5-2017

Landscape Manipulatives: A Study of Math Gardens and Learning Outcomes in Middle School Mathematics Education Research

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LANDSCAPE MANIPULATIVES: A STUDY OF MATH
GARDENS AND LEARNING OUTCOMES IN MIDDLE SCHOOL
MATHEMATICS EDUCATION RESEARCH

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Planning, Design, and the Built Environment

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by
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May 2017

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ABSTRACT

Human beings, especially children, need natural environments and outdoor play for their physical, mental, and spiritual well-being (Louv, 2008). Even though parents and teachers recognize the value of outdoor play, schoolchildren spend a diminishing amount of time engaging in outdoor activities (Clements, 2004). Furthermore, addressing strict state learning standards is the first priority for schools. Outdoor activities are often seen as extracurricular to those subjects typically emphasized and tested. As a result, outdoor landscapes such as science gardens, playgrounds, and experiential classrooms are often underutilized, discouraged since they can take away from more important, standard forms of pedagogy. Thus, traditional academic expectations associated with test scores can conflict with outdoor learning and play, this conflict becomes major obstacles to the implementation and use of outdoor learning environments. However, Lieberman (1998) has shown that environment-based education (EBE) actually facilitates standardized achievement in subjects like math, language arts, and science if specific EBE curriculums are developed based on a school's surrounding natural resources.

By borrowing from the EBE and other relevant learning theories, a new environmental design framework called landscape manipulatives (LM) is proposed. It explores the spatial and behavioral possibilities associated with learning. This study will look at how the design of LM can enhance student mathematics achievement in concepts like geometry and fractions.

The goal of this study is to help increase student achievement, particularly math scores, using LM. If successful, this new framework of LM will help environmental

designers and educators create learning landscapes that are essential counterparts to traditional math education.

Keywords: learning landscapes, environmental design, math instruction, school grounds, landscape manipulatives

DEDICATION

While writing this dissertation, my family is still 7000 miles away in China. I would first like to dedicate this dissertation to my parents. Both of them are researchers and educators who were committed to themselves to the environmental industries in China. They both have tremendous influences on me and support me through every part of my life.

Second, I would like to dedicate this dissertation to my loved wife, Qing Wei. She is my best friend in life and partner on work. She always helps me, understands me and inspires me on my side. No matter what kinds of difficulties I got, I know I am not alone because of her.

ACKNOWLEDGMENTS

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CHAPTER ONE

INTRODUCTION

1.1 Background

Natural environments are seen as the essence of both societal prosperity and individual health. Going outside to touch, smell, and sense the surrounding natural world is crucial for the development of human beings (Wilson, 1986). In particular, many scholars have demonstrated that children and youth need more connection with nature to sustain their physical, mental, and spiritual health (Kaplan & Kaplan, 1989; Louv, 2008).

Even though many educators and administrators realize the important relationship between learning, development, and nature, K-12 schools are continuing to decrease the outdoor time scheduled for students. As a result, more and more children cannot meet the minimum requirements of physical activities needed for proper health and growth (Clements, 2004; Hofferth & Sandberg, 2001). Additionally, campus landscapes such as a science gardens, playgrounds, and experiential classrooms are often underutilized. Together, these factors have led to a new problem called "Nature Deficit Disorder". This disorder leads to multiple symptoms including a diminished use of the senses, attention difficulties, higher rates of physical and emotional illness, ADHD, and obesity (Louv, 2008, p 99).

What prevents schools from promoting outdoor activities is often the burden of state requirements and testing. After the legislation of "No Child Left Behind", public schools chose strict conceptions of academic performance as the priority of their strategic planning (Education Trust, 2007). This led to enormous efforts and investments to increase

test scores, especially on routine standardized tests. Even with this herculean effort, many US students fail to meet states' standards. This is especially true in mathematics, where only 27% of eighth-grade students were testing at a proficient level (NAEP Nations Report Card, 2014). Understandably, teachers and administrators are becoming increasingly anxious about these challenges. As a result, they have decided to increase the time students spend engaged in formal classroom instruction even though research suggests that spending more time in seats is insignificant regarding improving test scores (Taylor, 2014).

To minimize the conflicts between outdoor activities and learning, many scholars have proposed new models of outdoor instruction such as Outdoor Learning, Environmental Learning, Place-Based Learning, Environment-based Education (EBE). For example, EBE has proven effective at facilitating learning on standard tests (Lieberman, 2013). More schools and states are attempting to include it in their formal curriculum. However, EBE and other outdoor pedagogic approaches often require significant time and costs, increasing perceptions about that they are difficult, inefficient, and not worth the investment (Ernst, 2007).

The challenges with outdoor learning reinforce the view that campus landscapes should be designed for recreational and decorative purposes only. Most schoolyard transformation ideas focus on introducing more pleasure gardens, ponds, and other natural habitats (Danks, 2010). Very few environmental designers have attempted to deal with alleviating challenges through campus design. This is partly due to the scant amount of literature advocating environmental designs that afford learning activities, especially those not focusing on play, and that no specific design framework purposefully addressing state

learning standards and design exists. As Kaplan and Kaplan (1989) have shown, physical environments have significant impacts on human behavior. Learning environments, when correctly designed and built, can help develop effective tools and resources that facilitate learning.

1.2 Research Goals and Procedure

This study will further investigate k-12 education, campus design, environmental design. By synthesizing multiple sources of literature and research in classical learning theories, instructional models, and environmental design, a new learning landscape framework called "Landscape Manipulatives" is proposed. The original analytic/design framework will integrate concepts of constructivism, environment-based education, math manipulatives, and play. Moreover, both programmatic and physical details will be identified.

Landscape Manipulatives (LM) are instructional interventions that integrate the power of outdoor landscapes into standard school subjects, like math. The result is not just a garden-like space, but an effective behavior setting for learning (Barker, 1976). Implementing LM create a dynamic learning environment that encourages meaningful and constructive learning. LM takes advantage of physical environments to enhance subject understanding and communication in math. Thus, my hypothesis is that students who use Landscape Manipulatives will show higher mathematics achievement scores on standardized tests and increased motivation for learning math on self-reported data when compared to a control group not exposed to the LM.

In this project, I am interested in finding causal relationships between learning and LM. Thus, I will examine the performance of Landscape Manipulatives by conducting a quasi-experiment in real middle school settings. One middle school in upstate South Carolina was identified. The prototype of Landscape Manipulatives will be constructed on their school ground. The experimental design uses Pretest-posttest design to compare the effects of the LM treatments between experimental group and control group. I will measure students' test scores and their math learning motivation levels. The math test scores will be developed by teachers. The math learning motivation levels will be collected with a questionnaire that has been validated in prior studies. To address selection and maturation bias, the experiment group and control group are randomly assigned. A teacher will administer LM treatments during the regular independent study class three times a week. The teacher that administrates LM treatments will be trained, he/she is not allowed to give any extra instruction during the treatment.

1.3 Research Questions and Significance

The major research questions are:

Q1: Do students who used Landscape Manipulatives show higher improvements on math homework scores than the students who not?

Q2: Do students who used Landscape Manipulatives show higher improvements on math learning motivation levels than the students who not?

If successful, a new environmental/pedagogic design framework with the power to facilitate students' learning and performance will be presented and validated. This will expand our understanding of the relationship between physical environments and learning

while initiating more academic discussions about the educational effects designed landscapes. Landscape designers, architects, planners, educators, and administrators may use "Landscape Manipulatives" in the future for many purposes. Additionally, scholars who are interested in education and school design will find this research valuable.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Natural Environments

2.1.1 The value of natural environments

According to Wilson (1986)'s hypothesis of Bio-philia, the natural environment is crucial to human beings' development. As human beings, we genetically evolved at two million years ago when all the ancestors lived in the savanna, caves, beaches, etc. Looking, touching and sensing living things in nature were deeply embedded in our genes. This strong affiliation with nature is one of the most basic needs from our biology.

The benefits from nature are not only physical but also mental. Kaplan & Kaplan (1989) have studied the human experiences of nature in the perspective of psychology. They noted that most people fail to regulate their time among work, relaxation, and recreation in modern lives. After intense efforts, worry/anxiety, and lack of physical activities, a spiritually "worn-out" state called Mental Fatigue (p.178) can emerge. This fatigue may cause attention issues and many unintentional mistakes during daily works. Connecting with nature can be a good way to help people recover from Mental Fatigue. In a ten-year Wildness Laboratory study (p.121-150), Kaplan& Kaplan (p.182) found that the outdoor challenge program had five psychological influences on the participants which are fascination, action, and compatibility, being away, and the concept of extent. These cognitive processes called Restorative Experiences are a self-recovering processes which will help rejuvenate people's mentality and spirits. Therefore, the restorative effects of nature cannot be ignored.

In particular, experiencing natural places such as savanna, forests, waterfalls, and wildflower meadows have even greater effects on children. Louv (2008) believes that natural environments are the Gifts (p.7) God gave to kids. In addition to the mental and physical benefits mentioned above, nature provides rich learning opportunities. At a very young age, children are active learners who are constantly learning as much skill and knowledge as they can from their surrounding environments. When children play in natural environments, all sensory skills and memories with sight, sound, smell, and gravity are stimulated and stored (Moore & Wong, 1997). They are encouraged to do more motor activities (Fjortoft, 2001). They also learned how to pay attention and make judgments in context. For example, natural play is unstructured activities with freedom and independence; the surrounding environments are so rich and complex that players are constantly taking appropriate risks and challenges. This ultimately helps cultivate children's awareness of safety (Wyver et al, 2008). Moreover, nature is a good place for creativity. In a world of leaves, tree branches, rocks, mud and all other natural elements, children have countless choices for Make-Believe play which promotes creative thinking, imagination, communication, and problem-solving (Singer & Singer, 2000).

On the other hand, when more kids are subject to insufficient contact with natural environments, they have a higher possibility of a mental illness called *Nature Deficit Disorder (*Louv, 2008, p99). This disorder will cause multiple problems such as diminished use of senses, attention difficulties, higher rates of physical and emotional illness, and the ADHD (attention deficit hyper activity disorder).

2.1.2 Lack of outdoor activities

Even though the benefits of natural environments were widely recognized, fewer children have actually engaged in outdoor play. Louv (2008) emphasized this lack of outdoor activities during the last 20 years. Playing in the woods or grassy area was normal activities in the past. Children climb trees, chase each other in grasslands, walk in the streams, and build tree houses in their backyards. They watch, touch, and manipulate natural things such as dirt, water, sand, and mud. Right now, nature becomes alien, dangerous and unhealthy places for them (p.10). Moreover, the modern culture and society have changed the parents' view of outdoor play. Parents have many concerns on traffic, uncertainty, strangers, animals, and bacteria when their kids playing outdoors. They tend to put more control and protection over their kids. Most allowed outdoor play is either overly scheduled or structured. Clements (2004) surveyed over 800 mothers in the United States to compare the differences in the outdoor lives between them and their kids. As Figure 2.1 shows, 71% of the mothers in the study said they had outdoor play every day when they were at the age of their children, while only 31% of their children did. In those interviews, all mothers did recognize the benefits of outdoor activities. But tight schedules and safety concerns prevent them from encouraging more outdoor play. Hofferth & Sandberg (2001) also have similar findings in their paper on examining how American children spent their time per week. In their results, 4¾ hours per week were spent in sports, 12 hours were spent in television watching, but only half an hour was spent in uncontrolled outdoor activities.
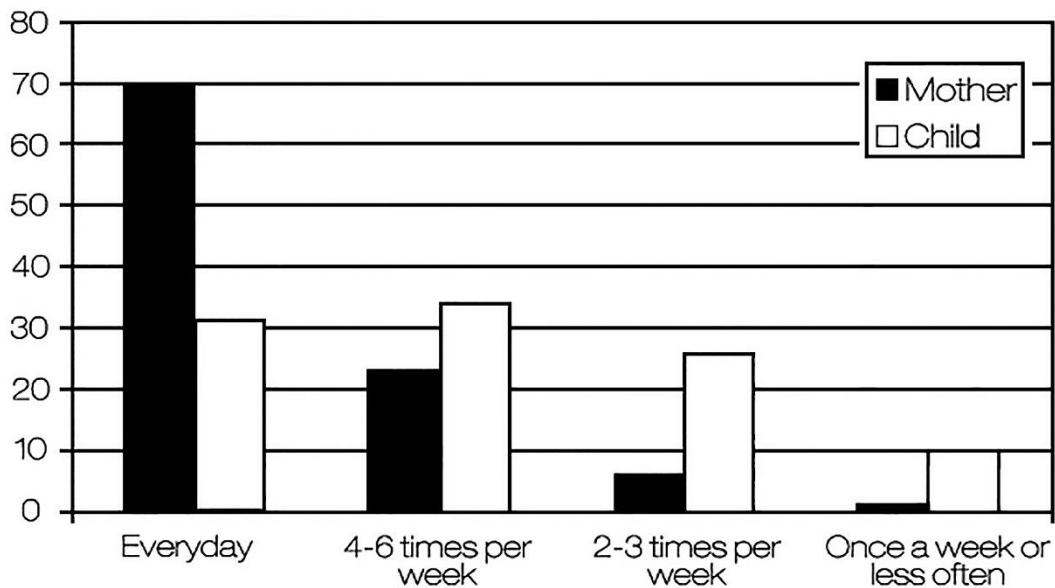
Figure 2.1: The frequencies of outdoor play between two generations (Clements,2004)

2.1.3 Schools' actions

Schools are supposed to play significant roles in promoting outdoor activities because children and youth spend most of their time in schools (Hofferth & Sandberg, 2001). However, this was not the case. In fact, US school system is very indifferent to promoting outdoor activities. Few effective policies exist. According to a study from the representative sample in National Health and Nutritional Examination Survey (NHANES), US students are facing serious decline of physical activities. Only 8% adolescents and 40% children met the recommended standards (Troiano et al, 2008). And only 48% high school students attended physical education classes in an average week. The high school students who took physical education classes daily also diminished from 42% in 1991 to 29% (CDC, 2014). As a result, this lack of physical activities became the main factor of the obesity epidemic in US (Dietz, 1998).

In fact, educators and administrators understand the benefits of physical activities. Guidelines on promoting physical activities were published as early as 1997 (CDC, 1997). However, depending on the guidelines was not enough. As Centers for Disease Control and Prevention (1997) noted, budget constraints and the growing pressure from academic requirements keeps many schools from implementing physical education for their students.

In a word, we see that people's attitudes and actions misaligned. Schools and parents did recognize the tremendous benefits of natural environments. But they do not promote outdoor activities for operational and other reasons. What creates this inconsistency? Why do schools fail to provide beneficial activities to their students?

2.2 Current Math Learning and Education

2.2.1 US math education is not satisfactory

In 2001, the legislation No Child Left Behind (NCLB) passed under President Bush's leadership. In this bill, all public schools were required to administer an annual statewide standardized test. These tests are a determining factor in schools' fiscal assistance. If certain academic requirements in the tests were not followed, schools faced decreased funding and other sanctions. Test scores become schools' first concern and of course a heavy load on teachers' shoulders (Education Trust, 2007).

In order to raise standard test scores, schools made significant efforts and investments to improve classroom instruction and learning. However, students still didn't perform as well as expected. Especially in mathematics, most American students remained at or below average in terms of mathematical achievement (Lee et al, 2007). According to the NAEP's report, the overall scores in mathematics did rise, but only 27% of eighth grade students were at a level considered proficient in the understanding of mathematical concepts (NAEP Nations Report Card, 2014)**.** South Carolina is even worse. As seen in Table 2.1, the percentage of students below basic achievement level increased from 29% to 31% (NAEP Nations Report Card, 2014). It's hard to say mathematical education is on the right track.

State	Achievement Level	Data Type	2005	2007	2009	2011	2013
South Carolina	Below basic	Percent	29%	29%	31%	30%	31%
	At or above basic	Percent	71%	71%	69%	70%	69%
	Below proficient	Percent	70%	68%	70%	68%	69%
	At or above proficient	Percent	30%	32%	30%	32%	31%

Table 2.1: the mathematical achievement in South Carolina from 2005-2013 (NAEP Nations Report Card, 2014)

A considerable number of scholars have studied the issues in mathematics instruction. One controversial topic is the traditional-based teaching approach called formal learning. Formal learning is a highly curriculum driven model used in structured class settings. In this model, teachers have specific curriculum and pacing guides to follow. Their instructions and feedbacks to students were all associated with grades (Gerber et al, 2001). This model dominates most public schools. Teachers support it because it provides a sense of control over students. It's also a type of instruction that is easy to prepare and evaluate.

However, formal learning is not a panacea. Since every student receives the learning content in an identical way, some scholars argue that excessive formal learning fails to accommodate various learning styles and intelligence (Battista, 1999). Without the customization for individual needs, it's hard to create students' understandings and apply what they learned in real world situations. Moreover, teachers who promote formal learning are interested in emphasizing competition, ability grouping, and students' relative ability (Anderman et al.1999). Outstanding students usually get more attention and instruction from their teachers. This creates a natural separation of the class. The students

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who fall behind in some subjects are not able to compete with advanced ones because they receive less help from teachers. This situation causes a stagnant learning environment where advanced students will always outperform underperformed students. Therefore, it constructs significant achievement gap in the class (Tate, 2006).

2.2.2 Math anxiety

Under extraordinary pressure, many students develop cognitive learning problems. Shulman (1999) concluded three learning pathologies that students are suffering from: 1) Amnesia where students regularly forget what they have learned in their classes; 2) Fantasia where students feel they know the concepts, but they actually misunderstand them; 3) Inertia where students don't do anything to learn, they just sit there.

These learning pathologies are concentrated in Math. Mathematics is a cumulative learning process where you have to gain an understanding of lower level concepts before moving forward to advanced ones. If students don't devote enough time and thought, they may not be successful. Unfortunately, many previous studies have shown that students' motivation for math learning has decreased (Anderman et al.1999). Poor performance in math tests may lead to math anxiety (Ashcraft, 2002) which is a negative feeling filled with concern, tension, and nervousness. If students fail to catch the passion and motivation in the beginning, they will be depressed time after time. This mental issue will lead to long-term avoidance of math learning (Hembree, 1990). It's like a negative feedback loop. Lower motivation leads to less learning efforts, then lower scores in the tests; lower scores then have negative effects back to students' motivation again.

2.23 Teach more

According to Shulman(1999), teachers often fail to make adjustments when facing difficult teaching challenges. They are subject to another pathology called nostalgia. In nostalgia, teachers would like to stick to the bedrock of formal learning when they find their students aren't learning well. They believe that students' failure is due to their insufficient teaching. When test scores decreased, teachers tend to increase the amount of instruction time to improve. This "teach more" endeavor did show meaningful gains in students' academic achievement. But in long run, it is a short-lived solution**.** According to Taylor's (2014) study, increased class time can only be a remedial intervention, the academic benefits of longer math instruction decay through time. Eventually, extra teaching will have no effects at all.

To summarize, most US math educators are in a difficult position. No Child Left Behind plays a big role in schools' policy. But their instructional approach is not efficient. Many students lose their innate passion of learning. Public schools should review and change their philosophy and management strategy. They need more effective instructional frameworks to motivate students and support their instruction.

2.3 Learning and Instruction Theories

2.3.1 Three paradigm

Ormrod (2011) defines learning as a process that "*acquire not only skills and knowledge but values, attitudes and emotional reactions as well*" (p.4). He believes that learning is mostly the result of environmental events. In the past century, many scholars have developed their conceptual frameworks to explain how learning works and which learning environments are effective. Here, I will discuss three influential paradigms in learning theories below.

The Behavioral education paradigm was by Watson (1913). Its core concept is conditioning (Myers, 2008) which assumes that learners are passive objects that constantly react to environmental stimulus. There are two types of conditioning. First is the classical conditioning where the behavior was essentially a reflex response to a stimulus. Second is called operant conditioning where the reward or punishment can increase or decrease the frequency of what associated with the stimulus. These two conditioning approaches were widely used in the Behavioral instruction. To create straight environmental stimulus, teachers usually choose to give consistent comments to their students. For example, they praise preferred behavior and criticize mistakes. This pattern of intervention then cultivates repetitive actions, students' preferred behavior will be reinforced time after time in the class.

As one extension of Behavioral instruction, Bandura (1963) proposed social cognitive learning which emphasizes the cognitive process in social context. He argued that behavior is not just dominated by reinforcements (rewards and punishments) but also

modeling which is a process of learning by observing others. Nowadays, social cognitive

learning is widely adopted in the form of students lead discussions, collaborative

working, peer tutoring, public speaking, and so on.

Then, the second paradigm Cognitivism was developed in the 1950s. Cognitivists

place a huge emphasis on thinking process. Rather than a response-stimulus model,

human learning is a mental process including attention, memory, and perception

(Lilienfeld et al. 2010). According to research in neuroscience and psychology, the

human brain acts like a computer: the data is imported, processed, coded, and then

directed to outputs. There are three memory processes in learning (Figure 2.2) which are

Sensory Memory, Working (Short-term) Memory, and Long-Term Memory (Ormrod,

2011). Working (Short-term) Memory is the central executive process that connects

Sensory Memory and Long-term Memory. This process contains two crucial elements: 1)

Attention: focusing on the material to activate sensory inputs 2)In-Depth Processing:

connect the sensory signal with previous memory. This model provides a deeper

explanation of the process of acquiring knowledge. When students pay attention to the

material and interpret them in their way, learning will be more meaningful; they also

understand things easier and faster (Ormrod,2011, p 192).
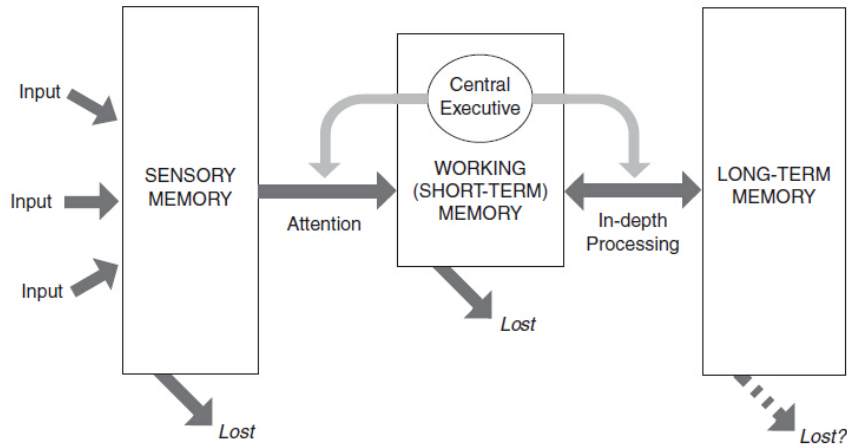
Figure 2.2: Memory process (Ormrod, 2011)

The third paradigm is Constructivism founded by Jean von Glasersfeld (1990). In Constructivism, construction is superior to instruction where learners construct their own interpretation and present the information based on individual experiences. The best learning approach is "Learning by Doing" rather than being told by the instructors. Constructivism is the foundation of many well-known learning theories and frameworks (Mooney, 2000). As the key learning paradigm in this study, three Constructivism theories will be discussed as following:

Founded in the 1930s, the first constructivism concept is Vygotsky's Sociocultural Theory of Learning. Vygotsky emphasizes the Social construction of meaning which suggests students and teachers should work and learn together. He was very interested in the interaction between students. Like class tutoring and collaboration, when students communicate and work with each other, talented students will help other classmates on their comprehension and understanding. This approach of apprenticeship is called

scaffolding. Under the process of scaffolding, more students will be introduced to the "Zone of proximal development" where they learn skills and knowledge beyond their actual capabilities (Ormrod, 2011).

The second influential theory is from John Dewey. In his book *How We Think*, Dewey made strong arguments for the value of Reflective Thinking. He believed that many behaviors were either impulsive reactions or routine actions in our daily lives. Authority, passion, dogmas and past experiences make people believe things without legitimate reasons. Few people can behave after they think critically and rigorously. At a very young age, it's recommended to have students receive purposive thought training to cultivate their critical thinking skills. Dewey proposed a model called reflective thinking which includes five logically distinct steps: 1) a feeling of difficulty, perplexity, question, etc; 2) the description of that question; 3) accumulating of a variety of alternative suggestions or hypothesis to answer the question; 4) weigh different suggestion and give final hypothesis; 5) test the value of this hypothesis (John Dewey, 1909, p72). By encouraging these steps, students can learn to make inferences and judgments using evidence instead of intuition. Based on the theory of reflective thinking, Blumenfeld et al. (1991) developed the well-known concept of inquiry-based learning. Like Dewey, inquiry-based learning also emphasizes the process of asking questions and searching for solutions. It encourages independent thinking and learning skills.

Project-Based Learning is another model based on constructivism. Contrary to paper-based, rote memorization, teacher-led classrooms, project-based learning emphasizes the collaborative investigations of "authentic problems" (Markham, 2011). It's

an informal learning that focuses on voluntary, semi-structured and interest-driven learning (Gerber, Cavallo, Marek, 2001). Therefore, Project-based learning is a good tool to motivate students. After transforming the content in textbook into real life situations, students will feel more interested and motivated in the learning content over time (Jarvis & Pell, 2005; Soloway, 1996; Rennie, 1994). Moreover, Project-based learning encourages the application of knowledge. It has shown many academic benefits including deeper knowledge of subject matter, improvement in critical thinking and problem solving (Soloway et al, 1996). Previous studies also found its positive effects on scientific reasoning abilities (Gerber, Cavallo, Marek, 2001) and the understanding of standard classroom content (Adey & Shayer, 1990).

2.3.2 Pedagogical rules

For decades, a considerable endeavor was made to integrate classical learning theories with the development of instructional strategies, policies, and guidelines in the teaching practice. In 1991, National Council of Teachers of Mathematics (NCTM,1991) published detailed guidelines regarding teachers' responsibilities for engaging and motivating students. These guidelines include 1) providing opportunities to deepen understanding; 2) orchestrating classroom discourse to promote investigation; 3) helping students use technology and other tools; 4) help students seek connections to previous experience and developing knowledge; 5) guiding individual, small-group and whole-class work. It's obvious that these items have similar characteristics with concepts like Reflective Thinking, Project-based Learning, Inquiry-based learning.

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Bloom's taxonomy is another important framework that identified different levels of instruction (Bloom et al. 1956). It provides a way to look at how administrators define the objectives of learning. Within the taxonomy, there are three big domains: cognitive, affective, and psychomotor. The cognitive domain is particularly related to thinking and comprehension. It identified six levels of learning. From lowest to the highest order, they are knowledge, comprehension, application, analysis, synthesis and evaluation. Figure 3 below shows the general criteria for each level. For example, if students can compare, distinguish, classify, and infer, they are at the Analysis level. Educators use *Bloom's taxonomy* to design their instruction plan. It's also the backbone of many teaching philosophies in public schools.

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Observe	Match	Choose	Compare	Construct	Judge
Memorize and recite	Explain	Sketch	Distinguish	Originate	Weight
Describe	Summarize	Organize	Classify	Plan	Criticize
Label	Give examples	Implement	Infer	Design	Recommend

Table 2.2: Cognitive domain of Bloom's taxonomy (Bloom et al. 1956).

We can see that many pedagogical frameworks adopted the constructivism concepts to guide the instruction and learning in public schools. However, theoretical support is necessary but not sufficient to meet the needs for guiding practical teaching jobs. Teachers need tools, resources, and protocols that can promote the application of Constructivism theory.

2.3.3 Tools and context for learning

   Different with Constructivism, Constructionism has a stronger focus on the process of making(Harel & Papert, 1991). In 1985, a media lab was built by Papert at MIT which creates advanced technology for the science of media. In this lab, Papert and his staff developed a computational tool called Logo language. By conducting multiple experiments in real educational settings, Logo language was proved to be helpful on learning fraction concepts. After the study of Logo, Papert argued that the most effective learning will take place when people are actively making tangible objects in real word (Cakir, 2008). He believed that learning-richness games like building and playing with sand castles, families of dolls, houses of Lego, etc. are powerful activities for learning. Students learn math best only when they want to make real world objects with math knowledge. Knowledge is abstract, but the making process can transform knowledge into concrete images and metaphors. Through this transformation, learning materials are more relevant than before; students will find it easier to interpret the knowledge with their understandings (Harel & Papert, 1991).

   After Constructionism, Papert defined the good learning tools as convivial tools (Harel & Papert, 1991, p29) which are the tool can "*give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision.*" All Convivial tools share two opposite but connected characteristics: 1) simplicity and transparency: they must be easy and obvious to use, even for users that are not experts; 2) complexity and opacity: the user should be able to explore lots of possibilities with the tool With c*onvivial tools,* students take real ownership of their learning. They have more

choices to explore their ideas. For example, pen and paper are powerful tools that allow people to express their ideas at low costs. Also like playing with the well-known Lego toys, every kid can be inspired just by manipulating small and simple blocks.

Different with Papert, Gee (2013) was more interested in building a learning platform. He studies human learning from the perspective of learning environments instead of tools. He believed that a digital game is a good platform for learning. Similar with the Constructivism, Gee argues that students should not spend the time to memorize facts in the textbooks, but should use those facts as tools to solve problems. What's special about Gee's theory is his emphasis on the specific context of learning which he calls situated learning. Learning different subjects needs different learning environments. If the learning material can be situated in the learning environments, students will be more engaged on learning. For instance, in digital gaming environments, students learn a large amount of knowledge and skills to win the game. They can train themselves to solve gaming problems without instructors and curriculums. Even though computer games (like Warcraft+ Civilization) are very complex and difficult to start, gamers can still make tremendous achievements and improvements whey the play. Gee believes that computer gaming is a good example of effective learning. If students can learn math, languages, science and history by playing games, they will be more successful.

Inspired by games in the entertainment industry, Gee wondered whether there is any chance to develop similar virtual environments for education. He identified 16 learning principles good educational games should follow. They include *identity, interaction, production, risk taking, customization, agency, well-order problems, challenge and*

consolidation, "just in time" and "on demand", situated meanings, pleasantly frustrating, system thinking, explore and rethink goals, smart tools and distributed knowledge, cross-functional teams, and performance before competence (Gee,2007). These principles are not only requirements for good learning games, but they are also applicable to help develop pedagogical programs in other authentic learning environments such as classrooms, labs, and colloquiums.

2.3.4 Manipulatives on math instruction

Gaming and digital media are popular topics these years, but they are still new concepts in the educational literature. When talking about good learning tools and platforms for math instruction, Math Manipulatives are one of the most influential examples.

In essence, Mathematics is a subject that teaches systematic thinking to produce solutions for problems in real-world situations (Durmas and Karakirik, 2006). But mathematics taught in public schools was often isolated from real life. This made math very difficult for kids. Because Piaget found that children do not have the mental maturity to grasp abstract mathematical concepts presented in words or symbols alone, they need more experience working with concrete materials and drawings. If educators can represent math concepts in a meaningful and tangible way, students will find it easier to recognize the connections between math and life.

To make math alive, Math Manipulatives were developed. They are interactive objects that students can manipulate to assist math understanding. Date back to 1830s, German educator Friedrich Froebel invented the first kindergarten. To help kids explore

geometry and count numbers, he designed a series of small tools and objects. He didn't notice how important these objects were in the beginning. However, his model was followed since then (Brosterman, N. 1997). Leinenbach and Raymond (1996) first used the terms "manipulatives" and "hands-on" when presenting their study about using algebra manipulatives to solve algebraic equations.

The original manipulatives were small unit squares arranged ten by ten with the total of 100 squares. Dienes (1963) developed a three-dimensional version called base ten blocks which include flats, units, rods, and cubes. Later Peter Rasmussen updates Dienes' work with more convenient base-ten tiles, which are the prototype of the popular Algebra Tiles and many other manipulatives (Picciotto, 2006). Even though there are many kinds of manipulatives products on the market, they still follow certain structures and patterns. *ETA Hand2mind* collected a glossary of all hands-on manipulatives in their websites illustrating the mostly used design of manipulatives. These prototypes for Grade 6-8 level were listed below in Figure 2.3.

*Figure 2.3: Glossary Of Hands-On Manipulatives. (n.d.). Retrieved November 30, 2014,
from http://www.hand2mind.com/resources/glossaryofhands-
onmanipulatives*

Lots of educators promote the use of Math Manipulatives. NCTM (2008) encouraged the Math Manipulatives use in math education or at all grade levels. Many states or local districts across the nation have even mandated the use Math Manipulatives. Some Textbook companies embedded manipulatives components in their series (Larson et al, 1999). Practical classroom activities with teaching strategies and detailed program guidelines are also developed to implement manipulatives (Thornton & Lowe-Parrino, 2004). These learning applications include: using graph paper for proportion, using number counters for rational numbers, using dot paper for geometry, using square tiles and number counters for number operations, using number cubes for data analysis, and using Geoboards for linear functions.

Heddens (2008) concludes the value of Math Manipulatives is: 1) relate real world situations to mathematics symbolism; 2) work together cooperatively in solving problems. 3) discuss mathematical ideas and concepts; 4) verbalize their mathematical thinking; 5) make presentations in front of a large group; 6) solve and symbolize mathematics problems

in different ways; 7) work on mathematical problems without just following teacher's directions. This indicates that Math Manipulatives are a good representation of many learning theories such as project-based learning, Vygotsky's sociocultural theory, Dewey's reflective thinking, Blooms' taxonomy, and Constructionism.

Moreover, a considerable amount of research has shown supportive evidence of the mental benefits of Math Manipulatives (Moyer, 2001).It is widely accepted that the instructional intervention with math manipulatives will result in a significant change in students' learning motivation(Scavo, 1996; Allen,2007; Betty, 2010). Ernest (1994) found that students who used manipulatives in classes were more engaged and excited about learning the class material. Their performance on class tests also increased. Buehl and Alexander (2005) found that manipulatives can encourage a higher level of learning authority on students who showed lower levels of motivation and task performances. This was also true for Tankersley's (1993) study which showed manipulatives' positive impacts on math anxiety and attitudes.

However, the researches on the effects of math tests' achievements were inconstant in previous literature. Suydam and Higgins (1977) analyzed 23 studies that used control groups who didn't use Math Manipulatives tools and treatment groups who did. In 11 studies, the treatment groups who used manipulatives showed significantly higher scores than the control groups. In 10 studies, there was no difference between two different groups. In the other two studies, control groups scored higher. Studies conducted in last 20 years also showed contradicting results. Lida (2009) synthesized the results of many previous studies in her dissertation (p.27-31).The positive correlation

between manipulatives use and achievement were found in the works from Bolyard (2005), Suh (2005) and Trespalacios (2008); neutral differences according to Drickey (2006), Posadas (2004); negative relationships in McClung's (1998). There is a great deal of variance from the research designs, time of treatment and confounding variables among these experiments. Therefore, the efficacy of manipulatives is still inconclusive.

Math Manipulatives are good tools but not magic. Hiebert and Wearne (1992) noted, manipulatives have sometimes been used in a *rote manner*. Moyer (2001) conducted a one-year study to investigate how teachers use manipulatives in typical classrooms. He found that manipulatives were sometimes used for learning and sometimes for enrichment activities or games. There are two notions in some teacher's mind when they teach a class. First is "fun math" which relate to games, enrichments, extra-time activities, and rewards. Second is "real math" which associate with textbooks, tests, procedures and algorithms, basic facts and paper-and-pencil work. Most teachers tend to describe their use of manipulatives as 'fun math' instead of "real math". They felt Math manipulatives should be used for playing, exploring, or a change of pace.

It's not surprising that teachers see manipulatives as 'fun math'. They still embrace the traditional instruction scripts which include 1) review previous material, 2) demonstrate how to solve the problems for the day, 3) practice problems, and 4) correct classwork and assign homework (Stigler& Hiebert, 1999). Teachers prepare a large amount of teaching materials following these procedures for many years. The stress from state requirements still has big impacts on teacher's preference. They tend to stick to the standard instruction routine (Talyor, 2014).   There is no spare time to plan for serious instruction with

manipulatives (Moyer,2001). Unless teachers know how to use manipulatives to increase students' test scores, they will see Math manipulatives as "fun math' forever.

2.3.5 Envirnment based education

1. Outdoor environments and learning have conflicting interests

Because of the concerns from learning requirements, it's difficult to implement natural environments into classes in public schools. Very few schools encourage outdoor activities in their formation instruction. Therefore, the concept of outdoor learning was proposed as one solution to mediate the conflicts between learning and outdoor activities. It aims to promote outdoor activities without sacrificing academic instruction. There are three major forms of outdoor learning: (1) fieldwork and outdoor visits; (2) outdoor adventure education; (3) school grounds and community projects. These forms of activities have shown increased passion, renewed spirits, and improved learning performance (Rickinson et al, 2004; Dyment, , 2005) . They transformed the context of learning from indoor to outdoor, from textbook-centered environment to nature-centered environment. When students have a chance to "handle, touch, smell, and even taste the materials they are learning with and from", learning becomes more meaningful (Dyment, , 2005, p 30).

However, outdoor learning is still not very popular for schools. According to Barker et al (2003), outdoor learning programs are suffered from a substantial decrease in recent years. UK-based Field Studies Council and British Ecological Society described their outdoor learning programs as 'heading for extinction'. In Canada, environmental science has been seen as a well-suited teaching subject for outdoor learning,they also removed it from their curriculum (Puk and Behm, 2003). Dyment(2005) surveyed 451 elementary

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schools and 102 high schools on the use of campus green grounds. As what the Table 2.3 shows, the most taught subjects on the school ground are physical education and science. While subjects relate to other standard tests such as math, language arts, and geography were not taught very often. Especially, only 12% respondents answered "Often/regularly" on Math.

		Percentage of respondents reporting		
	N	Never/ rarely	Sometimes	Often/ regularly
I use our school ground to help me instruct curricular material related to:				
(1) Language arts	127	41	39	20
(2) Mathematics	125	53	36	12
(3) Physical education	130	24	29	47
(4) Geography	128	46	32	22
(5) Science	134	21	32	47

Table 2.3: Percentage of respondents in one Green Ground Survey item (Dyment, , 2005)

After reviewing the literature on multiple studies of outdoor learning, Rickinson et al (2004) synthesized the reasons behind the decrease of outdoor learning. There are five key barriers as 1) Fear and concern about young people's health and safety (e.g. issues around liability); 2) teacher's confidence and expertise in teaching and learning outdoors (e.g. lack of pre- and in-service training for teachers); 3) The requirements of school curricula; 4)Shortages of time, resources and support (e.g. too much extra work for teachers, lack of funding, transportation complications); 5) Wider changes within the education sector and beyond (e.g. larger class sizes, institution-wide timetables limit opportunities for field work, emphasis on back to basics) (p.6).

To summarize**,** teachers always prioritize standard test scores. Outdoor learning still doesn't have effective support for academic learning. The outdoor learning class is seen as teaching jobs in addition to the mandatory standard curriculum. We need a more effective outdoor learning program that can effectively facilitate academic learning.

2. EBE is a successful strategy that integrates nature in standard learning with the aim of increasing test scores

In response to the shortage of outdoor learning, *Environment-based Education* is a standards-based instructional strategy that took academic performance seriously. The EBE approach takes advantage of natural environments to engage students in "real world" learning experiences. Its goal is to help students "*achieve higher levels of academic success, as well as an understanding of and appreciation for the environment and issues related to sustainability" (SEER, 2014).* This educational model was developed and copyrighted by the State Education and Environment Roundtable (SEER) (Lieberman, 2013).

EBE emphasizes students' proficiency on state and school district standards including the Common Core State Standards and Next Generation Science Standards. It is designed to be an integral part of the standard curriculum but to proceed in outdoor environments. For example, math teachers would take students in their math classes to the streams banks around the campus. It's a real course, teachers give homework assignments and interactive lectures. On the site, students learn skills on how to measure and calculate site slopes, stream depth, and water follow speed. They provide quantitative evaluations of bank erosion using the math knowledge learned in the classrooms before.
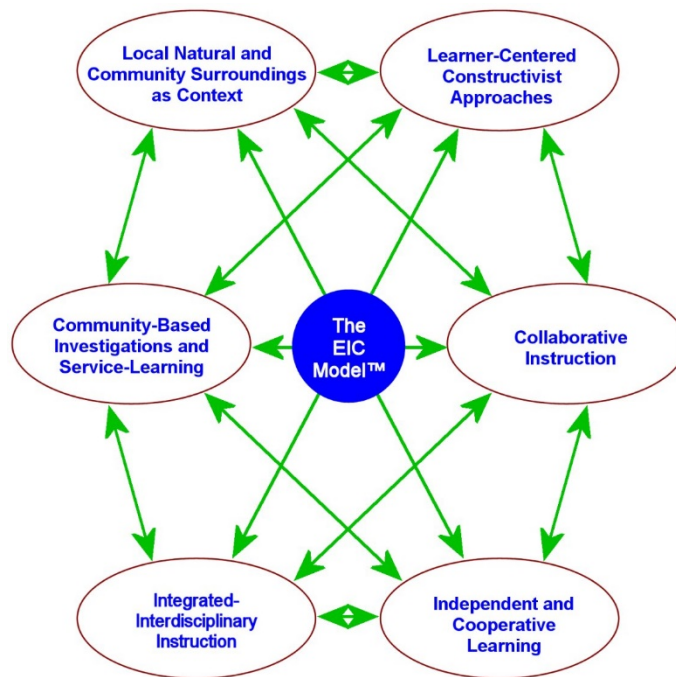
Figure 2.4: The EIC Model (SEER, 2014)

Moreover, EBE functions with a strong theoretical basis called EIC (environment as an integrated system). It is an integrated framework to facilitate meaningful learning. As what Figure 2.4 shows, EIC model weaves many constructivism educational principles including Local Natural and Community Surroundings as Context, Learner-Centered Constructivist Approaches, Community-Based Investigations and Service-Learning, Collaborative Instruction, Integrated Interdisciplinary Instruction and Independent Cooperative learning. These concepts enrich students' learning experience because of their emphasis on individual difference and social interaction. They provide platforms for constructing knowledge and meaning in the process of learning.

Because EBE programs are site specific, a good site is the first and most important step (Lieberman, 2013). Every school has to develop their own EBE curriculum based on

their site conditions. In order to accelerate the program developing process, SEER sends professional consultants to work with the school district and individual schools every year. Basically, SEER will work through the whole process including both implementation and evaluation (SEER, 2014). Their consulting work can guarantee the quality of EBE (Lieberman, 2013). They assist schools to identify and implement site-specific teaching programs. They also conduct workshops for professional training where teachers can learn operational skills on how to teach and evaluate EBE classes.

According to empirical research of 14 schools (Table 2.4), the academic efficacy of EBE is significant. In a total of 39 studies using comparative analysis, an average of 92% students who had EBE got better test scores than the students who didn't have EBE. For mathematics, 75% students improved their scores (Lieberman et al, 1998). This efficacy on improving academic learning is very important. It makes EBE a widely accepted and practiced model in public schools. In recent 18 years, SEER has worked for 700 schools across US. Twelve states (California, Colorado, Florida, Iowa, Kentucky, Maryland, Minnesota, New Jersey, Ohio, Pennsylvania, Texas, and Washington) have joined. More and more people are interested in implementing EBE for teaching English-language arts, math, science, and history-social science (SEER, 2014).

Area of Assessment	Assessments Indicating EIC Students Perform Better than Traditional Students		Total Assessments Administered
	Percent	Number	
Comprehensive Assessment	100%	9	9
Language Arts	100%	17	17
Math	71%	5	7
Science	75%	3	4
Social Studies	100%	2	2
Totals	92%	36	39

Table 2.4: The EBE research (Lieberman et al, 1998)

3. EBE's weakness

However, EBE has its own weakness. Ernst (2007) conducted a national survey with aconvenience sample of 287 K-12 teachers who used EBE in their classrooms. This survey investigated the barriers of implementing EBE for teachers. The result is different with the barriers of outdoor learning where academic requirements are the main obstacles, more of the factors influencing teachers' use of EBE are associated with practical issues. For instance, six of ten top items in Figure 8 below were problems like funding, time, transportation, training, administrative support, and safety. To establish an EBE program, schools need to pay consulting work of SEER. They also have to prepare operational equipment and tools for site specific classes. Moving inside to the wild is extra work for most teachers. Even if they are willing to, they can't afford. Moreover, good natural contexts like water bodies, woods, and streams are difficult to reach. Many campuses are not located around natural resources, more transportation and time is needed.

On the other hand, concerns on academic contribution are not the most significant factors in Ernst's study. As the results showed in Table 2.5, *"the emphasis on state standards"* were less significant than *"the lack of funding and planning time."* Some items with academic concerns such as "Emphasis on state standards," "the grade level I teach" and "the subject area I teach" have a lower value than practical items such as climate, safety, transportation, funding, time, etc. So teachers did have somewhat confidence in EBE's efficacy on academic performance. This is a huge improvement comparing to the Outdoor Learning model where academic performance is the largest concern. It indicates that EBE has better academic contribution than Outdoor Learning.

Barrier	M^a
Emphasis on state testing	2.61
Lack of funding	2.60
Lack of planning time	2.34
Emphasis on state standards	2.31
Lack of transportation	2.13
Lack of training or professional development	1.79
Concerns regarding safety, liability, and classroom management	1.79
Lack of administrative support	1.73
Lack of environmental content knowledge	1.64
Lack of procedural/pedagogical knowledge	1.61
Counter to school climate	1.61
Comfort level with traditional teaching	1.41
Lack of natural area to study	1.40
Lack of community interest/partners	1.34
Lack of parent support	1.30
The grade level I teach	1.15
The subject area I teach	1.13
Lack of comfort in the outdoors	1.13

Note. n = 62.
$^a 1$ = *not an obstacle* to 5 = *very strong obstacle.*

Table 2.5: Barriers to Teacher's Implementation of EBE (Ernst,2007)

2.4 Environmental Design

2.4.1 The power of environmental design

　　Physical environments play an important context for human behavior. Through proper planning and designing, environments can facilitate or depress specific human behaviors or activities. According to Kaplan (1989), when people interact with their surroundings, they cannot help to understand and explore the visual content and form of the environment. They are our immediate and innate reactions. If the environments are not compatible with our purposes, we will get lost and are unlikely to perform well. This is also true in Gibson & Pick (2003)'s concept of Affordance. When subjects are perceiving certain properties, the physical environment can stimulate, attract, or 'afford' human actions. For example, Cosco's (2006) study found a strong correlation between physical activities and environmental design features in multiple child centers. Through behavior mapping and video tracking, more physical activities and movement was shown in the area that contains natural elements and a wide, curvy wheeled toy pathway. In schools, the highly controlled and scripted learning activities in traditional classes are also (Stigler& Hiebert, 1999) reinforced by the design of classrooms. The orientation of blackboards, the arrangement of seats and tables is so static that it formulates the social interaction in classes. Teachers can have more effective control over students. In contrast, Papert designed new learning labs that aimed to facilitate the movement around the classrooms and help students integrate computer activities with normal learning activities (Harel & Papert, 1991). In this case, Papert found his new learning spaces shaped a better learning culture in the end.

Moreover, the power of environments was well recognized in the field of environmental design. In Barker's (1976) concept of Behavior Settings, he argues that people, physical components, and behavior are inseparable components in environmental design. Effective design guidelines should include identifiable boundary and spatial characteristics that support target behaviors. Interior design, landscape design, and architecture design are not just for decorative purpose. Nowadays, more and more designers were trying to integrate programmatic and behavior factors into their conceptual design. Design frameworks in the field of healthcare, work and production, resorts, transportation, etc., are also established and widely used in practice.

2.4.2 Landscape designs for children and youth

Regarding designing places for children and youth, there are two main foci in the existing literature: one is play, the other is natural environments.

Play is an indispensable topic for children. Brown& Vaughan (2010) proposed six play pattern systems as Attunement Play, Body and Movement Play, Object Play, Imaginative Play, Social Play, Storytelling and Narrative Play and Transformative-Integrative Play. Various play behavior concepts, such as Functional Play, Constructive Play, Symbolic Play, Sociodramatic Play are developed (Frost, 1991). These play theories were integrated into playground design through time. In the recent 200 years (1800s to the 1990s), from the outdoor gymnasium, sand gardens, kinder gardens, to public school grounds and parks, the evolution of playground design never stopped (Frost, 1991). Old playgrounds are usually simple and uniform, most slides and sand boxes use the same equipment, dimension, texture, and color. Right now, the form and

content of playgrounds are significantly customized and diversified. Frost (1991) believes that future playgrounds will be All-inclusive which can afford all kinds play behaviors and patterns, all ages, all ability levels, and all sensory types.

Risk and safety are the other big concern for play spaces. The traditional approach was to provide standardized play structures which are engineered according to the safety handbook. Safety designs such as round corners, soft surfacing, gentle steps, flat platforms, etc. were universal in many playgrounds. However, this "surplus safety" with engineered spaces fail to afford various play needs and even expose children to serious threats of accidents because of unconsci (Wyver et al, 2010).

In contrary to the structured environments, the free, unstructured play environments have messy and unorganized looks.Playing in these places are more fun and exciting because the spaces and materials in the playground are so diverse that every play is different. (Moore&Wong, 1997; Titman, 1994). It's reported that the richness and variations of topography and vegetation of unstructured natural playgrounds can encourage more motor movements such as climbing, jumping, running and also social skills (Fjortoft, 2001; Fjortoft & Sageie.,2000). They are also safer because children tend to have a stronger awareness of surroundings and safety consciousness when they play (Frost, 1991).

In recent years, many playground designers and landscape architects incorporate nature into their design. More and more professionals developed specific recommendations on how to design and construct effective natural environments for children. Tai et al. (2006)'s book identified key considerations throughout the design process such as

buildings, climate, geology and soils, hydrology, circulation, topography, utilities, vegetation, views, etc. She also included the guidelines for six design themes which are adventure gardens, edible garden, memorial garden, a music garden, storybook garden and water garden. Later, White (2008) proposed lots of practical suggestions on how to find natural materials, how to grow plants, how to conserve and reuse water, and how to encourage different kinds of play activities. He also shared various detailed techniques on how to take advantage of landscape features such as stepping stones, retaining walls, tree trunks, boulders, trellises, etc.

In terms of public schools, Danks (2013) criticized the traditional design strategy of school grounds. In her opinion, current schools only provide "one-dimensional environments" in which their designs have no consideration on students' exploration and discovery. The school designers should emphasize more on the ecological dimension. The school campus is also an ecosystem that includes the water cycle, energy, and food. When school yards transform to green habitats, there will be more dynamics to explore and investigate for both students and teachers. To achieve this, Danks (2013) has developed specific site design guidelines for green school including site selection, multipurpose design, space definition, place-making features, circulation, comfort, outdoor classroom space, and signage.

2.5 The Missing Piece

  This research aims to work on two issues in public education: 1) the lack of outdoor activities; 2) the failure of math instruction. In order to study the theoretical backgrounds of these issues, the previous sections have introduced the literature in four bodies of knowledge which are natural environments, learning and education, pedagogy, and environmental design. Most of this literature is interconnected. For example, the pedagogical concepts such of math manipulatives, outdoor learning and EBE are based on learning theories and education; The natural environment theories like Bio-philia (Wilson,1986) and natural learning(Moore&wong,1997) are also embedded in both pedagogical concepts (Outdoor learning /EBE) and environmental design.

  Unfortunately, the links between learning and environmental design seem to be missing. EBE is currently the most effective and comprehensive pedagogical framework that includes both learning and natural environments. It takes advantage of natural environments as the learning context to integrate with constructivism learning theories such as situated learning, project based learning, the sociocultural theory of learning, reflective thinking, etc. However, the lack of available green and poorly designed school grounds decrease teachers' interests in teaching outdoors (Dyment J. E., 2005; Ernst, 2007). Very few designers have the knowledge and theoretical support to appropriately design outdoor landscapes to encourage or support learning activities effectively.

  The missing piece in the environmental design literature is a framework that aimed to facilitate learning and support the implementation of EBE. Although Tai et al. (2006) and Danks (2013) mentioned the importance of connecting standard curriculum with

school design, there are still no specific design frameworks that can systematically integrate learning, instruction, and play. If a group of landscape designers would design a space for learning specific subjects like math, they have very little theoretical support. What should be the goals and objectives of their design? What should be the appropriate activities occurring on the site? What are the characteristics of place making features? How best to organize these features? How to effectively use the spaces? All these questions need to be addressed by developing a specific framework with strong theoretical basis so that designers can be more confident on their decision makings.

2.6 Landscape Manipulatives

To fill the gap in the existing literature, I proposed a new environmental design framework called Landscape Manipulatives (LM). This framework includes a theoretical framework and a Prototype design.

2.3.1 Theoretical Framework

The theoretical framework illustrates the behavioral and programmatic descriptions based on the theories embedded in outdoor learning, project-based learning, math manipulatives, instructional design, landscape design, and the design process. There are five interdependent layers and processes shaping LM to answer two questions: 1) how do students learn from landscape manipulatives? 2) How do we know if learning occurs? These layers and processes (Figure 2.5) are play, ownerships, manipulation, problem-based, situated learning and environment-based learning.

- Play (freedom, guided, fun, decision-making)

-This layer refers to theories of play patterns and play behaviors (Brown & Vaughan, 2010; Frost, 1991), and is an indispensable component in helping children to become engaged in learning activities. Specific learning objectives guide the learning and play events in LM but give students the freedom to make decisions on their learning approaches.

- Ownerships (relevancy, participation, meaning)

-LM emphasize a sense of ownership by creating environments that allow students participate in individualized learning activities with stronger relevancy and meaning.

- Manipulation (loose parts, choice, creativity, imagination)

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- The learning events in LM assimilate learning with Math Manipulatives. By taking advantage of loose parts to promote a sense of manipulation. More learning choices can inspire more creativity and imagination through the learning events.

- **Problem-Project (goals, indeterminate, interactions)**

- This layer demonstrates the essence of LM which is the constructivism learning paradigm which emphasizes individual growth, diversity, and social communications. All LM learning starts with as a problem and finishes as a project.

- **Situated Learning (relevancy, design-make, hands-on)**

- This layer emphasizes the environmental power in learning. By encouraging hands-on and design-make activities, LM creates situations that students can find the relevancy between themselves and learning contents.

- **Environment-based Learning (outdoor, standards, assessment)**

- Environment-based learning is what LM are based upon. Connecting with mathematical curriculum and supporting state standards will comprise the first objective of the study.
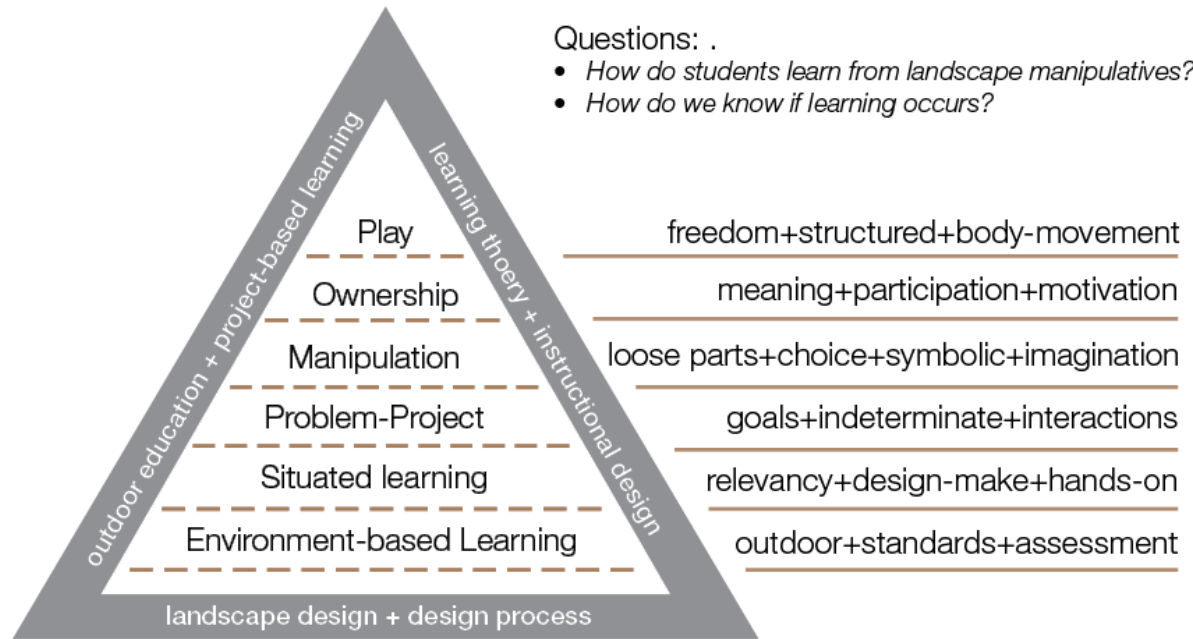
Figure 2.5: Landscape manipulatives framework

2.3.2 Prototype design

Based on the concepts in the LM framework, a prototype design was developed (Figure 2.6). This project consists of 36 square blocks with five vertical columns (5 sections). All points and edges are strictly measured and controlled. Inspired by the form of Math manipulatives, LM situate students in a real-world and human-sized 3D coordinate system. It aims to maximize their manipulation, ownership and play in the learning process. With the help of loose parts like plastic chains, aluminum spring snaps, tie out stakes, measuring tapes, flags, etc., students will be able to perform mathematical tasks in counting, sorting, ordering, recognizing geometric shapes, making measurements, using the base-ten system of numbers, mathematical operations, exploring and describing spatial relationships and representing mathematical ideas. The simplicity and flexibility of the

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design allow students to freely explore many kinds of geometries in the site that correspond

to the math concepts.
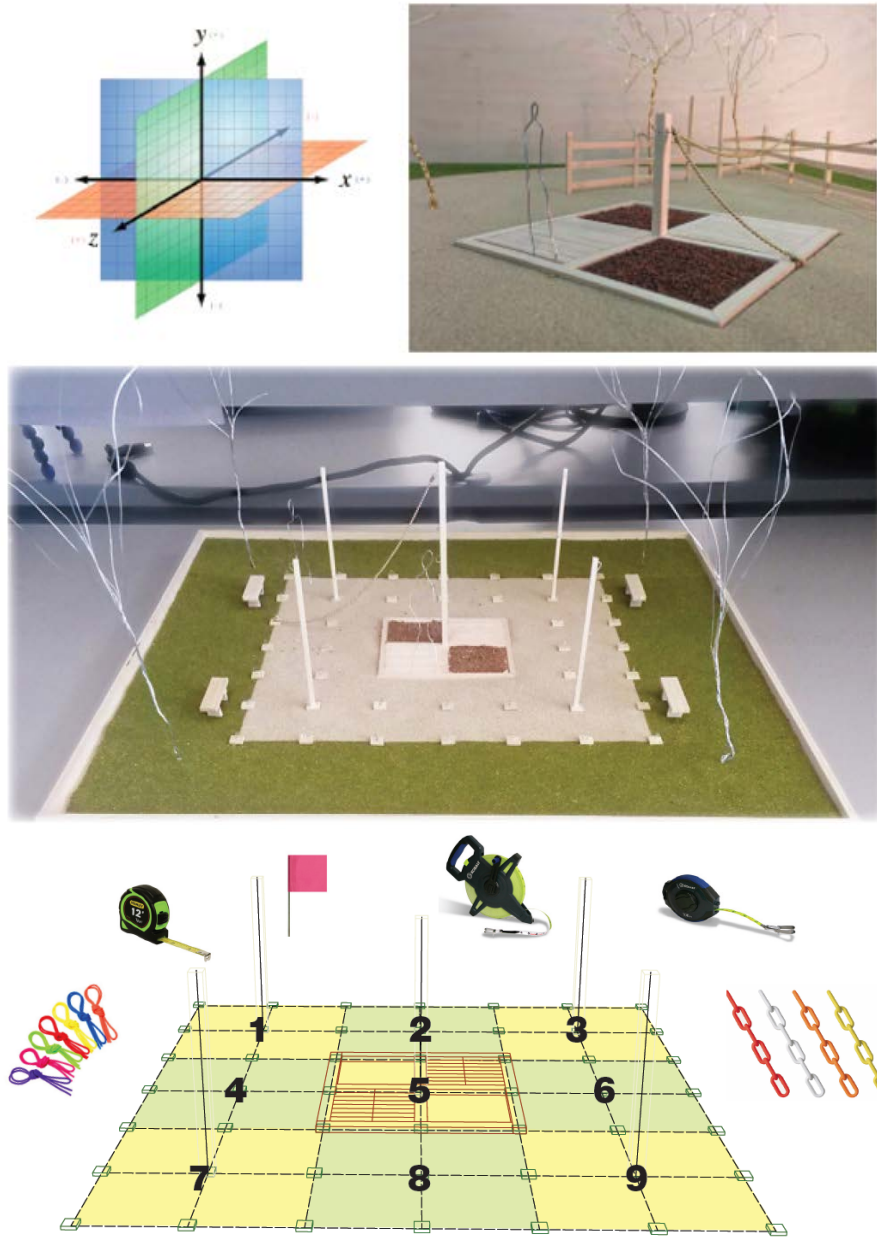
Figure 2.6 Landscape manipulatives prototype

2.3.3 Landscape Manipulatives treatment

To effectively take advantage of LM's power for learning, I also introduced a strategy for teachers to help students learn geometry concepts using the LM prototype. To control the quality of the LM intervention, a teacher will serve as a facilitator to the LM learning session, paralleling the classroom experience. He/she will follow a standardized procedure to use the space. This procedure includes three major components as described below:

1) Learning Initiation:

a) Students are separated into groups (4-9) within the math garden.

b) Teacher provides a sheet of the homework book with math questions to the students.

c) Teacher explains the task to students: Each group has to work on the math concepts by manipulating the loose parts provided.

2) Manipulation

a) Teacher distributes the loose parts to students, each group starts manipulating those loose parts to help represent the math concepts.

b) During the session, the teacher serves as an administrator and facilitator rather than an instructor. Students work on their own, but the teacher may answer students' questions. (Figure 2.7).

Figure 2.7: Students Using Math Manipulative for Geometry

3) Check the results

      a) Upon completing the math manipulation, student groups should hand in their homework to the teacher.

      b) Teacher provides constructive comments and feedback for student groups' work.

      As Figure 2.7 above shows, the first math manipulative was pilot tested at Dacusville Middle School in Easley, South Carolina. After a short training session, teachers were able to understand the standardized LM procedure and use the math garden appropriately for LM treatment. Additionally, students were also able to use the math garden in creative but appropriate ways.

CHAPTER THREE

METHODOLOGY AND RESEARCH DESIGN

The research questions require the establishment of causal relationships between the independent variable and dependent variable. At the same time, it's also preferred to have the study conducted in natural settings so the research events can have similarities to the everyday phenomenon. Therefore, this study will employ a quasi-experimental design in real middle school settings.

3.1. Research Method Overview

3.1.1 Research Questions and Hypothesis

The purpose of this study is to examine the efficacy of Landscape Manipulatives for middle school students' math learning. The major question will be: Does the use of Landscape Manipulatives improve students' academic performance and learning motivation in the subject of mathematics? To answer this question, Two research hypotheses based on specific measurements and research design are used:

Hypothesis 1: The students who used Landscape Manipulatives show greater performance on math test scores than the students who not.

Hypothesis 2: The students who used Landscape Manipulatives show higher performance on math learning motivation levels than the students who not.

The independent variable is whether or not students used Landscape Manipulatives for Math homework. The dependent variable is the students' math test scores and math learning motivation levels. The control variable will be the grade level of students. The

expected extraneous variables which also influence the dependent variable include students' gender, age, family background, classroom and school organizations, and math ability (Lamb & Fullarton,2000). Since this is an outdoor learning experiment, outdoor conditions such as weather, noise and site location can also be extraneous variables.

3.1.2 Measurements

The academic learning performance of math is the most important factor that this study will measure. There are two major components including math achievement and math motivation which are correlated with each other with strong positive feedbacks. Math achievement increases math motivation, and math motivation promotes higher math achievements. So if both motivation and achievements raise, we will be confident to conclude the math academic learning improved. The primary constructs and operational definitions are show in Figure 3.1.

```
                    ┌─────────────────────────┐
                    │      Math motivation    │
                    └─────────────────────────┘
            ┌───────────────┴───────────────┐
     ┌──────────────┐                ┌──────────────┐
     │ Expectations │                │    Value     │
     └──────────────┘                └──────────────┘
            └───────────────┬───────────────┘
                 ┌────────────────────────┐
                 │   Conley & Karabenick  │
                 │    (2006)'s study      │
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│Interests││ Achivement││ Utility ││ Cost  ││ Value ││ Confidence │
│         ││  /goals   ││         ││       ││       ││            │
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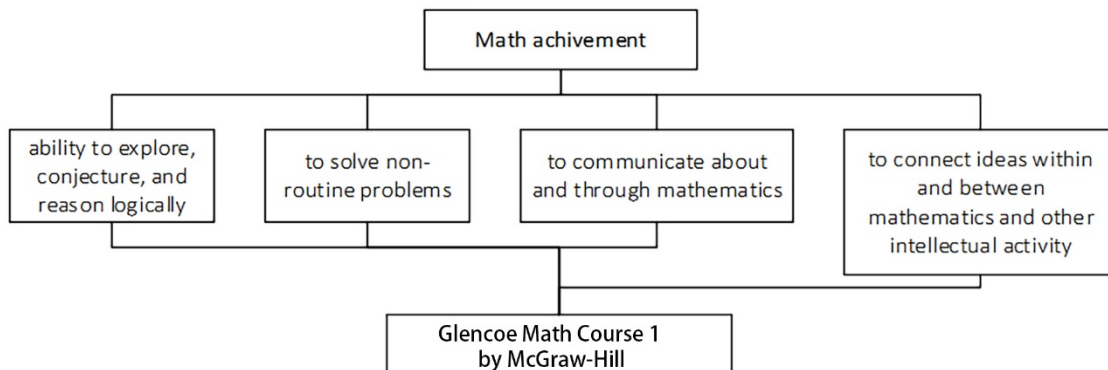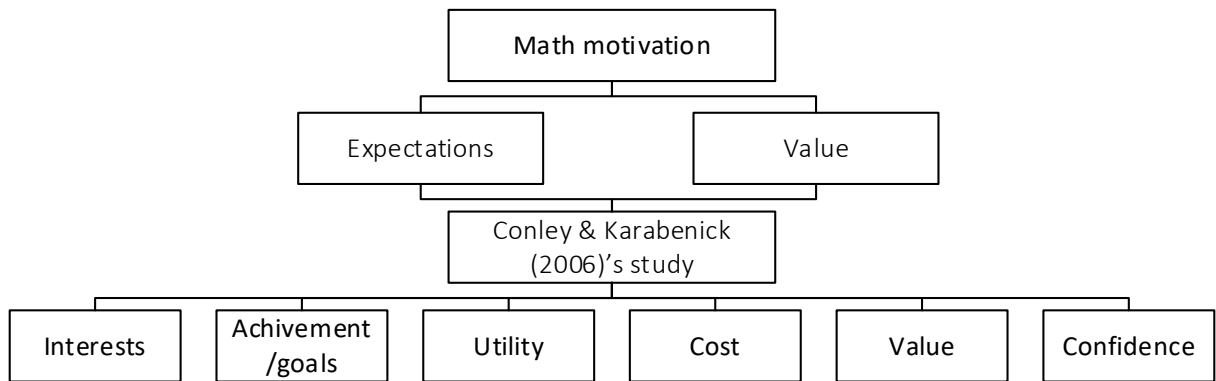
Figure 3.1 The operational definitions of measurements (NCTM,1989; Conley & Karabenick, 2006)

- Math Achievement

In 1989, National Council of Teachers of Mathematics (1989) published their requirements for students' math learning, which include the ability to explore, conjecture, and reason logically; to solve non-routine problems; to communicate about and through mathematics, and to connect ideas within mathematics and between mathematics and other intellectual activity. These requirements are the criteria most states tests are based. This study will use the online test called Glencoe Math Course 1 developed by the company McGraw-Hill which has been one of the most trusted sources for providing customized educational content. It was also the routine test book being used for many SC middle schools.

- Motivation

Motivation is the key component of math education. It significantly affects students' thinking, feeling, and behaviors in schools (Schunk et al., 2013). The empirical studies have shown that motivation has the predictive value of expectations on achievement (Boe et al., 2002) and choices on course selection (Jacob et al.,1998). Especially,

motivation promotes intellectual performance and the construction of knowledge (Sinatra & Pintrich, 2003). It is a salient factor in students' achievement particularly in mathematics and science (Singh et al., 2002). Therefore, this indicator was widely used in educational research.

The expectancy-value theory of motivation is one primary method to measure motivation levels. It includes two significant components which are students' expectations for success and relative value they ascribe to the task. The expectations are the representation of one's beliefs about the consequences of an action. The value relates to students' beliefs regarding the importance or usefulness of what they do (Wigfield & Eccles, 2002).

There are multiple versions of motivation tests following expectancy-value framework. Conley & Karabenick (2006) did a comprehensive study on the construct validity issues in the measurement of motivation. They surveyed 8429 students with 110 items of different categories and then conducted a factor analysis to examine the loadings of each item. The significant items are shown in Figure 3.2. These items were grouped into six categories which are interests, utility, cost, value, confidence and achievement/ goals. The results were then used and upgraded in Andrea et al. (2011)'s summer program study. This study also follows Conley & Karabenick (2006)'s findings to measure students' motivation level. This study will use Conley & Karabenick's results as the instruments for measuring motivation levels. The sample questionnaire was attached in Appendix B.

(Interests)
1. I enjoy doing math.
2. I like math.
3. I enjoy the subject of math.
4. How much do you like doing math?
5. Math is exciting to me.
6. I am fascinated by math.

(utility)
7. Math will be useful for me later in life.
8. Math concepts are valuable because they will help me in the future.
9. How useful is learning math for what you want to do after you graduate and go to work?
10. In general, how useful is what you learn in math?
11. Being good at math will be important when I get a job or go to college.
12. Compared to most of your other school subjects, how useful is what you learn in math?

(cost)
13. I have to give up a lot to do well in math.
14. Success in math requires that I give up other activities I enjoy.
15. It is important for me to be someone who is good at solving problems that involve math.

(value)
15. It is important for me to be someone who is good at solving problems that involve math.
16. Being someone who is good at math is important to me.
17. Being good at math is an important part of who I am.
18. It is important to me to be a person who reasons mathematically.

(confidence)
19. How sure are you that you can do even the most difficult math?
20. In the future, I think I will do well in math.

(achievement/goals)
21. My goal is to learn as much as I can
22. My goal in math is to look smarter than other students
23. My goal in math is to avoid looking like I can't do my work

(Conley,Karabenick, 2006)

Figure 3.2 The motivation items (Conley & Karabenick, 2006)

3.1.3 Sampling

The sampling starts with the study population which is the middle school students in South Carolina Upstate. There are than 100 middle schools with about 20,000 students located in this area. Most schools are public schools which are run and funded by the government. The sampling frame will be obtained by inquiring school districts for the students' lists. The sampling unit is the individual middle school student.

To effectively select the samples that represent the population, the sampling design will employ the multiple stage sampling. Under practical limitations, it's hard to sample students from the sampling frame directly. So the sampling process will split into two stages. The first stage is choosing schools. The researcher will contact all schools and ask for permissions to conduct the research, including Landscape Manipulatives

construction and treatment. Then the researcher will assign one school from the list of

schools who provide permissions. The second stage is choosing students. The students

who participate in the research will be all six grade students.

| Middle schools who provide permissions | → Permission → | Study schools | → Entire Six Grade → | Final student sample |
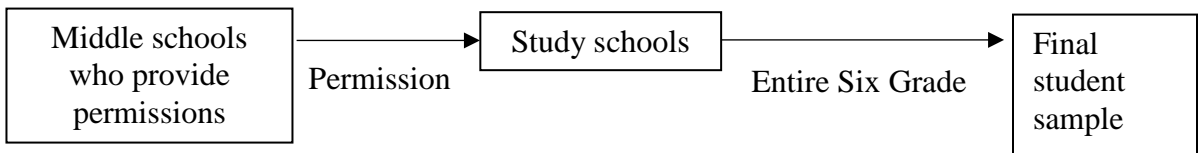
According to the estimate population size of 20 thousand, with the error of 10%

and 5% confidence level, the expected sample size will be 96.

3.2 Quasi-experimental Design

As early as 1958, Page conducted an experimental design in his study of teachers' comments on students' performance**.** Singleton (2009) complimented his research as the first to illustrate the significance of the experimental research. As the golden standard on developing causal relationships in the social phenomenon (Singleton, 2009)**,** the experimental research design was widely used and valued in social science studies.

3.2.1 Context

This study will conduct a quasi-experimental design in real educational settings. As Figure 3.3 illustrates, the middle schools have four nine-week sessions in their standard math curriculum every academic year. Based on different conditions of each participating school, this study will pick a one-month session in the curriculum cycle as research period. The schools in SC upstate share similar bell schedules and curriculum structure. There are six hours of standard learning classes including math, language arts, social science and science and one-hour classes or independent studies. For the independent study, students are randomly split into two groups with two different teachers. The Landscape Manipulatives treatment will be given to one student group known as the experiment group (n=127) for five total periods per school day. The other student group is the control group(n=123) for five total periods per school day.
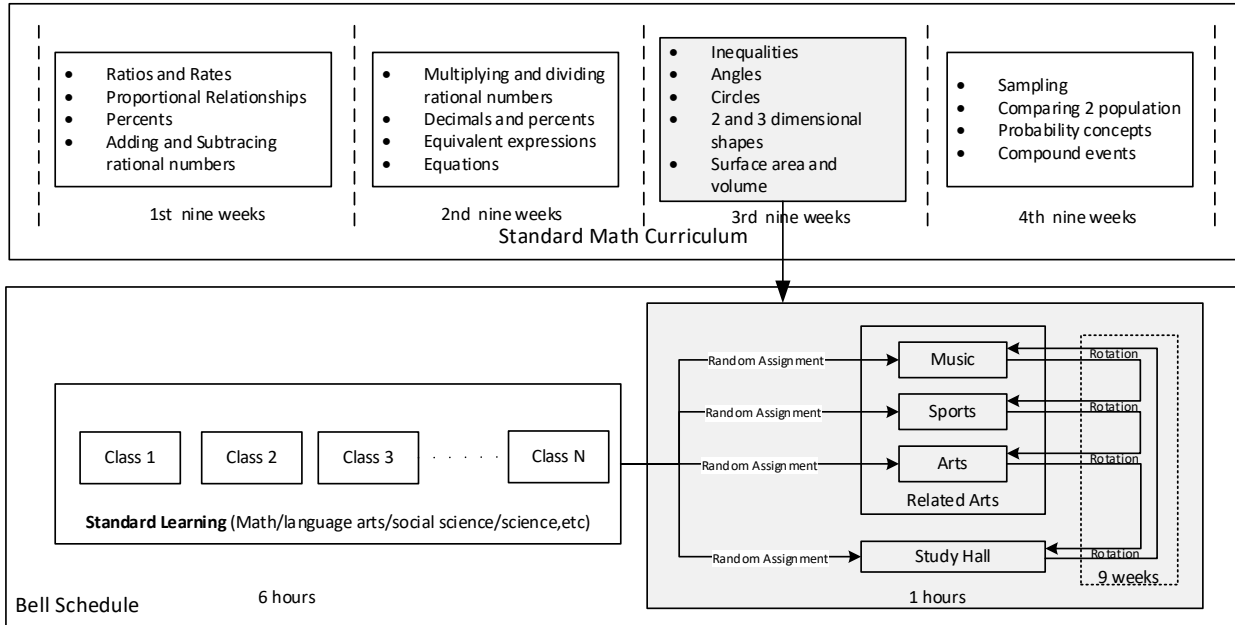
Figure 3.3 The context of the study

3.2.2 Landscape Manipulatives Preparation

The preparation of Landscape Manipulatives has two parts: 1) constructing the math garden on the school grounds; 2) obtaining the loose parts.

Math Garden Construction

As figure 3.4 shows, the design components of the math garden include a square grid in the field and seven vertical posts. Each grid square has a dimension of 4ft by 4ft. The whole site has 36 squares with a 24ft by 24ft size. Each vertical post is 8ft long with 2ft under ground and 6ft above the ground. At each grid point, there are hooks and stakes in the ground to help students connect ropes and chains. All grids and posts are strictly

measured and marked. This math garden conforms to the principle of the LM prototype design which represents a real-life 3D coordinate system with simplicity and flexibility.
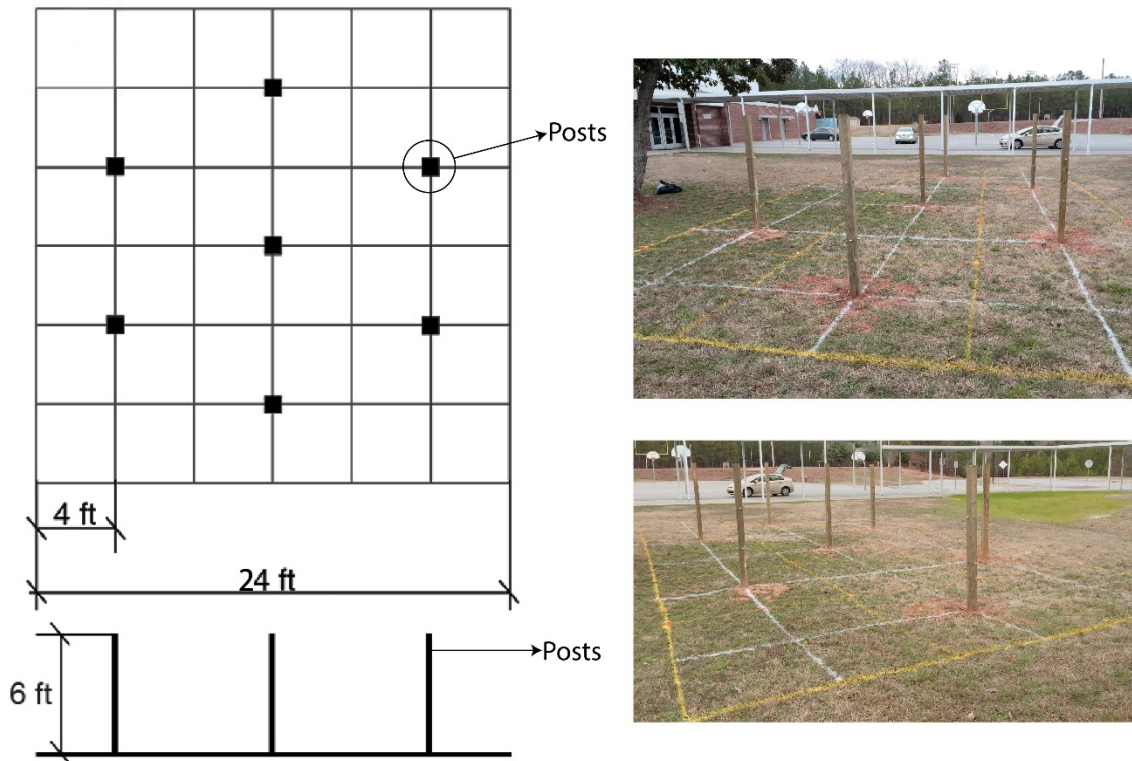
Figure 3.4 The design and construction of the math garden.

<u>*Loose Parts Preparation*</u>

Five student groups are using the math garden during the treatment session. They will need a lot of loose parts to make math manipulations. Therefore, all loose parts were put into five different boxes to make them well organized. As the figure 3.5 shows, each box includes:

1) plastic chains with multiple lengths(4ft,8ft,12ft)

2) 5 to 6 clipboard

3) 12 white and orange survey flags

4) 100ft length of Nylon ropes

5) connection tools (carabiners, scissors, pulley)

6) measuring tools (tape measures, angle finder)

Figure 3.5 The loose parts for LM treatment.

3.2.3 Data collection

<u>General Process</u>

In this study, the LM treatment will be tested by following the form of the Pretest-Posttest control group design (See Figure 3.6) to ensure the validity of data collection. There will be two groups of participants. The first is an experimental group of 127 six grade students randomly assigned to one teacher's class of study hall (independent study). The second is a control group of 123 six grade students randomly assigned to another teacher's class of study hall (independent study). With the Pretest-Posttest control group design, the

differences of posttests will not be impacted by maturation or instrumentation. Also, because the students are randomly split into two groups, the validity issue of selection bias may be avoided.

In a typical day of the experiment, both experiment and control groups go through the school standard bell schedule which is: period 1 (8-9am), period 3 (10-11am), period 5 (12-1pm), period 6 (1-2pm). The experiment group goes outside to work on their math homework, while the control group works on the same math homework inside the classroom without any other intervention.
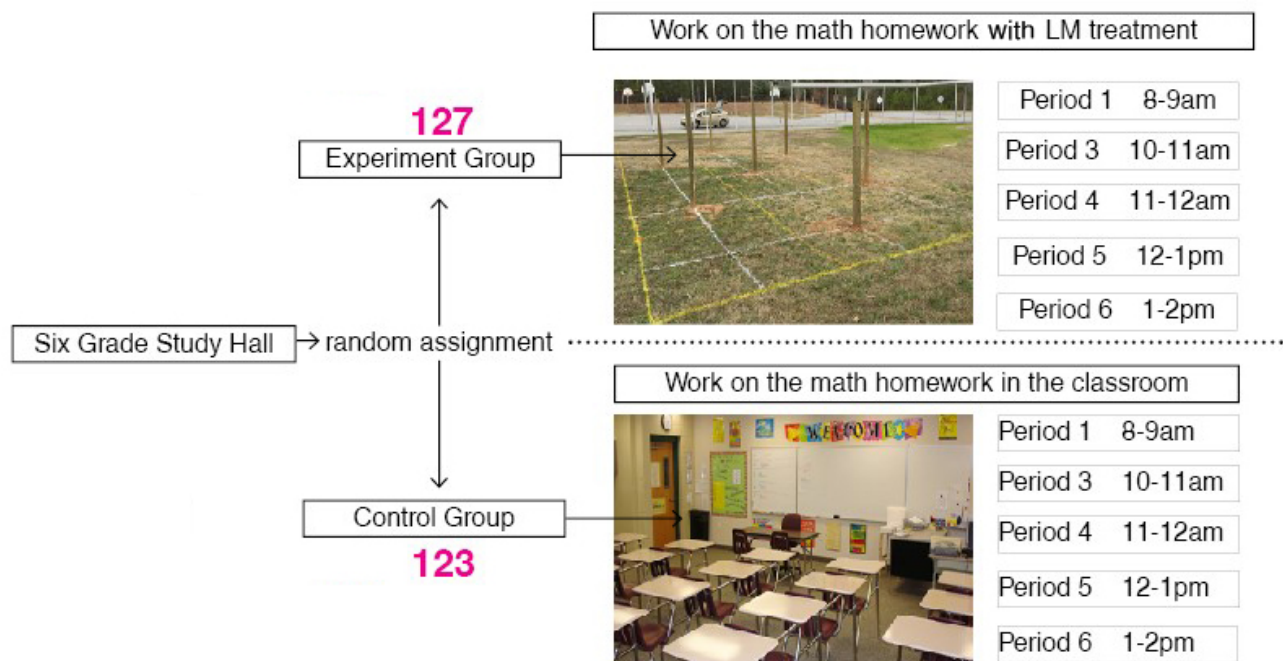
Figure 3.6 The experiment group and control group

The whole experiment includes three parts (Figure 3.7): the pretest, the two-week experiment period, and the posttest. The pretest was Jan 27[th] which is the school day before the two-week experiment period. At the pretest, both the experiment group and control

group took a math test (online) and a motivational questionnaire. The results were recorded. Then, the two-week experiment period of total six days including Wednesday, Thursday, and Friday for two consecutive weeks occurred. During these six days, the researcher made observations for each of the five periods of the experiment group using the LM treatment. Photos and observation notes were collected. No additional data was collected for the control group since they remained in the classroom without any intervention. Lastly, the posttest was on the school day following the two-week experiment period. For this, both experiment and control groups took the same math test (online) and motivational questionnaire for the second time. Their results will also be recorded.

Figure 3.7 The experiment process

Daily Procedures of LM treatment for the Experiment Group

To control the effects of LM treatment, this study adopted a standard daily procedure. This procedure uses the standardized procedure introduced in Chapter Two. The

scenes of the experiment were also listed below to illustrate the repetitive actions on the site.

1. Learning Initiation (Figure 3.8)

    a) Students are separated into five groups within the math garden

    b) Teacher provides a sheet of the homework from a book with math questions

    c) Teacher tells them to start: Each group works on the math concepts by manipulating the loose parts provided.
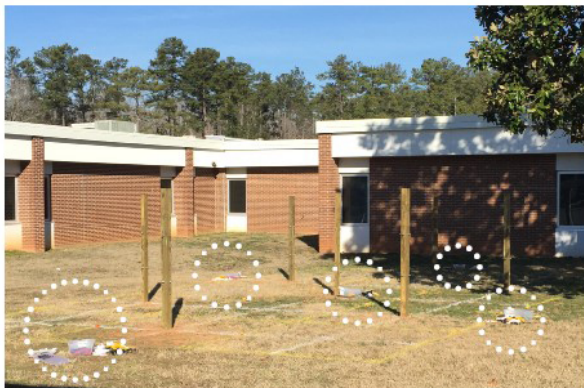
Start: lay the loose parts boxes on the ground   End: hand in the homework sheets

Figure 3.8 The learning initiation phase

2. Manipulation(Figure 3.9)

    a) Teacher distributes the loose parts to students; each group starts manipulating loose parts to help represent the math concepts.

    b) During the session, the teacher serves as an administrator and supervisor rather than an instructor. Students work on their own and in their assigned groups.
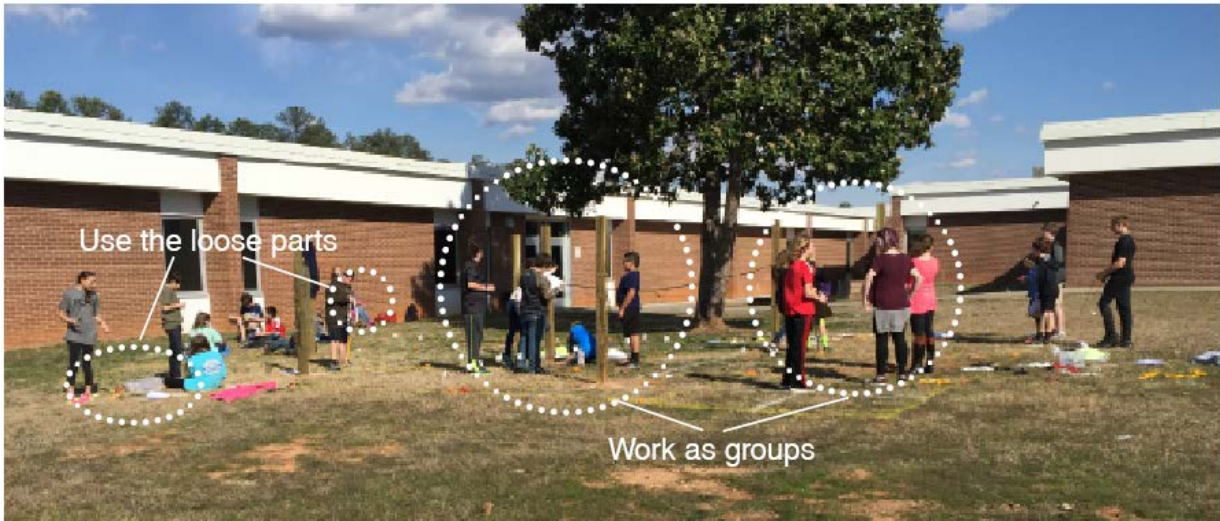
Figure 3.9 The manipulation phase

3. Check the results (Figure 3.10)

a) Upon completing the math homework, students hand it in to the teacher.

b) The teacher provides a few constructive comments and feedback for student groups' to consider when doing this homework.
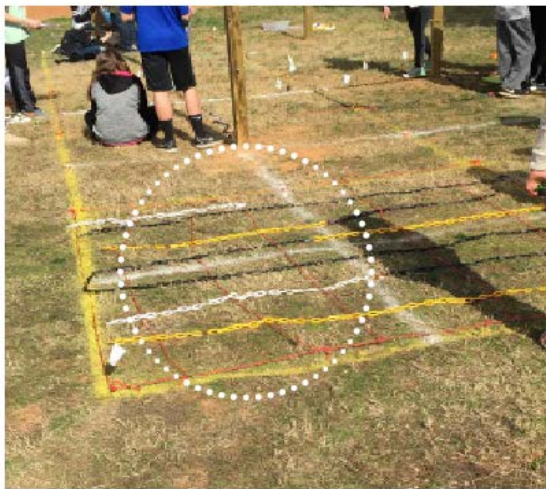
Figure 3.10 Check the results
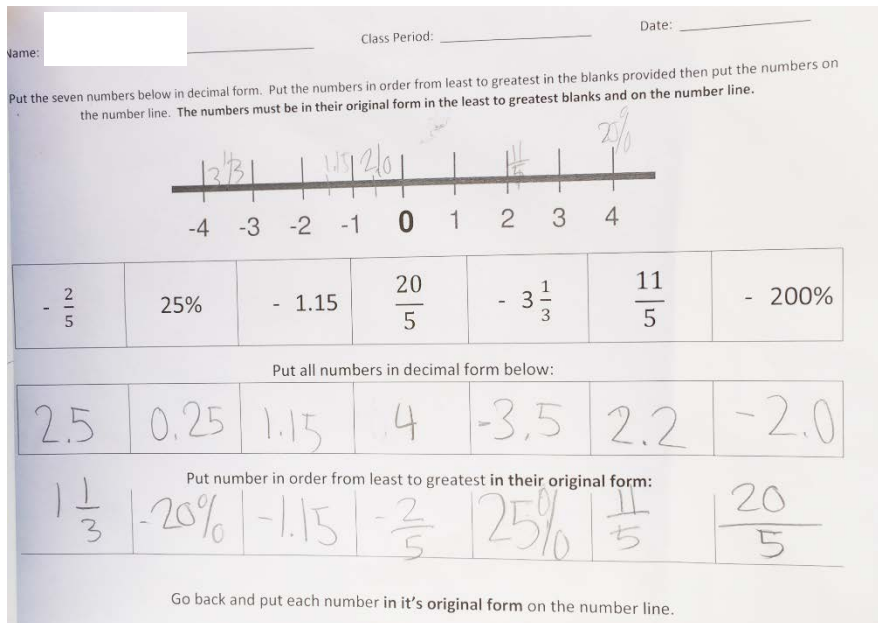
Figure 3.11 Homework sample

The experiment and control groups use the same homework which is created by the two six grade math teachers at the school. Students complete the homework as groups either in LM treatment or the classroom. Figure 3.11 showed a sample of a students' homework.

During the LM experiment, the researcher will took photos and filled out an observation protocol for every period. The photos represent students' manipulations, significant behaviors, and group communication. The observation protocol (Figure 3.12) is a form of different times as columns and different groups as rows. There are two kinds of information included which are significant behaviors on the left and behaviors counts on the right. Significant behaviors list behaviors the researcher saw as extraordinary with a repetitive pattern. Behavior counts show the number of negative behavior and positive

behavior the researcher observe during the LM treatment. Postive behavior was predefined as making shapes related to math, working with the group members, and focusing on math questions. Negative behavior means students are leaving their own group and disturbing other groups, making irrelevant shapes, and refusing to participate in LM. All the observation forms were collected and used for data analysis after the experiment.
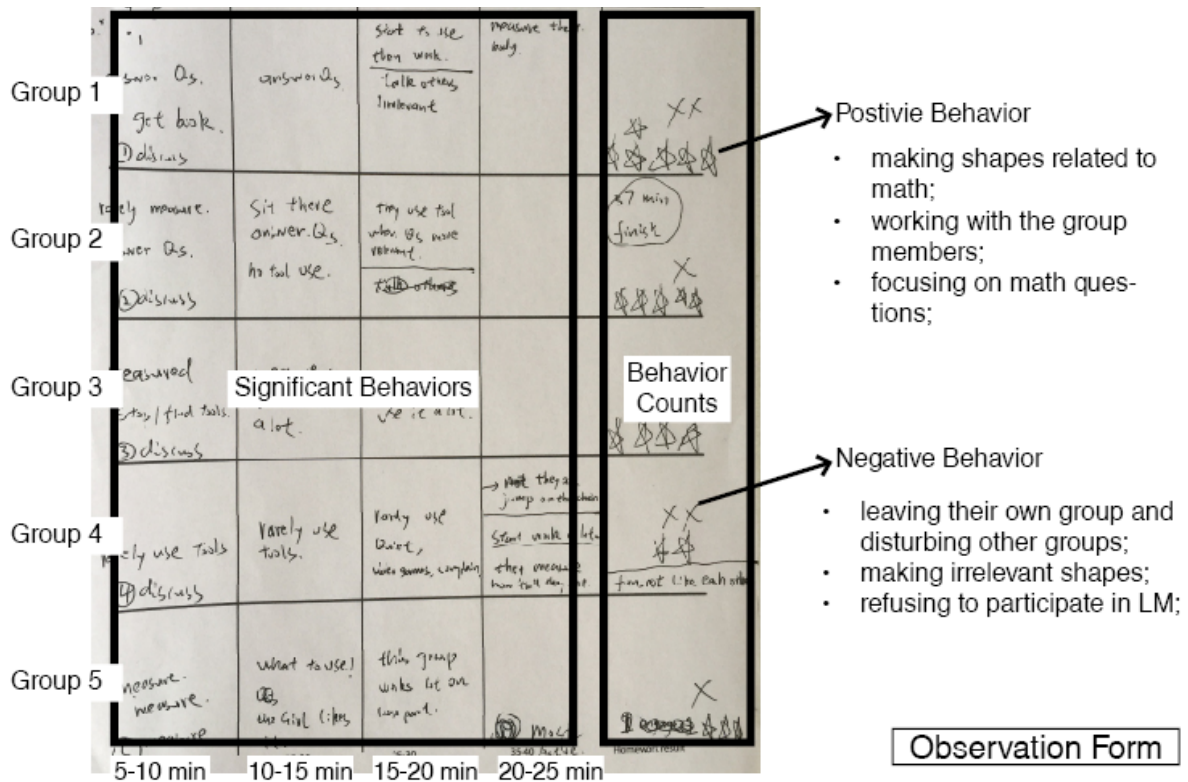
Figure 3.12 Check the results

3.2.4 Data analysis

Three types of data

After data collection, three type of data were sorted and organized for analysis. They were observations, math tests, and the math motivation questionnaire.

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The observation data includes photos and observation forms. All photos were categorized by periods and time. The researcher created an observation note by synthesizing the information on observation forms. This note presents the significant behavior patterns and engagement levels of all period in each day.

The math motivation questionnaire data includes both the pretest and posttest. Each test has 25 Likert-scale answers. All the answers will be typed into an Excel sheet with unique confidential student Ids.

Both pretest and posttest math test data were provided by the school teachers. The math test is an online test developed by McGraw-Hill, the test results are in an Excel sheet format with unique student Ids.

Moreover, both math motivation questionnaire and math test data were coded with experiment type, gender, and periods.

Statistical Analysis

All the research data will be imported into a statistical program called SPSS. All dependent variables are math test scores and math motivational scores which are all measured on a continuous scale. The independent variable is two independent groups of students who are the control group and experimental group. Therefore, the independent T-test is used as the primary statistical method to help identify whether or not there is a significant difference between the means of control and experimental groups. Detailed analysis of different subgroups like student gender, and periods was also performed.

Moreover, descriptive statistics were used as a supplementary illustration of the results of

the independent T-test.

3.3 Validity

The threats of construct validity come from the measurements. Both homework test scores and motivation questionnaire may not provide a good indication of students' math achievement. To address this, the researcher worked with teachers and checked the quality of the homework book and the items in the questionnaire. A pilot study were also deployed to examine whether or not the items in the questionnaire can be understood.

Addressing Internal validity threats are also the key to having a successful experiment. The threats and solutions are listed below:

- Demand characteristics/evaluation apprehension
    - Try not to change the natural setting of students, don't let students feel like they are participating in a study
    - Demonstrate the purpose of the study to teachers in study hall
- Experimenter bias
    - Double-blind the measurements. Both pretest and posttest of the math test will be online tests. Since a computer graded students answers, there will be no personal preference or bias on the math test scores.
    - Minimizing the interaction between subjects and experimenter. The teacher who administers the treatment was trained. He/she can answer students' questions, but not actively instruct any academic knowledge, his/her primary job is to ensure the right use of tools and safety. The students should complete all the math homework themselves.
- Selection

- A random assignment was conducted to assign control and experimental groups.

- History
  - Make sure subjects don't receive other special treatments during the study.
- Maturation
  - It's true that some students learn and improve more than others, this individual difference can be controlled by the random assignment.
- Testing/instrumentation
  - Homework is the assessment students had for years, they will treat them as usual.

As field research conducted in a natural setting, not a laboratory environment, this study has higher external validity and mundane realism than other designs. However, only the schools who provide permission can join the study. Thus the schools who participate in this research may share certain organizational characteristics or policies. This may will limit the capability of the results to predict the efficacy of LM for the whole population.

3.4 Pilot Study

3.4.1 Overview and Purpose

Because of the nature of research design, this study involves conducting educational experiments in real middle school settings. Many protocols and operational items will be questioned without specific pre-testing. Although a pilot study does not guarantee the success of the experiment, it can help address many issues and difficulties in advance. For example, the researcher may know whether or not the experiment is officially allowed; Assess whether the LM treatment activities are realistic and workable; Familiar with the procedures and instruments in terms of data collection; Identify expected problems which might occur; Acquire communicating and coordinating skills when working with students/teachers and administrators in educational settings.

This study deployed two pilot studies aimed to fulfilling different purposes.

3.4.2. Pilot I: Dacusville Middle School, SC.

The first study was conducted in April 2013 at Dacusville Middle School in Easley, SC. This study includes two objectives: 1) to learn about the interests and impressions of learning and outdoor activities in teachers and students by surveying participants; 2) to examine the feasibility of LM treatments by constructing a LM math garden on the school campus and testing standard LM learning session during a class day.

After communicating with the school principal and other relevant administrators, the research team was allowed to construct a LM math garden. The construction was harder than expected, site conditions, weather, and other school concerns had to be addressed

during the building process. However, the final condition of LM math garden was satisfying. During the process, all members of the research team gathered valuable experience in constructing a LM garden, especially calculating and measuring geometrical grids. The LM garden building process was shown in Figure 3.13.

Figure 3.13 the LM garden constructing process

A group of eighth-grade math students and several teachers were invited to participate in the LM treatment learning session on a normal day of the fall semester. After a simple introduction and training, the teacher asked students to create triangles that can represent geometric concepts of the Pythagorean Theorem using the "loose parts" such as flags, tape measures, plastic chains, etc. Students were separated four to a group. Each group was allowed to choose loose parts and to manipulate any scale of the triangle they liked. Many students were able to manipulate right triangles in different forms. There were even some students who utilized the vertical post to make 3D measurements and presentation. The site images during the LM learning session are shown in figure 3.14:

Figure 3.14 Scenes of the LM learning session in Pilot I

The images above show many behaviors and activities representing the components of the LM framework such as manipulation, play, ownership, situated learning, etc. There is a strong participation level during the session, most students were interested in the loose parts and engaged in the manipulation. Many students expressed that they'd like to use the space outside in the future. This adds confidence that the experimental research is acceptable in a real educational setting in SC.

However, a few teachers mentioned that they felt a little overwhelmed on how to structure their classes to use the garden. They asked for video instructions on how to use LM after the session.

3.4.3. Pilot II: Clemson University, SC

The second pilot was conducted on Feb 3, 2016. This pilot was intended to continue pilot I and further test the instruments and protocols. It has two focuses: 1) the student use of site grids; 2) the face validity of a motivational questionnaire to be used in the study.

Experiment images and results

In Pilot I, teachers expressed their concerns for structuring LM learning. The research teams developed several new instruments to help teachers control students' use of the LM space in Pilot II such as math homework sheets and more loose parts. Also, more complex site grids were used.
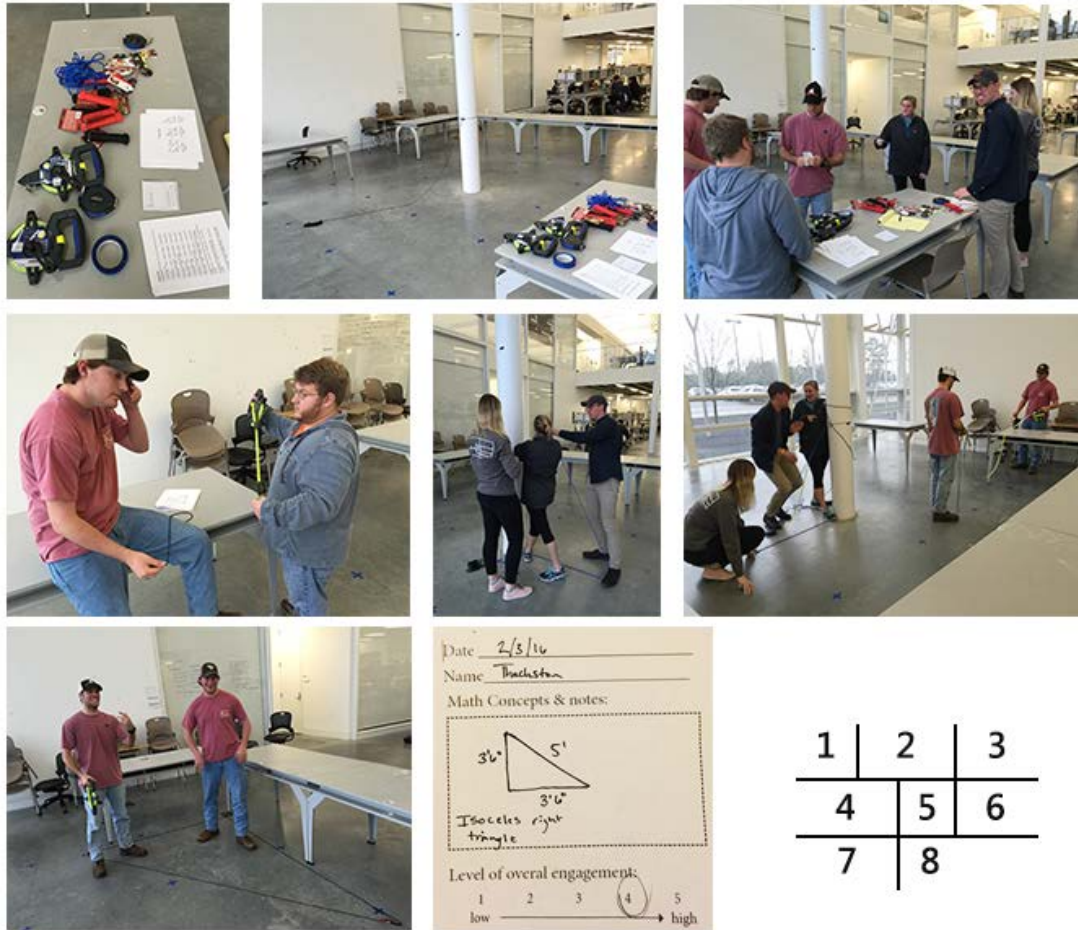
Figure 3.15 Scenes of the LM learning session in Pilot II

On Feb 3, 2016, a simple indoor site was created in Lee-hall at Clemson university. Six college students in landscape architecture joined the experiment. These students have no experience and knowledge about the LM experiments beforehand. After a short introduction, the researcher gave them concept cards that included the geometry of

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triangles and also cards to record their manipulations. Then they were separated into two groups and asked to manipulate one type of geometry using the loose parts. Moreover, they were specially required to start their geometrical shapes at one of the marked points on the site. After the manipulation, they have presented their manipulation to the researcher and filled out a manipulation cards. The images of the site are listed in Figure 3.15.

The Math homework sheets were turned out to be helpful to guide students' learning. The whole process went through very smoothly. After the introduction, the students were able to finish their work without any more directions. The larger site grids on the ground make the learning space more relevant to math. They also provide more choices and make the manipulation more fun and interesting.

After the treatment, the researcher gathered all the participants for a debrief and discussion about the study. Many students expressed their interests in LM. They thought the activity was a fun and practical learning approach. Moreover, making students physically move and collaborate was mentioned multiple times as another distinguish benefit. On the other hand, one student felt he doesn't know what is expected when he's using LM; another student didn't feel he was accepting instruction during the process. Generally, like Pilot I, students were very engaged in Pilot II. The instruments and procedures appeared to be understandable and appropriate.

Questionnaire and results

After the treatment, a math motivation questionnaire (the same questionnaire in Appendix B) was given to the participating students. During this time, the researcher observed all students. There was no hesitation or erasures when students were answering the questions. There was also no skipped questions in the questionnaires. The researcher also asked for verbal feedback about the clarity and difficulty of the question items from

the students. No negative comments were received. The results of the questionnaire are shown in Figure 3.16.
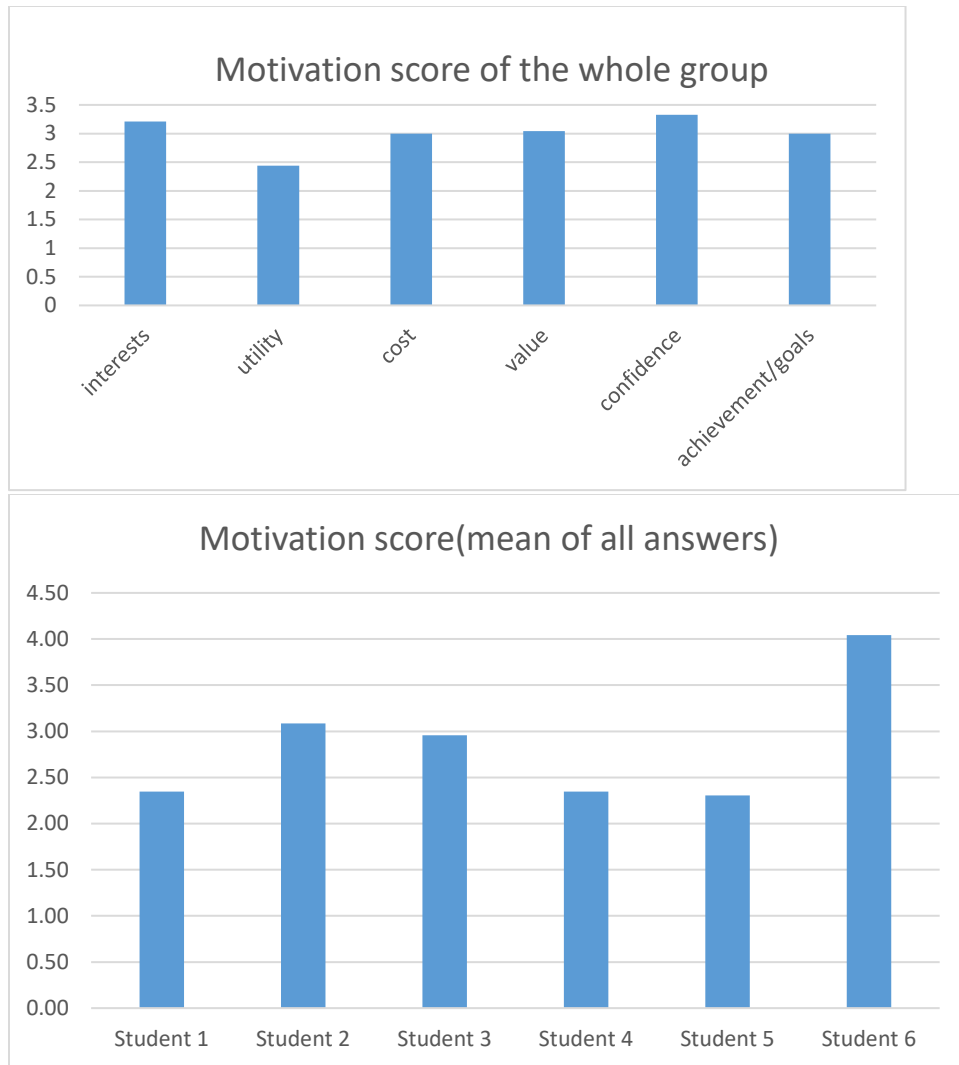
Figure 3.16 descriptive statistics of pilot questionnaire results

3.4.5 Conclusions

In summary, the two pilot studies have helped make the research design more realistic and workable. Pilot I assessed the feasibility of the LM research proposal, it may

help convince other schools to allow construction and testing of LM. The researcher also gained more experience in working with teachers and administrators during the process. Pilot II tested and developed more appropriate research instruments. I helped make the LM treatment procedures more effective. Overall, the two pilot studies have provided increased confidence and knowledge of LM research.

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

The data analysis examines the efficacy of LM on math test scores and math motivation levels. Observation, math tests, and math motivation questionnaires comprise three different categories of data, therefore, the data analysis and results are divided into three parts as well.

4.1. LM Observation Results

The LM observation includes the analysis of photos and observation forms. Two results are presented in two ways: engagement levels and behavior patterns.

4.1.1 Participants

Six periods groups of students participated in the LM treatment for a total 128 students in grade six. They are Period 1 (8-9am) with 25 students, Period 3 (10-11am) with 25 students, Period 4 (11-12 am) with 26 students, Period 5 (12-1pm) with 24 students, and Period 6 (1-2pm) with 28 students. During the two-week experiment, one student quit the experiment, so the actual number of experiment group changed to 127 students.

The researcher went to the site to observe the LM treatment on Wednesday, Thursday, and Friday for two weeks in a row. 258 photos and 29 observation forms were collected after the experiment.

4.1.2 Engagement level

The engagement level measures how well the students engaged in LM learning activities. Because only one researcher was making the observation, the engagement level will be measured by the periods instead of individual students.

The criteria for assigning engagement level are based on researchers' notes on the observation form. Each period has one observation form (Figure 22), there is a section called behavior counts where the researcher checks positive behaviors and negative behaviors to the groups of the period. Positive behavior includes making shapes related to math, working with the group members, and focusing on math questions; Negative behavior includes leaving their group and disturbing other groups, making irrelevant shapes, and refusing to participate in the LM. At the end of one experiment day, the researcher will have five of these observation forms filled for each period with behavior counts in them. Then the researcher sums up the behavior counts and gives a final rank to all the periods of the day. Specific comments and descriptions for each period (Figure 4.1) was recorded in a document called Observation Notes (Appendix A).

Period 1

Overall comments: This period is the first group. They have a good social environment, all group members like each other. Chains are the most used tools. However, after 30 mins, many students start to play with loose parts such as rope skipping, measuring school yard, measuring their own bodies. It's also really cold. Several students(group 1, group 4) are not focused on learning.

Behavior counts: positive 10, negative 6

Period 3

Overall comments: When space is occupied by other group members, the incentives of using LM get lower. Different groups have their own approach of using LM. Some students didn't use LM all time, but they did focus on math questions. Students in one group didn't fully collaborate, they separated to 2 small sub-group. Free plays such as tape measure as Yoyo, ropes on the neck were seen, but most students were involved in the math related activities.

Behavior counts: positive 13, negative 5

Period 4

Overall comments: Students cannot focus on the learning outdoor because of the noise. However, they are very engaged on the math questions. Some LM manipulations were made at a smaller scale. They are a little bit quiet.   **Period Comments**

Behavior counts: positive 8, negative 2   **Behavior Counts**

Period 5

Overall comments: they are very passive. Most time, they sit on the ground and work on their questions. Group 2 totally lost, they didn't look at questions but chat for something else.

Behavior counts: positive 8, negative 4

Period 6

Overall comments: All flags are used. All groups are engaged in the LM activities. I saw multiple forms of manipulation such as number lines using ground points + flags, geometry angles using posts + ground points. Flags are all used which is every unique for the day.

Behavior counts: positive 16, negative 4

Day 1 rank: Period 6- Period 3- Period 4- Period 1- Period 5 ⟶ Period Rank of the LM Engagement Levels

Figure 4.1 Observation Notes of a typical day of the LM experiment

As Table 4.1 shows, each period will have a rank (No.1 to No.5) in each day. No.1 means the highest rank of the engagement level at that specific day, No.5 means the lowest rank of the engagement level. The period with a higher rank has higher positive behavior counts and lower negative behavior counts. For instance, Period 6 ranks No.1 with 5 pts at Day 1. This means Period 6 has the most positive behaviors and least negative behaviors during that day. Altogether, this means Period 6 received more effective LM treatment than other groups.

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Day	No.1 (5 pts)	No.2 (4 pts)	No.3 (3 pts)	No.4 (2 pts)	No.5 (1 pts)
1	Period 6	Period 3	Period 4	Period 1	Period 5
2	Period 4	Period 1	Period 6	Period 3	Period 5
3	Period 4	Period 3	Period 1	Period 6	Period 5
4	Period 3	Period 4	Period 1	Period 5	Period 6
5	Period 4	Period 6	Period 3	Period 1	Period 5
6	Period 4	Period 3	Period 6	Period 1	Period 5

Table 4.1 Engagement levels in each day of the experiment

The engagement levels for the total six experiment days can be calculated by summing up the scores of each period. For example, Period 6 gets 5 pts on day 1, 3 pts on day 2, 2 pts on day 3, 1 pts on day 4, 4 pts on day 2, and 3 pts on day 6. For the total six experiment days, Period 6 gets 5+3+2+1+4+3=18 pts. Figure 4.2 shows the results of calculating the results for all periods.
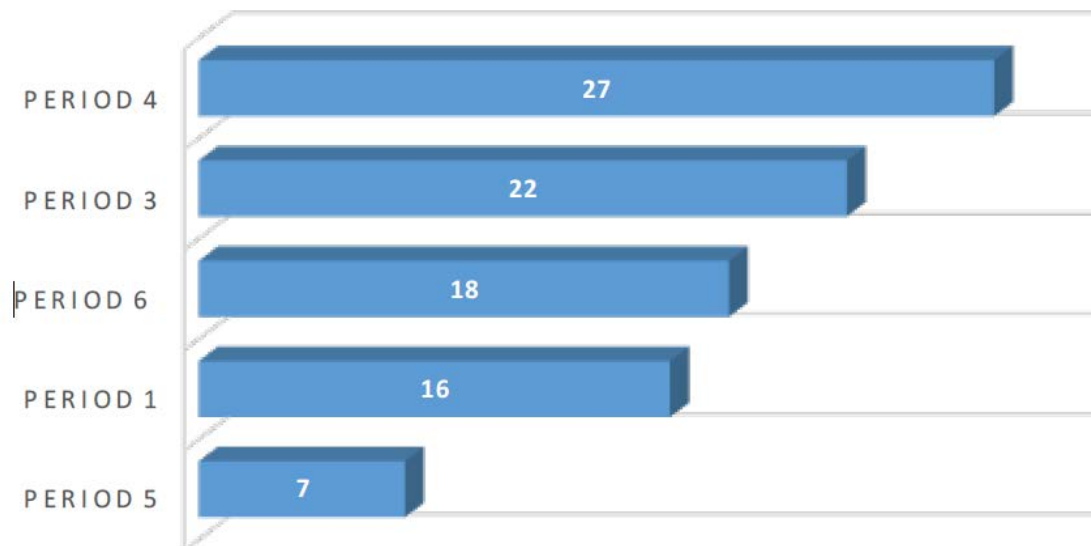
Figure 4.2 Engagement level rank totals for each period during the six-day experiment

From the results in Figure 4.2, Period 4 and 3 was the highest points. Period 6 and 1 are very close with only 4 pts difference. Period 5 ranks at the bottom with only 7 points.

The overall rank is Period 4> Period 3> Period 6> Period 1> Period 5. Even though this ranking involves the researcher's interpretation, there are still significant findings. For example, Period 4 and Period 5 are the two extremes with 27 points and 7 points; Period 6 and Period 1 are the average groups with no major difference between each other; Period 3 is the group performing above average.

By synthesizing site photos and observation notes, a short comment on each period was given to explain the legitimacy of the overall ranks below:

Figure 4.3 LM experiment scene of Period 4

Period 4, Most Engaged in LM:

As Figure 4.3 shows, all students were either making LM shapes or looking at math homework. This scene has been repetitively observed for every experiment day for Period 4. Period 4 heavily engaged in the LM experiment. Most students liked to using LM's loose parts and enjoyed learning with LM. By working as a group and helping each other; they created a constructive LM learning environment. Period 4 kept looking for ways to relate LM manipulations to math problems. The shapes they created were not for free play but more purposeful helping them understanding math. No matter what the climate was, they always focused on the math homework and had the most manipulations

of any group in the experiment. Few negative behaviors and distraction were seen.

Overall, Period 4 had an ideal level of engagement with the LM.

Figure 4.4 LM experiment scene of Period 3

Period 3, Homework Oriented:

Routine observations suggest that Period 2 takes math homework seriously. They all worked on their homework during the LM session. Period 4 sometimes forgot to use the loose parts, because they are so focused on answering questions on the math homework sheet. Figure 4.4 shows all students looking at their homework sheet instead of making shapes using LM. However, it's hard to deny their dedication to learning math during the experiment. Observations suggest that they might be not as involved in specific LM manipulations as Period 4, but they spend more time thinking about math.

Figure 4.5 LM experiment scene of Period 6

<u>*Period 6, Going Through the Motions:*</u>

In this period, routine observations suggest that some students have passive attitudes. They usually stand or sit on the ground waiting for the end of the class without doing anything. Maybe because this is the last session of the day, they just want to relax without working. Sunbathing, chatting, and relaxing are very common behaviors. Like Figure 4.5 shows, few students are working on the homework sheets and LM manipulations. Most of them stand on the edge of the site chatting. Overall, period 6's performance is mediocre with a few extremely negative and positive behaviors.

<u>*Period 1, Environmental influences:*</u>

Routine observations suggest that this period is interested in using LM and working hard on the math questions and LM manipulations (Figure 4.7). However, the weather was really cold at 8.am during the experiment days. As Figure 4.6 shows, the average temperature of the six-day experiment period is about 50 °F. At day 4, the temperature is even below 40 °F. The cold conditions prevented students from focusing on LM learning. Often, students were looking for sunshine or shelter because of the

severe weather (Figure 4.6). Overall, period 1 was significantly influenced by the

weather. As a result, Period 1 had fewer opportunities to learn with LM than other

periods.
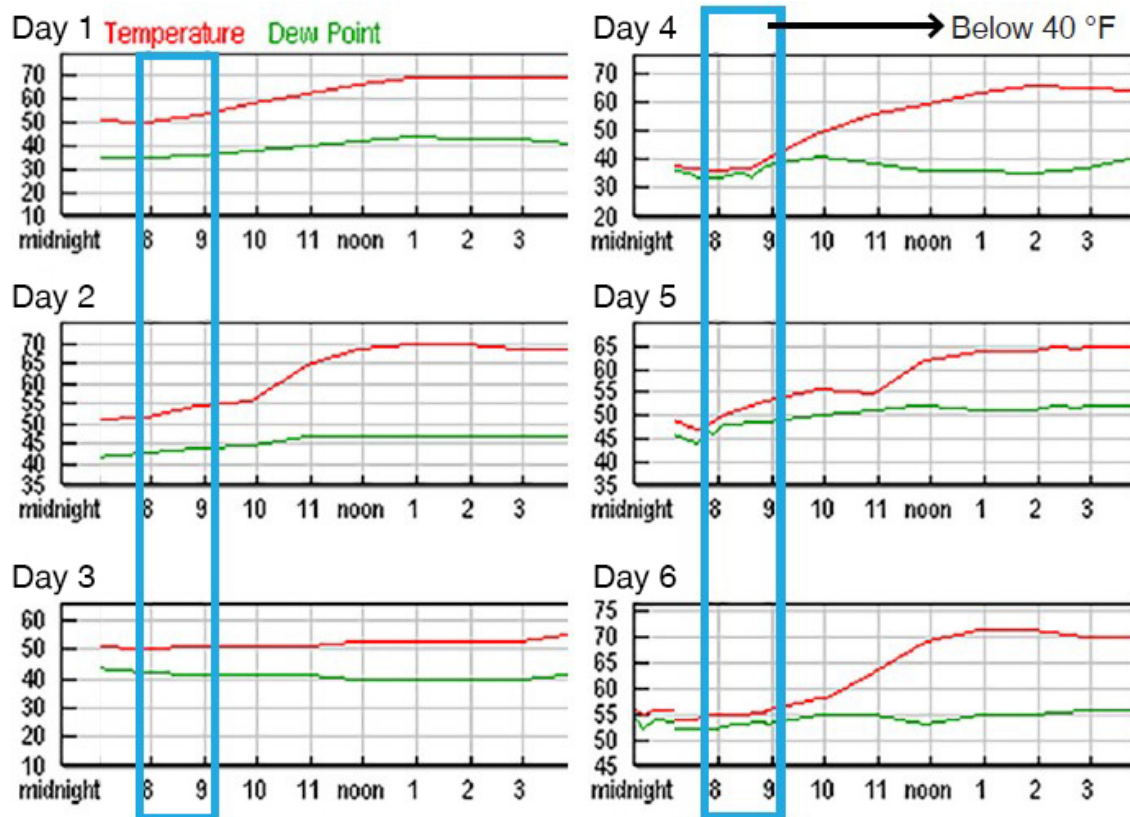
Figure 4.6 Temperature and dew point of the six-day experiment.

Figure 4.7 LM experiment scene of Period 1

Period 5, Disruptive behaviors (Figure 4.8):

Routine observations suggest that this period didn't use LM in positive ways. Period 5 is a good example of how LM can discourage effective behaviors when students become out of control. For example, several students never worked on any math questions. They liked to steal other groups' loose parts and throw flags at other students. Especially on day 5 and 6, there were two bullying incidents where 3-4 students destroyed another student's manipulation. Even students wanted to work on LM, many disruptive behaviors prevent them from doing so. Overall, routine observations suggest that Period 5 was not capable of LM learning of this time.

Figure 4.8 LM experiment scene of Period 5

4.1.3 Behavior Patterns

For each period, the researcher took notes on the significant behaviors observed on the site. Some of the behaviors were single incidents; some were repetitively presented as patterns. It's highly possible that these behavior patterns would still exist if the

experiment were to continue. In identifying these behavioral patterns, this study provides a more comprehensive explanation of the performance of the LM treatment. Moreover, it gives recommendations for future improvements of the design of LM garden and class structure.

Manipulation patterns

Even though the students make different manipulations each day, their manipulations fall into four categories: number lines, polygons, quadrants and coordinate grids. In every typical experiment day after they read the math questions, students appear to think about what loose parts to use and what shapes to make. As a result, number lines, polygons, quadrants, coordinate grids, as basic math structures, turned out to be very useful manipulations in helping students understand math concepts during the experiment periods. After Day 3, most groups choose one of them as their starting point of LM manipulation (Figure 4.9).

| Number Lines | Polygons | Quadrants | Coordinate Grids |
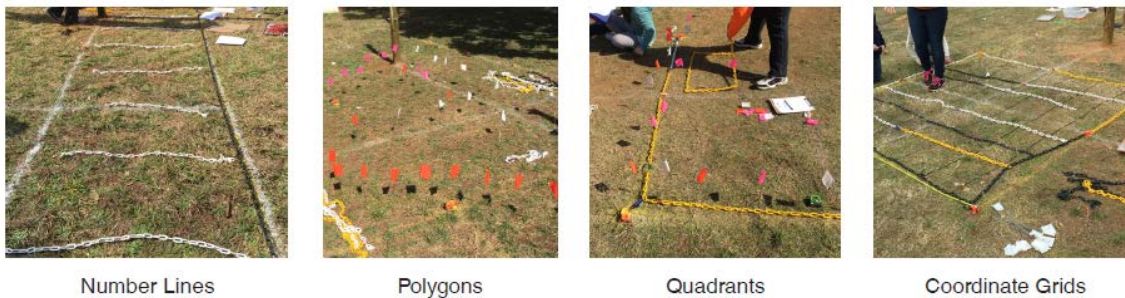
Figure 4.9 Manipulation patterns.

Manipulation patterns interpretation: The number lines, polygons, quadrants, and coordinate grids are math structures widely seen in the homework or textbooks. Manipulating them in the LM experiment means LM can enable students to relate abstract math concepts to real world situations. It also suggests that LM can be a

successful substitute for indoor classroom environments. By using grid structures and loose parts, students can make any geometric forms they want. There are very few limits regarding the making and illustrating of mathematical relationships with LM. More importantly, all the manipulations were problem-based which makes LM learning more interesting and meaningful.

Posts + chains for play

Hanging chains to the posts were the most popular ways of making manipulations for every group. However, observations suggest that chains on the posts are also a sign of playing (Figure 4.10). Most of the manipulations with chains and posts are not related to math questions but for play reasons. For example, many students had tied all chains together as walls and gather inside the 'walls' declaring they are the prisoners. Students had lots of fun from this, but it can also be a huge distraction to learning.

Figure 4.10 Posts + Chains for Play.

Posts + chains for play interpretation: The LM math garden can be a fun place. Loose parts and the grid system provide a rich setting for object play and imaginative play. This sense of play makes students more engaged in LM activities. However, too much free play can be a big distraction to math learning and may have negative

influences on the students' math performance. Therefore, an appropriate balance between free play and math learning is important.

Group separation

Students were assigned by the teacher to work as groups during the experiment. There are usually five students in a group. However, some group members don't like to work with their teammates, so they split into two subgroups and worked separately (Figure 4.11). This has some disadvantages. First, the separated group had less physical space for manipulation, since there are two manipulation projects instead of one. Second, splitting groups led to decreased communication between group members. In the end, these groups were more likely to stop early on their LM learning and not complete their homework.

Figure 4.11 Group separation.

Group separation interpretation: The social construction of meaning is a key component of LM learning. During the LM experiment, students have a better chance to

interact and learn from each other. However, this expectation does not work for every group in every situation. Sometimes group members just don't like to work with each other. Sometimes the math concept the students are working may inherently encourage them to split groups because some manipulations such functions have to be made by more than five students. By contrast, manipulations such as number lines and negative numbers are easier for only two or three students. Therefore, the group size should be wisely chosen to ensure effective collaboration, and to match the math problems being studied with group size.

Looking for space to sit

Observations revealed that after standing for about ten minutes, students began looking for seats. Some of them sat on the ground, some of them (especially females) left the site and looked for the cleaner pavement to sit (Figure 4.12). The need for seating was observed in every period. Lack of close-by seating made learning time dramatically decrease because it's undesirable for students to come back to the garden and learn from LM after learning the site.

Figure 4.12 Looking for space to sit.

Looking for space to sit Interpretation: One of the biggest differences between indoor classrooms and LMs is seating. In the classroom, every student has their seat. In LM garden, seats were not provided. As a result, students had to stand for 30-45 minutes or find somewhere to sit. Also, students needed to take notes and write answers on their homework sheets. By adding seats, LM learning and associated tasks like writing become easier and more comfortable. This should lead to enhanced learning.

25 minutes of time

It was common to observe students appearing fatigued or maybe bored after interacting with the LM for 25-30 minutes. In fact, 25 minutes was a very reliable stopping point, after that, most students found it difficult to continue with their math study. The students started to relax or play on the edge of the site (Figure 4.13). These observations were a very strong pattern for every period during the experiment.

Figure 4.13 25 minutes of time

Interpretation: Outdoor environments are changing all the time. There are very few control and lots of distractions. Also, outdoor environments, compared to indoor environments, require students to create their own learning materials and solve the math

problems themselves. For these reasons, students can lose the enthusiasm for learning, especially duration of the LM session lasts more than 25-30 minutes.

Cold and windy weather

Cold and windy weather makes LM learning very difficult. Especially for Period 1. In Period 1, most students refused to make any manipulations given the severe climate. When the temperature is lower than 50 °F, students usually sit on the ground and have very few LM movements (Figure 4.14). In fact, some students were only shorts on those days, these students did not participate on many days.

Figure 4.14 Cold and windy weather

Interpretation: The indoor classroom is a more comfortable and a stable environment with regarding to temperature and wind. Outdoor environments are dynamic. The environmental conditions change based on numerous factors outside the teacher's control. Thus, when it's getting cold, rainy, and windy, the weather becomes a significant problem for LM.

Communications between groups

During the experiment, the teacher was observed emphasizing to students that working and talking with other groups was not allowed. However, when students get into the garden and start manipulating the loose parts, it's common to observe some students leave their group and talk with another group. This communication between groups is very likely a sign of free play which can help learning. However, it makes students stop learning math and may become a detriment (Figure 4.15). Moreover, lots of loose parts eventually got stolen or lost when groups are working or playing together. This makes the LM class more difficult to organize.

Figure 4.15 Communications between groups

Interpretation: Outdoor environments have fewer constraints and rules than indoor classrooms. Students can talk and walk much more freely. This provides for a more dynamic interpersonal relationship within the class and makes LM learning more engaging

and meaningful. However, too much communication between different groups encourages more incentives for free play which might not always be helpful for math learning.

Male students and female students were observed to have different preferences and learning styles in the LM. The male students seemed to have more enthusiasm for using and playing with the loose parts. Males tend to stand for longer times in the garden. They were also more willing to dominate group discussions and manipulations. On the other hand, female students looked more for seats and tended to be passive participants during the LM. As Figure 4.16 shows, all of the females students are sitting on the ground, while all the male students are manipulating their loose parts. This scene has been a very strong pattern throughout all experiment periods.

Figure 4.16 Males and Females

Interpretation: Observation suggest that male students are more interested in shape making and body movements. They love to put their hands on the loose parts and manipulate shapes they want. They were also dominating in groups and didn't mind the

dirt as much. On the other hand, female students were more selective on LM. They use the loose parts only when they felt they have to for the math probelm.

4.1.4 Summary of observation

By analyzing the data associated with the observation of the LM during the treatment, this study has identified a new way of thinking about learning landscapes. Through the lens of engagement levels and behavioral patterns, researchers can conduct effective qualitative examinations of the learning landscapes (like LM) and designers can create more appropriate structures..

This study shows the engagement levels of all periods as Period 4> Period 3>Period 6>Period 1>Period 5. Periods 4 received the most effective LM treatment, while Period 5 had a negative LM treatment. Period 3 spent most of the time on homework. Period 6 worked passively on learning and manipulation. Period 1 significantly suffered from the severe weather.

The observation results of behavioral patterns suggest many significant phenomena during the LM learning. These obserrvations provide valuable insight and understanding of LM:

- **Amenities**: Seats are important. Shade is helpful. Less muddy materials.
- **Group size**: A group size of five might be too big in some cases.
- **Distraction**: Too much communication with other groups is not good for math learning.

- **Class time**: After 25 mins, students cannot focus on math learning. Keep lessons brief and take breaks.

- **Play**: Loose parts can be great tools for math learning and free play.

- **Climate**: The cold, rainy, and windy weather will have a bad influence on student learning and the LM. Plan for alternatives on bad weather days.

- **Gender**: Male students like to use loose parts more than female students. Females are purposeful and like to sit when writing homework.

4.2 Math Test Results

The results of the math tests identify the academic performance of the participating students in both control and experimental groups. The comparison of the results provides a strong indication of the efficacy of LM treatment. The main goal of the data analysis is to find out LM treatment effected on the experiment group and compare this to the control group.

4.2.1 Participants and data preprocessing

As discussed in Chapter Three, the math test data was provided by the teacher. This data include both pretest and posttest data from the same online test developed by McGraw-Hill. Two hundred and fifty total participants took the tests with 130 in the experimental group and 120 in the control group. Scores were imported into a statistic software SPSS and coded for editing and analysis.

Some questionable data was removed to ensure the quality of the research results. Thus, data preprocessing activities were conducted:

<u>Delete incomplete items.</u>

Some participants only participated in the pretest or posttest. These students have either a pretest or posttest with a grade of 0. Items like these have missing information, so they were deleted.

1) Some students only got 10 pts out of 100-total points. This is not a reasonable indication of their math performance because students will receive at least about 25 points by choosing all the same answer for every question. Therefore, these students may failed to complete the test or didn't take the test seriously.

2) Some students have lower posttest scores than pretest, and the scores of both tests are less than 25 total points. After two weeks of learning, posttest scores should certainly be higher than pretest. It's also abnormal that the posttests get lower than 25 because they can get at least about 25 even they choose all the same choice for every question. Therefore, these students' data was deleted because they did not complete the test or perhaps missed the in-class math instruction during the experiment period.
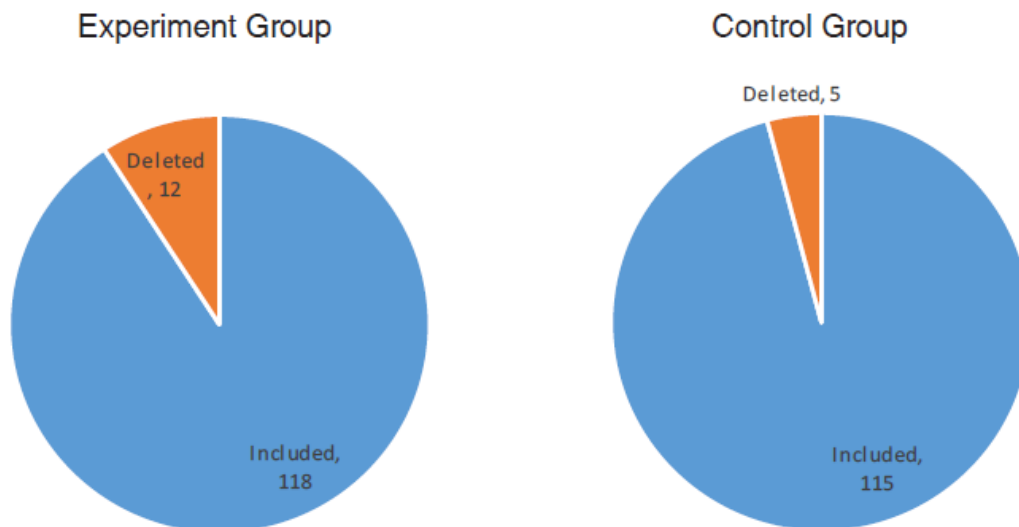
Figure 4.17 Participants and data preprocessing of math tests

As the Figure 4.17 shows, 12 participants were deleted, and 118 participants were included in the experiment group. Five participants were deleted and 115 participants were included in the control group.

4.2.2 Result #1: There are no significant differences in overall performance.

<u>Analysis Results</u>

The first analysis compares the performance of the whole control group to the whole experimental group. If the mean of the experimental group is significantly higher than the control group, then it's safe to conclude that LM led to increase the math test scores.

As the Table 4.2 shows, the analysis includes three parts of data: Pretest, Posttest, and Posttest-Pretest. The Pretest and Posttest are the original scores of every participant. The Posttest-Pretest is the score difference between posttest and pretest. It is calculated by using Posttest minus Pretest. In the Pretest, the control group performed better (mean 41.32) than the experiment group (mean 38.29). In the Posttest, the control group still has a higher mean score (76.16) than the experiment group (71.96). For the Posttest-Pretest, the control group still has a higher increase (mean 34.83) than the experimental group(mean 33.67). On the other hand, the Standard Deviation of control group decreased (from 17.414 to 14.256) while the experimental group increased (from 14.663 to 17.342). This means that LM treatment led to a higher variance on experiment group than the control group.

Group Statistics

	types	N	Mean	Std. Deviation	Std. Error Mean
Pretest	control	115	41.32	17.414	1.624
	experiment	118	38.29	14.663	1.350
Posttest	control	115	76.16	14.256	1.329
	experiment	118	71.96	17.342	1.596
Posttest-	control	115	34.83	14.815	1.382
Pretest	experiment	118	33.67	14.636	1.347

Table 4.2 Descriptive statistics for the overall performance in math tests

A T-test for equality of means was conducted to check whether or not the control and experimental group are statistically different (at the significant level of 0.05). As the Table 4.3 shows, the Pretest was barely the same (Sig 2-tailed of 0.151), while the posttest was significantly different with Sig 2-tailed of 0.045 (control group performs better than experiment group). However, it's not safe to conclude that the LM made the experimental group worse than the control group because the control group has already performed better than the experiment group in the Pretest (P-value 0.151 is still small). This is confirmed by the test of Posttest-Pretest which shows the control group and experimental group have no difference (Sig 2-tailed of 0.546).

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Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	3.242	.073	-1.440	231	**.151**	-3.034	2.107
Posttest	6.622	.011	-2.016	231	**.045**	-4.199	2.083
Posttest-Pretest	.032	.858	-.604	231	**.546**	-1.165	1.929

Table 4.3 Test of Equality for the overall performance in math tests

Therefore, based on the analysis above, there are no significant differences between the control group and experimental group in their overall math test performances.

Interpretation

The slightly better-performing control group continued to show higher scores than the experiment group in the posttest. However, the control group's growth increase was not significantly higher than the experimental group. Therefore, the LM treatment had no significant impacts on the overall performance of the experimental group. Moreover, the experiment group showed increased variance, while the control group had decreased variances. This means that the indoor classroom has more control over students' academic performance than LM.

4.2.3 Result #2: LM's performance is not as stable as an indoor environment, but it outperforms the indoors when the outdoor environments are suitable, and the students are engaged.

Analysis Results

Since different periods are significantly different in engagement levels, it's worth looking at LM's effects on individual periods. By coding all participants in each period numbers, all students in the control group and experimental group could be analyzed.

Figure 4.18 shows the mean grades for all periods. It's clear that both the control group and the experimental group have similar variations. However, the posttest is significantly different. All periods in the control group perform at a range of 73.96 to 79.67, while all periods in the experimental group perform at a range of 59.27 to 86.18. The grades of period 3 (86.18) and period 4(85.17) in the experimental group were higher than all periods in the control group. The grades of period 1 (62.64), period 5 (59.27) and period 6 (62.48) are lower than all periods in the control group. So it's obvious that the grades in control group are more stable than the experimental group and that the experimental group had more extreme results.
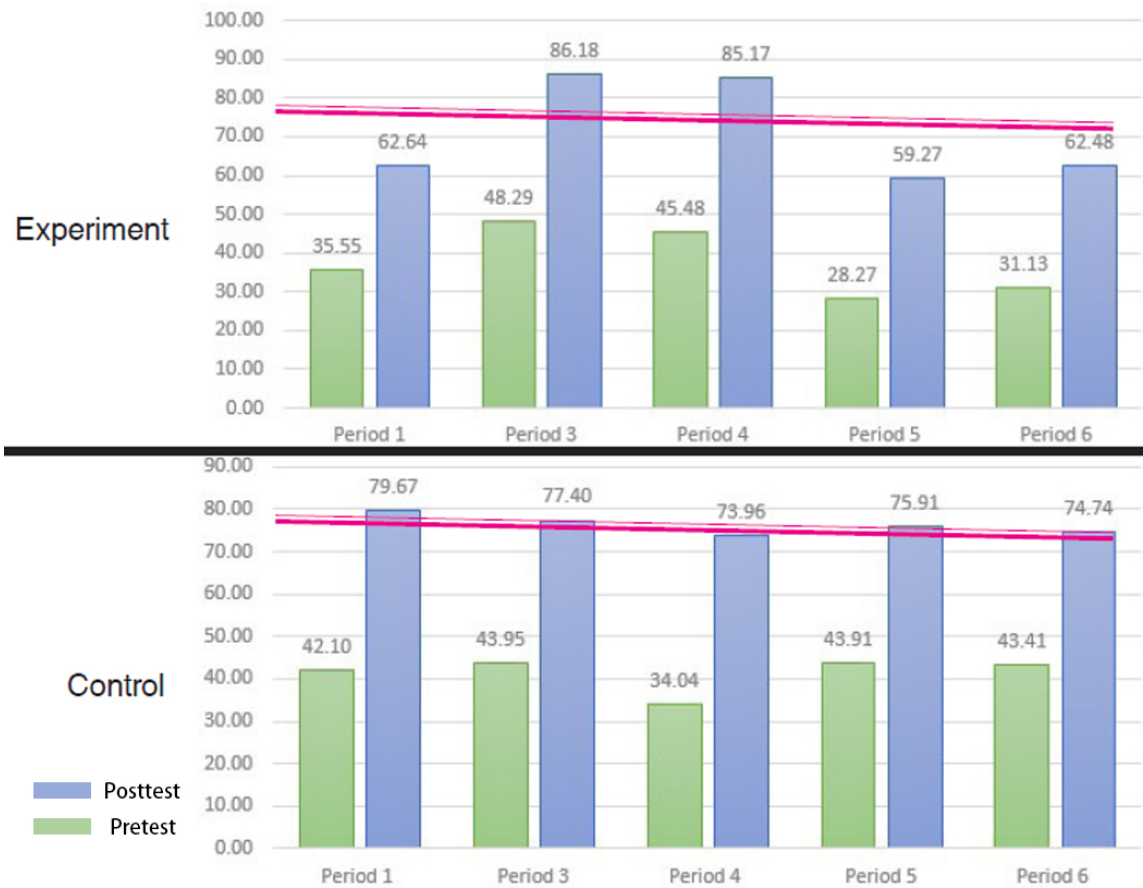
Figure 4.18 Math Tests Grades of different periods

The statistic tests on the equality of means include three forms of data: pretest, posttest, and posttest-pretest. The pretest and posttest are the original scores of every participant. The posttest-pretest is the score difference between posttest and pretest. It is calculated by using posttest minus pretest.

Among all the periods, only period 1 and period 3 showed sizable differences between the control and the experimental group. Based on table 4.4, the control group period 1 performed better than the experimental group period 1 on both pretest and posttest. The posttest-pretest of the experimental period 1 is 27.09, the posttest-pretest of control period 1 is 37.95. It's obvious that the control group had a higher increase on their posttest

than the experimental group. The t-test for equality of means also approves this conclusion. The experimental period 1 and the control period 1 are barely the same in the pretest (sig. 2 tail of .144), while the experimental period 1 and control period 1 are significantly different in the posttest (sig. 2 tail of .001). In addition, the posttest-pretest is significantly different (sig. 2 tail of .026), indicating the control period 1 had more improvement than the experimental period 1.

Group Statistics

	Period	N	Mean	Std. Deviation
Pretest	Experiment Period1	22	35.55	12.990
	Control Period1	19	41.26	11.337
Posttest	Experiment Period1	22	62.64	15.753
	Control Period1	19	79.21	11.998
Posttest-Pretest	Experiment Period1	22	27.09	14.706
	Control Period1	19	37.95	15.288

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	1.090	.303	-1.490	39	**.144**	-5.718	3.838
Posttest	1.257	.269	-3.742	39	**.001**	-16.574	4.430
Posttest-Pretest	.017	.898	-2.314	39	**.026**	-10.856	4.691

Table 4.4 T-test of period 1 in math tests

Based on table 4.5, the experimental group period 3 perform better than the control group period 3 on both pretest and posttest. The posttest-pretest of experimental period 3 is 37.89, the posttest-pretest of control period 3 is 33.45. It's obvious that the experimental group had a higher increase on their posttest than the control group. According to the t-test for equality of means, the experimental period 1 and control period 1 are the same in the

pretest (sig. 2 tail of .37), while the experimental period 1 and the control period 1 are significantly different in the posttest (sig. 2 tail of .007). This means the effects of LM made the Period 3 in experimental group better than the Period 3 in control group on math scores.

Group Statistics

	period id	N	Mean	Std. Deviation
Pretest	Experiment Period3	28	48.29	15.287
	Control Period3	20	43.95	17.772
Posttest	Experiment Period3	28	86.18	8.611
	Control Period3	20	77.40	13.092
Posttest - Pretest	Experiment Period3	28	37.89	13.634
	Control Period3	20	33.45	11.019

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	.393	.534	.905	46	**.370**	4.336	4.789
Posttest	5.021	.030	2.804	46	**.007**	8.779	3.130
Posttest- Pretest	1.521	.224	1.203	46	.235	4.443	3.695

Table 4.5 T-test of period 3 in math tests

In summary, two results were identified:

1) The periods in the experimental group has higher variance than the control group. The experimental period 3 and 4 are the best performing groups.

2) The experimental period 3 had a higher increase on their grades than the control period 3. The control period 1 had a higher increase on their grades than the experimental period 1.

The control group in the classroom environment had more stable test scores than the LM experimental group, but they were limited to a ceiling of 80 points. The LM experiment group got low scores when things went wrong, but they also could achieve highest scores (Experimental Period 3 86.18, experimental period 4 85.17). Thus, the dynamic environment of the LM produced more fluctuated academic performance than the static indoor environments, though it had promise for the highest scores.

From the LM observation results, the rank of engagement levels are period 4>period 3>period 6>period 1>period 5. The rank of posttest scores of LM experiment periods presents the same pattern as period 4>period 3>period6>period 5>period 1 with the only exception of period 1. The Period 1 suffered from severe weather during the experiment, this might explain their extraordinary low performance. Also, the T-test has proved that the experiment period 3 (engagement level ranked second) outperformed the control Period 3, while the experiment Period 1 (engagement level ranked forth) failed to the control Period 1. This indicates a strong correlation between highly engaged LM student groups and better-performed test scores.

Therefore, LM is not a panacea for all situations of math learning. A certain level of engagement and the right climatic condition are necessary for students using the LM to outperform the students in classroom.

4.2.4 Result #3: LM improves test scores for male students more than female students.

<u>Analysis Results</u>

Gender is another important factor in this study. All participants' gender information was coded into SPSS to analyze how LM might influence the math test results between male and female.

As with previous analyses, three kinds of data were included: pretest, posttest, and posttest-pretest. The pretest and posttest are the original scores of every participant. The posttest-pretest is the score difference between posttest and pretest. It is calculated by posttest minus pretest.

Table 4.6 shows the data analysis of the male students' scores for both the control and the experiment group. In the pretest, the male experiment group (37.39) has lower scores than the male control group (43.34); In the posttest, the male experiment group (73.88) still performs lower scores than the male control group (76.71). However, the male experiment catches up to the male control group from the result of posttest-pretest with 36.49 for the male experiment group and 33.38 for the male control group. Moreover, the T-test showed the male control group's score to be significantly different than the experiment group in the pretest (Sig. 2 tail of .065), while the male control group and the experiment group performed the same(Sig. 2 tail of 0.35). This indicates a strong positive effect of LM on the experiment group, since the LM treatment raised the male experimental group from lower than the the control group to the same as the control group. Thus, it's safe to conclude that the LM experiment has better effects on math learning for male students than for males in indoor environments.

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Group Statistics

	type_gender	N	Mean	Std. Deviation
Pretest	Male Experiment	59	37.39	15.032
	Male Control	56	43.34	19.081
Posttest	Male Experiment	59	73.88	17.390
	Male Control	56	76.71	15.093
Posttest_Pretest	Male Experiment	59	**36.49**	15.267
	Male Control	56	**33.38**	15.561

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	2.883	.092	-1.862	113	**.065**	-5.949	3.195
Posttest	1.115	.293	-.931	113	**.354**	-2.833	3.043
Posttest_Pretest	.010	.922	1.084	113	.281	3.117	2.875

Table 4.6 T-test of the male students in math tests

On the other hand, female students revealed opposite results with male students. In Table 4.7, the female control group (mean 39.41) and the female experimental group (mean 39.19) were the same as the Pretest with Sig. 2 tail of 0.936 on T-test. The female control group(mean 75.63) is significantly higher than the female experiment group (mean 70.03) with Sig. 2 tail of 0.052 on the T-test. This indicates that the LM treatment raised the scores of the female experiment group from the same as the female control group to lower than the female control group. Therefore, the LM treatment is less effective at improving math scores for female students than indoor environments.

Group Statistics

	type_gender	N	Mean	Std. Deviation
Pretest	Female Experiment	59	39.19	14.356
	Female Control	59	39.41	15.592
Posttest	Female Experiment	59	70.03	17.226
	Female Control	59	75.63	13.521
Posttest_Pretest	Female Experiment	59	30.85	13.521
	Female Control	59	36.22	14.064

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	.780	.379	-.080	116	.936	-.220	2.759
Posttest	4.846	.030	-1.962	116	.052	-5.593	2.851
Posttest_Pretest	.000	.983	-2.115	116	.037	-5.373	2.540

Table 4.7 T-test of the female students in math tests

In summary, the LM helped male students perform better on the math tests more than female students.

<u>*Interpretation*</u>

Male students and female students have been shown to have different learning styles(Anna,2002). Most males are kinesthetic, tactual, and visual. They also like body movements and informal learning environment more than females. In social settings, males may break the rules; they tend to learn less by listening to the teacher. They are also more likely to be motivated by peers. On the other hand, females prefer auditory oriented learning environments like a conventional classroom (P.65).

Therefore, it's not surprising that male students perform better when interacting with the LM. As an informal learning activity, LM provides more ownership of learning,

body movements, and social communication. Being outside, touching the loose parts, and working on their projects are engaging for male students. They also have more tolerance for the discomforts of severe weather, the fatigue, and the dirt. On the other hand, the learning style of female students doesn't fit easily with LM. Female students were observed in a more a passive engagement with the LM.

4.2.5 Summary of Math Tests

This study examined the efficacy of LM on math test scores by analyzing both the control and experiment group, the differences in gender, and the differences in engagement levels by period.

According to the analysis, the LM treatment didn't have a significant effect on the whole experiment group. However, students with higher engagement levels and in the right climatic environments did show better performances with the LM than with the indoor environments. Male students also had higher scores when interacting with the LM than indoor environments. Overall, LM may not be a solution than the indoor classroom for all situations. However, it can be a strong supplement to existing math instruction if the teacher uses LM as well.

4.3 Math Motivation Questionnaire Results

The results of the math motivation questionnaire identifies the motivation levels of the participating students. The survey suggests that students with higher motivation levels tend to be more active learners and be more successful on math long term. The goal of this analysis is to understand how LM impacts students' math motivation levels by comparing LM to the indoor environments.

4.3.1 Participants and data preprocessing

As discussed in Chapter Three, the motivation questionnaire data was provided by the teacher. This data include both pretest and posttest of a written questionnaire. 216 questionnaires were received with 114 in the experimental group and 102 in the control group. Each questionnaire had 25 question items. All items were coded and typed into a statistical software called SPSS.

The data preprocessing work includes two parts:

Delete incomplete items.

Because all of the questionnaires were filled by hand, there is incomplete data (no names, no second page) . These items have missing information, so 25 participants (17 in the control group and 9 in experiment group) were deleted.

Delete questionable items.

1) Some questionnaires have either 1s (strongly agree) or 5s (strongly disagree) to all questions. These participants didn't treat the motivational questionnaire

seriously. 15 participants were deleted (6 in control group, 9 in experimental group).

2) Some students gave totally opposite answers to their questionnaire. With a difference of more than 60 pts (125 total), these participants chose the opposite answer for every question. For example, they choose strongly agree(1) on the pretest and strongly disagree (5) on the posttest. Two participants were deleted. As Figure 4.19 shows, 13 participants were deleted, and 101 participants were included in the experimental group. 23 participants were deleted, and 79 participants were included in the control group.
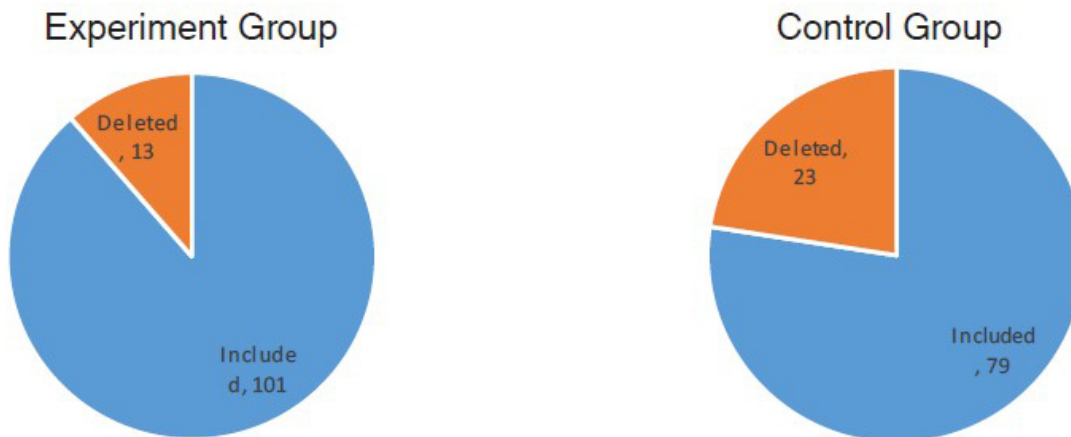
Figure 4.19 Participants and data preprocessing of motivation questionnaire

4.3.2 Result #1: LM works better than indoor environments on students' math motivation level.

Analysis Results

Group Statistics

	types	N	Mean	Std. Deviation	Std. Error Mean
Pretest	experiment	101	79.21	17.727	1.764
	control	78	83.08	14.828	1.679
Posttest	experiment	101	78.03	15.312	1.524
	control	78	80.09	15.515	1.757
Posttest-Pretest	experiment	101	**-1.18**	23.758	2.364
	control	78	**-2.99**	23.763	2.691

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means					
					Mean Differenc e	Std. Error Differenc e	95% Confidence Interval of the Difference	
	F	Sig.	df	Sig. (2-tailed)			Lower	Upper
Pretest	.012	.913	177	**.097**	3.869	2.321	-.712	8.450
Posttest	3.106	.080	177	.409	2.060	2.491	-2.857	6.977

Table 4.8 the statistic results of overall motivation levels

Similar to the math tests analysis, this analysis compares the performance of both the control group and experimental group. As the Table 4.8 showed, both the control group and experimental group had lower motivation posttest scores than the pretest. However, the experimental group had less decrease (-1.18) than the control group (2.99) did.

In the T-test, the control group and the experimental group were barely (Sig 2-tailed of 0.151) different in the pretest. The control group (80.09) had higher motivation score than experimental group(78.03). In the posttest, the control group and experiment group were statistically the same (Sig 2-tailed of 0.409). This indicates that the experiment group

change from less motivated than the control group to the same motivated as the control group.

Interpretation

Studies show that middle school students have worse performance on math motivational level tests is lower than those of elementary school students (Jacquelynne et al., 1993). Middle schools tend to have larger class size, less student autonomy, and strong teacher control and discipline. This can lead to a mismatch between students' desires and classroom opportunities that can lead to motivation declination. The results of this study confirm these studies results. In this study, both control group and experimental groups decreased their motivation levels after the two-week period.

However, the declination of the experimental group is much less than the control group. LM as a situated learning environment provides hands-on and design-make activities that help students find ownership and relevancy in their learning. Thus, it led to stronger facilitation of students' math motivation compared to indoor classroom environments.

4.3.3 Result #2: LM made students feel math is more important and useful.

Analysis of Results

The motivation questionnaire measured six factors of math motivation. Factors include "interest", "utility", "cost", "value", "confidence", and "achievement". Each factor was addressed by several questions in the questionnaire.

This study summed up the scores of all questions and answers for each factor, then posttest scores of each factor result minus the pretest scores of that factor results. Then, the

scores for each factor between the posttests and pretests were calculated and weighed by the number of questions. For example, "Interest" (Post-Pre) means the change of motivation scores of all the questions in the factor of "interest". It was calculated as:

Interest(Post-Pre)= (Posttest of Ti – Pretest of TI)/Ni
Ti=Total score of questions in the factor interest
Ni=Total number of the questions in the factor interest

As Table 4.9 shows, value and utility were two significant factors indicating the biggest differences between experimental and control groups. The experimental group in tearms of "value" scored 1.18 (5 in total) more than the control group did. The experimental group in terms of utility scored 0.52 (5 in total) more than the control group did.

	types	N	Mean	Experiment - Control
Interest (Post-Pre)	Experiment	101	-.46	0.28
	Control	78	-.73	
Utility (Post-Pre)	experiment	101	.11	0.52
	control	78	-.41	
Cost (Post-Pre)	experiment	101	.16	0.36
	control	78	-.21	
Value (Post-Pre)	experiment	101	-.10	1.18
	control	78	-1.28	
Confidence (Post-Pre)	experiment	101	.11	0.07
	control	78	.04	
Achievement (Post-Pre)	experiment	101	-.63	-0.45
	control	78	-.18	

Table 4.9 means of the score changes on different motivation factors

The factor "Value" asks students how important math is. It includes questions: (1)It is important for me to be someone who is good at solving problems that involve math; (2) Being someone who is good at math is important to me; (3)Being good at math is an important part of who I am; (4)It is important to me to be a person who reasons mathematically.

The factor "Utility" asks students how useful the math is. It includes questions: (1) Math will be useful for me later in life; (2) Math concepts are valuable because they will help me in the future; (3) How useful is learning math for what you want to do after you graduate and go to work; (4) In general, how useful is what you learn in math; (5) Being good at math will be important when I get a job or go to college; and (6) Compared to most of your other school subjects, how useful is what you learn in math?

Figure 4.20 shows that the questions of "Value" and "Utility" perform better than other factors in the math motivation questionnaire. This indicates LM made students feel that math is more important and useful. It means LM successfully related math concepts to real world problems that students care about. LM is a learning method that is more tangible, flexible and meaningful. It changed students' impression of math. By making LM manipulations, students can experience new ways of learning math and enriching their understanding of what math can do. When students pay attention to learning materials and interpret them in their way, they tend to feel that math is more important and useful than before.

Figure 4.20 differences of the motivation levels between the experiment group and the control group

However, the factor "Achievement" for the experimental group reveal lower math

motivation levels than the control group. This is possibly because of the influence of

increased "Value" and "Utility" levels. If students feel that math is more important and

useful, they might think that there are much more things to learn in math. Thus, they are

more likely to be unsatisfied with their math performances.

4.3.4 Result #3: The relationship between students' motivation level changes and engagement levels is unclear.

Analysis of Results

Figure 4.21 shows the posttest- pretest of motivation scores for each period.

Higher posttest- pretest scores mean better performance on improving students'

motivation levels. As the figure shows, there is no significant patterns or trends between

the control periods and the experimental periods. Also, the performance of the

experiment periods ranks as period 1> period 4> period 3>period 6> period 5. Analysis

shows no correlation with the ranks of engagement levels which is period 4> period 3>

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period 6>period 1> period 5.
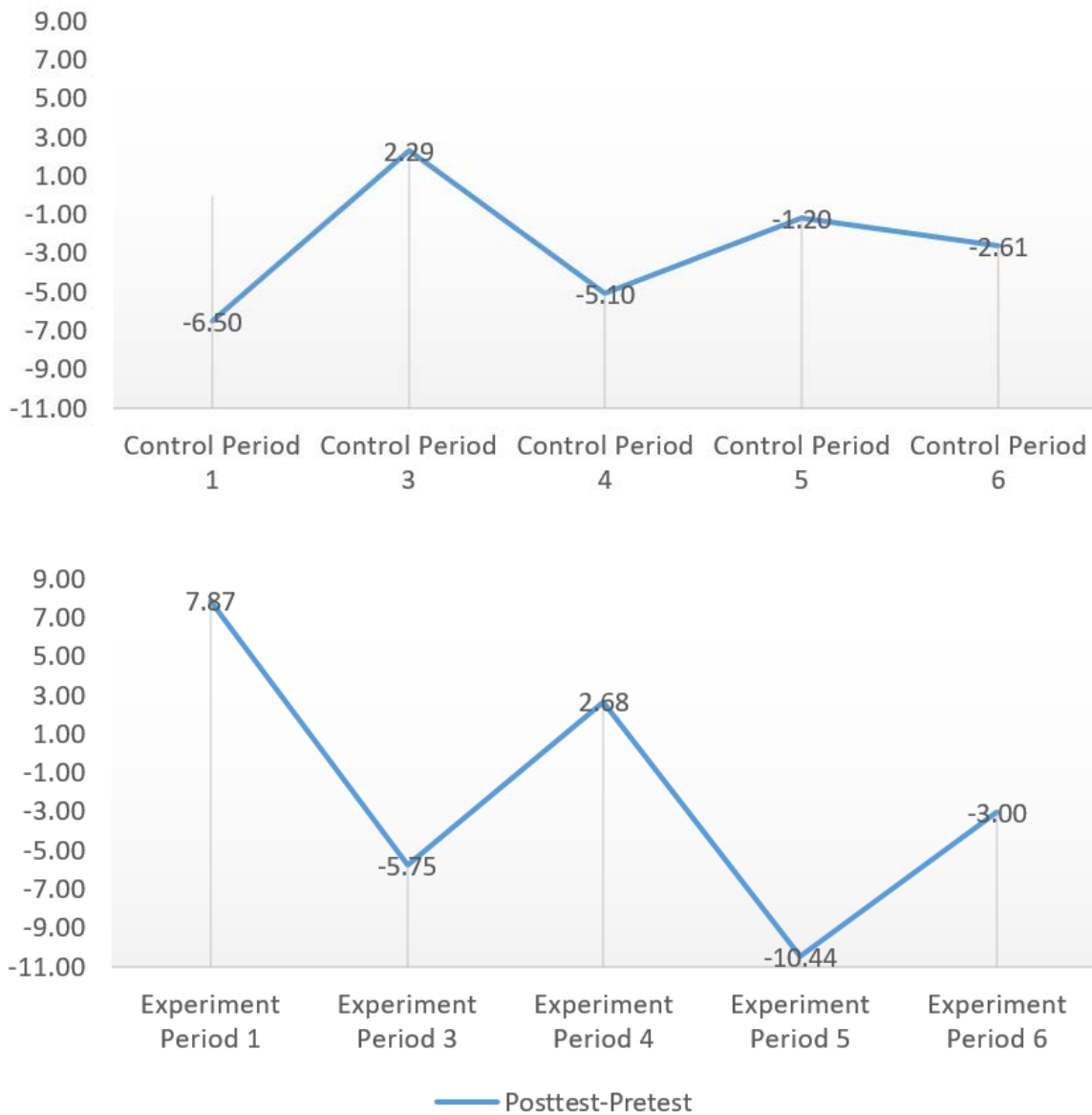
Figure 4.21 Motivation scores for each period

<u>*Interpretation*</u>

It's expected that higher engagement levels would result in higher motivation
levels. However, the analysis results refute this assumption since period 1 experiment
(low engagement level) has the highest motivation improvements on motivation

questionnaire tests. This indicates that LM's effects on students' math motivation levels are not correlated with their engagement levels.

4.3.5 Result #4: LM increased males' motivation levels instead of female

<u>Analysis Results</u>

This analysis, like the math tests analysis, included all participants' gender information into SPSS to see how LM influences math motivation between males and females.

Table 4.10 shows the motivation analysis of the male students for both the control and the experimental groups. In the pretest, males in the experimental groups has lower motivation scores (77.44) than male (84.36). This difference is also statistically significant (Sig. 2 tail of .038). In the posttest, males in the experiment male have higher motivation scores (83.24) than those in the control group (78.31). However, this difference is not statistically significant (Sig. 2 tail of .196). Overall, this indicates that LM changed for males in the experiment group from lower than the males in the control group to the same as those in the control group. Moreover, males in the experimental group increased their motivation scores by 5.8 points (total 125), while males in the control group showed decreased motivation scores by -6.06 (125 total). Overall, there is a 11.86 difference between the two groups (5.8+11.86). So male students with LM treatments had higher math motivation improvements than the male students in indoor environments.

Group Statistics

	gender_type	N	Mean	Std. Deviation
Pretest	Experiment Male	50	77.44	15.412
	Control Male	36	84.36	14.379
Posttest	Experiment Male	50	83.24	17.604
	Control Male	36	78.31	16.896
Posttest-Pretest	Experiment Male	50	**5.80**	24.452
	Control Male	36	**-6.06**	25.510

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	.112	.739	2.112	84	**.038**	6.921	3.277
Posttest	.094	.760	-1.304	84	**.196**	-4.934	3.784
Posttest-Pretest	.098	.755	2.178	84	.032	11.856	5.442

Table 4.10 T-test of male student group for in motivation questionnaire

On the other hand, female students had the opposite results of male students. As Table 4.11 shows, in the pretest, the experimental group of female students had lower motivation scores (80.94) than the control female students (81.98). However, this difference is not statistically significant (Sig. 2 tail of .754). In the posttest, the experimental group of female students had lower motivation scores (72.92) than the control group of male students (81.62). This difference is statistically significant (Sig. 2 tail of .006). Overall, this indicates that LM changed the scores of the female students in the experimental group from the same as the female students in the control group to lower than the female students in the control group. So female students with LM treatments had lower math motivation improvements than the female students in indoor environments.

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Group Statistics

	gender_type	N	Mean	Std. Deviation
Pretest	Experiment Female	51	80.94	15.165
	Control Female	42	81.98	16.520
Posttest	Experiment Female	51	72.92	16.462
	Control Female	42	81.62	12.808
Posttest-Pretest	Experiment Female	51	**-8.02**	21.131
	Control Female	42	**-.36**	22.128

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	.088	.768	.315	91	**.754**	1.035	3.290
Posttest	1.604	.209	2.796	91	**.006**	8.697	3.110

Table 4.11 T-test of the female students in motivation questionnaire

<u>*Interpretation*</u>

Analysis of the motivation questionnaire revealed the same results regarding gender differences as the math tests. Both of the math tests and math motivation questionnaire tests have the experiment group of male lower than the control group of male in the pretest, and the experiment group of male the same as the control group of male in the Posttest. Both of the math tests and math motivation questionnaire tests have the experiment group of female the same as the control group of female in the pretest, and the experiment group of female lower than control group of female in the Posttest. This reinforces the conclusion that LM is a more effective learning environment than indoor environments at facilitating math learning for male students.

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4.3.6 Summary of Motivational Questionnaire Tests

This study examined the efficacy of LM on math motivation levels by analyzing the control and the experimental groups, as well as the differences in gender, and engagement levels between students in both groups.

According to the data analysis, LM works better than indoor environments at improving the experimental group's math motivation. By interacting with LM, students feel that math is more important and useful. Male students were also more motivated than female students were. However, higher engagement levels didn't have a strong correlation with math motivation for any group.

Overall, LM provides an effective learning environments for increasing students' math motivation. It did a more effective job at motivate students than indoor environments.

4.4 Chapter Summary

This chapter examined the efficacy of LM on math learning in an experiment of Edwards middle school.

By analyze the observation data, this study showed the engagement levels of all periods as Period 4> Period 3>Period 6>Period 1>Period 5. The observation results of behavioral patterns suggest many significant phenomena during the LM learning: (1) Seats are important, shade is helpful; (2) A group size of five might be too big in some cases; (3) Too much communication with other groups is not good for math learning; (4) After 25 mins, students cannot focus on math learning; (5) Loose parts can be great tools for math learning and free play; (6) The cold, rainy, and windy weather will have a bad influence on student learning and the LM; (7) Male students like to use loose parts more than female students.

According to the analysis on math tests, the LM treatment didn't have a significant effect on the whole experiment group. However, students with higher engagement levels and in the right climatic environments did show better performances with the LM than with the indoor environments. Male students also had higher scores when interacting with the LM than indoor environments. Overall, LM may not be a solution than the indoor classroom for all situations. However, it can be a strong supplement to existing math instruction if the teacher uses LM as well.

In terms of math motivation questionnaire, LM works better than indoor environments at improving the experimental group's math motivation. By interacting with LM, students feel that math is more important and useful. Male students were also

more motivated than female students were. Overall, LM provides an effective learning environments for increasing students' math motivation. It did a more effective job at motivate students than indoor environments.

CHAPTER FIVE

RESEARCH CONCLUSIONS

5.1. Key Findings

This study examines several relationships between math learning and landscape manipulatives (LM). The study uses a quasi-experiment conducted in a real middle school setting to address two primary research questions:

1) Do students who use Landscape Manipulatives to complete their math homework show greater improvements on standard math test scores than students who use a typical study hall to complete their homework??

2) Do students who use Landscape Manipulatives to complete their math homework show greater math learning motivation compared to students who use study hall to complete their homework?

Importantly, there is no absolute answer to either of these research questions since they are bound by many dynamic variables like environmental context, participants, and class administration. To explain how LM performed in this study and best answer the research questions,, the conclusion has been organized into three dimensions (1) applicability and efficacy, (2) design recommendations, and (3) class management.

5.1.1 Efficacy and Applicability

Based on the analysis, LM has large impacts on the math learning of the experiment group. For test scores, LM students showed better scores than typical indoor environments when students are engaged, and the environments are right. For math motivations, LM

students presented stronger motivation levels regardless their engagement levels. And LM fits male students better than female students for both the math tests and motivation questionnaire.

Landscape Manipulatives have demonstrated a strong potential for complementing current math instruction at themiddle school levels. Lanndscape Manipulatives provide an effective solution for some of the previously documented problems assoicated with traditional-based teaching approachesfor math including issues tied to indoor and outdoor learning environments. The outside environment in this study supports Kaplan and Kaplans' (1989) finding that the natural envirohment can provide great opportunities for physical activities and relieve students from mental fatigue. The problem/project-based learning activities, such as LM, help students solve "authentic problems" and encourage independent thinking and learning skills. The process of making and manipulating assists learners with developing their understanding of math, and how math works in the real world. Through careful observation and quasi-experimentation, this study has shown that LM can provide a powerful, alternative setting for learning math that reaches needy students in unique ways and in a very short time (2 weeks) leads to improved math test scores and motivation levels.

Itis worth noting that LM is not a panacea for all situations encountered in math education. It also has implementation restraints like lack of environmental control compared to indoor environments. Also, students may find self-regulation difficult during unstructured LM use. Therefore, LM's can underperform if the school or teacher don't

effectively plan and supervise the use of LMs. Based on this study, the researcher suggests considering the following guidelines when implementing LM in middle school studies:

1. *Make LM part of normal curriculum activities.*

   Teachers can use LM when students have a difficult time understanding math problems, or when specific math concepts need human-sized, real-life demonstration.

2. *Use LM as an approach to adjusting the pace of teaching.*

   When teachers see significant mental fatigue from students, learning may benefit from using LM to take a break and rejuvenate their class while boosting learning that would otherwise continue to lag.

3. *Regularly use LM as a program for promoting math motivation.*

   In this study, after using LM, students felt math was more important and useful. This change in attitude will have a long-term beneficial impact on both the student(s) and math learning progress at the school.

5.1.2. Design Recommendations

As part of the pedagogic domains of situated learning and environment-based learning, LM's performance is significantly influenced by dynamic behavioral settings (Barker, 1976). To this point, this study shows that an appropriate balance between learning and free play is one key to the success of LM. One important way to structure and balance free play with learning is through the physical design of the LM. To assist designers of LM environments, , the researcher suggest three dimensions of design

recommendations, based on observations of LM learning activities. These design recommendations include:

Amenities

1) *Provide at least two movable seats for each group.*

   From the observation, many students actively look for seats after 10 minutes of LM. If seats are available in the field, students don't have to leave the site and disrupt LM learning.

2) *Use topographical or vegetational features to create a sense of nclosure for the site.*

   One big challenge facing LM is the element of distraction that routinely occur on school grounds. Making terraces, vegetative screens, and/or other buffers can effectively define the site boundary and create a sense of enclosure such that students can focus better on LM activities.

3) *Provide shades or shelters with trees and pavilions.*

   Severe weather like strong winds and cold temperatures discourage LM use and undermine outdoor math learning. Having trees and pavilions gives students the space to protect their belongings and find refuge in a severe climate. These spaces are also good places to have group discussions and demonstrations.

4) *Each group should have at least two posts.*

   During the experiment, shared posts become distractions that encourage unnecessary communication between different groups. If each group has at

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least two posts then students can connect chains to different posts without using other group's posts or engaging in unnecessary interaction like talking.

Spatial Organization

1) *Design a buffer area between different groups.*

    The communication between different groups should be discouraged because it promotes too much free play for the students. Designing a buffer area using shrubs or retaining walls could effectively separate spaces for different groups.

2) *Further define each group's territory by using pavement or elevation changes.* Working as a group is important during LM learning, so it's recommended that each group space should have different pavement or elevations levels to create a sense of territory and focus as well as interest in the landscape.

3) *Use the biggest size block possible, at least 5ft by 5ft.*

    In the experiment, each block had a size of 4ft by 4ft. This size turned out to be too small to accommodate LM activities. A larger block such as 5ft by 5ft or greater should be helpful.

Loose Parts

1) *Differentiate the color of the loose parts for different groups.*

    During LM use, loose parts can get mixed up among different groups. Many loose parts can also miss or get broken. Providing different colors of loose

parts to different groups makes parts easier to organize and monitor. It also promotes a sense of ownership and relevancy to the students.

2) *Provide more flags and carabiners.*

Flags and carabiners provide even more flexibility to the LM Every time students make measurements or find specific points/angles they use flags and carabiners. This study shows that there can be a significant shortage of them when needed.

3) *Provide chains longer than 10 ft.*

Most of the chains in the experiment were 4ft long. These turned out to be too short because the chains were used to connect posts or ground points that are at least 8ft. apart in distance. Thus, the length of chain should relate to the overall grid size and a mix of short and long chains included.

The recommendations above are the researcher's own recommendations based upon observations in the field and discussions with those teachers involved in the study. The recommendation is not necessarily based on the results of the study. Therefore, the recommendations are considered design guidelines only and additional modifications to LM are welcomed. The main goal of the recommendations is to provide more control to the LM teacher, designer and student which in turn will, encourage more learning instead of unstructured free play while promoting constructive group communication.

5.1.3. Class Management

Since LM activities emphasize the social construction of meaning then the interaction between students is crucial to LM's success. Obviously, positive interaction works best and is recommended. During the study, students were encouraged to communicate and work with each other so talented students could help other classmates on their comprehension and understanding of math concepts. However, this did not always occur. Therefore, to help foster positive interaction, the researcher proposes the following class management guidelines, organized into three related dimensions:

<u>*Administration and Supervision*</u>

1) *Deter disruptive behavior immediately.*

    Disruptive behavior happens when students try to disturb the normal learning process of other students. This significantly discourages learning and undermines LM. Therefore, it's important for the teacher to immediately stop disruptive behavior once he/she sees it.

2) *Have the appropriate amount of homework.*

    In the experiment, there were too many questions in the homework to be finished during the LM period. Since students knew it was impossible to complete all of the homework, they didn't treat it seriously enough.

3) *Control the plan and learning ration.*

    Focusing on math questions is important to achieve better academic performance. If the teacher sees students not working on math questions,

he/she should immediately stop it. Likewise, the teacher should monitor the amount of work and problems students manipulate so that total LM time is less than 30 minutes.

Group Size and Assignment

1) *Assign group members appropriately.*

From observation, the groups with strong cohesion as a team are more engaged. It's important to assign group members that like to work with each other.

2) *Make group size match math concepts.*

Different math concepts need different manipulations. If the math concept is number lines, for example, then two students in a group is enough to make the manipulations. If the math concept is geometry, five students are necessary because of manipulations are more complex.

3) *Consider having at least two male students in each group.*

According to the study results, LM has more signfricant implication for male learners and observations suggest that they engatged in manipulations more than females. This suggests that male students are more involved and active in LM learning overall. Thus, having at least two males in each group may encourage all members become more engaged in LM.

Time and Dates

1) *Twenty-five minutes as the maximum time length for LM.*

Students cannot focus on LM and math learning for very long time. In the experiment, 25 minutes was an important milestone between learning and excessive free play. Therefore, it's recommended to have LM classes no longer than 25 minutes in the future.

2) *Choose the days with good weather conditions, avoid windy and cold days.* It's important to have good climatic conditions when conducting LM learning. If the weather is cold and windy, it's difficult for students to learn math outside.

5.2 Limitations

First, the two-week experiment period might be too short to study the efficacy of the LM. A longer experiment time may have made the differences between LM and the indoor environment more distinct. Second, only one school participated in this study. The student sample, the school site, and the teachers would likely all be different in different schools. Adding more schools in the region and beyond may increase the reliability of the research results. Third, this research deployed a limited observational procedure. There was only one researcher attempting to observe 30 students in each period. This made it difficult to conduct a thorough observation of student learning and behavior. More researchers may help provide additional information and more accurate interpretations of student behavior. Also, using video recording techniques, which were not used, could have captured more behaviors and contexts of interaction. Fourth, the weather had a big impact of the study. It was cold and windy in the morning during the experiment days. This might be the reason why Period 1 presents abnormal results on math tests and the motivation questionnaire. Having all periods in a similar climate condition will make them more comparable. Fifth, the math tests have testing effects on students' math learning. The posttest might be not a great representation of students' performances. Finally, there is too much homework for time used in the experiment. Unlike the control group, few students in the experimental group finished their homework. Therefore, the experimental group has less practice on math questions than the control group. This can be an important extraneous variable on the research results.

5.3 Significance

The significance of the study lies in the three aspects that advance knowledge and practice as following:

1. In the existing literature, very few studies attempt to improve math learning by promoting physical activities. There are also few practical cases in existing school systems whereby mathematics is taught within an outdoor, campus environment. Current approaches and theories of outdoor and environmental learning approaches such as place-based learning and environmental based learning as theoretical learning frameworks rarely address mathematics and have yet to show how outdoor learning can support academic efficacy in math education. Therefore, this project introduces LM to fill these gaps by providing students the opportunity for active learning events which encourage the body movement of learners in outdoor environments, and simultaneously facilitate math learning. This project also provides empirical evidence on learning outcomes related to LM in natural educational settings.

2. In contrast to EBE, LM address most safety and transportation concerns by utilizing existing school campuses as the learning context (see chapter 2). Landscape manipulatives can easily be replicated and implemented to most existing campus landscapes with minimal implementation costs – including those associated with the math manipulative design itself. Moreover, what LM promotes is a self-regulated and student-oriented learning process whereby teachers make fewer direct interventions. Therefore, using LM requires no professional development training which too often

amounts to increased workload for teachers. Nonetheless, training is likely beneficial and can be provided for enrichment purposes. Overall, LM's benefits outweigh some of the potential disadvantages associated with EBE especially in terms of costs, safety, access, land use, implementation, and training.

3. Complement indoor learning. Reinforces indoor learning. Provide a new way of learning that helps students, especially those who learn best kinetically. In addition, students who have difficulties comprehending mathematics problems, especially geometry, on traditional blackboards and notebooks, can use LM to see shapes, functions, and other math entities in human scale. This allows for life sized experiential and hands-on learning to occur which complements existing in-class instruction.

5.4 Future Studies

This study proposed a new interaction between middle school students and outdoor environments called Landscape Manipulatives, and conducted a quasi-experimental study to examine the efficacy of the LM learning. The following future investigations may continue this topic in the following two areas:

1) *Conduct more experiments with stronger validity and reliability.*

   With all the limitations discussed above, more experimental studies can be conducted at other schools with longer time lengths. By adopting the recommendations in the key findings (see Chapter five 5.1), new math designs and a specific class management protocol can be implemented. It will also be interesting to look at the females and males, or to compare the efficacy for different grades. Therefore, the efficacy of LM can be further examined.

2) *Study the implementation of existing math curriculum of US middle school systems.*

   According to the findings, LM cannot totally replace the traditional math instruction approach in middle schools. It's not a panacea that will work under all situations. Therefore, an implementation plan is needed to apply LM into real US middle schools effectively. This may include questions like How do teachers and administrators think about and use LM? What's the role of LM in the existing curriculum? What are the math concepts most suitable for LM classes? What is the best time to implement LM classes?

5.5 Summary

In this study, a new learning landscape framework called Landscape Manipulatives (LM) was proposed by synthesizing the literature in learning theory, natural environments, and environmental design. The study uses a a quasi-experiment conducted at Edwards Middle School, SC to examine the efficacy of LM on students' math learning. The study's results, based upon analysis of observations, math test scores, and math motivation questionnaires suggests that LM can serve as an effective outdoor environment for promoting math motivation and math test scores, especially when weather conditions are suitable. The results also suggest LM are particularly helpful for male students. Overall, when students were engaged in the LM and the outdoor conditions was reasonable then the LM led to greater math test scores and motivation compared to students who worked indoors on their homework in study hall. The study also provides a series of implantation recommendations and design guidelines based upon the researcher's observations and suggestions from teachers.

APPENDICES

Appendix A

Site Observation Notes

Day 1

Period 1

•Group 4 didn't use that much LM; they work on the questions a lot for the first 20 mins
•Group1, Group3 are interested in the tools, in the beginning, they are looking at the box to see what they have there, they also start to relate LM to questions early compare to other groups, in the first 10min.
•Later for all groups, they work on LM when they find a relation between their questions and LM.
•Group 5 deeply involved in the learning.
•After 30 min, some students cannot get focused, they start to play with irrelevant things such as rope skipping, measuring school yard, measure their bodies.
•They use LM to counting and measure the length relationships. They all use chains to hang on the grid on the ground.
•Group 2 finished their work at 37 mins.

Behavior Counts: positive 5, negative 2
Overall comments: this period is the first group; they have the good social environment. All group members like each other and most of them are engaged.

Period 3

•Group 4 and 5 is very creative. Group 4 build a 'wall' using ropes and chains. Group 5 build a ground grid using chains.
•Group 3 is not involved; they seat on the ground just work on their questions. Group 5 and Group 2 occupied Group 3's land, maybe that's the reason.
•Group 2 said they are confused in the first, but they start working at about 15min
•Group 2 and Group 4 used tree as new post
•Non-learning activities: Tape measure as yo-yo, rope on the neck
•Group1 separated to two teams 2+3,

Behavior Counts: positive 8, negative 3
Overall comments: When the land occupied by other groups, the incentives of using LM get lower. Different groups have their approach of using LM.

Period 4

- Group 1 measured their height, arm at the 5min.
- Group 3 use LM at a very small scale. They did some counting on the hooks of the chains.
- Except Group 3, few students engaged in the LM. The basketball field has a lunch recess. Noise and people disturbed the learning, hard to focus.
- Group 2 gathered together, under the tree.

Behavior Counts: positive 6, negative 2
Overall Comments: Students cannot focus on the learning outdoor because of the noise. Other activities and people in 100 feet are a big distraction.

Period 5

- Again, group 2 is working under the tree. The tree is more interesting than the LM field.
- It's very windy in this period. Students suffered.
- Except Group 4 and 5, very few students used LM. They played with the tools for a while, but few manipulations related to Math.
- There is still noise and distractions from basketball field.
- Most tools are not well organized in the beginning; ropes are entangled.
- After 25 mins, all girls are still working on the questions; boys began to play with LM.

Behavior Counts: positive 5, negative 3
Overall Comments: LM is more attractive to boys and Kinesthetic learning style. The Wind is a bad factor. Tools need to be well organized before use.

Period 6

- All group start in a quiet environment, no distraction. And tools are well organized.
- Group 4 is extremely involved in the LM space.
- Multiple forms of manipulation are seen: number lines using ground points, geometry angles using posts + ground points, flags are used a lot on the site.
- After 20 mins, all groups fully involved in the LM space.
- Girls like to sit on the ground more than boys.

Behavior Counts: positive 12, negative 3
Overall comments: All flags are used. All groups are engaged in the activities.

Day 1 Rank: Period 6- Period 3- Period 4- Period 1- Period 5

Day 1 Findings:

- Flags and chains are used a lot. Posts are more popular than ground points.
- Most manipulations are about number lines, angles, and proportions.
- Group 2 likes to take advantage of the tree beside.
- Noise and nearby activities are a huge distraction. The Wind is a bad environmental factor.
- Boys like the LM more than girls. Groups with better collaboration and social relationships use more LM.
- Every group has different ways of using LM.
- The teacher expressed positive comments about the activity.

Day 2

Period 1

•The second group hook ropes on the post and find midpoint on the rope
•Group 4 is still different with other groups; they work on the Qs without relating with LM that much, then they use LM for fun.
•Group 4 and Group 5 broke the tape measures.
•Group 3 is quiet, and they did some small scale work.
•Group 1 began to split into two teams. Group 2 would seat for five mins and then start work again.
•They made more complex shapes; pulleys and ground grid became more popular.

Behavior Counts: positive 10, negative 4
Overall comments: they did more LM learning than the Day 1. They are more familiar with the tools, so they focus more on making shapes.

Period *3*

•Group 1 made ropes and chains on the post. This is the approach many groups use also.
•After 15 min, group 2 start to seat on the side. They don't like us LM at all. They just look at the Questions trying to finish them.
•Group 3 don't try any LM for the first 15 mins. They finished their questions at 25 mins. Then, they went crazy with LM tools; they made big complex shapes there. Maybe just for showing off.
•Group 4 disappeared for a moment, they just went to other groups and talked.
•It's obvious that students in this period are looking for a place to seat all the time. On the grass, on the edge of the walkway, under the tree, etc. Group 2/3/4 are good examples.

Behavior Counts: positive 7, negative 3
Overall comments: Cold and cloudy weather is not good for them; Seats are important. They need to seat for five mins after they made a shape. It seems like this period didn't perform as well as Day 1.

Period 4

•All groups start in a good way. They manipulate and relate to the questions very well.
•Group 3 made a nice ground grid. Then all groups followed.
•Group 2 has a student leave the team and work with other groups.

•The crowd and distraction came at ten mins; Group 1/4/2 say hi to their friends outside of class. Other teachers.   However, this time the distraction lasted about five mins, all groups went back to LM learning again.
•At 20 mins or 25 mins, it's obvious many students felt bored.

Behavior Counts: positive 11, negative 3
Overall comments: This period did much better than Day 1. The distraction from basketball field still exists. However, it only lasts for five mins. Also, all groups look boring after 25 mins.

Period 5

•Start early, all groups start with posts.
•Groups 2 lean on a tree, not participate.
•Group 4/5 did much better on LM learning. They discuss as a group on Math problems.

Behavior Counts: positive 6, negative 3
Overall Comments: Except for group 2, all other groups did much better than Day

Period 6

•All group starts by looking at questions.
•Group 2 connects chains with tree and making 3d coordinates there.
•After 25 mins, there are students asking the time.
•Group 2 and Group 5 have leaders to get other teammates involved.

Behavior Counts: positive 7, negative 2
Overall comments: This period is involved. Every team has their way of manipulation.

Day 2 Rank: Period 3- Period 1- Period 4- Period 5- Period 6

Day 2 Findings:

•Pulleys and ropes are used more than Day 1. All tools are well used because of increased familiarity on loose parts.
•All groups made more complex shapes based on Math problems. They are more engaged.

•Teams in each period learn from each other. Major ways are ground grids, flag grids, chain lines on posts.
•Distraction from basketball field decreased for Period 4 and Period 5.

Day 3

Period 1

•Group 2,1 repeat the structure they use before. The same. G1 use ground coordinates, G2 use post number line.
•G1 is more engaged in the first 5m because of the updated loose parts.
•Group 3 start to use flag to relate Questions at smaller scale
•G1 still love to play with the pulley.
•G1 finished at 35min, G2 finished at 20min, G3 finished at 25min
•Some students stop working and play with loose parts. The teacher called them. It works.

Behavior Counts: positive 7, negative 3
Overall Comments: The level of engagement keeps but not higher. After 20 mins, there is more playing than learning. The teacher is really important to balance their activities.

Period 3

•G4 dancing, G2 on trees in the beginning.
•G3 made the same thing as last day.
•They are interested in using loose parts.
•G1 is working on Qs all the time. Few LM learning.
•Eight students came to the teacher; they said it's freezing.

Behavior Counts: positive 9, negative 4
Overall Comments: It's really cold 50 degrees. I see more body play such as rope skipping, limbo dance, running, jumping.

Period 4

•G2 separate to 2+2 mode. G1 are not good friends with each other.
•They made the nice detailed grid in the beginning.
•Again, there are distractions from basketball field.
•G1,4 didn't use LM very much.
•G3,5 learned a lot with LM.

Behavior Counts: positive 13, negative 4
Overall comments: This period did better than Period 3. G3+G5 might be at the best engagement level.

Period 5

- Still cold in the beginning.
- G3 is not engaging for the first 5mins.
- G2,4 came together.
- Start from 20 mins. All groups start playing. No LM learning.

Behavior Counts: positive 4, negative 6
Overall comments: Very few learning, the math garden turned into a playground. All groups started playing at 20 mins. When G2 started to play, all groups follow them.

Period 6

- G2 hook chains on the tree again.
- G3 went to the hallway.
- G4 focus on Questions, very few LM.
- After 20 mins, they started running, jumping, more body movement.

Behavior Counts: positive 6, negative 3
Overall Comments: Even though the cold weather, this period keeps the engagement level as much as they can.

Day 3 Rank: Period 4- Period 3- Period 1- Period 6- Period 5

Day 3 Findings:

- Coldness is a really bad factor for outdoor learning. 50 The degree is not good.
- Teachers' administration is important to balance the ration of learning and playing.
- Each team formed their approach to Manipulation. Each period also has its characteristics.
- Students who are engaged are always engaged; even the teammates are not.
- After three days, team chemistry is important. If team members don't like each other, the team separated into two mini-groups.

Day 4

Period 1

- After a week, they still remember their favorite shape structures to start with.
- All groups are learning and using LM.
- Because of fewer Questions, they can finish Qs at 20 mins. G5 30 mins.
- G4 didn't focus on learning; they like playing with LM.

Behavior Counts: positive 8, negative 2
Overall comments: the pattern of 20 mins still exists. After four days, the engagement level still keeps. They focus on learning more than play.

Period 3

- They work on questions well.
- G2 go back under the tree.
- They looked at their question sheet more than using LM. However, they use LM when necessary.

Behavior Counts: positive 16, negative 3
Overall comments: They are focusing on the questions more. Temperature and weather are good.

Period 4

- Maybe the questions are easy to understand. They don't use LM all the time.
- Group 1,3,2 began to hang chains on legs, necks, etc.

Behavior Counts: positive 12, negative 2
Overall comments: They formed a routine for LM. They know what shapes to start, and when it's useful. Also, there are always students finding ways to play.

Period 5

- The boy troublemaker in G2 missed the class today; it's good news.
- Shapes are not as complex as last time. Maybe it's because of the questions.
- Great weather, the sun is good. Students(G1,3,5) seat on the grass, lie down to the grass, they feel comfortable.

Behavior Counts: positive 8, negative 3

Overall comments: When the weather is comfortable, they can focus. When the wind is blowing, they tend to sit on the ground more.

Period 6

- •G2 hook chains on the tree again.
- •G4 work with G2 again.
- •Other classes came to the site, so many students stopped LM.
- •The teacher usually works on her things in the afternoon.

Behavior Counts: positive 9, negative 5
Overall Comments: Even though the cold weather, this period keeps the engagement level as much as they can. However, other class created chaos. The site boundary is important. You don't want to break that boundary.

Day 4 Rank: Period 3- Period 4- Period 1- Period 5- Period 6

Day 4 Findings:

- •The learning today is all good because of appropriate questions. Most students finished in 20 mins.
- •Shapes they made are not as complex as before, but more math related.
- •Good weather helps. Seats helps.
- •Boys like LM more than girls.
- •Some students began to make troubles to the whole learning period. Students in one group will go to other groups for fun.
- •Teacher's administration is important. When the teacher didn't watch LM learning, students tend to broke the rules more than before.
- •Even though the engagement level varies, all students have some moments to manipulate loose parts using related with math.

Day 5

Period 1

•G2,3,4 had a good start. Some use LM. First, some use Questions first.
•All groups are learning and using LM at ten mins.
•G5 did many LM experimentation from 5mins to 15 mins. They use flags and chains.
•The G1 has two girls won't participate with LM always.
•At 23 mins, they began to hook chains to their bodies for play

Behavior Counts: positive 8, negative 3
Overall comments: this period performs better than the last day. But some students till were not interested in learning math with LM.

Period 3

•The wind got bigger and bigger. Groups felt something wrong with the environment, they all look at the questions first.
•G4 and G2 have several girls are not participating well for a long time.
•Also, if some students strongly oppose LM, they will influence the other team members.
•First 20 mins are not good, Groups talk to each other, sit around the well. Didn't use LM very much.

Behavior Counts: positive 9, negative 3
Overall comments: This period has difficulties to fully engaged in LM. The seat is important, they don't have a place to sit, so they left the site instead.

Period 4

•Good group relationships, G5 has a very enthusiastic male student.
•The began to throw flags into the ground after five mins. All group did that. Maybe because of the new flags.
•Geometry questions drive them to use more LMs.
•G5 and G3 behave well throughout the session

Behavior Counts: positive 24, negative 5
Overall comments: This period fits the LM very well. They have very few group issues. They like to try experimenting LM with math.

Period 5

- Two boys in G2 maybe is the biggest trouble maker. (steal other groups' tools, destroy shapes, bullying, etc.)
- The teacher didn't intervene because fatigue or other works to do. For this period, the teacher usually fails to observe LM learning.
- G2 steal tools from G5, one boy in G5 cried.
- Even though two boys are making trouble, G1 and two girls in G2 did well. G3 make some shapes also.

Behavior Counts: positive 6, negative 10
Overall Comments: The only issue with this period is some boys in G2+G4. They like to disturb other groups. However, we can see some students still like it and using LM.

Period 6

- G2 hook chains on the tree again.
- G2 seat under the tree lot.
- G3/G5/G2 are the good group on this one. The whole period is good.
- Shapes are still normal ones seen in the previous days.

Behavior Counts: positive 10, negative 3
Overall comments: This period has better relationships with each other. No students leave their group and disturb other groups. LM turned questions into the project; many students felt that way.

Day 5 Rank: Period 4- Period 6- Period 1- Period 3- Period 5

Day 5 Findings:

- Weather is acceptable
- Shapes they made are not as complex also.
- LM became their routine; they are not new anymore. So they don't make unnecessary shapes, most shapes they made related to math.
- Students who like LM always engage no matter what distraction they had.
- Students who don't like LM are always looking for ways to play.
- Teacher's administration became more important once students get used to LM.
- After five days, some students perform better, some worse.

Day 6

Period 1

- Today is really cold; temperature is 30. Frost on the ground.
- Nobody movement for the first five mins, then they are looking for places having the sunshine.
- G1 did not engage.
- After 15 mins, some students began a few manipulations.

Behavior Counts: positive 5, negative 4
Overall comments: Too cold, not a great session. Sitting and standing ratio is important. You don't want to sit or stand for too long.

Period 3

- Still cold.
- G5 is using flags. Other groups almost ignore tools. However, they are working on questions seriously.
- No groups using chains, too cold.
- After 15 mins, G1,2,4 began to run and jump on the site.

Behavior Counts: positive 9, negative 4
Overall Comments: Still cold but better, few engagement like period 1.

Period 4

- Good groups always perform well like G3 and G5.
- Throw flags on the ground again. This kind of play shows up again and again.
- They've learned for 18 mins then they began to play.
- After six days, a good period follows this pattern: look at Questions, find tools, make shapes, answer questions, have fun with the shapes made for learning.

Behavior Counts: positive 18, negative 4
Overall comments: This period made nicer LMs today. They had a bad day 1; then they became better and better. The distraction from basketball field disappeared.

Period 5

- Two troublesome boys in G2 still destroy the site. However, one girl in G2 work on her own.
- The boy in G5 also work on his own, he is engaged for all six days.

- The period receives the least control from the teacher.
- G1 has good relationships with each other, and they are always experimenting with LMs.

Behavior Counts: positive 5, negative 8
Overall comments: This period showed us how students could make a negative impact on LM learning. The boys in G2 make trouble in these ways: steal tools, destroy shapes, throw tools to people, chain people to the post, shake posts.

Period 6

- G2 didn't hook chains to the tree. Their leader didn't come today.
- All groups are making shapes and think about questions. G3 is really good.
- G5 became bored with LMs. They like to sit on the ground and talk something else.

Behavior Counts: positive 8, negative 4
Overall comments: This period is good overall, no disturbances and trouble makers.

Day 6 Rank: Period 4- Period 3- Period 6- Period 1- Period 5

Day 6 Findings:

- Weather is too cold.
- Period 3,1,5 rank low for multiple days.
- The level of playing and learning is the key to the effectiveness of LM.
- The rank of tools: flags, chains, ropes.
- The disturbance between different groups occurred multiple times.

Motivation Questionnaire

Math Questionnaire   *Name:*

Instructions: Please check the box next to the answer. Select only one choice for each question.

1. I like math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

2. Math is exciting to me.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

3. I am confident that I can do even the most difficult math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

4. Math will be useful for me later in life.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

5. I enjoy doing math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

6. I think that math is useful for what you want to do after you graduate and go to work.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

7. I enjoy learning math from my math teacher.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

8. My goal in math is to avoid looking like I can't do my work
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

9. I have to give up a lot to do well in math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

10. Success in math requires that I give up other activities I enjoy.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

11. I am fascinated by math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

12. It is important for me to be someone who is good at solving problems that involve math.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

13. Being someone who is good at math is important to me.
☐ Strongly agree   ☐ Agree   ☐ Neutral   ☐ Disagree   ☐ Strongly disagree

14. In general, how useful is what you learn in math?

☐ Extremely useful ☐ Very useful ☐ Somewhat useful ☐ Not very useful ☐ Useless

15. Being good at math is an important part of who I am.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

16. It is important to me to be a person who reasons mathematically.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

17. Math concepts are valuable because they will help me in the future.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

18. I enjoy the subject of math.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

19. In the future, I think I will do well in math.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

20. My goal is to learn as much as I can
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

21. Being good at math will be important when I get a job or go to college.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

22. I like to do math.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

23. My goal in math is to look smarter than other students
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

24. Compared to most of your other school subjects, how useful is what you learn in math?
☐ Extremely useful ☐ Very useful ☐ Somewhat useful ☐ Not very useful ☐ Useless

25. My math teacher is good at teaching math concepts.
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

Parent Permission Form
Clemson University

Math Garden: A Study of Outdoor Environments and Learning Outcomes in
Middle School Mathematics Education

Description of the Research and Your Child's Part in It

Dr. Matthew Powers, Associate Professor in the Department of Landscape Architecture at Clemson University and Yang Song, a PhD student are inviting your child to take part in a research study. The purpose of this study is to examine the performance of a math learning garden designed on the Middle School campus (figure 1).

Figure 1: Math Garden. Size is approximately 18'x18'
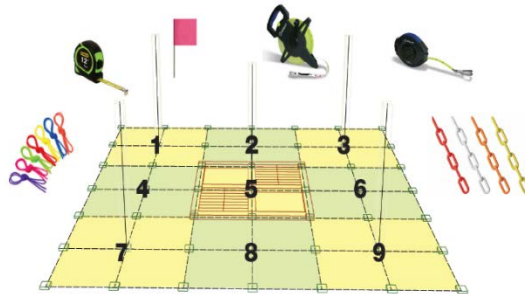
The student's part in this study will be to:
1) Participate in six math garden learning sessions over a two-week period. Each learning session will involve the student using various manipulatives like ropes and measuring tools to create geometric shapes and solve math problems previously discussed inside the classroom (figure 2).
2) Answer two surveys about math learning

Figure 2: Example of geometric shape created by students with the math garden

Student participation will occur during a two-week period sometime in December 2016 or January 2017.

Risks and Discomforts

We do not know of any risks or discomforts to your child in this research study. The math garden is a fun way to learn about math concepts in outdoor settings.

Possible Benefits

There are many different benefits of this study. Your child may develop a greater interest and motivation for math learning while reinforcing concepts learned inside the classroom. Students will also be able to enjoy learning outside the school within the campus landscape. The results of the study may also support the design and implementation of future math gardens on additional middle school campuses around South Carolina and beyond.

Protection of Privacy and Confidentiality

To maintain privacy, all student-related information will be coded using a number system rather than student names. Only the researchers will know which names correspond with which numbers. Photographs of students using the math garden will be taken to document how the garden is used. The images of children's faces will be blurred unless additional consent is obtained through a separate parental permission form. All data, including photographs and images, will be secured and kept confidential for 18 months then erased. Overall, the results of this study may be published in scientific journals, professional publications, or educational presentations; however, no individual participant will be identified by name.

Choosing to Be in the Study

Your child does not have to be in this research study. You do not have to let your child be in the study. You may tell us at any time that you do not want your child to be in the study anymore. Your child will not be punished in any way if you decide not to let your child be in the study or if you stop your child from continuing in the study. Your child's grades will not be affected by any decision you make about this study.

We will also ask your child if they want to take part in this study. Your child will be able to refuse to take part or to quit being in the study at any time.

Contact Information

If you have any questions or concerns about this study or if any problems arise, please contact Matthew Powers at Clemson University at 864-656-4408 or powers8@clemson.edu.

If you have any questions or concerns about your child's rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-0636 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC's toll-free number, 866-297-3071.
A copy of this form will be given to you.

Appendix D

**Student Agreement to be in a Research Study
Clemson University**

*Math Garden: A Study of Outdoor Environments and Learning Outcomes in Middle
School Mathematics Education*

You are invited to participate in a research study. Below you will find answers to some of
the questions that you may have.

Who Are We?

Dr. Matthew Powers, Associate Professor in the Department of Landscape Architecture
at Clemson University and Yang Song, a PhD student are inviting you to take part in a
research study.

What Is It For?

We are conducting a study to examine the performance of math learning garden designed
on the middle school campus. The math garden concept involves building a physical
coordinate system with multiple site grids on the ground plane so students can represent a
wide range of mathematic relationships. Each student is expected to explore previously
introduced math concepts within the math garden in a fun and effective way.

Why You?

All students in the 7th grade have been asked to participate in some way. More
specifically, you were randomly selected to explore the math garden, practice math
problems you've learned in the classroom, and take two standard 10 minute surveys.

What Will You Have to Do?

1) Participate in six math garden learning sessions over a two-week period. Each learning session will involve using various manipulatives like ropes and measuring tools to create geometric shapes and solve math problems previously discussed inside the classroom.
2) Answer two surveys about math learning.

What Are the Good Things and Bad Things that May Happen to You If You Are in the Study?

By exploring the math garden and taking the two surveys, you may develop a greater understanding of your own motivation for math learning. We expect you to have fun exploring the garden and learning math in a new way. Your participation will also provide context for the larger study of outdoor math learning environments and may lead to improvements in math learning outcomes and motivation for middle school students in South Carolina. There are no known risks or discomfort involved in this research study. The study will not affect your grades in any way.

What If You Want to Stop? Will You Get in Trouble?

Your participation of this study is totally voluntary. You don't have to be in the study and you can choose not to take explore the math garden or take the two 10 minute surveys. Your grades will not be affected by choosing to participate or not participate in the study. However, if you choose to participate we do ask that you answer the survey questions as honestly and accurately as possible while having fun exploring the garden.

Do You Have Any Questions?

You can ask questions at any time. You can ask them now. You can ask later. You can talk to the researchers at any time during the study. If you have any questions or concerns about this study or if any problems arise, please contact the primary research, Dr. Matthew Powers from Clemson University at 864-656-4408 or powers8@clemson.edu.

By being in this study, I am saying that I have read this form and have asked any questions that I may have. All of my questions have been answered and I understand what I am being asked to do. I am willing and would like to be in this study.

A copy of this form will be given to you.

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