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Kindergarten Mathematics: An Observational Study of Learning Centers in Diverse School Settings

Juliana MacSwan
University of Connecticut - Storrs, julie.macswan@gmail.com

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Kindergarten Mathematics: An Observational Study of Learning Centers in Diverse School Settings

Juliana MacSwan
University of Connecticut, 2012

University Scholar Thesis
Honors Thesis
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Chapter 1

Introduction

The National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) stated, “A positive attitude toward mathematics and a strong foundation for mathematics learning begin in early childhood” (NAEYC/NCTM, 2002, p. 18).

In 2002, the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) published a position statement about the importance of high-quality mathematics instruction for all children ages three to six years old. Three important points are emphasized. First, students should have the opportunity to learn from research-based curriculum with rich, challenging experiences. Second, mathematics helps children build a strong foundation for future learning and gives them the opportunity to explore their world. Third, there should be more focus on mathematics in early elementary school (NAEYC/NCTM, 2002).

Kindergarten is very important for long-term academic success as students learn essential skills for success in school in the future (Ray & Smith, 2010). In particular, high-quality mathematical experiences are essential in early education. In fact, the level of math skills in kindergarten has been shown to be a predictor of math ability in the future (Locuniak & Jordan, 2008 in Ray & Smith 2010).

In Crisis in Kindergarten (2009), the Alliance for Childhood called for researchers to “expand the early childhood research agenda to examine the long-term impact of current preschool and kindergarten practices on the development of children from diverse backgrounds” (Miller & Almon, 2009, p. 7). With this in mind, this study looked at kindergarten students from
an array of different backgrounds as they explored math learning centers while taking part in a National Science Foundation curricula research project, Project M²: Mentoring Young Mathematicians.

The following research questions were explored:

1. What is the connection between the math center objectives and those of the unit?
2. What do students engage in while participating at the centers?
3. How does the context of the centers contribute to the amount of accessibility students have in investigating the mathematics?
Chapter 2

Review of Literature

Recommendations for Early Childhood Mathematics Learning

The NAEYC/NCTM position statement (2002) addresses various recommendations to be implemented within the early elementary mathematics classroom. First, mathematics curricula should build on children’s natural interest in mathematics, which helps them make sense of the physical and social world around them. Second, children should be encouraged to develop confidence in their ability in mathematics at a very young age and learn to enjoy it. Third, it is essential to build on children’s previous knowledge and experience and customize learning for individual variations (NAEYC/NCTM, 2002). Mathematics curricula should focus on the “big ideas” of mathematics coined by Clements and Sarama in Engaging Young Children in Mathematics (NAEYC/NCTM, 2002, p. 8). Young children should experience organized learning experiences in mathematics that dive deeply into key concepts. The conceptual background and real understanding of key mathematical concepts are more important than the accumulation of many skills, which is often emphasized in the early grades.

The content, what students learn, as well as the process, essential competencies such as reasoning and communication, enable students to acquire content knowledge and are fundamentals of an excellent mathematics curriculum (NAEYC/NCTM, 2002). Teachers should explain concepts in a variety of ways so that all students will understand. Teachers should have knowledge of child development and a deep understanding of the mathematical content (NAEYC/NCTM, 2002). Research-based learning paths that are shown to be appropriate for many students should be used while also considering individual variation. Teachers should incorporate mathematics throughout the day and across disciplines so that students learn that it
has a strong real-world connection (NAEYC/NCTM, 2002). For young students, play helps them to learn problem solving strategies and how to communicate their ideas and opinions. Assessment is also an important component of learning and instruction since it enables teachers to monitor students’ strengths and weaknesses and help individual students deepen their understanding of mathematics (NAEYC/NCTM, 2002).

A developmentally appropriate field-tested system to guide instruction and assessment in mathematics should be created for teachers (NAEYC/NCTM, 2002). There should be more joint in-service programs so child care workers and elementary school teachers can collaborate about what is taught at each grade level (NAEYC/NCTM, 2002). Resources are needed in all communities so that all children can manipulate and explore mathematics (NAEYC/NCTM, 2002).

**Early Childhood Mathematics**

Mathematics is a core component of cognition. In fact, mathematical achievement at an early age has been shown to predict reading as well as mathematical ability later in life (Clements & Sarama, 2009). The NAEYC and NCTM (2002) have asserted that high-quality, challenging, and accessible mathematical experiences are essential for future mathematics learning.

Mathematics is a discipline that is vital in virtually everyone’s life. Children must learn major mathematical concepts in school so that they will be able to use these skills later in life (Clements & Sarama, 2009). Unfortunately, most children in the United States are not getting the chance to experience a rich mathematics curriculum in school (Clements & Sarama, 2009). Therefore, mathematics should be a major focus in early elementary school. Young children enjoy exploring their worlds mathematically and should have numerous opportunities to do so.
Geometry and measurement are generally not concepts emphasized in early elementary school mathematics. There may be a misconception that young children are not able to understand spatial reasoning at this age so it should not be addressed in early elementary school. In fact, children use spatial reasoning in play and in manipulating their environments beginning at a very early age (Clements & Samara, 2009).

According to the NCTM content standards (2000), geometry and measurement should together account for about half the mathematics curriculum in grades preK-2.

![NCTM content emphasis across grade level bands (2000, p. 30).](image)

However, traditional mathematics curricula used by schools in the United States heavily focus on numbers and operations with less attention to geometry and measurement.

Other recommendations have been made by experts in the field of education about how geometry and measurement should be taught to early elementary school students. For example, Clements and Sarama (2009) created and researched mathematical expectations for each age in the form of learning trajectories.

**Learning Trajectories for Measurement**
(As summarized by Gavin, Casa, Chapin, Copley & Sheffield, 2011, p. 6-7)
<table>
<thead>
<tr>
<th>Stage</th>
<th>Age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Orderer to 6+</td>
<td>5</td>
<td>Orders lengths, marked in 1 to 6 units.</td>
</tr>
<tr>
<td>End-to-End Measurement</td>
<td>6</td>
<td>Lays units end to end, may not recognize the need for equal-length units.</td>
</tr>
<tr>
<td>Primitive Coverer and Area Unit Relater and Repeater</td>
<td>5</td>
<td>Draws a complete covering, but with some errors of alignment. Counts around the border, then unsystematically in the interiors. Can count correctly one row at a time with help.</td>
</tr>
<tr>
<td>Partial Row Structure</td>
<td>6</td>
<td>Draws and counts some, but not all, rows as rows. May make several rows but then reverts to making individual squares.</td>
</tr>
<tr>
<td>Capacity Indirect Comparer</td>
<td>5</td>
<td>Compares two containers using a third container and transitive reasoning.</td>
</tr>
<tr>
<td>Primitive 3-D Array Counter</td>
<td>6</td>
<td>Partial understanding of cubes as filling a “space.” Usually does not count internal cubes.</td>
</tr>
</tbody>
</table>

**Learning Trajectories for Geometry**
(As summarized by Gavin, Casa, Chapin, Copley & Sheffield, 2011, p. 7-9)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side recognizer</td>
<td>4-5</td>
<td>Parts: Identifies sides as distinct geometric objects.</td>
</tr>
<tr>
<td>Most Attributes Comparer</td>
<td>4-5</td>
<td>Comparing: Looks for differences in attributes, examining full shapes but may ignore some spatial relationships.</td>
</tr>
<tr>
<td>Corner (Angle) Recognizer</td>
<td>4-5</td>
<td>Parts: Recognizes angles as separate geometric objects, at least in the context of “corners.”</td>
</tr>
<tr>
<td>Shape Recognizer – More Shapes</td>
<td>5</td>
<td>Classifying: Recognizes most familiar shapes and typical examples of other shapes, such as, hexagon, rhombus, and trapezoid.</td>
</tr>
<tr>
<td>Picture Maker (2-D)</td>
<td>5</td>
<td>Puts several shapes together to make one part of a picture. Uses trial and error. Fills “easy” Pattern Block Puzzles that suggest the placement of each shape.</td>
</tr>
<tr>
<td>Shape Composer (2-D)</td>
<td>5</td>
<td>Composes shapes with anticipation. Rotates and flips intentionally. In puzzles, all angles are correct.</td>
</tr>
<tr>
<td>Shape Composer (3-D)</td>
<td>4-5</td>
<td>Composes shapes with anticipation, understanding what shape will be produced with a composition of two or more other shapes. Can produce arches, enclosures, corners, and crosses systematically. Builds enclosures and arches several blocks high.</td>
</tr>
<tr>
<td>Substitution Composer and Shape Composite Repeater</td>
<td>5-6</td>
<td>Substitutes a composite for a congruent whole. Builds complex bridges with multiple arches, with ramps and stairs at the ends.</td>
</tr>
<tr>
<td>Local Framework User</td>
<td>5</td>
<td>Represents objects’ positions relative to landmarks and keeps track of own location in open areas or mazes. Some use of coordinate labels in simple situations.</td>
</tr>
<tr>
<td>Beginner Slider, Flipper, and Turner</td>
<td>5</td>
<td>Uses the correct motions, but not always accurate in directions and amount. (Knows a shape has to be flipped to match another shape, but flips it in the wrong direction)</td>
</tr>
</tbody>
</table>

**Measurement for Kindergarten Students**
Measurement is a content area that is not given much time in traditional elementary mathematics curricula. NCTM (2000) recommends that children should have hands-on experiences with measurement. Estimation prior to measuring can help students learn and develop number sense. Teachers should begin by allowing children to experience measuring items using nonstandard measuring tools such as cubes, pencils, etc. Later teachers can introduce students to standard measuring tools like a ruler (NCTM, 2000). Students should learn the nature of units and appropriate tools used to measure many different attributes such as length, area, weight, volume of objects and figures.

The Common Core State Standards for kindergarten measurement require students to “describe measureable attributes of objects, such as length or weight and directly compare two objects with a measureable attribute in common, to see which object has “more of”/ “less of” the attribute, and describe the difference” (Council of Chief State School Officers & National Governors Association Center for Best Practices, 2010, p. 12). They also require students to “classify objects into given categories; count the numbers of objects in each category and sort the categories by count” (Council of Chief State School Officers & National Governors Association Center for Best Practices, 2010, p. 12).

In 2006 the Curriculum Focal Points were created by the National Council of Teachers of Mathematics to outline the three major areas for teaching and learning at each grade level. The Focal Points should be part of a curriculum that “promotes problem solving, reasoning, communication, making connections, and designing and analyzing representations” (NCTM, 2006, p. 12). According to the Focal Points, children in kindergarten should be able to use measureable attributes to solve problems by comparing and ordering objects (NCTM, 2006). They should be able to compare the lengths of two objects directly (comparing) and indirectly (comparing both with a third object) and order several objects according to length (NCTM,
The Project M² measurement curriculum focuses on these standards and the centers give students the opportunity to explore these concepts independently and with their peers.

**Geometry for Kindergarten Students**

Geometry is another mathematical concept that is not usually focused on in the early elementary grades even though it should be about one-third of the mathematics curriculum in grades pre-K to 2. The main focus in geometry in kindergarten is to be able to describe shapes and space. Children should use geometric ideas to interpret their world and use spatial reasoning to create complex shapes and mimic their environment (NCTM, 2006).

The Common Core State Standards require kindergarteners to analyze and compare two- and three-dimensional shapes using informal language about their attributes (Council of Chief State School Officers & National Governors Association Center for Best Practices, 2010, p. 12). They also require that students in kindergarten explore shapes and learn the correct terminology for two- and three-dimensional figures including squares, circles, triangles, rectangles, hexagons, cubes, cones, cylinders, and spheres and describe relative positions (Council of Chief State School Officers & National Governors Association Center for Best Practices, 2010, p. 12).

Being able to navigate using a mental map is an important math skill for young children. Teachers can foster this skill by doing navigational activities (NCTM, 2006). One example of a navigational activity shown below is in the kindergarten unit of Project M²: Mentoring Young Mathematicians, a National Science Foundation supported curriculum program for primary students (Gavin et al., 2011). The Project M² geometry unit is designed based on these standards and the centers give students the opportunity to explore shapes and navigate on a map independently.
Mathematics Instructional Strategies

Experts have presented new instructional strategies that encourage students to learn and understand mathematics (Carpenter & Gorg, 2000; Chapin, O’Connor & Anderson, 2009; Clements & Sarama, 2009; Gavin & Adelson, 2008; Tomlinson, Kaplan, Renzulli, Purcell, Leppien & Burns, 2009). Classroom culture and the role of the teacher are important influences on student achievement (Pianta, La Paro, Payne, Cox & Bradley, 2002). Students should be given the opportunity to express their ideas to each other and to the teacher before being told whether their ideas are correct (Chapin et al., 2009). Teachers should accept all ideas and allow
students to debate which answers make sense and why (Chapin et al., 2009). This is a drastic contrast to many curricula which emphasize finding the correct answer instead of understanding the mathematical concepts. Classroom discussion, guided, but not controlled, by the teacher is one way to emphasize communication in mathematics. It is important that students get the opportunity to experience mathematics on their own rather than being told each step to solve a mathematical problem. Walshaw and Anthony (2008) concluded from various research studies in their review of the research that “class work is more enriching when there is a co-construction of mathematical knowledge through respectful exchange of ideas” (Walshaw & Anthony, 2008).

**Mathematical Authority**

Math is a living discipline so teachers have the “responsibility to help learners become part of that living discipline” (Towers & Hunter, 2010, p. 26). One mechanism teachers can use is giving students mathematical authority. Hamm and Perry (2002) define mathematical authority as “inviting students to assume responsibility as members of a mathematical community” (p. 135). Unfortunately traditional mathematics curriculum, especially in the early elementary grades, focuses on teacher-guided instruction during which students learn algorithms for solving problems. Students develop the misconception that they should rely on their textbooks for the correct answer rather than their mathematical reasoning ability (Hamm & Perry, 2002).

**Student Capabilities**

Students are quite capable of assuming mathematical authority (Hamm & Perry, 2002). Reasoning and proof is an essential mathematical process that begins to develop at a very early age. Logical reasoning begins to develop early in life and is modified by experiences (Carpenter & Gorg, 2000). Students as young as six are capable of making conjectures and giving evidence to prove or disprove their ideas. They are also able to expand on and provide support for their
ideas (Carpenter & Gorg, 2000). Students should explain their answer using logical reasoning, and teachers should model and encourage students to use mathematical language in their explanations (Carpenter & Gorg, 2000). Students should build mental connections and work together to discover mathematical truths (Chapin, O’Connor, & Anderson, 2009). NCTM recommends teachers should provide independent hands-on experiences for students so that they are given the opportunity to explore, look for patterns and then make generalizations about mathematical concepts (NCTM, 2000). One way to do this is to provide learning centers as part of the mathematics instruction.

**Classroom Culture**

Teachers can encourage students to contribute to mathematics by establishing a classroom culture of a community of learners where the authority is shared (Hamm & Perry, 2002). According to Maturana and Varela (1992) and Davis (1996), based on responses and student understanding from their research, learning is dependent on choices made by the teacher but not determined by the teaching (Towers & Hunter, 2010). Therefore, teachers can build a classroom culture to support or undermine student authority. It is important for students to learn math skills, but sometimes clear procedures for solving problems can hinder student ability to understand math concepts and apply their knowledge to other contexts (Hamm & Perry, 2002). Teachers should guide learning and not just “dispense knowledge” (Hashimoto, 1999, p. 108). They should provide developmentally appropriate learning experiences for their students and should have a complete understanding of elementary mathematics (Clements, 2004). Centers can be a part of these experiences that allow students to exert mathematical authority in an independent setting.

**Kindergarten Centers**
Centers provide the opportunity for students to exert mathematical authority during independent learning experiences designed by teachers with enough instructional support for students to be able to successfully complete the activity on their own. La Paro and colleagues in a 2009 study used observational data collected in 730 kindergarten classes in six states to examine the quality of children’s learning opportunities. The results indicated that there are low levels of instructional supports in kindergarten classes (La Paro et al., 2009). The researchers found that children in kindergarten experience more seatwork and less individualized child-centered experiences than in kindergarten in previous years and than in pre-kindergarten. In addition, they found that kindergarten classes that scored high on the Classroom Assessment Scoring System (CLASS) manual on Concept Development and Quality Feedback emphasized the learning process, allowed ample time for brainstorming, connected learning to student’s lives and provided frequent feedback and strategies about learning. The authors suggest that these instructional supports occur in the context of centers and small groups (La Paro et al., 2009).

Implementing centers solely as a physical space in the classroom is not enough. Young students should participate in “rich, experiential activities” (Miller & Almon, 2009, p. 5). Kindergarteners learn best when adults offer them age-appropriate materials to explore independently (Tomlinson, et al., 2002), which can include math centers. Math centers provide an opportunity for students to investigate the mathematical concepts and grasp a better understanding. Activities like these can give them mathematical authority, or the ability to “use information to reason and think creatively and to formulate, solve, and reflect critically on problems” (NCTM, 2000, p. 205). These meaningful independent learning experiences are essential for young children (Tomlinson et al., 2002).

However, a study of 223 kindergarten classes in three states (Pianta, La Paro, Payne, Cox & Bradley, 2002), found that the average kindergartener spent 44% of the day engaged in whole-
group activities with the teacher transmitting knowledge. Only 18% of the time was spent in small-group activities, such as centers. On the other hand, in child-centered classes, teachers allowed students to choose a developmentally appropriate activity in which to participate and students spent more time in small-group activities. This gave students time for guided exploration in a context in which they have authority. They had the opportunity to interact with their peers and create their own culture and friendships independently of the teacher (Ray & Smith, 2010).

**Project M² Curriculum**

This research study focused on the center aspect of the Project M² measurement and geometry units. These high-level geometry and measurement units focused on students reasoning and communicating about the mathematics both verbally and in writing and were created by a team of experts in the field of mathematics as well as early childhood education (Gavin, Casa, Chapin, Copley & Sheffield, 2011). Each kindergarten student had a mathematician journal where they completed all their work for the unit usually explaining their mathematical reasoning with writing and drawings. There were a variety of grouping strategies including whole group investigation led by the classroom teacher usually to introduce a new concept and small group instruction with the classroom teacher while the other students worked independently in centers. This small group instruction gave the teacher an opportunity to focus on a few students and target instruction accordingly. The students also worked in small groups with the teacher when they worked on the think deeply question which challenged students to think beyond on a question related to the main mathematical idea presented in the lesson (Gavin et. al., 2011). The centers were intended by the authors to be based on the unit objectives. They were designed to give students additional practice with the mathematical concepts or to allow students time to explore concepts before they formally learned them (Gavin et. al., 2011).
Although there were recommended centers, teachers chose which centers they made available to students each day. At the end of each lesson there was a whole class wrap up as well as a two-part chapter check-up assessment to determine what students learned. At the beginning and end of each unit students took a pre- and post-unit assessment to measure students’ performance on the unit objectives.

**Conclusion**

Students in the United States are trailing behind those in other nations in the world in mathematics achievement (National Center for Education Statistics, 2009). So, in an effort to increase achievement, rich curricula that follow research-supported content standards and instructional strategies are being created for early elementary school mathematics. However, a major challenge still exists in developing effective mathematics curricula: the great disparity between abilities within a classroom and tailoring instruction to accommodate for these differences. An individualized student-centered approach that focuses on learning crucial mathematical concepts while utilizing reasoning and communication skills seems to be a promising solution to help young students excel in mathematics.

In the Project M\(^2\) units, the centers are spaces in which students explore mathematical concepts related to the unit objectives independent of the teacher, thereby having an opportunity to assert their mathematical authority. When children are empowered with mathematical authority, they are then able to experience the concepts for themselves and have the confidence to reach their full potential. This study will explore kindergarten students’ ability to investigate the mathematical concepts independently at the Project M\(^2\) centers in diverse school settings.
Chapter 3
Research Design

Methodology

Research Questions. The following research questions were explored in this study:

1. What is the connection between the math center objectives and those of the unit?
2. What do students engage in while participating at the centers?
3. How does the context of the centers contribute to the amount of accessibility students have in investigating the mathematics?

Setting and Sample. The sample is composed of all five teachers from Connecticut who were field-testing the Project M² units during the 2010-2011 school year and their kindergarten students participated. Two of these classes are in larger districts that have a high proportion of students eligible for free and reduced lunch and have a diverse student population. The three other classes are in a smaller district with a low ethnic and racial diversity and few students qualify for free and reduced lunch (National Center for Education Statistics, 2008-2009).

Maple Magnet School is located in an intra-district magnet school in an urban district with a diverse student body (80% minority) and a significant percentage of students who live in homes where English is not the primary language spoken (32%) and 27% of students are receiving English Language Learner (ELL) services. Three-fourths of kindergarten students attended a preschool or some type of schooling before kindergarten. One-third of the students in the kindergarten class are eligible for free or reduced lunch (Strategic School Profile, 2006-2007).

Lakeside Elementary is also a magnet school that draws a diverse student body (91% minority) from urban and suburban towns in the surrounding area with 30% of students live in
homes where English is not the primary language spoken and one-fourth of students in the class receive ELL services. Two-thirds of kindergarten students attended a preschool or some type of schooling before kindergarten (67%). Over half of the students are eligible for free or reduced lunch (59%) (Strategic School Profile, 2006-2007).

North Elementary is located in a suburban community surrounding a university. Seventy-seven percent of students are white and most students speak English as their native language (84%). One-third of students in the class are eligible for free or reduced lunch. Most kindergarten students attended a preschool or some type of schooling before kindergarten (91%) (Strategic School Profile, 2006-2007).

Garden Elementary is located in a suburban community surrounding a university. Three-fourths of the students are white and most students speak English as their native language (82%). Approximately twenty-nine percent of students in the observed class are eligible for free or reduced lunch. Many kindergarten students attended a preschool or some type of schooling before kindergarten (84%) (Strategic School Profile, 2006-2007).

West Elementary is located in a suburban community surrounding a university. The majority of students are white (84%, 80% in class) and almost all students speak English as their native language (96%). Twenty percent of the students are eligible for free or reduced lunch in the observed class. Most kindergarten students attended a preschool or some type of schooling before kindergarten (91%) (Strategic School Profile, 2006-2007).

Data Collection

This was a qualitative methods research design. In order to triangulate data there were three qualitative sources of data; researcher observations using an observation protocol to observe kindergarten students engaging in centers, observations from the professional development staff on the implementation of the units that included three questions about the
centers, and discussion about the centers in teacher exit interviews conducted by the professional development staff at the end of each of the two units.

**Center Observation Protocol.** Observations of the kindergarteners as they engage in centers were conducted by this researcher three times in each of the five classes using an observation protocol (Appendix A). Each class was coded to ensure confidentiality of the classes following the Internal Review Board requirements for this research study. The first page of the protocol included information to provide context including the class code, observer name, observation date and time, time spent in math, time spent in centers as well as identifying the unit, lesson, and part of the lesson that was taught. The time was used as a data source and the unit and lesson were used to determine which centers were connected to the unit. The observations examined students’ mathematical authority and focused on the connection between the center and unit objectives, the set-up of the centers, and how students engage while at the centers. Each question was answered with “yes,” “somewhat,” or “no” depending on the occurrence of the item being observed. Most questions had a space for an explanation with more details to explain what was observed. There was also a section for other comments and for a diagram of the classroom and the centers. The last section included a description of each center and the amount of time each student participated in each center. In order to limit the affect that time might have on students’ ability to take on a greater amount of mathematical authority (e.g., getting used to the routine of selecting centers), the observations were conducted throughout the field test period with the first set of observations in the beginning of the measurement unit (the start of the Project \( \text{M}^2 \) field test), the second set of observations at the beginning of the geometry (the middle of the Project \( \text{M}^2 \) field test), and the final set of observations at the end of the geometry unit (end of the Project \( \text{M}^2 \) field test).
**Project M\(^2\) Teacher Observation Scale.** This scale (Appendix B) was developed as one of several measures used to monitor the fidelity of implementation of the Project M\(^2\) curriculum and embedded instructional practices and to assist with professional development during the field test. This fidelity scale was completed by a trained Project M\(^2\) professional development staff member after each weekly classroom observation. Three items were included for space centers. They included active engagement in centers, if the center set-up supported students’ abilities to investigate the mathematics independently, and the connection between the centers and the unit objectives. The other aspects of the observation scale were not used as they did not relate directly to the research questions in this study. Inter-rater reliability for the Teacher Observation Scale has not been established.

**Teacher Exit Interviews.** Teachers participating in the field test were asked a series of questions related to the implementation of the units by the professional development staff at the teacher exit interview conducted at the end of each unit. Each of the five teachers participated in two exit interviews, one after each unit. These interview questions were created by the project researchers. One question relating to centers, “How did the centers enhance/foster independent learning experiences for your students?” was analyzed for this study.

**Data Analysis**

The purpose of qualitative data analysis was to determine the accessibility kindergarten students had to mathematics centers that were connected to the unit objectives and their engagement in centers related to unit objectives. Merriam (2009) described qualitative data analysis as the “process of making sense out of data” (p. 193). Corbin and Strauss (2008) *Basics of Qualitative Research* was used for data analysis.

Corbin and Strauss (2008) describe diagrams as “conceptual visualizations of data” (p. 124). Diagrams are one way to organize data to illustrate conceptual relationships. They usually
require many revisions before the final version. Diagramming was used to compile data in this study and allowed for ease in comparing classes and looking for trends. The data were compiled into one document for each class based on results from the observation protocol, Professional Development staff observations, teacher exit interviews, and demographics. Using these data, the researcher created a summary of each class, organized by research question. The first research question is the connection between the center objectives and unit objectives. For the first question there was a diagram which included the date and lesson, the ratio of centers connected to the unit objectives, the centers with descriptions, and unit objectives that were fulfilled by the centers observed by this researcher. For the second and third research questions the information from all the observation protocols were compiled by question. The demographic information was compiled and percentages for ethnic groups and other populations such as students who qualify for ELL services and free or reduced lunch were recorded. A list of all the centers observed by this researcher using notes on the center observation protocol for each class was compiled. This list had the number of minutes each student spent at each center. To maintain confidentiality, students’ names were not used instead a number was assigned to each student. (See Appendix D to see how the data were triangulated).

Once data were organized into a diagram the context, “the sets of conditions that give rise to circumstances which individuals respond by means of action/interaction/emotion,” was analyzed (Corbin & Strauss, 2008, p. 229). Coding, “deriving and developing concepts from data,” was used to determine the most prevalent mitigating factors in each class (Corbin & Strauss, 2008, p. 65). This was determined by looking for consistent factors throughout the three observations by this observer that were also usually expressed by the teacher responding to the question “How does the set-up of the centers contribute to the amount of independence students
have in investigating the mathematics?” in one or both of the exit interviews conducted at the end of each unit.

Another important aspect of the data analysis is the process, “ongoing responses to circumstances arising out of the context” (Corbin & Strauss, 2008, p. 229). In this research study the process was addressed in the second research question, “What do students engage in while participating at the centers?” The data came from the center observation protocol center descriptions and observation notes as well as the question about engagement in the center observation protocol and the Project M² observation scales. This process is closely tied with the context which makes sense in this research study because the context may have, and probably did in fact, influence the process. In other words, certain factors influenced how and what students participated in during centers.

In the diagram there were one to three columns for each research question. The first research question is the connection between the unit objectives and center objectives. For this question two ratios were calculated for each class. The first ratio compared the centers connected to the unit objectives to the total centers made available to the students by the teacher. In order to find the number of centers related to the unit objectives this researcher counted from the center observation protocol which centers were connected to the unit objectives and Dr. Gavin, director of the project, confirmed these decisions. Then data were gathered from three observations for each class on the center observation protocol completed by this researcher. (Overall, do the space center activities connect to the unit concepts? What is the connection between the math center objectives and those of the unit?). Below is an example of how this ratio was calculated:

\[
\frac{\text{Number of centers connected to unit objectives}}{\text{Total number of centers available}} = \text{availability}
\]

Ex. North Elementary: \(\frac{14}{15} \approx 93\%\) so all except one of the centers connected to the unit objective
The next ratio compared the total time students spent in these objective-related centers to the total time students spent in centers. These data were from the last page of the center observation protocol collected by this researcher when the centers were listed with the number of minutes each student spent at each center. The lists of all the centers from each class were used and all the minutes that each student spent at each center that was connected to the unit objective were added. Then all the minutes that any student spent at any center were added. These data show how often the kindergarteners participated in mathematical centers.

\[
\frac{\text{Time (min) in unit related centers}}{\text{Total time (min) in centers}} = \text{how often students participated in mathematical centers}
\]

Ex. North Elementary: \( \frac{551}{551} = 100\% \), so the whole time was spent in unit objective centers

The second research question was the outcome and engagement in the centers. The first data source was a ratio of the number of students who spent at least some time in a unit-related center compared to the total number of students who participated in centers. These data were gathered from the list of all the centers in each class on the center observation protocol with the amount of time each student spent at each center. This shows how many students participated in at least one mathematical, objective-related center.

\[
\frac{\text{Number of students who participated in at least one unit objective related center}}{\text{Total number of students who participated in centers}} = \text{students who participated in at least one unit objective}
\]

Ex. North Elementary: \( \frac{25}{25} = 100\% \), so all students practiced at least one unit objective related center

The next source of data was a compilation of information about what students were doing, whether they were engaged. There is a question on both observation protocols, (Are
students actively engaged in mathematics?) This was calculated by determining the ratio of how
students were engaged on the observation protocol on a scale of “yes,” “somewhat,” and “no.”
Other data for this research question came from the question, (How do students participate in the
center activities?) from the center observation protocol as well as the Project M² observation
scales conducted by the professional development staff. This question looked at whether student
engagement was related to mathematics and the unit objectives or not. Data were used from the
descriptions and objectives of the centers students engaged in to describe the engagement. The
question about what students were doing in centers is answered in the diagram, see Appendix C,
based on observation notes about the centers.

The third question was about the mitigating factors that may have influenced the
outcomes. These provided context for what was going on in each class. These factors came from
the center observation protocol questions about various aspects of the centers (How does the set-
up of the centers contribute to the amount of independence students have in investigating the
mathematics? Does the set-up of the space centers support students’ ability to investigate the
mathematics more independently?). Some factors came from observation notes on the protocol
about factors that seemed to influence students’ experiences at the centers. Other data came from
the teacher exit interviews and what the teachers think impacted the students’ experiences at the
centers. For each class there were three or four important mitigating factors that could have
impacted student engagement and the outcome the most. These factors were determined based on
frequency of observation as well as the frequency of the factor expressed by teachers on the exit
interviews.

The final diagram, see Appendix C, had a row for each class with a column for each
source of data described above. This allowed the researcher to look at each class separately first
then to look across classes using comparative analysis. Comparative analysis was used to
analyze the results further and determine which incidents (classes) were similar to and different from each other and to find overall trends among classes. Constant comparisons are made when one incident, in this study classes, is compared with other incidents for similarities and differences. There are clear ways to differentiate between one category or theme and another (Corbin & Strauss, 2008). In the results and discussion sections common themes among classes are discussed.
Chapter 4

Results

The tabulated results shown for each class in each school are in the chart mentioned (see Appendix C). A summary of the results by research question and trends found in the data are shown next.

Research Question 1

What is the connection between the math center objectives and those of the unit?

There is a range in the number of centers connected to the unit objectives that are available to students. North Elementary and West Elementary, located in a middle class, suburban community with relatively little ethnic diversity, had 93% and 87% of their centers connected to the unit objectives and students spent 100% of time in unit related centers. Students spent all of their time engaged in unit related centers. Maple Magnet, located in an urban district where one-third of students qualify for free or reduced lunch and 80% of students are minorities, 86% of the centers connected to the unit objectives and students spent 99% of their time at unit related centers. Therefore, these students have the same opportunity to engage in unit related centers. Garden Elementary, also located in the suburban district, had 70% of the centers connected to the unit objectives and students spent 92% of time in unit related centers. At Lakeside Elementary, located in an urban district where over half of students qualify for free or reduced lunch and over 80% of students are minorities, 45% of the centers connected to the unit objectives and students spent 46% of time at unit related centers. This is much lower than most of the other schools. Therefore, these students had much less of a chance to engage in unit related centers.
Looking across the five classes there were some trends. The first research question was the connection between the math center objectives and the unit objectives. In four out of the five classes at least two-thirds of the centers connected to the unit objectives. At Lakeside Elementary less than half the centers related to the unit objectives. In this class some of the centers focused on literacy instead of math and so students spent less than half the time in unit related centers. In four of the five classes students spent over 90% of their time in unit related centers. Therefore, in most of the classes students had access to mathematical, unit-related math centers.

**Research Question 2**

*What do students engage in while participating at the centers?*

The second research question concerns what students were engaged in at the centers, was it mathematical in nature, and did it relate to the unit objectives. To better understand what the students were doing, the unit objectives are presented first.

The unit objectives for length measurement:

- Students compare and order three or more lengths from the shortest to the longest.
- Students understand linear measure as an accumulation of units.
- Students understand the need for standard, equal-length units, and measure starting at zero with no gaps or overlapping strips.

The unit objectives for area measurement:

- Students cover an area with equal-sized units and count how many units it takes to cover the area without gaps or overlaps between units.
- Students explain and represent the inverse relationship between the size of units and number of units.

The unit objectives for volume measurement:

- Students determine the volume of containers by counting cubes.
• Students compare two containers and determine which has a greater volume.
• Students understand what it means to fill a container and when a container is full.
• Students learn that a cup is the standard unit used to measure capacity in the U.S. customary measurement system.

One popular measurement center among the five classes observed gave students the opportunity to measure a distance or a strip of paper using a variety of units of measure such as popsicle sticks and toothpicks. Students also played games on the computer to practice measurement skills such as ordering objects according to their length. Refer to Appendix C for a listing of the measurement centers in each class.

The geometry unit objectives:

• Students compose a 3-dimensional structure using blocks to match a model pictured in a 2-dimensional photo.
• Students use properties and names of basic 3-dimensional shapes.
• Students develop spatial reasoning as they recognize 3-dimensional figures in different orientations, inspect their relative positions, and use vocabulary such as “left,” “right,” “between,” “inside,” and “outside.”
• Students describe 2-dimensional shapes and compose and decompose spatial designs.

One geometry center that all the classes used gave students the opportunity to create designs and puzzles with tangrams (two-dimensional shapes). There were also many centers where students could build with three-dimensional blocks and play computer games to manipulate shapes. Refer to Appendix C for a listing of the geometry centers in each class.

At North Elementary, West Elementary, and Maple Magnet all of the students participated in at least one unit-objective center during a classroom observation by this researcher and were actively engaged in the mathematics all the time. At Garden Elementary
96% of students participated in at least one unit related center and were engaged in mathematics 90% of the time, and 57.1% participated at Lakeside Elementary and 60% of the time they were engaged in mathematics.

In three of the five classes each student participated in at least one mathematical, unit-related center. In most of the classes almost all of the students were actively engaged in the mathematics except Lakeside Elementary where only 60% were actively engaged and 40% were somewhat engaged. With the exception of Lakeside Elementary most engagement was mathematical and related to the unit objectives.

**Research Question 3**

*How does the context of the centers contribute to the amount of accessibility students have in investigating the mathematics?*

The third research question was about how the context contributed to the amount of accessibility students had. This, in turn, connects to how much mathematical authority students were allowed in independent activities at the centers. There were a few common mitigating factors for all the classes. One factor throughout seemed to be the number of adults in the room. At West Elementary, there was only one teacher in the room and no one to monitor the centers. Students had the freedom to choose which centers and struggled with transitions and staying on-task. The classes with two or three adults in the room monitoring centers helped students stay focused on the math, at Maple Magnet and Garden Elementary. But with more than three adults the adults were telling students what to do and they had less independence and less mathematical authority.

Transition time moving from one center to another also contributed to the amount of accessibility students had. At Maple Magnet the teacher had an effective system where students had to check with the Instructional Assistant before they could move on to the next center. In
other classes students moved when they wanted which did not seem to be a problem. However, in classes where there were no adults to direct students, students were having difficulty transitioning to a new center. Therefore, modeling procedures and effective classroom management were important factors in whether students could fully take advantage of the math centers.

Choice was another common theme among all of the classes. All teachers gave students the ability to choose which center they wanted to participate in. Most classes had mainly hands-on centers giving students the opportunity to work together and practice the mathematics. The exception was Lakeside which emphasized more structured centers focusing on the writing component more than hands-on activities. In this class there were usually only one or two students at each center making it more difficult for students to work with others. This actually may have given these students more mathematical authority because they were able to investigate the mathematics on their own without input from peers. In the other classes students worked in small groups or with partners. Therefore, students were able to work together to help as well as challenge each other and keep each other on-task when they were paired well.
Chapter 5
Discussion and Implications

Although there were only five schools in this study there are some connections among the data that are noteworthy. The number of adults in the room seemed to be an important factor among the classes. There seemed to be an ideal number of adults. Too few adults led to management problems such as at West Elementary and Lakeside Elementary where students were unable to transition efficiently and therefore wasted a lot of their center time transitioning from one center to another instead of engaging in the mathematics. However, at West Elementary, once students were at a center they were on-task and focused on the mathematics that related to the unit. At Lakeside Elementary about 60% of students stayed on-task within the center and most of the centers were more writing and literacy based with less emphasis on the mathematical tasks connected to the unit. However, writing was a focus of the Project M² curriculum units and this additional practice writing may have contributed to the fact that these students performed well on the project open-response assessment that had written explanations required. Students had more practice expressing their ideas in writing and explaining what they learned in math to Freeda the frog in centers than students in the other classes.

At North Elementary there were more than four adults, almost one for each center, and this decreased the amount of mathematical authority students had. Since some of these adults were volunteers they may not have understood the goal of independence for students and gave direct instruction to students making it less of a center and more of a lesson. The ideal number for optimal student authority seemed to be between two and three adults including the teacher. Maple Magnet School and Garden Elementary had this number and students were engaged and on-task in centers. They also efficiently transitioned from one center to the next well and were
able to explore the mathematics on their own without direct instruction from an adult.

Another reason for the transition difficulty in some classes may have been a failure on the part of the teacher to effectively model the expectations for transitions and establish a routine students knew. This is a challenge especially with kindergarten students who need many reminders.

Within the centers engagement seemed to be high in most classes and perhaps this is due to the fact that students could choose which centers to participate in and move freely from one to another in most classes. Some classes required students to check-in with a teacher before moving on, but this did not seem to hinder their choice and decrease engagement. Since students chose they had an interest in that center unless all the other centers they liked were full. When this happened in some classes students wanted to wait until their favorite center was available. However, this was not feasible so they usually chose one center for a short time waiting for their first choice. Even during this time students were engaged in the center. The exception was Lakeside Elementary where 40% of students within centers students were off-task. One example is the water table where students began to play with toys instead of practicing pouring into various containers and learning the concept of capacity.

The content of the centers seemed to be similar among all the classes where students practiced the same key skills taught in the units. Students practiced measuring with units and tape measures, playing computer games related to geometry and measurement, designing tangram figures, and building with 3-D blocks. Students worked together in centers to discover mathematical truths (Chapin, O’Connor & Anderson, 2009). However, at Lakeside the main focus was on writing and communicating instead of hands-on centers in a group as it was in other classes. However, even though this class had the least percentage of centers connected to the unit objectives, students performed quite well on the project open-response assessment. This
may be connected to the fact that students were encouraged to write their mathematical ideas and use the word wall and math vocabulary they were learning.

Although it is not appropriate to make generalizations from this small sample size, the data show that providing a classroom environment that allows accessibility to kindergarten students to centers designed with mathematical objectives directly related to unit objectives being studied increases student engagement with the mathematics. In four of the five classes students working in centers were on-task and engaged in the centers. Centers gave students the opportunity to assume responsibility to engage with the mathematics (Hamm & Perry, 2002). Students seemed to enjoy the mathematical activities within the centers. There were a variety of centers available to students at each time and students chose their favorite. Students assumed mathematical authority within the centers especially when there was not an adult giving direct instruction. Teachers in most classes introduced and modeled each center so students could work independently without help from the teacher or another adult. They provided independent hands-on experiences for students to engage in mathematics (NCTM, 2000). Most of the kindergarten students across the five classes sat down at the centers and almost immediately started working on the task at hand until they were finished.

Therefore, the use of centers is an instructional strategy that provided an opportunity for students to work at their own pace. Some students finished quickly and did not have to wait for all the other students to finish before they could move on. In whole class and even small group instruction some students will master the content in two minutes and others may take twenty minutes. In classes with effective transition systems and enough adult support, once students were finished they chose and moved to another center and began working. In classes without an effective transition system students spent more time deciding which center to choose. Therefore, students in classes with effective transition systems had more time to exert their mathematical
authority within centers. This is because, as Towers and Hunters (2010) suggest, teachers built a classroom culture to support student authority.

**Limitations**

Several limitations exist in this study. First, this is a complex social unit with multiple variables influencing what is happening. A classroom is ever changing and unpredictable. There is no way to conduct a study as controlled as it would be in a lab in a situation. There are many factors including the teacher, instructional leadership, instructional philosophy, teacher content and pedagogical knowledge, and parental support that contribute to influencing the outcome. Limitations related to the collection of the qualitative data through observations include possible participant observer bias. In addition, it may not be possible to understand everything about the centers in each class in three observations. However, two methods were used in responding to the threats to the validity of the qualitative portion of the study (Merriam, 2009). First, multiple qualitative data sources were collected; center observation protocol, Project M$^2$ observation scale conducted by trained staff working on the study, and interview data. This enabled the researcher to triangulate the data related to student engagement in centers. Second, the researcher sought the input of the Principal Investigator and Co-Principal Investigator of the Project M$^2$ study to review the codes and to determine the appropriateness of the findings that emerged from the data.

There is also a small sample size of classes. There were only five classes in this study so it is not possible to generalize to other situations that may seem similar as is the case in most qualitative studies.

**Directions for Future Research**

In *Crisis in Kindergarten*, the Alliance for Childhood called for researchers to “expand the early childhood research agenda to examine the long-term impact of current preschool and
kindergarten practices on the development of children from diverse backgrounds” (Miller & Almon, 2009, p. 7). Therefore, there must be a basis of knowledge about what early childhood education practices are and then these can be monitored over time and tied to achievement later in life in students from many different backgrounds.

A study examining the influence of the content and information learned in centers on the mathematical achievement of students is warranted. This would compare the growth of achievement of students who do and do not participate in centers to determine if centers are an effective instructional strategy.

**Helping to Narrow the Achievement Gap**

The school environment and school resources influence students’ academic performance, and school-related factors present a solution for closing the achievement gap (Chatterji, 2005; Cheadle, 2008; Han & Bridglall, 2009; National Research Council, 2009). School-level factors explained at least one third of the reduction in differences in scores (Han & Bridglall, 2009). Educational institutions may need to make up for “complex problems surrounding the social inequality that arises from family life” (Cheadle, 2008, p. 26).

Weaknesses in early math achievement for African American, Latino, and students of lower SES need to be addressed or the gap will continue (NCTM, 2009). Positive teacher expectations are essential, especially for African American and Latino students for whom the impact of teacher expectations is three times greater than for white students (Chatterji, 2005; Nieto & Bode, 2008). Equity in education goes beyond providing the same resources and opportunities for students, providing students with the real possibility of equal outcomes (Nieto & Bode, 2008). Higher expectations coupled with high-level mathematical tasks in which students have greater mathematical authority may help close this gap. Further research should be conducted to see if the use of centers in kindergarten classes in diverse school settings help
increase student achievement and thus narrow the gap.

Another study that looks at one particular mitigating factor that may have influenced the outcome could be focused on directly. For example, one research study might look at the number of adults as it affects engagement or achievement.

From this research study it is evident that providing students with mathematical centers related to the unit objectives can increase students’ mathematical authority in the classroom, giving students the opportunity to engage in the mathematics independently. Effective classroom management, a carefully designed and practiced center transition system, and one or two additional adults in the classroom promote the optimal student engagement and authority in mathematics.
References


### Project M² Component

<table>
<thead>
<tr>
<th>Space Centers</th>
<th>Project M² Component</th>
<th>YES</th>
<th>Somewhat</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the connection between the math center objectives and those of the unit?</td>
<td>The center objectives are related to the unit objectives.</td>
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<tr>
<td></td>
<td>The center objectives that are identical or closely connected to unit objective(s) are advanced for kindergarten students.</td>
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<tr>
<td></td>
<td>The students are practicing a skill afterward instruction.</td>
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<td></td>
<td>The students are investigating a concept prior to a</td>
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</table>
formal introduction.

Explain:

2. How does the set-up of the centers contribute to the amount of independence students have in investigating the mathematics?

   The center activities are open allowing students more freedom.

   Explain:

   Students are able to choose which centers they wish to participate in.

   Explain:

   The materials used at the centers are mathematical in nature.

   Explain:

   The centers are differentiated.

   Explain:

   The centers are accessible to students.

   Explain:

   The word wall is accessible to students working at the centers.

   Explain:

   Students are able to use the word wall independently.

   Explain:

3. How do students participate in the center activities?

   Student engagement is:
   a) mathematical and connected to the unit objective(s)
   b) mathematical and not connected to the unit objective(s)

   Students use mathematics vocabulary appropriately.

   Explain:
<table>
<thead>
<tr>
<th>Project M² Component</th>
<th>YES</th>
<th>Somewhat</th>
<th>NO</th>
<th>N/A</th>
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<tbody>
<tr>
<td>4. Are students actively engaged in the center activities?</td>
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<td>Explain:</td>
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<tr>
<td>5. Does the set-up of the space centers support students’ ability to investigate the mathematics more independently?</td>
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<td>Explain:</td>
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<td>6. Overall, do the space center activities connect to the unit concepts?</td>
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<td># connected to mathematical objectives:</td>
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<tr>
<td># connected to a thematic aspect (e.g., frogs, space):</td>
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<tr>
<td># NOT connected to any unit concept:</td>
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</table>

<table>
<thead>
<tr>
<th>Project M² Component</th>
<th>YES</th>
<th>Somewhat</th>
<th>NO</th>
<th>N/A</th>
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<tbody>
<tr>
<td>7. Does the teacher assign students to groups?</td>
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<td>Explain:</td>
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<tr>
<td>8. Are students grouped by mathematical ability?</td>
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<td>Explain:</td>
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<tr>
<td>9. Are students grouped by social/communication ability?</td>
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</tbody>
</table>

Other comments:

Diagram of the classroom with the space centers and word wall:
<table>
<thead>
<tr>
<th>Center Descriptions</th>
<th>Project M² Component</th>
<th>Student</th>
<th>Minutes on task</th>
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<tr>
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</table>
# Appendix B

**Project M² Observation Scale: Field Test**  
*(Gavin & Casa, 2010)*

<table>
<thead>
<tr>
<th>Project M² Component</th>
<th>YES</th>
<th>Somewhat</th>
<th>NO</th>
<th>N/A</th>
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<tbody>
<tr>
<td>Space Centers</td>
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</tr>
<tr>
<td>1. Are students actively engaged in the center activities?</td>
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<tr>
<td>Explain:</td>
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<tr>
<td>2. Does the set-up of the space centers support students’ ability to investigate the mathematics more independently?</td>
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<tr>
<td>Explain:</td>
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<tr>
<td>3. Overall, do the space center activities connect to the unit concepts?</td>
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<tr>
<td># connected to mathematical objectives: _______</td>
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<tr>
<td># connected to a thematic aspect (e.g., frogs, space): _______</td>
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<tr>
<td># NOT connected to any unit concept: _______</td>
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</table>
## Appendix C

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>What is the connection between the math center objectives and those of the unit?</th>
<th>What do students engage in while participating at the centers?</th>
<th>How does the context of the centers contribute to the amount of accessibility students have in investigating the mathematics?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Centers connected to unit objectives total number of centers available</td>
<td>Time(min) in unit related centers total time (min) in centers</td>
<td>Number of students who participated in at least one unit objective related center total number of students who participated in centers</td>
<td>Are students actively engaged in mathematics? (Yes, somewhat, no)</td>
</tr>
<tr>
<td>North Elementary</td>
<td>14/15, 93%</td>
<td>551/551, 100%</td>
<td>25/25, 100%</td>
</tr>
</tbody>
</table>

- **Measurement:** Students played a computer game where they had to order the objects by size. They measured how far critters moved with measuring tape. Students played a pattern blocks game where they named the shapes and counted how many of each shape. They compared lengths using sticks and other units of measure.
- **Geometry:** They used tangram puzzles and were engaged in the math. They sorted and built with three-dimensional blocks and were on-task. Students used play-doh to see the faces of three-dimensional blocks. Most students were not on task but rather playing with the play-doh. Students were playing with puzzles. Students used foam shapes to

**Key**

- o (observed by researcher)
- t (teacher response in exit interview)

- Students were able to choose which centers and there were no assigned groups. There were usually three or four students at each center at a time. (o)
- The centers were open-ended, giving students hands-on practice to work together and share with peers. (o, t)
- There were typically three adults, usually one monitoring each center and the teacher. (o)
make a picture then completed a worksheet describing their pictures and how many shapes they used. Students created designs using shapes on a magnetic board and their partners had to reproduce it using the directions from their partner. Students also played a tangram game on the computer where they had to fill in the shapes that fit in the picture.

- **Engagement:**
  Students were focused and excited about math activities. Their engagement related to the unit objectives.

- **Measurement:**
  Students compared weights of various small animals on a balance scale and determined which was more or less. Students used pattern blocks to make designs. They measured using different units and filled out a worksheet. Students worked on the vocabulary words in their math journals about measurement and labeled the pictures with the correct words. They could use the word wall on the board to help them.

- **Geometry:**
  Students used tangram pattern blocks to replicate the designs they saw. Students used

<table>
<thead>
<tr>
<th>West Elementary</th>
<th>13/15, 87%</th>
<th>674/674, 100%</th>
<th>25/25, 100%</th>
<th>12/12, 100%</th>
</tr>
</thead>
</table>

- Transitions from one center to another were disorganized. If a student’s first choice was full he would wait in front of the board where they put their names next to the centers. It was very time consuming and the teacher had to step in to help a few times. (o)

- The teacher was alone in the classroom to teach and monitor centers (o, t)

- Students were able to choose which centers they wanted to do unless it was full. (o)
pattern blocks to fill-in a shape three different ways. They played a hungry caterpillar game where they had to use a shape to fill-in the caterpillar. Students were able to build something using 10-20 blocks. Students had a shape restaurant where different shapes cost different amounts of money and they had to add up the total cost of all the shapes they bought. Students played the lily pad space station floor plan game where they had to follow directions. Students played a mystery block game where they had to feel the block inside a box without looking and guess what it was based on its attributes. All but two students were completing the activity as it was intended. Students played a computer game where they made designs with tangrams. They played a frog hop game where they gave directions to their partner about where to hop on the lily pads.

- **Engagement:**
  Students engagement was related to the unit objectives approximately two-thirds of the time. They were engaged and focused while participating in centers.
• **Measurement:**  
Students played computer games about measurement. They had to measure the lengths of various objects and determine which object was longer or shorter and bigger or smaller. Students listened to a frog storybook on tape and some students were not on-task. Students put three to five rods in length order. Students had to compare lengths and determine which was shorter and longer. Students jumped and measured how far they could jump using popsicle sticks as the unit. Students compared the lengths of three space shuttle strips.

• **Geometry:**  
Students played a computer game where they could practice manipulating and moving shapes. They used tiles to create a picture and design. They built a structure with three-dimensional blocks and graphed how many of each shape they used. Students played with puzzles. They listened to the *Jack the Builder* book on tape. Students participated in a shape hunt where they looked around the room for items that were cylinders, triangular prisms, rectangular prisms, spheres, and

- There was an effective transition system. Students had a checklist with each center and showed the aide before moving to next center. (o)
- The teacher taught the lesson while the aide monitored the centers. (o)
- Students were able to choose centers and went to almost all of them over the few days they were available. (o)
- Students had partners and they were accountable to each other for two weeks until they switched. Students were grouped by social/communication ability. Towards the end of the unit they were grouped by homogeneous or heterogeneous math ability. (o)
cubes. Students made prints of each face of the 3-D figures on play-doh. In their math journals they glued the various shapes and wrote about them.

- **Engagement:** Students were on-task working on the math and engagement was related to the unit objectives. Students were more off-task and talkative during the last observation possibly because it was after spring break.

- **Measurement:** Students played with pattern block puzzles. They played a bean bag toss game and measured the distance they tossed the frogs. They built with 3-D blocks. They played a computer game where they counted how many shapes were in a design or figure. Some of these centers related to geometry even though students were still learning measurement.

- **Geometry:** Students created tangram pictures where they filled in designs with different shapes. Each shape was not outlined so it was more challenging for students to choose the correct shapes. Students played a Curious George maze game where

<table>
<thead>
<tr>
<th>Garden Elementary</th>
<th>9/13, 69%</th>
<th>442/483, 92%</th>
<th>24/25, 96%</th>
<th>9/10, 90% yes</th>
<th>1/10, 10% somewhat</th>
</tr>
</thead>
</table>

- There were three adults. The teacher was teaching the small group lesson while two volunteers helped with centers. They monitored students carefully, sometimes giving direct instruction. (o)
- Students were able to choose which centers and move as they finished. (o)
- There were mathematical, unit objective related centers before and after the lesson as well as the regular math curriculum to review for ITBS which were not related to unit. (o)
they used map skills to navigate. Students were supposed to use shaving cream and make the faces in the cream but most students were off-task. Students built a ten-block train and had to try to make it as long as they could. Many students were building other structures with the 3-D blocks. Students played the lily pad pond game where they decided which cup to put Freeda the frog under then tell their partner directions to find the correct cup. Students played a pennies and dimes game where they tried to make $0.30 first. This was a review for ITBS as part of the math program and did not relate to the unit objectives. Students played a computer game where they had to fill-in designs with tangram shapes. Students used blocks to build a nature trail and draw pictures of their design. Students were supposed to write directions for the frogs but most did not get to this step.

- **Engagement:** Students were focused and excited about math activities. Their engagement related to the unit objectives.
<table>
<thead>
<tr>
<th>Lakeside Elementary</th>
<th>9/20, 45%</th>
<th>308/676, 46%</th>
<th>16/28, 57%</th>
<th>6/10, 60% yes, 4/10, 40% somewhat</th>
</tr>
</thead>
</table>

- **Measurement:** Students played a computer game where they had to determine which figure was longer or shorter and bigger or smaller. Students were writing words and letters on a white board that were unrelated to mathematics. Students were playing at the water table and instead of exploring the concepts of capacity and volume, students were playing with the animals. One student was writing words and drawing pictures and at the end she began writing a letter about space but did not include any math content or vocab. Students listened to a book on tape at the reading center that was unrelated to the unit. Students built structures out of Legos and measured how tall it was using a cube as a unit.

- **Geometry:** One student practiced writing her numbers and then wrote to Farley about what she was learning about using the math word wall. This student seemed to have a good understanding of the math. Students poured water into different types of containers at the water table. They did not seem to understand how this connected to math.

- **The teacher needed management help with centers so she used more structured centers.**
- The teacher had to teach and at the same time monitor the centers. Therefore, students had a lot of independence to do what they wanted and usually stayed at one center the whole time.
- There were some math materials but not as many as in the other classes. There were more play items.
- Writing and vocabulary were a major focus.
Students played with the pretend kitchen and with dolls at a dramatic play center. Students played a literacy activity on the computer. Students built with Legos and one student voluntarily used vocabulary to identify the shapes he was using. One student was painting a picture. A few students played with puzzles. Students were reading and writing a book report about the story. Students played with tangram puzzles where they had to place the tangrams in various designs. Students made shapes out of play-doh but most students were just creating designs and were playing. One student was playing a computer game where he chose the picture that matched the word dictated. Many of the centers in this class did not relate to the unit or to mathematics.

- **Engagement:** Many students were off-task. There were many students walking around not working in centers. There was some engagement with the mathematics but most students were playing instead of working on the mathematics objectives.
Appendix D

Triangulation of Data Across the Research Questions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Sources and Collection Schedule</th>
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</thead>
</table>
| 1. What is the connection between the math center objectives and those of the unit? | • Center observation protocol  
  o Late January/February (beginning of measurement unit)  
  o March (beginning of geometry)  
  o Late April/May (end of geometry unit)  |
| 2. What do students engage in while participating at the centers? | • Center observation protocol  
  o Late January/February (beginning of measurement unit)  
  o March (beginning of geometry)  
  o Late April/May (end of geometry unit)  
  • PD observation of Project M2 curriculum implementation  
    o Weekly (12 weeks) |
| 3. How does the context of the centers contribute to the amount of accessibility students have in investigating the mathematics? | • Center observation protocol  
  o Late January/February (beginning of measurement unit)  
  o March (beginning of geometry)  
  o Late April/May (end of geometry unit)  
  • Teacher Exit Interviews  
    o Measurement unit  
    o Geometry unit |