to make sure her shapes were accurate

Student B's Work:
1. A woman did not make the crazy quilt – Fred and Rodney
2. Martha patterned her quilt after bouquets from her garden – Flower Quilt
3. Fred's interest in astronomy influenced his design – 5 Star and Swirly
4. Nicole's quilt used patriotic colors – Red, White and Blue
5. Sarah used a compass to make sure her shapes were accurate – 5 Star, Circle in Circles and Swirly

Figure 4.9. Student B's Work and Problem – Quilt Problem

In this particular problem, student B never even finished the problem. She was asked to determine which quilter made which quilt. She has a few people for each of the quilts, however, she never really determined who made which quilt. Student A's work was not organized for her to clearly see which quilter made which quilt. After asking student B to reflect on the problem and tell me a strategy that she could have used to solve this problem, she was able to determine that making a table or chart would have helped her to solve the problem more accurately. "I used the clues to solve the problem. Some of the clues pointed right to which quilter made which quilt. Like I knew who made the flower quilt because it said that Martha patterned her quilt after bouquets from her garden. I guess I never really figured out who made what though.

It is kinda hard to tell from my work too. I could make a table to solve the problem. That strategy might help me." Student B solved the problem a second time and was able to accurately solve the problem by using a table or chart.

The Happy Quilters Club is having a show to display the quilts made by club members this year. Use the clues below to determine the quilt made by each quilter.

Quilters = Rodney, Nicole, Sarah, Lena, Fred and Martha

Quilts = 5 star, Flower, Crazy Quilt, Circle in Circles, Red, White and Blue, and Swirly

Clues:
1. A woman did not make the crazy quilt
2. Martha patterned her quilt after bouquets from her garden
3. Fred's interest in astronomy influenced his design
4. Nicole's quilt used patriotic colors
5. Sarah used a compass to make sure her shapes were accurate

	5 Star	Flower	Crazy Quilt	Circle In Circles	Red, White & Blue	Swirly
Rodney			X - yes			
Fred	X – yes		X			
Nicole					X – yes	
Sarah	X			X - yes		X
Lena						X - yes
Martha		X - yes				

Figure 4.10. Student B's Work and Problem – Round 2 - Quilt Problem

Student B would have benefited more from increasing her mathematical understanding through the problem solving process rather than just being worried about having the correct answer and jumping right into the problem. Student B seems to forget about the strategies and immediately tries to solve the problem.

On a similar note, student C who is much more capable mathematically capable also jumped right into the computations and did not feel the need to try a strategy. He was obviously confident enough about his mathematical understanding that he did not feel the need to have a toolbox of strategies to use. While working on the quilt problem, student C highlighted information in the clues he was using to solve the problem. He also listed the names of the club members next to each clue. He quickly crossed off the names that would not work as he read more clues. Student C did not use a specific strategy taught to him during the learning centers, however, he did make somewhat of a list to solve the problem. This can count as a strategy for student C considering his conceptual understanding of mathematics.

The Happy Quilters Club is having a show to display the quilts made by club members this year. Use the clues below to determine the quilt made by each quilter.

Quilters = Rodney, Nicole, Sarah, Lena, Fred and Martha

Quilts = 5 star, Flower, Crazy Quilt, Circle in Circles, Red, White and Blue, and Swirly

Clues:
1. A woman did not make the crazy quilt Rodney ~~or Fred~~
2. Martha patterned her quilt after bouquets from her garden Flower
3. Fred's interest in astronomy influenced his design 5 Star
4. Nicole's quilt used patriotic colors Red, White and Blue
5. Sarah used a compass to make sure her shapes were accurate Swirly

Figure 4.11. Student C's Work and Problem – Quilt Problem

However, all three students would have increased their overall mathematical understanding for future problems by learning how to apply these strategies.

Furthermore, the students did not consistently apply the strategies because they were originally taught in isolation. This was apparent through the interviews and mini-lessons. First of all, it became clear that students were taught a specific strategy in previous grades that related to a specific problem or problems. "We would use a strategy for a little while and then we would use another strategy for awhile", stated student B. They did not make the connection that the strategy could be used for various problems or that they were building a toolbox full of strategies to be used when problem solving. The students were under the understanding that the strategy taught to them worked for that particular problem or similar problems.

Second of all, it became clear that problem solving in itself was a specific unit or lesson. Students might have learned the strategies for problem solving, however, they were only using those strategies when told it was a problem solving task. For example, student C stated that "I have attended problem solving centers in the past. I would use the strategies we were taught at that center. I guess I didn't use the strategy unless I was at the center."

Lastly, the students were not consistently applying the strategies because they did not have enough time to be truly interacting with the strategies. For example, when I used a poster of eight different strategies they could use, students were surprised that there so many strategies. It would be beneficial for students to try each strategy for various lengths of time to become comfortable and build their understanding of the strategies and then be able to connect them to different problems. Students did not seem to know so many strategies existed because they had not been using them for large lengths of time. For example, students were asked if they use strategies to solve a problem during in the student survey. Student A stated "no" and that she was not aware of any strategies. Student B and C said "yes". Therefore, I had students elaborate on their use of strategies during a student interview. I asked all three students to list the strategies they were aware of. The following table is a list they created together.

Problem Solving Strategies

1. Choose an operation (multiplication, division, add or subtract)
2. Read the problem
3. Use math materials (manipulatives)
4. Check answer with friend
5. Check answer – Does it make sense?

Figure 4.12. Case Study Students List of Problem Solving Strategies

Based on the students' list of problem solving strategies, they are apparently not aware of the many strategies they can use to help them solve a problem. Therefore, it would be beneficial for students to be interacting and using the strategies for an increased amount of time. It would also be beneficial to have students make a connection that there is no one right or wrong strategy to use. The strategies they have been immersed in are all acceptable ways to solve a problem. They problems should not be taught in isolation and should be used throughout the course of the year. Furthermore, it would be beneficial for students to be interacting with the problem solving strategies at all grade levels. It was obvious that the three case study students were taught different strategies but did not have a large bag of tricks for solving problems. Mathematics teachers should be congruing about the strategies taught and used in previous grades. This would help students not to view the strategies in isolation as well as to be actively involved with numerous strategies.

The most common strategy used at the learning centers by all three case study students was *Choose an Operation.* It became apparent that this was the most commonly taught problem solving strategy as well. Students were most comfortable with it as a way to solve a problem. Perhaps teachers are most comfortable with the strategy and therefore it is utilized the most by both teachers and students.

The Choose an Operation strategy could work for the majority of the problems students were asked to solve. However, it was not always the best strategy for student A and B to use. Since student C had a strong mathematical background and was very confident in his mathematical skills, this strategy seemed to work just fine for him. However, he did have an understanding of other strategies that he could use. Student A and B were not always capable of performing the operations correctly. The students associated mathematics with numbers. Therefore, these two students were always looking for the numbers and then choosing an operation to solve the problem. Consequently, they did not always solve the problem correctly and did not understand the problem correctly. Some of the other strategies would have worked better for these students. For example, student A and B chose division as a way to solve the following problem. Both students were correct in the fact that they could use division for this problem; however, they did not have the skills to divide with decimals. Instead, A and B could have made an organized list or made a table to complete the problem.

Edison's early films were shown on Kinetoscopes. Only one person could see the film at a time and it cost .05 cents. Today a movie ticket can cost as much as $10. How many of Edison's films could a person watch for the price of a movie ticket today?

Student A Work	Student B Work
Choose an Operation	*Choose an Operation*
.05 ÷ 10	10 ÷ .05

A strategy that would have worked better for A & B:
Make a table

.05 = 1 movie
.10 = 2 movies
.20 = 4 movies
.40 = 8 movies

Figure 4.13. Student A and B's Work - Edison's Film Problem

Overall, I found that students were not consistently applying the strategies taught to them in the past or throughout the learning centers. It was also found that the strategies were beneficial and helpful to the students when solving difficult problems. Therefore, the learning centers would be extremely beneficial for students to become more comfortable and immersed within the problem solving strategies. The strategies can help students move through their zpds as well as to help scaffold student learning.

Summary

Overall I found that looking at data more than once and over a period of time enabled me to gain more insight to my students' construction of knowledge. I was able to uncover themes and patterns by triangulating data from the case studies. In addition, I was able to answer my main research question as well as the sub-questions. I answered these questions not only from student work samples, but also through anecdotal observation notes, student interviews and observations during small mini-lessons. Through reflections in my notes and the uncovered themes, I was able to see how problem solving centers support students' understanding and development as problem solvers, while also challenging all students at their own individual levels. Furthermore, my analysis helped me to better understand how to support my students at the learning centers.

Chapter 5: Conclusions and Recommendations

The research project I conducted focused on three of my students. The three students varied in academic strengths. Over the course of eight weeks, students participated in small mini-lessons and center time activities. My main research question was: How can problem solving centers be incorporated into my classroom to support students' understanding and development as problem solvers, while also challenging all students at their own individual levels? The following is a list of sub-questions that guided the study: How might learning centers support the learning of diverse students in my classroom? How might learning centers support students' problem solving capabilities? How might learning centers create an opportunity for students to collaborate?

Throughout the research process, I found that reflecting on my own teaching and my students' learning helped me to achieve a deeper understanding of my students as mathematicians. I also spent time reflecting on my original guiding questions in relation to the data to determine the effectiveness of the centers. The role of reflection in research became evident as I began to answer my research questions.

To answer my research questions about learning centers, I observed and took anecdotal notes on problem-solving skills, strategies for solving problems, students' confidence while working on a mathematical task, misconceptions, connections students make to prior learning as well as connections to real world word problems, and students' understanding of mathematical concepts and the degree of student's engagement through hands on activities as well as student collaboration. I also answered the research questions by looking at student work and reflecting in my own personal observation notes.

My reflection began by thinking about how learning centers benefit diverse students. *How might learning centers support the learning of diverse students in my classroom?* Learning centers provide students an opportunity to become empowered with their own learning. Teachers set up an environment that allows students to learn how to develop their understandings while the teacher guides the students through the process (Elam & Duckenfield, 2000). Learning centers also allow students to construct their own meanings be assuming responsibility and using teachers as guides who only intervene occasionally (Brooks & Brooks, 1993).

The mathematical learning centers provided opportunities for students to be working at their own individual levels. The three case study students were able to experience a concept or problem as they worked through their ZPD. Students were allowed time to work through their own difficulties and were not forced to move along with the group. Students were able to construct their own meanings of mathematical problem solving at the centers.

Still, there were some implications that surfaced during the learning centers due to students working at their own individual levels. While there are many benefits to the learning centers, the students quickly realized each other's strengths and weaknesses. Students were metacognitively aware of each other's abilities and the differentiation that took place. As referred to in chapter four, two students were self-conscious about the work they were completing compared to each other and compared to the third student. The differentiation seemed to add stress to the two of them. For future implementation of the learning centers, I would like to learn more about how a classroom climate can be created that is truly inclusive and where students do not feel embarrassed about differentiated instruction.

In addition, the learning centers supported the diverse learners in my classroom by increasing their overall confidence towards mathematics and problem solving. Students' confidence was a consistent theme found throughout the research process. The centers helped to address this issue by allowing students to be immersed in the problem solving process for greater lengths of time. Students became more confident the more they were involved in the learning centers. The centers also helped to increase the confidence of the diverse learners in my classroom by allowing me to spend more time interacting with the students. I was able to spend more time with the students in small groups as well as spend more time observing students behaviors and interactions with each other.

Finally, the learning centers supported the diverse learners in my classroom by allowing me to better understand my students. Throughout the eight week process, I was able to reflect on parts of planning and teaching where I could have asked different questions or set up the center differently. Through reflection and experience, I became more aware of the areas where I need to guide and scaffold my students as well as areas I need to learn to back off and keep my mouth shut. I learned to better support my students through the learning centers by facilitating discussions rather than leading discussions. As a teacher it is important to help guide students to a better understanding of their mathematical learning process. I also learned to be more aware of students' background knowledge and to be prepared to give real life examples so that students could make connections to learning. The centers also enabled me to really get to know my students learning styles which better supports their own learning. Continuation of learning centers would involve constant reflection on my part. I would need to be evaluating the centers as well as student progress. The learning centers would allow for more individualized reflection of each student as they work through the center rather than reflections of a whole class during a lesson or skill. Reflective practice allows teachers to learn from experience (Clegg, 2003). Reflection is key to active learning as well as sense making for all learners (Branscombe, Castle, Dorsey, Surbek, & Taylor, 2003).

My reflection also focused on *how might learning centers support students' problem solving capabilities?* The learning centers supported students' problem solving capabilities. Students do not generally construct mathematical understanding by absorbing rote mathematical procedures as a teacher models. Students develop an understanding for mathematical ideas and concepts if they are doing something and reflecting on their own actions. This means the students are engaged in their own learning. Students were not only using their hands to manipulate tools, but they were also making connections to their prior experiences and to the real world. This supported their problem solving potential and capabilities. Students were becoming more independent and capable of solving problems as the centers progressed. Furthermore, with the new math standards focusing more on the process of solving a problem rather than the actual answer, it is apparent that the new standards require students to become more engaged with their learning and understanding.

However, while the learning centers seemed to support students' problem solving capabilities, students seemed to be using only one or two strategies to help them solve a problem. *Choose an operation* was the most common strategy used by the students. Why do students automatically infer they first need to decide on a strategy? Why are students most comfortable with this strategy? Are we as teachers stressing this strategy? Are we focusing more on the answer than the process? What can be further done to increase students' awareness of problem solving skills so they continue to be successful throughout middle school, high school, college and life? Before the learning centers are implemented again, I would like to learn more about teaching problem solving skills rather than how problem solving can be incorporated into the learning centers. My analysis definitely suggested that students were more successful with problem solving due to the learning centers. This was evident because of the increased time spent immersed in problem solving. Therefore, how can time spent on learning about problem solving increase students' problem solving capabilities as well as their understanding as mathematicians?

Lastly, my reflection centered around the idea of *how might learning centers create an opportunity for students to collaborate?* The mathematical learning centers created an opportunity for students to collaborate together. In the Vygotskian perspective, the zone of proximal development is regarded as an indicator of cognitive development rather than what children can accomplish independently. "Productive interactions are those that orient instruction toward the zpd" (Palincsar, 1998, p.352). The three case study students were all working at various levels with some degree of collaboration. However, at the start of the learning centers, two students needed a great deal of support from a more knowledgeable peer or adult, but eventually they were led to independence. A new zpd was then needed for the students and once again a more knowledgeable peer or adult scaffolded their instruction so that the learners could become independent.

Students worked with their peers and adults throughout the eight weeks. They collaborated on problem solving strategies, manipulatives to be used, mathematical operations, mathematical vocabulary and the problem solving process and end result.

Students were engaged in natural discussions at the learning centers. This supports the constructivist perspective that students learn best through peer collaboration.

Recommendations

Based on my analysis of the impact of mathematical learning centers on students' mathematical learning and understanding, students showed an improvement in their problem solving ability. As a result of teacher and peer modeling of the problem solving process and strategies, collaboration on problems, the use of manipulatives, the student problem solving process sheet, and problems related to student interests, all three students were able to more confidently approach an open ended constructed task in order to solve it. Therefore, I would recommend using centers for future work with problem solving.

First of all, learning centers are recommended based on my analysis because the three case study students improved their mathematical understanding through the use of problem solving centers. Initially, the problems were challenging for all three students. Mini-lessons on problem solving strategies, whole group analysis of the language used in the problem, as well as identification of the central problem and data to be used in solving it, appears to have helped these students become more confident in their approach to problem solving. The cooperative group setting was also particularity conducive to student success. The students were able to listen and share ideas using mathematical language, problem solving strategies and manipulatives in a way not observed before the learning centers began.

Second of all, my analysis recommends learning centers because there was an improvement in the student's ability to independently solve a problem. Before the intervention, the students would rely on teacher direction and guidance throughout the process. However, this improved by the end of the data collection period with students increasing both their independent analysis and solution of the problem. These students now appear to be less hesitant and more confident in approaching this type of task with minimal support.

Lastly, learning centers are recommended based on my analysis because students demonstrated a noticeable improvement in the use of the mathematical language to explain the solution to a problem. Before the learning centers were set up, these students utilized a minimum of mathematical language to express their thinking in regards to an open ended problem. "Teachers should use every means possible to encourage students to think, reflect, question, imagine. And how do we do that? With language – with expressive and receptive language - speaking, writing, listening and reading (Hyde, 2006, p.4). Language became critical throughout the problem solving process and especially so in the debriefing process. After the learning centers, it is clear that the students are more apt to independently use mathematical language to express their solution strategies. Students will understand mathematical ideas more clearly when they use both language and thought (Hyde).

Upon reflection at the closure of this study, I believe that mathematical learning centers should be continued in the classroom as they proved to be an integral part of students' overall improvement in their problem solving learning and understanding. However, there are a few things to consider before implementing the learning centers again.

First of all, the type of open ended constructed tasks needs to be given more careful consideration. Some of the problems required unique mathematical skills. These open ended tasks involved multiple steps. Sensitivity to student experience in both mathematical skill level and approaches to multi-step problems is important to take into consideration. One should also tailor the choice of an open ended constructed task to most optimally match the students' present abilities in these areas.

Additionally, before implementing the learning centers again, I would be connecting current lessons with the work at the learning centers. The centers were used as an enrichment opportunity or a skill building opportunity. However, I would like to see the centers and math lessons relate to encourage student understanding. For example, if the students were working on a unit in fractions, then a fractions task would be most appropriate because the students would have the necessary schema required for successful solution.

Finally, a cautionary word needs to be added with regard to the time frame necessary for student completion of a given problem as well as to document student improvement over time. The students were usually restricted in time because of the need to leave for lunch, specials, instrument lessons, etc. More flexibility in scheduling would alleviate some of the stress associated with limited time in the problem solving process and permit students to cultivate their thinking to a greater degree.

Overall, the success of the learning centers surprised me. I had hoped that the mathematical learning centers would improve students overall understanding, however, I misjudged the impact that they could have over such a short time. It is obviously important to have the students immersed in problem solving to improve their use of strategies, selecting manipulatives and their mathematical understanding. If eight weeks improved and impacted all three students' mathematical problem solving learning and understanding, just think what a whole year would do.

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Appendix A

The Impact of Mathematical Learning Centers on Students' Mathematical Learning and Understanding

Parent Consent Form

1. I understand that my child will participate in research to study the impact of mathematical learning centers on students' mathematical learning and understanding.

2. I understand the research includes surveying my child, interviewing my child, observing my child, and collecting my child's work samples.

3. I also understand that the learning centers will not take my child away from instructional time. The learning centers will be additional opportunities for enrichment and skill building. The learning center work will not ever become homework.

4. The results of this research will be published in Erin Lantzer's masters thesis project. The following steps will be taken to protect the confidentiality of my child's identity and the information he or she has contributed:
   a. Students' first and last names will not be used. Students will be assigned a pseudonym.
   b. Students will be identified by pseudonym, age and sex only.
   c. No reference will be made to the school that my child attends.

5. Participation in the research project is voluntary. If I choose not to give permission for my child to participate in the study, my child will not be penalized in any way. My child may withdraw from participation in the research study at any time during the project.

6. I can contact Mrs. Erin Lantzer or Dr. Sue Novinger, the thesis advisor, via email at any time with questions or concerns about the project.

Mrs.Erin Lantzer
Graduate Student

Dr. Sue Novinger
Thesis Advisor, SUNY Brockport
snovinge@brockport.edu
585-395-5935

□ Yes, I hereby consent to allow my minor child, ______________________
to take part in the research project directed by Erin Lantzer in fulfillment of the SUNY Brockport graduate thesis project.

Signature ____________________________________ Date __________

□ No, I do not consent to allow my minor child, ______________________
to take part in the research project directed by Erin Lantzer in fulfillment of the SUNY Brockport graduate thesis project.

Signature ________________________________ Date ____________

Appendix B

May 1, 2007

Dear Parents,

As a graduate student at SUNY Brockport in the department of Education and Human Development, I am fulfilling my thesis requirement by implementing learning centers into our classroom. I will be investigating the impact that learning centers have on students' mathematical learning and understanding. I will be setting up learning centers in a designated area of our classroom for students to attend throughout the day. All students will be able to participate in the centers.

If you grant consent for your child to participate in the study, he or she will be involved in the following:

- I will give your child a math survey and ask your child some questions before he or she attends the centers.
- I will observe and interview your child about his or her problem solving process as they complete a center.
- Data will be collected through student work samples, observations, field notes, and a pre and post learning assessment.

The information gathered from the learning centers will be used to analyze the impact of participation in mathematical learning centers on students' learning and understanding. Results will not be used for assessment or grading purposes.

The enclosed Parent Consent form includes information about your child's rights as a project participant, including how I will protect your child's privacy. Please read the form carefully. If you are willing for your child to participate, please indicate your consent by signing the attached statement.

Thank you in advance for your consideration.

Most Sincerely,

Erin Lantzer
SUNY Brockport Graduate Student

Dr. Sue Novinger
Thesis Advisor, SUNY Brockport
snovinge@brockport.edu
585-395-5935

Appendix C

Problem Solving Center Survey

Student Name ________________________________ Date ______________

Please circle Yes, No or somewhat to the following questions.

1. Do you enjoy math?

   Yes No Somewhat

   Why:____

   ____

2. Do you do well in math?

   Yes No Somewhat

   Why:____

   ____

3. Do you like solving word problems?

   Yes No Somewhat

   Why: ____

   ____

4. Do you use strategies to help you problem solve?

   Yes No Somewhat

   Why:____

   ____

5. Do you enjoy using manipulatives (tools) in math?

   Yes No Somewhat

   Why:____

   ____

6. Do you use manipulatives to solve word problems?

Yes No Somewhat

Why: ____

____

7. Do you like to collaborate with a partner to solve a problem?

Yes No Somewhat

Why: ____

____

8. Do you enjoy attending learning centers?

Yes No Somewhat

Why: ____

____

9. Do you know any problem solving strategies?

Yes No Somewhat

Can you give me some examples? ____________________________

____

10. Do you feel you are being challenged in math?

Yes No Somewhat

Why: ____

____

11. Anything else you would like to tell me about yourself and Math?

Appendix D

The Impact of Mathematical Learning Centers on Students' Mathematical Learning and Understanding

Semi-Structured Interview Questions

Prior to the administration of the Learning Centers:
(After student completes survey)
Go over student responses to problem solving center survey

Possible questions from survey:

1. Why did you answer ________________ on question # _____?
2. Tell me more about....
3. What would your ideal math class be like?

Introduce the Learning Centers
Observe students at the learning centers
Interview Questions

1. How do you pick a problem to solve?
2. When are trying to solve a math problem, what are some thoughts going through your head?
3. How do you choose your manipulatives?
4. When you are trying to solve a problem and you come to something you don't know, what do you do?
5. Who is a good math student that you know?
6. What makes them a good math student?
7. What could have been done differently to help you solve these problems?
8. Have you learned anything after attending the learning centers?
9. Are the learning centers helping you to understand problem solving better? Why or why not?

Continue to observe student at the learning centers
2nd Interview

1. How do you pick a problem to solve?
2. When are trying to solve a math problem, what are some thoughts going through your head?
3. How do you choose your manipulatives?
4. When you are trying to solve a problem and you come to something you don't know, what do you do?
5. Who is a good math student that you know?
6. What makes them a good math student?
7. What could have been done differently to help you solve these problems?
8. Have you learned anything after attending the learning centers?
9. Are the learning centers helping you to understand problem solving better? Why or why not?

Appendix E

Problem Solving Process Sheet

Student Name ______________________________ Date _________________________

Binder Color __________ Red ___________ Blue ___________ Yellow

Problem Number _________________

Collaboration with a Partner: _________ No _________ Yes

Partner name ______________________________

Strategies Used to Solve Problem

_________ Choose an Operation

_________ Find a Pattern

_________ Make a Table

_________ Use Logical Reasoning

_________ Make an Organized List

_________ Draw a Picture or Diagram

_________ Guess and Check

_________ Work Backwards

Student Reflection

On a scale of 1 – 10 with 1 being extremely easy and 10 being extremely difficult, how would you rate the problem you solved?

1 2 3 4 5 6 7 8 9 10

Why?____

____

____

On a scale of 1 – 10 with 1 being not so well and 10 being awesome, how did you do on the problem solving task today?

1 2 3 4 5 6 7 8 9 10

Why?____

____

____