AUGMENTED REALITY ACTIVITIES FOR CHILDREN: A COMPARATIVE ANALYSIS ON UNDERSTANDING GEOMETRIC SHAPES AND IMPROVING SPATIAL SKILLS

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ABSTRACT

AUGMENTED REALITY ACTIVITIES FOR CHILDREN: A COMPARATIVE ANALYSIS ON UNDERSTANDING GEOMETRIC SHAPES AND IMPROVING SPATIAL SKILLS

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The main purpose of this study is to compare the use of virtual manipulatives such as Augmented Reality (AR) applications to traditional techniques (physical manipulatives) for teaching geometric shapes and improve spatial skills to preschool children. The lesson content was determined, and the materials were designed for children. A quasi-experimental study was conducted in a public primary school with 72 participants. The children were randomly assigned to the experimental and control groups. Spatial ability tests (Picture Rotation Test, Spatial Perception Scale), and Geometric Shape Recognition Task as pre-test were implemented to preschool children. As the treatment, experimental group children used tablet computers with AR applications that present virtual manipulatives supporting the learning of geometric shapes and improving spatial skills. The control group used physical manipulatives for doing similar activities. After four weeks of treatment to both groups, the post-tests were utilized. A sample of the children in both groups and their teacher and parents were interviewed to figure out their thoughts about the activities and manipulatives. The analysis of the collected data of Geometric Shape Recognition Task revealed that there was no statistically significant difference between the groups in the circle classification task, while statistically significant differences were found between the groups in triangle, rectangle, and square classification task in favor of the experimental group. In addition to this, spatial ability test results showed that virtual manipulatives had a statistically significant difference in children's scores. The interviews with subjects revealed that not only children but also parents and teachers have positive thoughts about virtual manipulatives.

Key words: Spatial Ability, Spatial Skills, Geometric Shapes, Manipulatives, Virtual Manipulatives, Mobile Learning, Augmented Reality, Preschool Education

ÖZ

OKUL ÖNCESİ ÇOCUKLAR İÇİN ARTIRILMIŞ GERÇEKLİK ETKİNLİKLERİ: GEOMETRİK ŞEKİLLERİ ANLAMANIN VE UZAMSAL BECERİLERİ GELİŞTİRMENİN KARŞILAŞTIRMALI ANALİZİ

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Bu araştırmanın temel amacı, Artırılmış Gerçeklik (AG) gibi sanal manipülatif uygulamalarının, okul öncesi çocuklara geometrik şekillerin öğretilmesinde ve uzamsal becerilerin geliştirilmesinde, geleneksel teknikler (fiziksel manipulatifler) ile karşılaştırılmasıdır. Ders içerikleri belirlenip, materyaller her iki grup için geliştirilirmiştir. Çocuklar rasgele olarak deney ve kontrol gruplarına ayrılmıştır. Öncelikle Uzamsal testler (Resimli Döndürme Testi ve Uzamsal Algı Testi) ve Geometrik Şekilleri Tanıma Formu çocuklara ön test olarak verilmiştir. Deney grubunda geometrik şekillerin öğretimini ve uzamsal becerilerin gelişimini desteklemek için tablet bilgisayarlar aracılığı ile AG uygulamaları kullanılmıştır. Kontrol grubunda ise benzer etkinlikler yapmak için geleneksel olarak fiziksel manipülatifler kullanılmıştır. Her iki gruba dört haftalık deney süreci sonrasında son testler verilmiştir. Her gruptan gönüllü çocuklar, onların öğretmenleri ve velileri ile görüşmeler yapılıp, çalışma hakkındaki görüşleri alınmaya çalışılmıştır. Çalışma sonunda toplanan verilerin analizleri yapılmıştır. Geometrik Şekilleri Tanıma Formu sonuçlarına göre gruplar arasında daire şeklinin sınıflandırılmasında anlamlı farklılık bulunmaz iken, kare, dikdörtgen ve üçgen şekillerinin sınıflandırılmasında deney grubu lehine anlamlı farklılık bulunmuştur. Ayrıca uzamsal beceri testleri sonuçları da AG uygulamalarının çocukların başarı puanları üzerinde olumlu etki bıraktığını göstermiştir. Yapılan görüşmeler sonucunda yalnız çocuklar değil, velilerin ve öğretmenlerin de sanal manipulatifler hakkında olumlu düşüncelere sahip olduğu ortaya çıkmıştır.

Anahtar kelimeler: Uzamsal Yetenek, Uzamsal Beceri, Geometrik Şekiller, Manipülatifler, Sanal Manipülatifler, Mobil Öğrenme, Artırılmış Gerçeklik, Okulöncesi Eğitim

To my dear family…

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LIST OF ABBREVIATIONS

AR: Augmented Reality

PRT: Picture Rotation Test

SPS: Spatial Perception Scale

GSRT: Geometric Shape Recognition Task

TRT: Triangle Recognition Task

RRT: Rectangle Recognition Task

SRT: Square Recognition Task

CRT: Circle Recognition Task

CHAPTER 1

INTRODUCTION

This part presents information regarding emerging information technology tools, manipulatives, and spatial ability and also provides background information on the problems in learning geometry. Moreover, in this section statement of the problem, the purpose of the study, research questions, the significance of the study and definition of terms are presented.

1.1 Background of the Study

There are lots of learning opportunities from both the real and the digital world tools and resources for today's children. Especially mobile devices (Tablet PC, smart phone, PDA, cell phones, etc.) provide ease of portability and access to different information in the real-world environments and introduces the notion of ubiquitous learning (Redd, 2011). Ubiquitous learning environments enable the user to learn at any time and any place by implying innovative learning concepts (Li, Zheng, Ogata, & Yano, 2005; Ogata & Yano, 2004).

In the field of education, the developing technologies (mobile devices, the internet, virtual reality, augmented reality, etc.) could be taken into consideration to improve the potential of children. Especially in the fields of teaching where additional learning support is needed, these technology tools might provide new solutions that have the potential to enhance learning. Teachers and instructors could take advantage of these emerging technologies by integrating them into their classes. Moreover, educators and instructors could integrate these technologies into classroom practice by developing new strategies (Hennessy, Ruthven, & Brindley, 2005).

The potential fields that could be supported by teaching-learning technologies where students have learning problems are mathematics and geometry. Several research findings showed that children have problems in learning mathematics and geometry (Clements, 1998; Duval, 2006; Mitchelmore, 1997; Mulligan, 2011; Prescott, Mitchelmore, & White, 2002). Some children have difficulties in learning basic geometric concepts and solving geometric problems during especially primary school (Clements, 1998). Trends in International Mathematics and Science Study (TIMSS) results indicated that Turkish children's geometry scores were under the average (Mullis, Martin, Foy, & Arora, 2012). For the young learners, geometry is necessary to develop spatial reasoning that requires spatial visualization and mental rotation (B. Casey, Erkut, Ceder, & Young, 2008).

The early childhood years are very crucial for the overall development of children (Chambers & Sugden, 2002) and could affect children's later school success. Children's knowledge of mathematics or geometry predicts their future achievements in school (Clements & Sarama, 2011; Duncan et al., 2007; National Research Council, 2009).

Spatial abilities are very important for developing skills. Moreover, they are significant for children's future career choices and scientific achievement in STEM subjects which stands for, science, technology, engineering, mathematics (Quaiser-Pohl, Neuburger, Heil, Jansen, & Schmelter, 2014). STEM occupations are trending nowadays and developing children's spatial skills could be effective in being successful at these STEM majors.

Some of the studies showed that manipulatives might contribute to the development of spatial skills (Casey, Andrews, Kersh, Samper, & Copley, 2008; Sarama & Clements, 2004). Manipulatives are materials which are "designed to represent explicitly and concretely mathematical ideas that are abstract" (Moyer, 2001, p.176).

Piaget (1952) suggested that to comprehend abstract mathematical concepts, children need to gain more experiences with concrete materials.

A meta-analysis study conducted by Carbonneau, Marley, and Selig (2013) to examine the impact of using manipulatives on teaching abstract symbols in mathematics. The meta-analysis study included samples from kindergarten to college level. The results presented that the impact of manipulatives was very small for the 3 to 6-year-old children. Although there was a significant difference for using manipulatives in the learning environments, their usage by the educators was also very important. The analysis for specific learning outcomes indicated moderate to large effects on retention but small effects on problem solving, transfer, and justification. Clements (1999) declared that using manipulatives could be successful when it helps children to build, strengthen, and connect several representations of abstract mathematical concepts.

Educators are very familiar with concrete manipulatives such as geoboards, bean sticks, wooden blocks, tangrams, etc. There are many different kinds of manipulatives. In addition to physical ones there are also technology-based manipulatives. As Clements and Sarama (2016) stated, these types of manipulatives have several advantages. Technology based manipulatives can transfer mathematical concepts to conscious awareness, simplify and complete explanations, help mental actions, enable manipulation, and represent mathematical concepts, etc. (Clements & Sarama, 2016).

The rapid growth in technology enables a new type of manipulative which is called the virtual manipulative or computer based manipulative that combines useful properties of concrete manipulatives and computers. A virtual manipulative is defined as "an interactive, technology-enabled visual representation of a dynamic mathematical object, including all of the programmable features that allow it to be manipulated, that presents opportunities for constructing mathematical knowledge" (Moyer-Packenham & Bolyard, 2016, p.3).

Suh, Moyer-Packenham, and Heo (2005) stated that virtual manipulatives have an unexplored potential for developing students' visual and conceptual skills in geometry and mathematics education. Since these manipulatives are interactive and have colorful graphics dynamic nature, they grasp and hold the interest of children. Although the majority of virtual manipulatives are free for schools and teachers, if the schools' technological infrastructures are inadequate or poor, this would affect students' and educators' consideration for using them (Suh et al., 2005).

Moreover, Clements (1999) stated that both physical and virtual manipulatives could be useful for the learning of geometry. However, he also emphasized that manipulatives "must be used in the context of educational tasks to actively engage children's thinking with teacher guidance" (Clements, 1999, p.56).

In today's world, technology is one of the common elements in most children's lives, and it takes place in many school systems as a learning tool (Murphy, DePasquale, & McNamara, 2003). Emerging technologies could have the potential of presenting many facilities to improve the learning environments for the early childhood education (Clements, 1994, 2002). If the appropriate technologies are used with young children, they could promote scientific achievement of children (Weiss, Kramarski, & Talis, 2006).

AR is one of the technologies, that has the potential to make children's interaction with the virtual content easier. It provides a natural environment where young children can both engage with virtual educational content and interact with the physical world. This natural interaction can help to develop other skills such as motor manipulation, attention and spatial cognition (Bujak et al., 2013). AR has the potential to facilitate children to learn spatial content since AR environment makes it possible for the learner to explore three-dimensional spaces from different views (Bujak et al., 2013). According to the Horizon Report (2012), AR is a well-understood technology, and it has been used effectively in business and entertainment industry (Johnson, Krueger, & Conery, 2012). The report also indicated that although it is easy to create and use AR applications now than ever before, AR has the place on the far-term horizon (within four to five years) due to its limited school-based examples (Johnson et al., 2012).

Some of the research studies showed that AR applications could be used to improve spatial skills (Kaufmann & Schmalstieg, 2003). AR environments can be used for visual and highly interactive forms of learning by superimposing virtual images on real-world settings (Johnson et al., 2012). Thanks to the various usages of AR technology, likelihood of creating new kinds of educational manipulatives that are the combination of physical and virtual objects can be increased (Bujak et al., 2013). The present study aims to investigate the benefits of using virtual manipulatives such as Augmented Reality (AR) technologies to teach geometry skills to young children.

1.2 Statement of the Problem

This current study focuses on presenting alternative ways of learning and teaching abstract geometrical concepts. As it was stated before, children might face with problems during learning mathematics and geometry concepts. The results of the international exams indicated that Turkish children did not show high performance at mathematics and geometry which are considered as necessary to improve high order thinking abilities such as spatial reasoning (Mullis, Martin, Foy, & Arora, 2012; B. Casey et al., 2008). The early achievement has a direct effect on future in success mathematics (Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Therefore, it is important to improve preschool children's skills.

Spatial skills are very crucial in today's world. There are lots of future careers for people in which spatial skills are significant. Smith (1964) stated that there were 84 jobs which required spatial skills in the US. Similarly, Contero, Company, Saorin, & Naya, (2006) declared that spatial ability is very important for the engineers of future. Moreover, Delialioğlu and Aşkar, (1999) stated that spatial and mathematical skills have an impact on physics achievement. Their study searched for the contribution of these skills on high school students' physics performance. According to the study results, the combination of spatial and mathematical skills had a significant influence on students' physics success (Delialioğlu & Aşkar, 1999).

P. Smith (1992) stressed that spatial skills are essential for children or students', not only for their educational success but also their professional success in the future, so teachers or educators need to widen their views to acquire children to these skills. These skills are also significant for the daily competence of children (P. Smith, 1992). In his dissertation, Lohman (1996) also emphasized the importance of spatial ability for higher order thinking in math and science, being creative in many fields, etc. To develop children's performance in geometry and math, it might be significant to improve their spatial abilities (Xistouri & Pitta-Pantazi, 2006). Mohler (2006) mentioned about the significance of spatial ability which affects many fields and disciplines and might be determinant for success in many domains such as architecture, engineering, astronomy, mathematics, physics, biology, chemistry, music, etc. Consequently, mathematics and geometry are two of these disciplines which are related to spatial skills.

It is a general understanding that geometry is strongly associated with the spatial ability. The relation between spatial ability and geometry success has been investigated by several researchers. The result of these researches (Battista, Wheatley, & Talsma, 1982; Y.-L. Cheng & Mix, 2014; Newman, Hansen, & Gutierrez, 2016; Sorby, 1999; Tzuriel & Egozi, 2010; Yildiz, 2009) indicated that spatial skills could be improved with training. Consequently, the geometry learning in preschool and primary education might influence the future success of children in learning these skills. Therefore, it is still crucial to understand how emerging technologies could be employed to improve children's spatial ability.

Rapid improvements in technology enable diversity in the learning environments. Augmented Reality (AR) is one of these technologies that is relatively new in the field of education. Especially, it might be helpful for visualization of abstract geometrical concepts, in preschool education. AR activities might bring outside world into the classroom with three-dimensional models. Therefore, this study tried to find out virtual manipulatives' effects on preschool children's understanding and improvement of spatial skills and geometric shape recognition levels.

Moreover, to open parents' and teachers' minds regarding usage of technology and virtual manipulatives is another important issue. Both parents and teachers should be careful about using these tools in education. The current study also aims to determine the opinions of students, teachers and parents about using virtual manipulatives as a technological tool in preschool education for teaching geometry concepts.

1.3 Purpose of the Study

The primary goal of the study is to compare physical manipulatives with virtual manipulatives to explore the educational use of virtual manipulatives such as AR based applications implemented with a mobile device to improve young children's spatial skills and understanding geometric shapes.

1.4 Research Questions

The study will examine the following questions:

1) Is there a significant difference between preschool children's spatial ability test mean scores exposed to virtual manipulatives and physical manipulatives?
2) Is there a significant difference between students' pre and post spatial ability achievement scores
   a) within the experimental group taught through virtual manipulatives?
   b) within the control group taught through physical manipulatives?
3) Is there a significant difference between preschool children's geometric shape recognition task mean scores exposed to virtual manipulatives and physical manipulatives?
4) Is there a significant difference between students' pre and post geometric shape recognition levels
   a) within the experimental group taught through virtual manipulatives?

b) within the control group taught through physical manipulatives?

5) What are young children’s opinions related to virtual and physical manipulatives?

6) What are parents’ opinions related to their child’s experience in doing activities with manipulatives?

7) What are teacher’s opinions related to virtual manipulatives?

1.5 Significance of the Study

It is important to find innovative ways in the instruction of mathematics and geometry to increase students’ achievements. Nowadays, young children are very comfortable when they are interacting with technological devices such as computers, mobile phones and tablets and children can also easily adapt to touch screen technologies (Clements & Sarama, 2003; Couse & Chen, 2010; McKnight & Fitton, 2010).

Before starting school, children have little knowledge of geometry. The perceptions about geometric shapes begin to develop before starting school. In order to learn and name concepts correctly, children need to look shapes from different perspectives and discover the properties of objects. As it was mentioned before both concrete and virtual manipulatives could be used as an assistant tool in geometry learning (Clements, 1999). Concerning physical manipulatives, virtual manipulatives are new and practical tools for enhancing mathematics and geometry instructions in schools. They might present dynamic visual images which are not possible for physical manipulatives (Reimer & Moyer, 2005).

This study aims to explore the benefits of using virtual manipulatives such as AR technologies to teach geometry skills to preschool children. AR is an improving technology, and this study is a practice of integrating this AR application into early educational settings. AR technology has a potential to widen children’s world by visualizing different kinds of objects in the classroom or learning environment if it is used appropriately. The findings of this study are expected to present new insights about using AR technology for supporting the preschool settings.

Moreover, in order to enhance children's learning, skills and participation, the preschool curriculum requires a variety of teaching and learning materials. This study is also significant for preschool teachers and preschool settings. AR is a very new technology for teachers and it might provide an enriched teaching and learning environments. With the help of AR technology, teachers could create dynamic and flexible learning environments to present rich learning experiences for preschool children. Therefore, the results of this study are expected to guide educators and teachers to create dynamic and enriched teaching and learning materials.

As it was stated before, AR is a very new technology, especially in the field of education. Therefore, integrating this kind of new technologies to preschool education is essential. Since there are not so many studies about AR technology usage in early childhood education, this study is one of the large-scale studies, presenting a new technology for preschool children.

This study's purpose is to provide both a framework for analyzing children's spatial ability and some insight into how AR based activities may affect children's spatial skills and geometric shape recognition levels. The present study also investigates the role of AR activities as a virtual manipulative and how it could be employed to form effective learning environment for the improvement in spatial skills and understanding geometric shapes. Moreover, the current study aims to present students', teachers' and parents' opinions about these activities.

1.6 Definition of Terms

The goal of this part is to provide definitions of terms that are used in the current study.

Manipulatives: Materials which are "designed to represent explicitly and concretely mathematical ideas that are abstract" (Moyer, 2001, p. 176).

Virtual manipulatives: They are defined as "an interactive, technology-enabled visual representation of a dynamic mathematical object, including all of the programmable features that allow it to be manipulated, that presents opportunities for constructing mathematical knowledge" (Moyer-Packenham & Bolyard, 2016, p.3).

Mobile learning: It is defined as "in which learners may move within different physical and virtual locations and thereby participate and interact with other people, information or systems-anywhere, anytime" (Koole, 2009, p. 25).

Augmented Reality: It is defined as "a variation of virtual environments" (Azuma, 1997, p. 355).

Spatial ability: It is defined as "the ability to generate, retain, retrieve, and transform well-structured visual images" (Lohman, 1996, p.188).

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter provides the review of the literature related to early childhood education, physical and virtual manipulatives, mobile learning, AR, spatial ability, geometric shapes, preschool children achievements, van Hiele's instructional model. The relevant literature was analyzed and synthesized regarding the research questions.

2.1 Early Childhood Education

The main aim of early childhood education is to enhance young children's cognitive and social skills, and it is also required for future achievement (Essa, 2012). Once children start to walk, they get the opportunity to discover more than they have. In this period, children are gaining much experience in mathematics by classifying objects they see in their surroundings, shopping, measuring, weighing, imagining calculations, building buildings with blocks during imaginary games. These experiences are the basis of children's mathematics education in the future (Charlesworth & Lind, 2012).

Early childhood is a very significant period for the development of children's core competencies effectively; therefore preschool and primary education have a critical role in child development (Chambers & Sugden, 2002; Clements & Sarama, 2011; Duncan et al., 2007; National Research Council, 2009). Campbell, Pungello, Miller-Johnson, Burchinal, and Ramey (2001) emphasized that the influences of early childhood education on cognitive and affective domains are significant for future academic achievement. To stress the importance of early childhood education Clements and Sarama, (2007) stated that early mathematical interventions enable children to improve or constructs simple mathematical concepts, especially in children who have fewer opportunities. A comprehensive preschool curriculum which provides organized exercises for children could enhance children's learning and improve their mathematical knowledge and skills (Clements & Sarama, 2007). It may offer environments for children in order to strengthen their development in areas such as social-emotional, intellectual, physical, and also promote their life skills (Copple & Bredekamp, 2010). Besides these, emerging technological devices (computer, tablets, smartphones, etc.) could be used to create an environment that might assist to improve children's skills. Both the Internet capable laptops and pad-based computers are part of young children's lives (Geist, 2012). Therefore, their usage in the early childhood classroom is now an emergent topic in educational studies.

2.2 Manipulatives and Their Use in Education

There are many methods in children's education and training and day by day more efficient, and new methods are also added to them. Especially, there are various techniques and strategies in geometry learning for 5 to 6-year-olds who have difficulty in developing abstract thinking. Manipulatives are used as supportive tools in these methods. Manipulative was defined by Kelly (2006) as "any tangible object, tool, model, or mechanism that may be used to demonstrate a depth of understanding, while problem-solving, about a specified mathematical topic or topics" (p.184). Moyer (2001) briefly explained that "manipulatives are designed to represent explicitly and concretely" to present concepts that are abstract (Moyer, 2001, p. 176). The history of using manipulatives depends on theories of Bruner, Piaget, and Montessori who stated that in the learning process while improving and building knowledge children transfer real experiences (with manipulatives) to abstract thinking (McNeil & Jarvin, 2007).

Piaget (1952) stated that children's and adults' thoughts, behaviors, attitudes show differences in terms of quantity and quality. Piaget (2003) suggested that children's development in thinking happens while they are getting older. According to Piaget (2003), learners' development in various fields moves through four stages which are sensorimotor (0-2 years), preoperational (2-7 years), concrete operations (7-12 years) and formal operations (12-18 years). He also asserted that children need to experience hands-on activities, real materials, and manipulatives in order to comprehend abstract mathematical concepts.

Physical or concrete manipulatives are defined as concrete objects which enable children to discover concepts through their visual and tactile senses (McNeil & Jarvin, 2007). With the support of technological development, a new categorization for manipulatives called "virtual manipulatives" emerged. At first, Moyer, Bolyard, and Spikell (2002) defined the virtual manipulative "as an interactive, Web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge" (Moyer et al., 2002). After fifteen years, Moyer-Packenham and Bolyard (2016) updated the definition of virtual manipulatives as "an interactive, technology-enabled visual representation of a dynamic mathematical object, including all of the programmable features that allow it to be manipulated, that presents opportunities for constructing mathematical knowledge" (p.3). They updated the definition in order to stress the difference between what is virtual manipulative and what is not. The most important requirement to refer as a manipulative is that users need to interact (move or manipulate) with dynamic objects for developing and construing knowledge (Moyer-Packenham & Bolyard, 2016).

Clements (1999) stated that good manipulatives should have some properties such as being meaningful to the user or learner, enable control and flexibility to the user, and they should have characteristics that reflect cognitive and mathematics structures and help learners to connect various pieces and types of knowledge. According to him, virtual manipulatives can serve that function (Clements, 1999).

Clements (1999) also declared that manipulatives should be used with a proper educational task. Similarly, Moyer-Packenham and Bolyard (2016) stated that virtual manipulative does not directly provide learning, they are technological tools that present users chances for learning and teaching process. Suh (2005) said that virtual manipulatives enable children especially younger ones to relate their prior knowledge and practice to abstract concepts in mathematics.

Manipulatives are very commonly used in geometry and mathematics education. In the recent years, studies that examine the use manipulatives have increased. The effects of both usage of physical and virtual manipulatives had been studied by many researchers (Kim, 1993; Reimer & Moyer, 2005; Steen, Brooks, & Lyon, 2006; Suh et al., 2005; Yaman & Şahin, 2015; Zacharia & Olympiou, 2011).

Kim (1993) tried to determine the effects of virtual and physical manipulatives on preschool children's success in seriation, classification, geometric, and arithmetic concepts. While children in the control group were taught by geoboards, attribute blocks, and Cuisenaire rods, the children in the experimental group were taught by the software program, Hands-On Math. Although virtual manipulatives presented more interesting learning environment for children, the results showed that there was no statistically significant difference between groups achievements (Kim, 1993).

Suh et al. (2005) searched for the effects of virtual manipulatives on fifth graders. The results of the study presented that using virtual manipulatives had positive effects on learning of equivalence and fraction addition at fifth graders. As a result, virtual manipulates have supported children's understanding in mathematics education (Suh et al., 2005).

In their study, Reimer and Moyer (2005) aimed to find the effects of using virtual manipulatives for third graders fraction instruction. The study's findings showed that there were significant improvements in children's conceptual knowledge. Moreover, analysis of interviews and attitude surveys of children revealed that manipulatives were helpful in the learning process by giving immediate and specific feedback, easier than traditional paper-pencil methods, and increased children's enjoyment (Reimer & Moyer, 2005).

The study Moyer-Packenham, Niezgoda, and Stanley (2005) examined the effects of virtual manipulative as compared to concrete materials on kindergarten children. The study results showed that compared to physical material, studying with virtual pattern block manipulative enabled children to form a greater number of patterns, create more complex and creative patterns (Moyer-Packenham et al., 2005).

In their study, Steen et al. (2006) investigated the effects of virtual manipulatives on first grader's success. During the treatment, the children received geometry instruction; the control group studied with physical manipulatives and the experimental group studied with virtual manipulatives. According to the post-test results, the experimental group outscored the control group; however, this difference was not statistically significant. Researchers also stated that, the children in the experimental group showed increased motivation (Steen et al., 2006).

In their study, Zacharia and Olympiou (2011) examined the effects of concrete and virtual manipulatives on science concepts in the concepts of heat and temperature at the university level. There were four experimental conditions; virtual manipulative experimentation, concrete manipulative experimentation and two sequential grouping of them. The analysis of pre-test and post-test results showed that there was a significant difference in favor of experimental groups. All experimental groups were equally effective in supporting undergrads understandings of concepts (Zacharia & Olympiou, 2011).

Yaman and Şahin (2015) aimed to determine the effects of manipulative-assisted education on fifth graders building and drawing geometric structure achievements. They used concrete and virtual manipulatives together in order to assist instruction. According to their findings, there was a statistically significant difference in favor of experimental groups. In other words, supporting lesson with both concrete and virtual manipulatives had a positive effect on children's success in building and drawing geometric structure (Yaman & Şahin, 2015).

2.3 Mobile Learning and Mobile Devices

In the recent years, the popularity of wireless technology has increased; number of affordable priced mobile devices increased and thus wireless technology had become more popular. These developments have enabled a new way of learning that is called mobile learning. Mobile learning can be defined in numerous ways; however, all these definitions can be simply explained by the connection between using mobile devices and the occurrence of learning, in other words, mobile devices mediate learning process (Kearney, Schuck, Burden, & Aubusson, 2012).

There are various mobile learning frameworks which have different theoretical backgrounds, purposes, and characteristics. One of these frameworks offered by Koole (2009) which is called "The Framework for the Rational Analysis of Mobile Education" (FRAME) presents three characteristics of mobile learning which are the device, the learner, and the social environment. This model (see Figure 1) defines learning "in which learners may move within different physical and virtual locations and thereby participate and interact with other people, information or systems-anywhere, anytime" (Koole, 2009, p. 25). The framework aims to help practitioners and educators to design more efficient mobile learning environments by using these benefits (Koole, 2009).

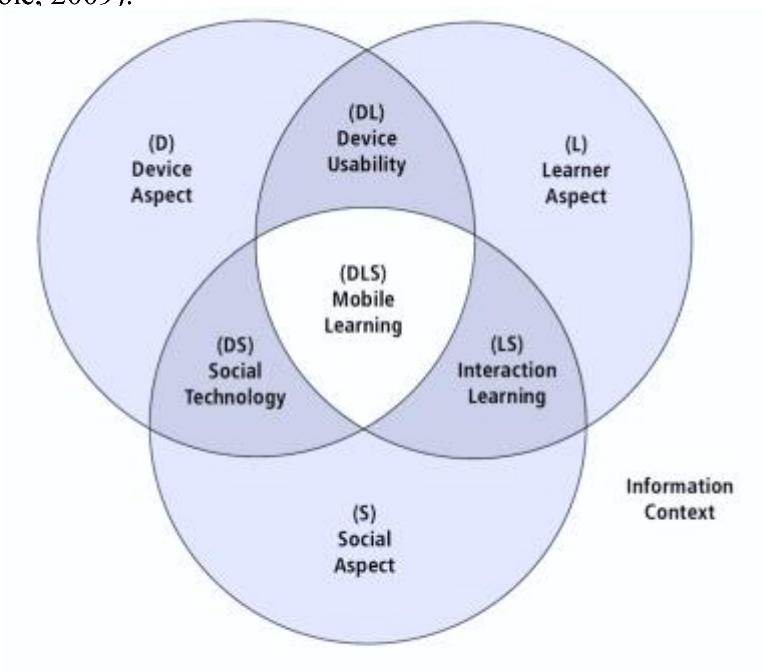


Figure 1: The FRAME model of mobile-learning

Ching, Shuler, Lewis, and Levine (2009) stated that mobile technologies have the potential to provide digital equity since they have ubiquitous, low-cost, and user-friendly designs. They also have the potential for closing the gap between formal and informal education by providing anytime, anywhere availability (Ching et al., 2009). Mobile devices have become a rapidly growing technology in human history, and nowadays researchers concentrate on the studies which are based on using technologies that enable or enhance "anywhere and anytime" learning (Cao, Tin, McGreal, Ally, & Coffey, 2006; Houser, Thornton, & Kluge, 2002).

So (2008) outlined the most important dimensions of mobile learning as (Figure 2);

- location independence→ learning not restricted to a fixed location
- time independence→ asynchronous and synchronous learning
- meaningful content→ the content is suitable to be delivered with the media, devices and communication settings.

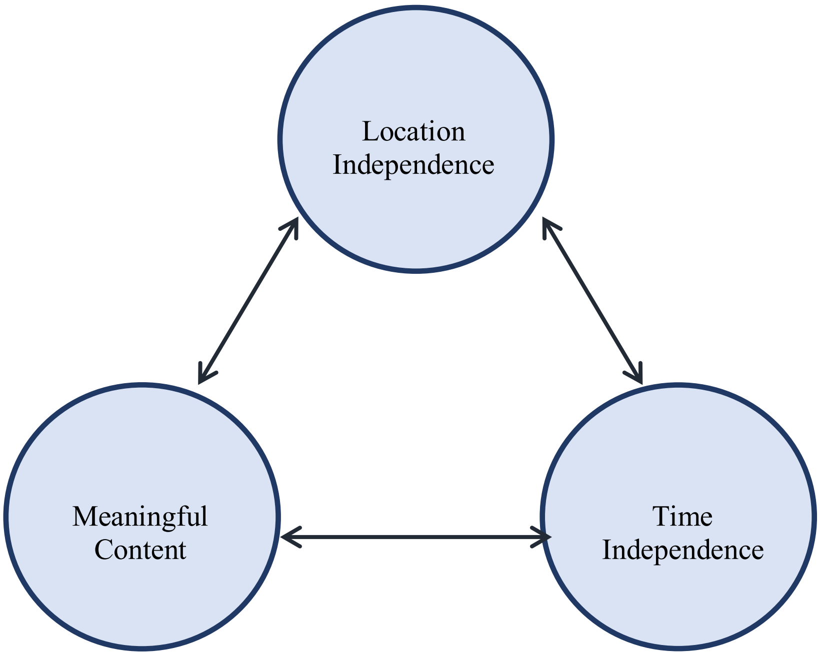


Figure 2: Three important dimensions in mobile-learning

These three dimensions influence the effectiveness of mobile learning. "Location independence" provides collecting and recording information from nearly everywhere; "time independence" present asynchronous and synchronous learning environments for the learners and "meaningful content" is about considering quality and appropriateness of content (So, 2008).

Ozcelik and Acarturk (2011) stated that digital and real world learning context could improve students' learning interest, motivation, and their learning achievement. Accordingly, mobile devices (smartphones, PDAs, etc.) might provide the opportunity for users to integrate online information sources and printed information sources. Their study found that mobile devices had further benefits over desktop computers in learning with multiple information sources (Ozcelik & Acarturk, 2011).

Lai, Chang, Wen-Shiane, Fan, and Wu (2013) studied a mobile learning method that incorporated QR codes. The study aimed to achieve the objectives of outdoor education where teaching and learning take place outside the classroom or school building by creating a dynamic educational environment. It was also aimed to increase mobile learning for practical use in a diverse range of outdoor locations. The results showed that mobile learning devices and system reached the planned learning goals, provided extra chances for interaction and simplified teaching in a different variety of locations (Lai et al., 2013).

2.4 Augmented Reality

Augmented reality (AR) is one of the crucial and popular environments, which has served in many areas as visualization, training aid, annotation, etc. Research studies related to AR date back to the beginning of the 1990s and it continues to develop in different fields such as medical, military, architecture, education, commerce, entertainment, sports, navigation, etc. In the light of previous studies Azuma (1997) defined AR as "a variation of virtual environments" (p. 355). AR presents an environment to the user that combines the real world with virtual objects (Azuma, 1997). Azuma (1997) stressed the three characteristics of AR to eliminate the limitations to specific technologies: firstly, it combines real and virtual world; secondly, it is interactive in real time, and lastly, it is registered in three-dimension where real and virtual objects are arranged accurately.

One of the research studies (Bujak et al., 2013) suggested that AR could enhance learning experiences of students by making it possible not only to reach relevant content for students but also collaborate around virtual content. Another research study (Kaufmann & Schmalstieg, 2003) mentioned that complicated geometric problems and relationships could be understood easily by working directly in a three-dimensional environment with the help of AR. Moreover, Boletsis and McCallum (2013) stated that AR has the potential to form an engaging and enjoyable learning environment for the students. Thornton, Ernst, and Clark (2012) stated that AR is an emerging technology which should be incorporated not only science, technology, engineering and mathematics (STEM) education but also in other disciplines.

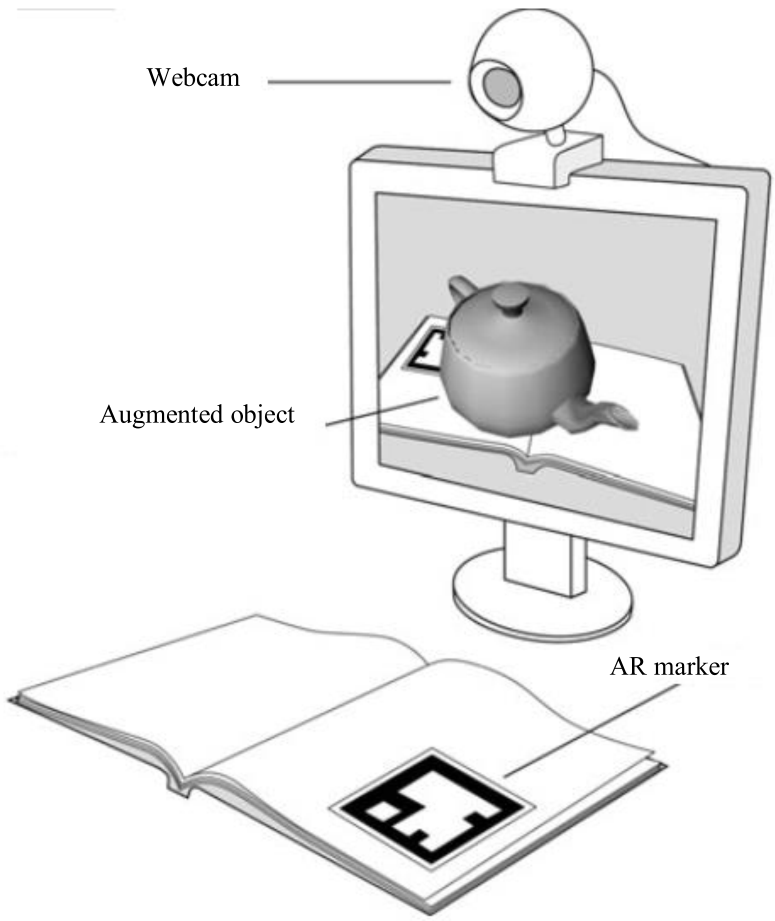


Figure 3: Example of a marker label in image-based AR

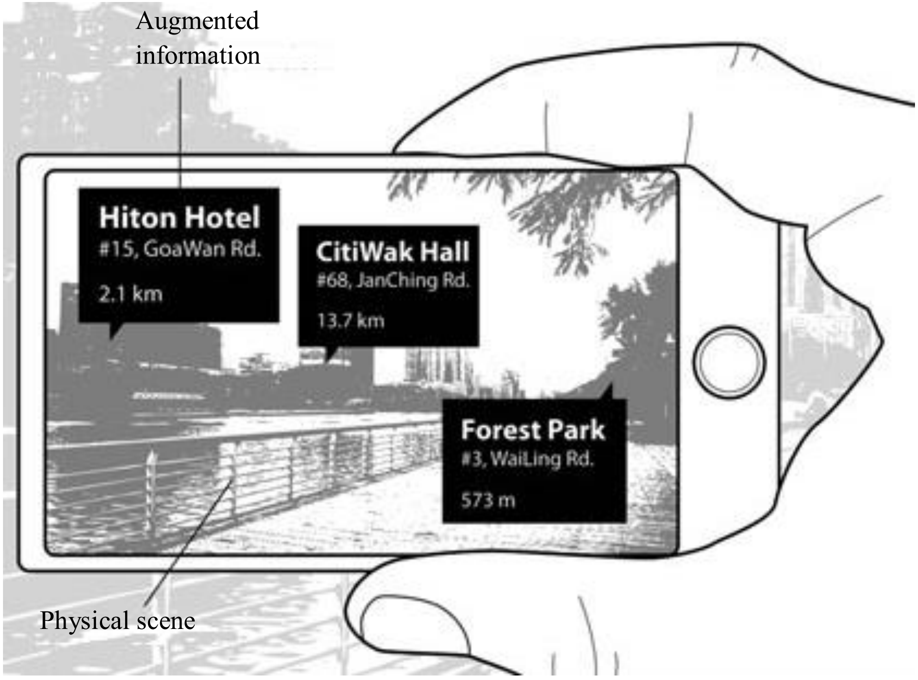


Figure 4: Example of a markerless AR label

The logic behind the AR technology is "to track the position and orientation of the user" to create a visual representation of a relevant context (Henrysson & Ollila, 2004, p. 41). According to the 2012 Horizon Report, an AR application can be marker based (Figure 3) (Lin, Hsieh, Wang, Sie, & Chang, 2011) or markerless (Figure 4) (Cheng & Tsai, 2013) to generate visual information of a relevant object (Johnson et al., 2012). Cheng and Tsai (2013) defined marker-based AR as an environment that requires a specific visual label to present virtual three-dimensional objects on the real world model and stated that markerless applications use location-based data launched from mobile devices. Cheng and Tsai (2013) also indicated the similarities and differences between marker-based and markerless (location-based) AR with Figure 5.

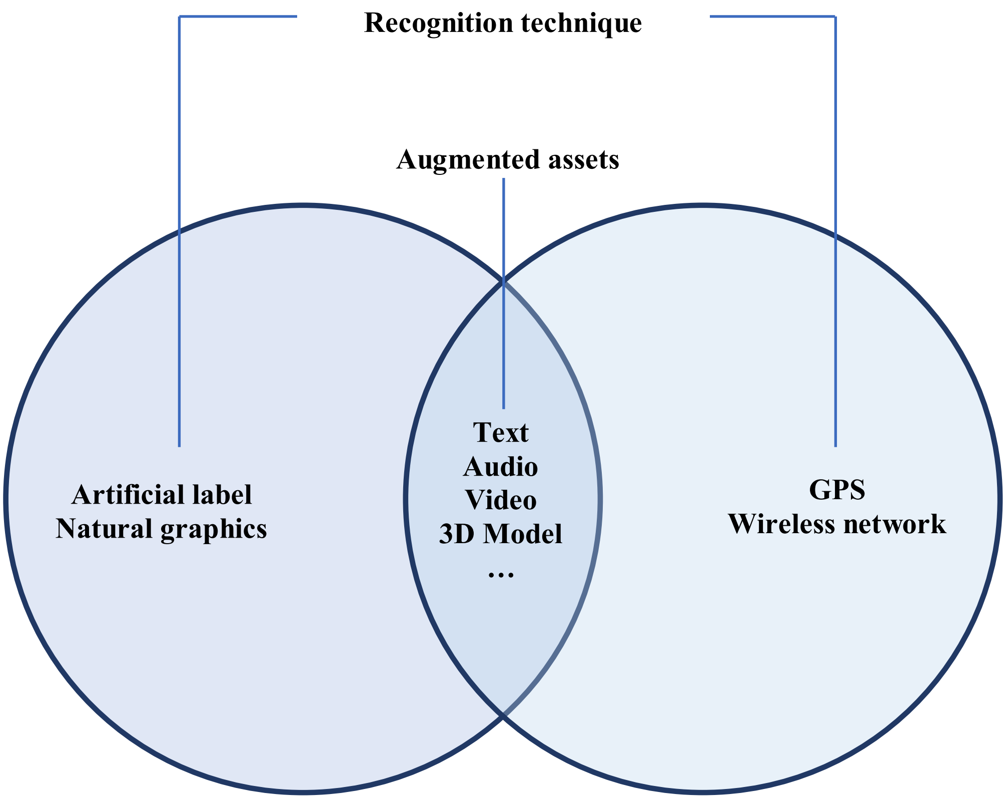


Figure 5 :A comparison of marker-based and markerless (location-based) AR

2.5 Augmented Reality Applications

There are several companies (such as Layar, Wikitude, Junaio, etc.) that are creating AR applications for mobile devices in the market. There are both open and closed source platforms. Layar (www.layar.com) and Wikitude (www.wikitude.org) browsers are based on registered protocols, closed source users and data formats that strictly limit user-side functionality (Hill, MacIntyre, Gandy, Davidson, & Rouzati, 2010).

Aurasma is an AR platform that uses image identification technology to detect all kinds of labeled triggers, from printed material to real objects. The AR content which is called "Aura" can be interactive, three-dimensional and even animated. Users could create their Aura by tagging a trigger image via their phones or tablet computers and then assigning it an overlay. When the app sees the trigger image, it shows the overlay which is provided by device or Aurasma's library (Betts, 2013).

The free software ARIS (www.arisgames.org) allows designers to create AR environments for users. The developers of ARIS stated that it is an open-source platform for designing mobile games, various tours, and interactive stories. GPS and QR code technology also help users to be a part of the virtual hybrid world by experiencing interactive characters, objects, and media in physical space (www.arisgames.org).

2.6 Augmented Reality in Education

AR applications serve in the field of education in various areas, such as history, mathematics, science, etc. (Carmigniani & Furht, 2011). AR is commonly used more effectively by a museum and cultural organizations that are the first ones using them in the learning sectors (Johnson et al., 2012).

Wasko (2013) stated that teachers and educators should take into consideration the potential benefits of AR which is one of the innovative forms of instructional delivery. The availability of hardware and software resources give opportunities to both educators and teachers for designing, sharing and using AR based learning and teaching environments in their classes. The researcher also said that both teacher and students had a positive attitude towards AR enhanced instructional environments (Wasko, 2013).

Freitas and Campos (2008) designed an educational system called "SMART" that used AR for teaching concepts like transportation to second-grade children. According to the results of the study, the system had a positive effect on children's learning experience, especially on slow learning students. Moreover, SMART had an effective role to keep children's motivation high (Freitas & Campos, 2008). Similarly, Dunleavy, Dede, and Mitchell (2009) designed an AR environment for tablet computers in order to teach mathematics, language arts, and scientific literacy. The researchers developed an augmented reality based game named *Alien Contact*, and scenarios for students to solve problems and puzzles, where they collected and shared information. After the treatment, there was an increase in the middle and high school students' motivation and understanding of mathematics and their development of literacy skill. Moreover, students and their teachers stated that AR based learning system was highly engaging (Dunleavy et al., 2009).

In their study, Liu, Tan, and Chu (2010) presented the handheld English language learning organization, HELLO, to provide engaging learning activities to increase undergraduate students' motivation in English learning. HELLO was a new QR code based, AR supported mobile learning system for handheld devices. Study results showed that most of the students found the course interesting and some of them found it easy to use and useful for assisting learning. Additionally, the analysis results showed that HELLO not only increased students' motivation to learn but also enhanced their learning outcomes (Liu et al., 2010).

Shelton and Hedley (2002) used AR to teach the undergraduate students an earth-sun relationship. During the study, students experienced three-dimensional models that were designed to teach rotation, revolution, solstice, equinox, seasonal variation, etc. The results of the survey they used to collect data showed that AR exercises had an impact on improvement of students' understanding of geography students about the earth-sun relationship. Furthermore, AR practices provided a decrease in students' misconceptions (Shelton & Hedley, 2002).

P. H. E. Liu and Tsai (2013) conducted an exploratory case study about the use of AR-based mobile learning material that enabled learners an English composition course with increased information expressions, visual information explanations, and improved information accessibility. During the study, the students were asked to describe their campus. They had a short trip on campus while using the AR-based learning material by mobile phones. Depends on the learner's location, the AR material provided some captured images and generated information about the place. After the study had concluded, the learner who took advantage of AR-based learning material which presented linguistic and content knowledge, produced meaningful essays in English (P. H. E. Liu & Tsai, 2013).

Pérez-López and Contero (2013) searched for the use of AR for presenting multimedia content to support the instructional process of the science lesson at primary level and its impact on knowledge retention. They used AR system as a combination of oral explanation, and animations and three-dimensional models of anatomical structures. Based on the study results, AR system outperformed traditional setting in increasing knowledge retention. In other words, AR application was a promising tool to enhance children's motivation and interest, and also in presenting dynamic learning and teaching environment.

Bressler and Bodzin (2013) examined students' flow experience while they were playing a mobile AR science game in the school environment. According to the results, interest in science was not significant in predicting flow experience. The findings of the study also showed that mobile AR science game has a potential to enhance science interest and help children improve collaboration skills. It concluded that middle school students were highly engaged while they were playing AR based science game (Bressler & Bodzin, 2013).

Cascales, Laguna, Pérez-López, Perona, and Contero (2013) examined the effect of AR tool for developing learning process of preschool children. The participants stated that AR was a useful tool in the learning and teaching process. They also mentioned that AR helped children to achieve more learning goals. The activities with AR was more playful and fun for both preschool children and their teachers (Cascales et al., 2013).

Tian, Endo, Urata, Mouri, and Yasuda (2014) studied the impact of AR based mobile learning system for moon observation to teaching the concepts of lunar phases to university students. The study also searched for the usefulness of the system. The study results showed that AR based mobile learning system was effective in improving learning of participants and in enhancing their motivation to subject (Tian et al., 2014).

Thornton et al. (2012) stated that using AR in the learning environment could be effective in improving children's spatial and visual skills. Several research studies

(Hartman & Bertoline, 2005; Kaufmann & Schmalstieg, 2003; Martín-Gutierrez, Trujillo, & Acosta-Gonzalez, 2013) found that AR applications have a positive impact on the user improving his/her spatial skills while using them. Kaufmann and Schmalstieg (2003) designed mobile collaborative AR system, Construct3D, for geometry and mathematics education. With the design of this system, researchers aimed to improve spatial abilities and maximize the transfer of learning. Their evidence supported that Construct3D has the potential to improve spatial skills and encourage experimentation with geometric constructions. Furthermore, Martín-Gutierrez et al. (2013) designed an AR based application for the development of the spatial skills of engineering students. The findings of the study indicated that engineering students who are trained by AR application improved their spatial skills.

2.7 Spatial Ability

Spatial ability and spatial skill are used interchangeably in the literature; however, there is a difference between them. Spatial ability is an ability that an individual has already had before having any training, a person is born with it, but spatial skill is improved or learned through training (Sorby, 1999).

Different researchers in several ways defined spatial ability. McGee (1979) stated that spatial ability is "the ability to formulate mental images and to manipulate these images in mind" (p. 267). Linn and Petersen (1985) defined spatial ability as a "skill in representing, transforming, generating, and recalling symbolic, non-linguistic information" (p.1482). Lohman (1996) defined spatial ability as "the ability to generate, retain, retrieve, and transform well-structured visual images" (p.188).

In the literature, researchers divided spatial ability into several different components. Smith (1964) categorized three factors under the title spatial that are "relations, orientations, visualizations". Similarly, Lohman (1979) stated that spatial ability has three components; "spatial relations, spatial orientation, and visualization". He defined spatial relations as solving spatial problems rapidly (mental rotations) and spatial orientation as the ability to transfer the viewer on different perspectives and classify between left and right, and spatial visualization as the capacity to explain complex spatial problems (Lohman, 1979).

D'Oliveira (2004) mentioned about three categories about spatial ability: "visualization, spatial relations, and dynamic spatial ability". Linn and Petersen (1985) categorized spatial abilities as "spatial perception, mental rotation, and spatial visualization". Kimura (1999) identified six spatial factors which are "spatial orientation, spatial location memory, targeting, spatial visualization, disembedding and spatial perception". Some of the researchers (Clements & Battista, 1992; McGee, 1979; Pellegrino, Alderton, & Shute, 1984) agreed that the spatial ability consists of two components which are "spatial relations and spatial visualization".

Spatial ability or skill can be assessed with several tests. According to Sorby (1999), most of the tests have been developed to determine individual's skill levels in the first two stages of development. For the first stage, person's topological skills (two-dimensional), where person able to notice an object's closeness to the others, are assessed. For the second phase, people's projective skills are assessed which are related to visualizing three-dimensional objects by observing them from different perspectives (Piaget, 1969; Sorby, 1999).

Topological skills could be assessed by tests such as the Minnesota Paper Form Board (Likert, 1970) and the Group Embedded Figures (Oltman, Raskin, & Witkin, 1971). Figure 6 and 7 shows a visualization items similar to those found on these tests (Lieu & Sorby, 2008; Sorby, 1999).

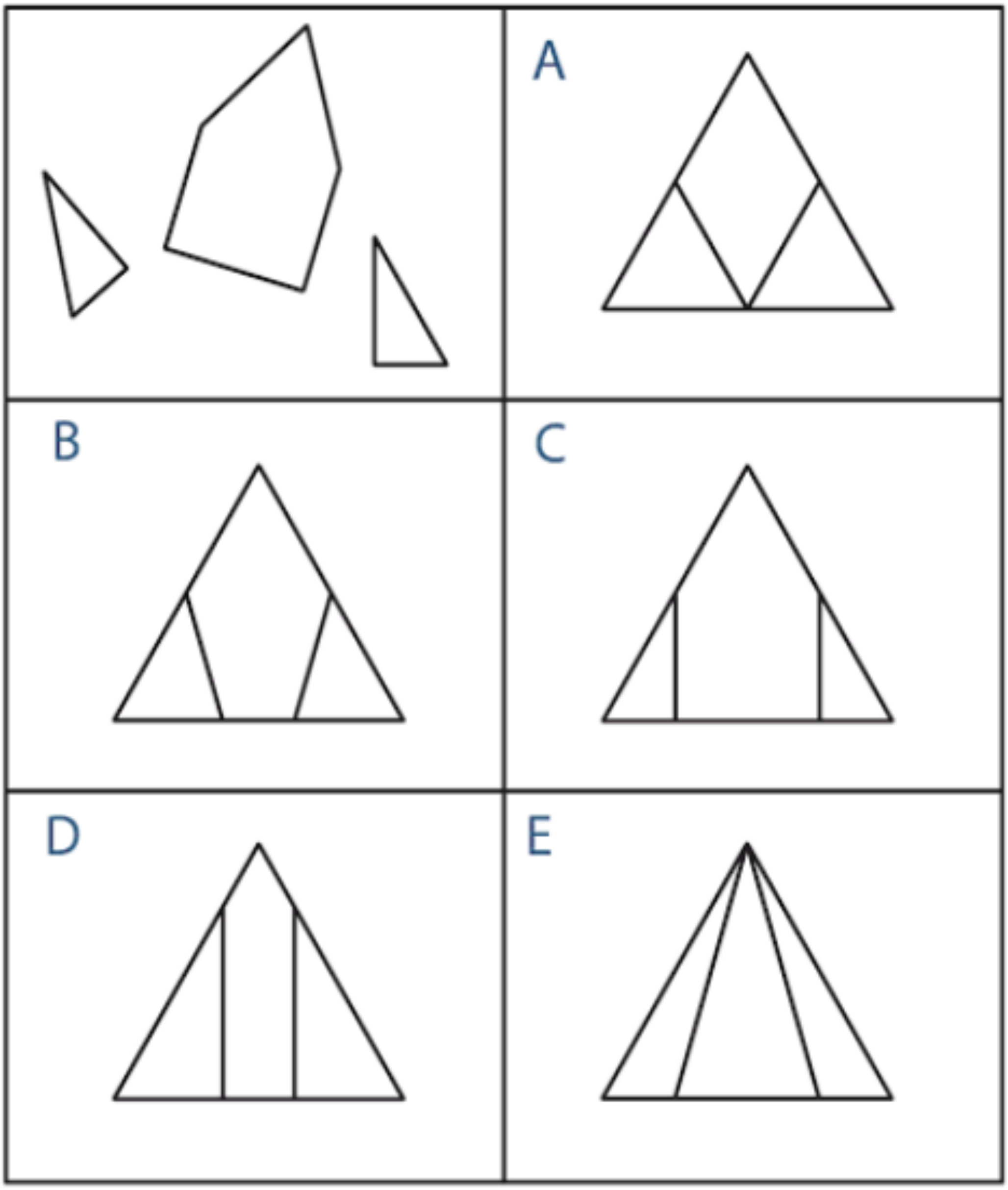


Figure 6: Similar item found on Minnesota Paper Form Board Test

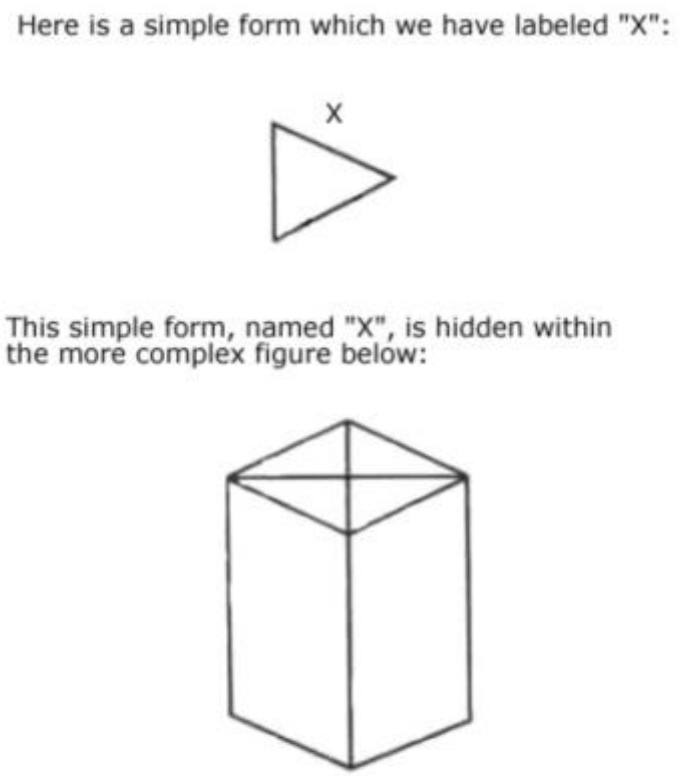


Figure 7: Similar item found on Group Embedded Figures

Projective skills of a person could be assessed by the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1973), the Mental Cutting Test (CEEB, 1939), the Mental Rotation Test (Vandenberg & Kuse, 1978), etc. The Figures 8, 9 and 10 shows sample visualization items those found on these tests (Lieu & Sorby, 2008; Sorby, 1999).

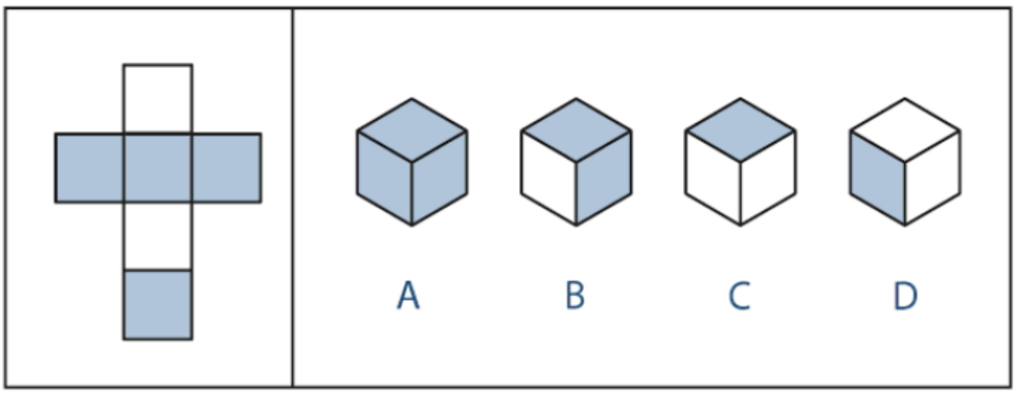


Figure 8: Sample item found on the Differential Aptitude Test

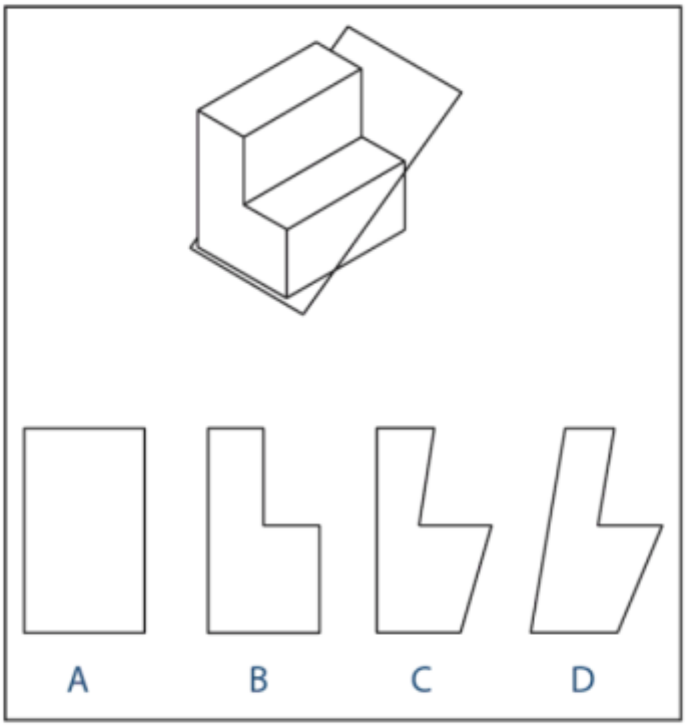


Figure 9: Sample item found on the Mental Cutting Test

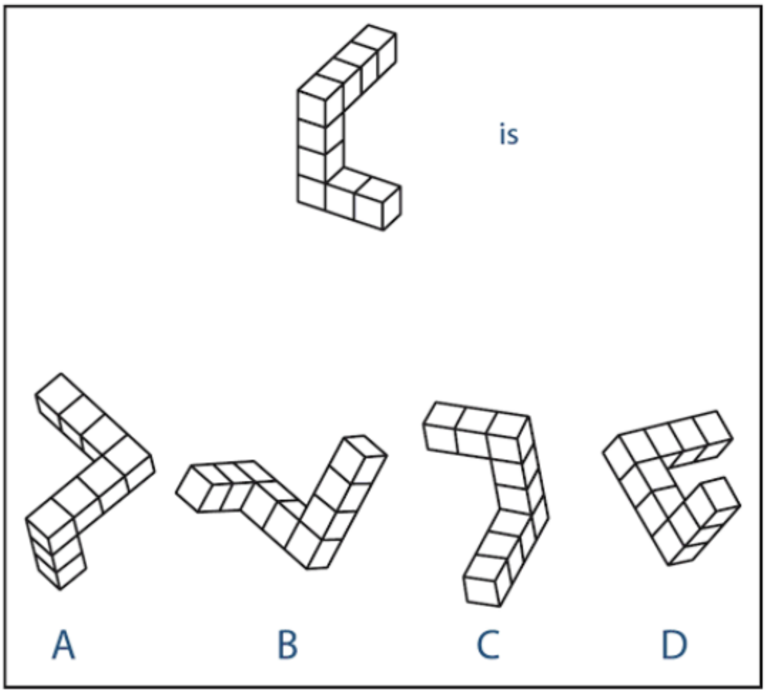


Figure 10: Sample item found on the Mental Rotation Test

There are several studies to determine how spatial skills are improved. Sorby (1999), summarized the activities that are helped to develop spatial skills such as playing with construction toys in early childhood, participating in courses like drafting or mechanics in school, playing three-dimensional video or computer games, involving in sports activities and having high scientific skills. Consequently, activities which require eye-to-hand coordination could be supportive of improving spatial skills (Sorby, 1999).

Spatial skill is significant for improving mathematical success (Clements, 1998; Humphreys, Lubinski, & Yao, 1993). Some studies (Gunderson, Ramirez, Beilock, & Levine, 2012; Verdine et al., 2013) suggested that improving mathematical problem-solving skills can depend on spatial skills. Therefore, there is an early link between mathematical and spatial skills. Some studies indicated that spatial ability play critical role to be successful in STEM (science, technology, engineering, and mathematics) (Wai, Lubinski, & Benbow, 2009), arithmetic development (Zhang et al., 2014), science achievement (Ganley, Vasilyeva, & Dulaney, 2014). Similarly, another study (Verdine, Irwin, Golinkoff, & Hirsh-Pasek, 2014) stated that spatial ability is very crucial for improving school readiness for math and the for future mathematics performance.

Gunderson et al. (2012) presented two longitudinal studies to show how and why spatial skills are related to young children's mathematics success. The results of the studies revealed that there was a strong relationship between spatial skills, number line knowledge, and math achievement (Gunderson et al., 2012).

In their study, Battista et al. (1982) searched for the effect of hands-on activities, manipulative materials and some concrete models on spatial ability. The results of the study showed that using these materials improves the spatial ability of teacher candidates. In other words, using this kind of activities have a direct impact on the development of spatial visualization ability (Battista et al., 1982).

Verdine et al. (2013) investigated children's spatial skills and the relationship between these skills and mathematical skill. During the experiment, children were asked to form their constructions by observing three-dimensional, intact, glued-together model construction. After the study had completed, it was found that spatial skill independently predicted the variability in mathematical performance (Verdine et al., 2013).

In their study, Tzuriel and Egozi (2010) searched for the effect of spatial training program on first graders mental rotation abilities scores After eight weeks treatment gender differences in spatial ability in the beginning disappeared. The girls in the experimental group improved spatial skills more than the control group. The gender gap was gone at the end of treatment (Tzuriel & Egozi, 2010).

In his dissertation, Yildiz (2009) examined the effects of three-dimensional learning environments and physical manipulatives on spatial visualization and mental rotation ability of fifth graders. The researcher designed three-dimensional virtual unit block simulation for the experimental group and learning environment with unit blocks for the control group. When the study's results were examined, it was concluded that there was a significant difference between pre-test and post-test spatial visualization scores in both groups. However, there was a significant difference between pre-test and post-test mental rotation ability test scores just in the control group. Moreover, there was no significant difference between the groups in terms of spatial ability scores (Yildiz, 2009).

Y.-L. Cheng and Mix (2014) studied whether spatial (mental rotation) training will improve math performance in early elementary-aged children. The treatment group was trained with a mental rotation practice; on the other hand, the control group was trained with a crossword puzzle. The results showed that training on a mental rotation task improved performance on calculation problems in young children (Y.-L. Cheng & Mix, 2014).

Newman et al. (2016) searched for the effects of playing with blocks (physical manipulatives) and word game on spatial ability. Children in groups attended five-session activities with structured block play or word game. Before and after activities, researchers scanned children's brain activities while they were solving mental rotation tasks. Children who played with blocks showed better performance in in reaction time, and accuracy and also more activity in brain regions those were related to spatial processing and spatial working memory (Newman et al., 2016).

2.8 Geometric Shapes

Geometric shapes are one of the core subjects of the preschool mathematics education. The curriculum in Turkey for early childhood education aims to teach just two-dimensional geometric shapes such as triangle, rectangle, square, circle and ellipse. The geometric shape ellipse is a newly added to the curriculum. Sarama and Clements (2009) stated that for teaching geometric shapes to preschoolers, there are limited educational materials which are essential for shaping children's thinking for the rest of their lives. Moreover, Clements (2004) stated that most of the students taught with limited geometry instruction.

Before starting school, each child has an opportunity discover the geometric shapes in daily life. According to van Hiele (1999), geometric thinking in children begins with recognizing geometric shapes based on their appearance and determining their properties. Moreover, van Hiele (1999) underlined the significance of experience in geometry learning. Battista (2007) mentioned that just getting older does not confirm the development in geometric understanding, children need to practice and involved in several activities to learn and discover geometric concepts.

There were several studies which were examined the development of geometric concepts in children. In their studies, Clements, Swaminathan, Hannibal, and Sarama (1999) stated that children were able to identify circles, however, they had difficulty in categorizing squares. Similarly, Clements (2004) declared that children had difficulty mostly in identifying rectangles and triangles. According to his study results, children identify particular rectangles and triangles as an isosceles triangle and its prototypes.

In their study Fisher, Hirsh-Pasek, Newcombe, and Golinkoff (2013) searched the impact of guided play condition in teaching geometric shapes to preschool children.

For children, the researchers created three different learning environments which are: guided play, didactic instruction, and free play. The results of the study revealed that children who were taught in guided play environment showed better performance in shape knowledge compares to other conditions. The researchers emphasized that using proper framework might assist geometric shape learning (Fisher et al., 2013)

Aslan and Arnas (2007) aimed to determine three to six years old preschool children recognition of geometric shapes. According to the finding of the study, the preschool children showed better performance in the circle classification task and followed by the square classification. The preschoolers found harder to classify triangle shape among others. Moreover, children had difficulty in identifying shapes which were had different orientation, ratio, skewness or size (Aslan & Arnas, 2007).

2.9 Theoretical Perspective

Children's ways to comprehend the space are "starting with smaller scale perspectives on geometric shape, including composition and transformation of shapes, and then turning to larger spaces in which they live". Children have the potential to improve spatial thinking levels as they learn geometric shapes (Clements, 1998). Clements (1998) stated that van Hiele believed that this development requires instruction. van Hiele (1999) stated that there are different geometric thinking levels (visual, descriptive/analytic, informal deduction, formal deduction and rigor levels). He also recommended that for guiding children from one level to the next, instruction should follow five phases (van Hiele, 1999, p. 315–316):

- <u>Phase 1 - Inquiry:</u> in which materials lead children to explore and discover certain structures.
- <u>Phase 2 - Directed Orientation:</u> tasks are presented in such a way that the characteristic structures appear gradually to the children,
- <u>Phase 3 - Explication:</u> the teacher introduces terminology and encourages children to use it in their conversations and written work about geometry.

- Phase 4 - Free Orientation: the teacher provides tasks that can be done in different ways and supports children to become more proficient with what they already know.
- Phase 5 - Integration: children are given opportunities to pull together what they have learned.

van Hiele's (1999) geometric thinking model is not the central interest of this research since this model much more related to promoting children’s geometric thinking. This study is more concern with developing children’s spatial abilities and geometric shape recognition level through van Hiele's (1999) five sequential phases of learning by using manipulatives.

Siew, Chong, and Abdullah (2013) tried to determine the effects of van Hiele’s instructional phases of learning geometry by using concrete manipulative as tangrams. The study conducted with third graders. The children learned two-dimensional geometry and symmetry through van Hiele’s instructional model. A geometric thinking test was given to children as a pre-test and post-test. After the intervention, the data was analyzed, and the results showed that there was a statistically significant difference between test scores of third graders in terms of geometric thinking. The results also indicated that the intervention (teaching with tangrams as concrete manipulative) which based on van Hiele’s phases of learning could improve geometric thinking level of children. According to results, children with low ability performed better than moderate and high ability children in geometric thinking (Siew et al., 2013).

It can be assumed that young children have little or no information about geometric figures by teachers or curriculum developers (National Research Council, 2009). The curriculum for early childhood education aims to teach just introduce shapes in four basic categories: circle, square, triangle, and rectangle, however, children could learn about the differences between two-dimensional and three-dimensional shapes informally (National Research Council, 2009). The present study also aims to present new geometry learning tools (virtual manipulatives) for preschool children to enrich typical curriculum materials by taking into account van Hiele's instructional levels.

2.10 Summary

This chapter covers the relevant literature review with the main standpoints in the study. Furthermore, the results of the other related studies about early childhood education, physical and virtual manipulatives, mobile learning, AR, spatial ability, geometric shapes, preschool children's achievements, van Hiele's instructional model were discussed. It could be concluded that if children were trained their spatial skills and geometric shape recognition could improve (Aslan & Arnas, 2007; Battista et al., 1982; Y.-L. Cheng & Mix, 2014; Dunleavy et al., 2009; Fisher et al., 2013; Newman et al., 2016; Tzuriel & Egozi, 2010; Verdine et al., 2014; Yildiz, 2009).

As mentioned before, AR is a new technology, and its educational use is becoming widespread. Moreover, according to the literature review, the number of the studies, which examined the effects of using AR as a virtual manipulative in preschool education, was not very high. In other words, there are no more detailed studies including AR technology for preschool education. Therefore, it is important to review the effects of AR technology a virtual manipulative for improving spatial skills and geometric shape recognition levels of preschool children. Furthermore, there is a need to examine how to best integrate these emerging technologies to preschool children's learning environments.

The use of the appropriate instructional model in training, teaching and learning through manipulatives, augmented reality, spatial ability, geometric shapes are the main titles of the chapter.

CHAPTER 3

METHOD

This part discusses issues related to the methodology of the study such as the design of the study, sampling, instruments for data collection, variables, procedures, teaching and learning materials, treatment, and the analysis of the data collection.

3.1 Purpose of the Study and Research Questions

The purpose of the study is to compare physical manipulatives with virtual manipulatives in improving young children's spatial skills and understanding of geometric shapes. It explores the educational the use of virtual manipulatives such as AR based applications implemented with a mobile device. The study will examine the following questions:

1) Is there a significant difference between preschool children's spatial ability test mean scores exposed to virtual manipulatives and physical manipulatives?
2) Is there a significant difference between students' pre and post spatial ability achievement scores
    a) within the experimental group taught through virtual manipulatives?
    b) within the control group taught through physical manipulatives?

3) Is there a significant difference between preschool children's geometric shape recognition task mean scores exposed to virtual manipulatives and physical manipulatives?
4) Is there a significant difference between students' pre and post geometric shape recognition levels
    a) within the experimental group taught through virtual manipulatives?
    b) within the control group taught through physical manipulatives?
5) What are young children's opinions related to virtual and physical manipulatives?
6) What are parents' opinions related to their child's experience in doing activities with manipulatives?
7) What are teacher's opinions related to virtual manipulatives?

3.2 Research Design

To answer the research questions, a mixed method design combining both quantitative and qualitative research approaches was used in this study (Figure 11). Specifically, the explanatory mixed method was used in this research study as it includes the analysis of qualitative data after the analysis of quantitative data, collected from preschool children, their parents, and their teachers.

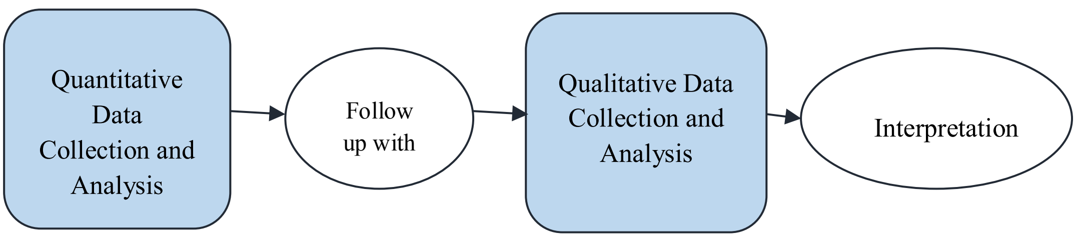


Figure 11: Explanatory research design

The quasi experimental design was implemented in this present study since the schools were chosen by the convenience non-random sampling which is a technique where individuals were selected because they are voluntarily available for study (Fraenkel, Wallen, & Hyun, 2011). However, an experimental group and a control group with random assignment of subjects were formed. In other words, every subject had equal and independent chance of involving in the experimental or control group. Pre-test post-test approach was utilized. The measurements or observations were done at the same time for both groups. The time frame was the beginning of the second semester; therefore, their teachers did not expose preschool children to the same content. When the preschool children were covering general curriculum, basic geometric shapes were taught after the current study was completed. Moreover, during the study, all teachers followed the general curriculum and did not interfere the study.

After collecting quantitative data, one-on-one interviews were carried out to collect qualitative data. 39 children, 35 parents and six teachers volunteered to participate in interviews. In the interviews, the researcher asked questions to and recorded answers from only one participant at a time (Fraenkel et al., 2011).

The present study aimed to determine the effects of AR media on spatial skills of preschool children. There were two groups in the process, and basic geometrical objects were taught. The experimental group was taught by AR application; the control group was taught by physical manipulatives such as brick toys or blocks. The treatment took four weeks. Table 1 summarizes the design of the study:

Table 1: Research design of the study

Groups	Pre-test	Treatment (4 weeks)	Post-test	Interviews
Experimental	Spatial Ability Tests Geometric Shape Recognition Task	AR applications	Spatial Ability Tests Geometric Shape Recognition Task	One-on-one interviews with a sample of children, teachers and parents.
Control		Physical manipulatives		

3.3 The Role of the Researcher

The researcher had several roles throughout the study such as designing and developing of learning materials and environments. The researcher was responsible for the communication with preschool principals, teachers and parents. The researcher also collected all the data (pre-tests, post-tests, and interviews) from participants. The researcher taught preschool children in both the experimental and the control group. The collected data was also analyzed by the researcher. In the analysis of semi structured interviews, regarding the inter-coder reliability concern, different coders also analyzed the interview transcribed data by examining categories and themes.

3.4 Procedure of the Study

Two different instructional practice for teaching basic shapes to preschool students were designed and developed. The instruction in each group was designed with respect to the van Hiele instructional phases and lasted for four weeks. The instructional materials (handouts, virtual manipulatives) were developed, and pilot studies were done in small groups.

van Hiele's (1999) instructional phases were applied throughout the treatment in both groups. These learning phases are; inquiry, directed orientation, explication, free orientation, and integration.

Phase 1 - Inquiry:

At the inquiry phase, children studied in groups of three or four. They tried to explore the properties of geometric shapes. The preschoolers experienced to classify and recognize geometric shapes by using manipulatives (shape cards and wooden blocks as physical manipulative in the control group; AR application as a virtual manipulative in the experimental group). Throughout this process, children were familiarized with a variety of two and three-dimensional geometric figures (triangle, square, rectangle, circle, ellipse, cube, prisms, sphere, cylinder). For example, take into account the development of the concept of a square. In the inquiry phase, children might classify all of the following as squares (see Figure 12).

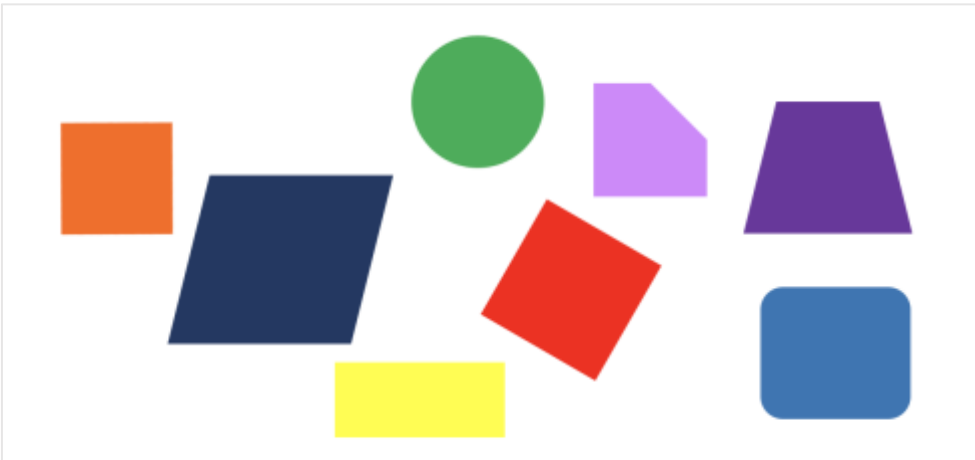


Figure 12: Development of the concept of Square at the Inquiry Phase

Phase 2 -Directed Orientation:

In this phase, children were asked to observe the properties of two and three-dimensional geometric shapes. With the help of researcher, the children explored the given geometric shapes. Moreover, some photographs of geometric objects from daily life presented to children. The researcher asked children to give different examples to enhance their understanding. For instance, by using sorting task, children might classify squares (see Figure 13).

Squares Not Squares

Figure 13: Development of the concept of Square at the Directed Orientation Phase

Phase 3 - Explication:

Children were introduced to the new vocabulary of geometric shape. They were taught to classify and name geometric shapes correctly. For example, the researcher used accurate language by helping children to verbalize that a square is a shape with four equal sides and four corners.

Phase 4 - Free Orientation:

In this phase, children had to study on various task. The preschool children were given handouts where they were to classify various geometric shapes. The children had to explore various geometric shapes by manipulating the different size of geometric shapes in different positions or colors (see Figure 13). The preschoolers were also given an opportunity for manipulating and identifying samples and objects from daily life to investigate the properties (see Figure 14 and 15).

Squares with same color Squares with same size Squares with same position

Figure 14: Development of the concept of Square at the Free Orientation Phase

The experimental group The control group

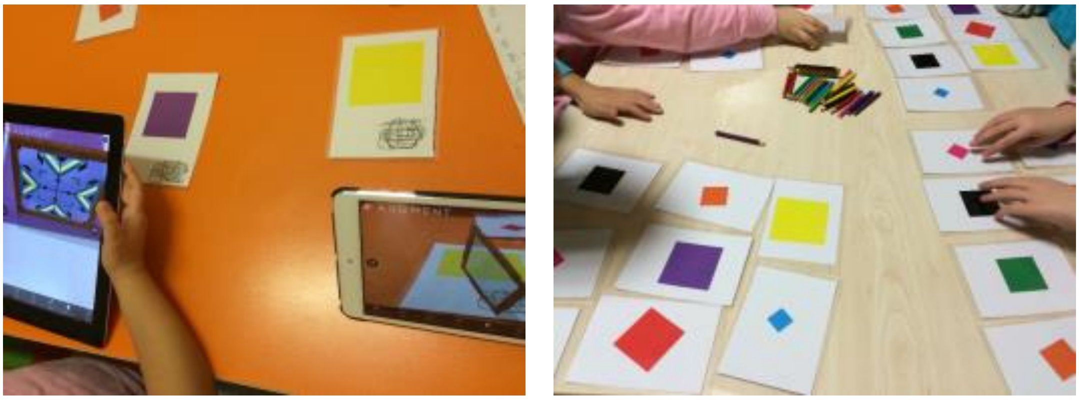


Figure 15: Development of the concept of Square at the Free Orientation Phases in both groups

Phase 5 - Integration:

At this stage, the researcher asked children to explain or summarize what they have learned (geometric shapes and their properties) throughout the lesson. For example, during this phase children may complete a task where they need to use various squares to make a picture.

Before starting the study, the researcher conducted a short meeting with teachers and the principal for explaining study details. The rationale behind the study, the aim, significance, and benefits of the study were explained. Then, the researcher made contact with parents through letters in which intent of the study and the procedure was explained. Parents were asked for permission for their children's participation in the study. Parents also were requested to fill the Demographic Information Form.

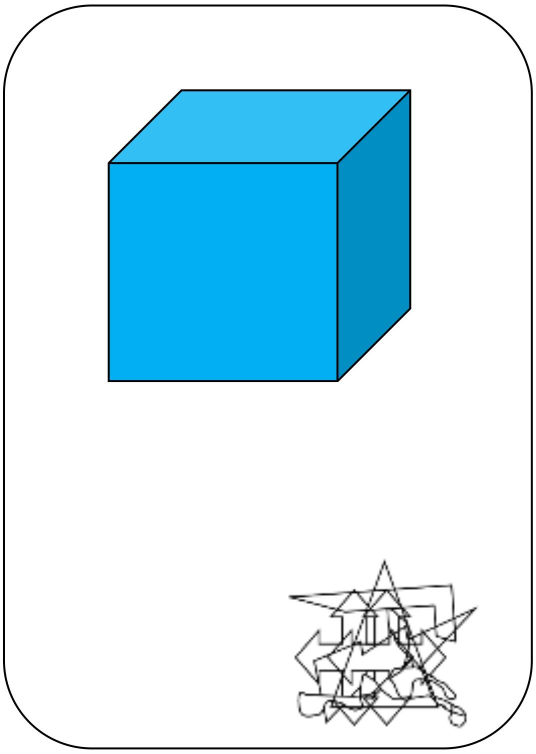


Figure 16: An example of tracker card

At the beginning of the treatment, each of the groups took the pre-tests (Spatial Ability Tests and Geometric Shape Recognition Task). Each child was tested separately in a different room at their school. The test materials were presented on a desk, with the researcher seated next to the child. After pre-tests were over, the treatment started. During the instruction, preschool children in the experimental group used tablet computers with AR applications as virtual manipulatives to learn two and three-dimensional objects. They used these tablets to study with AR application. The preschool children also had colorful and various shape tracker cards (see Figure 16) those open three-dimensional virtual manipulatives on AR application. The control group used physical manipulatives to learn the same content. These physical manipulatives were wooden blocks of three-dimensional shapes and colorful and various shape cards. Both groups were taught with pictures of two and three-dimensional objects. During the study, all children studied in a small (3 or 4 children) groups. Furthermore, each group was lectured and guided by the same instructor (the researcher). During the study, all children in the groups were taught basic geometric two-dimensional (square, rectangle, circle, triangle, ellipse) and three-dimensional (cube, prisms, sphere, cylinder) objects and their daily life forms. After the treatment, post-tests (Spatial Ability Tests and Geometric Shape Recognition Task) were implemented. Moreover, volunteer children from both groups were interviewed to determine their opinions related to virtual and physical manipulatives. Also, semi-structured interview questions about virtual and physical manipulatives were asked teachers and parents (see Figure 17).

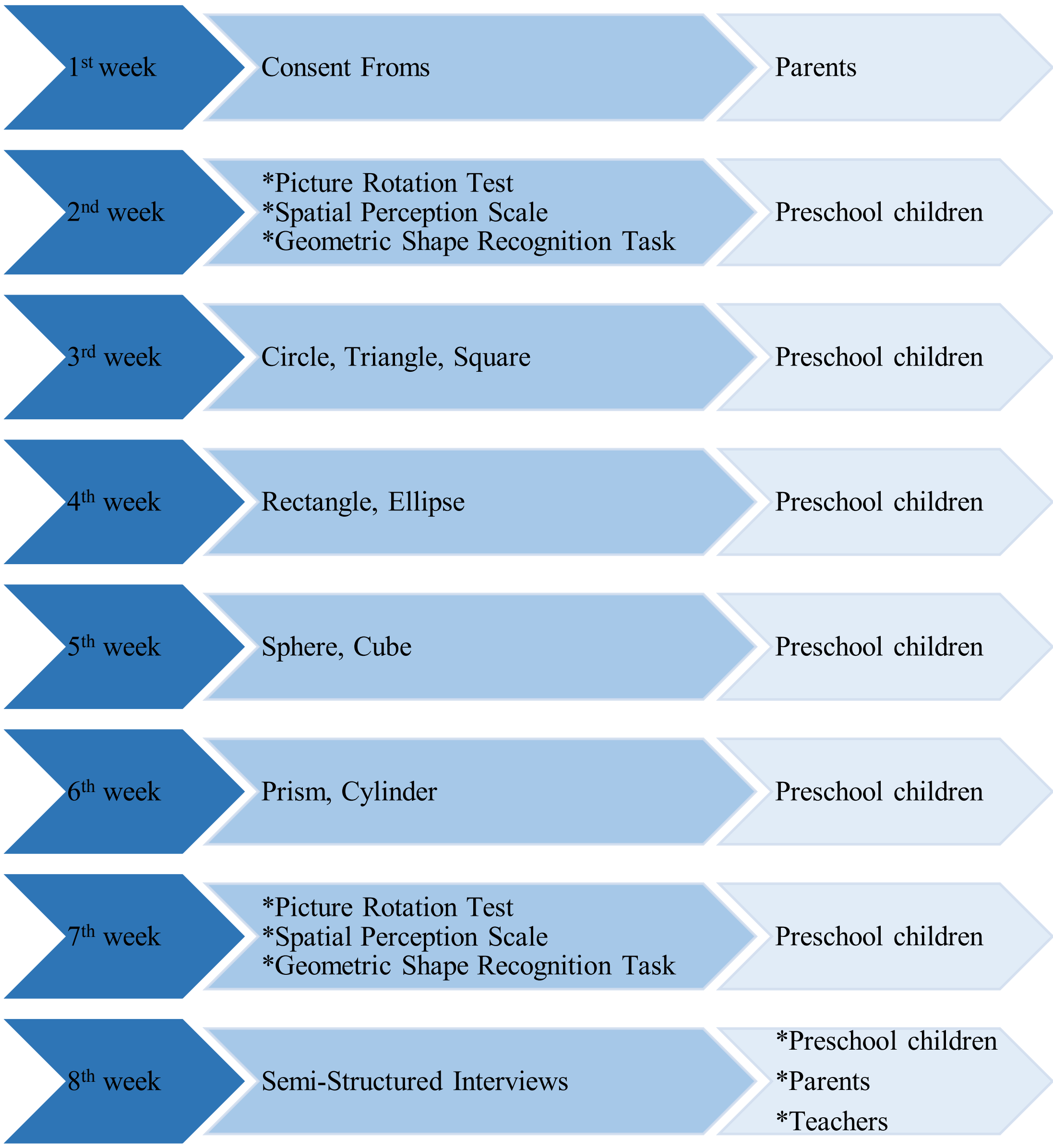


Figure 17: Timetable of the treatment process

3.5 Timetable of the Study

Febuary 2014 - May 2014	•Determining the problem
June 2014 - September 2015	•Design and development of the study
October 2015 - November 2015	•Pilot study •Data collection and analysis of the pilot study
November 2015 - December 2015	•Redesign and development of the study
January 2016 -March 2016	•True experiment •Data collection
March 2016- December 2016	•Transcribing the data •Analaysis of the data
January 2017 - June 2017	•Thesis writing

Figure 18: Timetable of the study

3.6 Participants

The target population of this study was preschool children between 5 to 6 years old, their teachers and parents in İstanbul. The study was carried out with preschool students' enrollment in public school in Istanbul in the 2015-2016 academic year. In this current study, random sampling was hard to do because of the absence of parents' and schools' allowance. Thus, permissions from METU-Ethics Committee and The Ministry of National Education were taken for two schools (Appendix E, F).

After random assignment of children to the group, there were 38 children in each group (experimental group with 21 girls & 17 boys; control group with 19 girls &19 boys). However, four children (two from the experimental group and two from the control group) who could not complete the treatment process and excluded from the study.

Table 2: Basic information of the children

		f	%
Gender	Female	40	52.6
	Male	36	47.4
Going pre-kindergarten	Yes	32	42.1
	No	44	57.9
Child has computer	Yes	53	69.7
	No	23	30.3
Touchable screen experience	Yes	76	100
	No	0	0

As it is shown in Table 2, 52.6 % of the children were female, and 47.4% were male. 57.9% of the students had pre-kindergarten experience. Approximately equal distribution in gender and pre-kindergarten experience. A majority of the children (69.7%) owns a computer (desktop PC, laptop or tablet PC) at home, and 100% of them are familiar with touchable screens.

3.7 Context

The study was carried out in the classes of a public primary school. In order to prevent external distraction that could affect the children, the study was conducted in a separate, special classroom arranged by the teachers. This class included tables and benches as it can be seen in Figure 19.

Figure 19: Classroom appearance

The materials for the control group were pictures of daily life objects and physical manipulatives (shape cards and wooden blocks). The materials for the experimental group were pictures of daily life objects, shape cards as trackers, virtual manipulatives (AR activities) (see Figure 20 and Figure 21). The technical properties of the tablet are presented in "Appendix G".

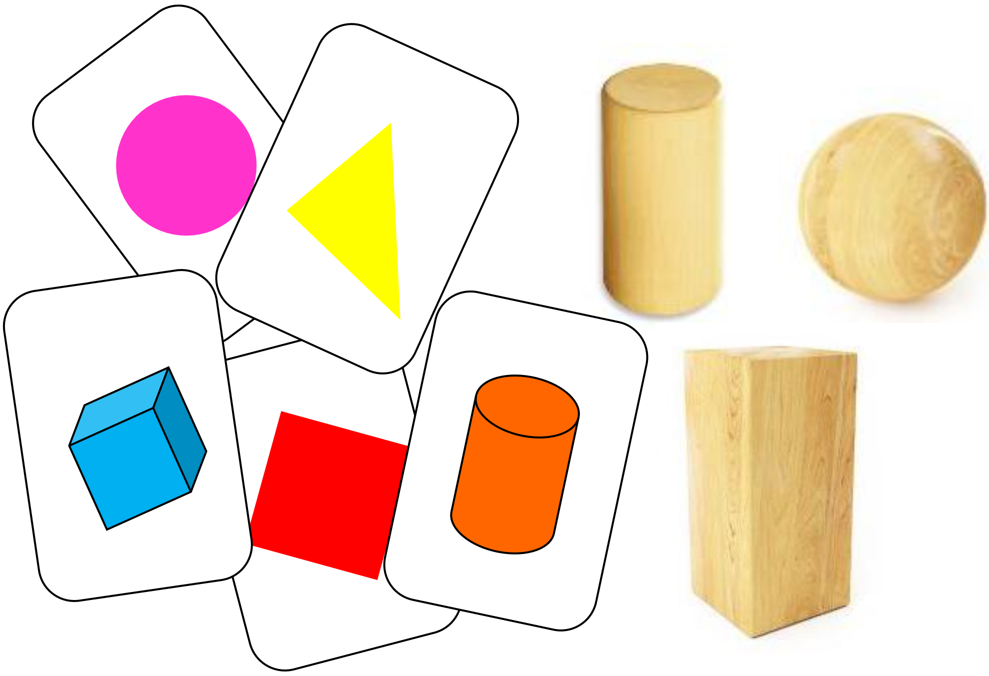


Figure 20: Materials for the control group

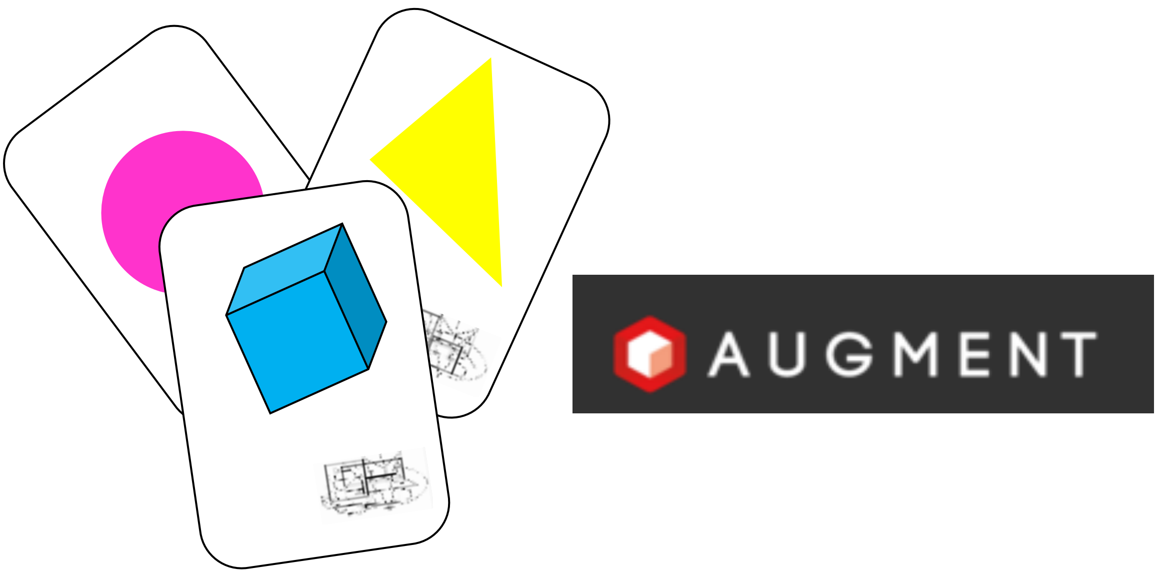


Figure 21: Materials for the experimental group

3.8 The Augment Application and Virtual Manipulatives

Augment application is a platform, which enables visualization of “three-dimensional models in the real environment, in the real time, and at scale” (www.augment.com). It creates a link between the virtual and physical worlds. For the application students, teachers, and academic institutions are provided free subscriptions. With the aid of Augment Manager, users easily upload and manage three-dimensional models and custom trackers. The Augment application is both compatible with smartphone and tablet PC (see Figure 22 and Figure 23).

Figure 22: Screenshot from smartphone

Figure 23: Screenshot from tablet PC

The content of the study was the topics of “geometric shapes” for preschool level. Preschool education is a non-compulsory educational process for children from 3-5 (36-66 month) years old in both public and private schools in Turkey (Ministry of National Education, 2012). Curriculum for the preschool education aims to teach basic geometric shapes in four basic forms: circle, square, triangle, and rectangle. The children can learn the differences between two-dimensional and three-dimensional shapes as extra-curricular activities or in informal settings (National Research Council, 2009). Besides physical manipulatives, to present new learning tools and enrich typical curriculum materials, virtual manipulatives (AR applications) through tablet computer were used in the experimental groups.

3.9 Experimental Procedure

In the experiment, as the first thing teachers collected written parent consent forms from all the child participants. After random assignment of children to the control and experimental groups, the treatment lasted for four weeks. While the experimental group used tablet computers with AR applications presenting virtual manipulatives (see Figure 24), the control group used physical manipulatives for doing activities with geometric shapes (see Figure 25).

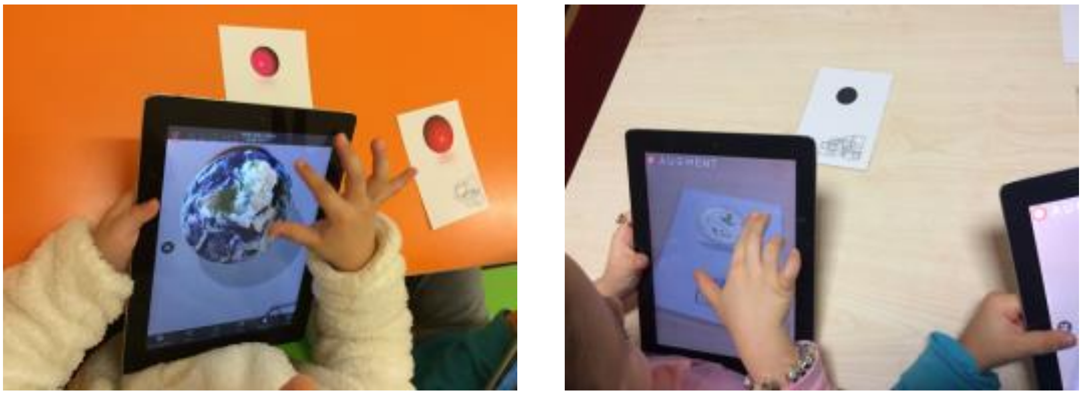


Figure 24: The experimental group manipulatives

Figure 25: The control group manipulatives

In each group, there were 36 children. The distribution of gender among the preschool children in the study was 38 girls (52.8%) and 34 boys (47.2%). As it is shown, in the experimental group, there were 21 girls (58.3) and 15 boys (41.7) and in the control group, there were 17 girls (47.2) and 19 boys (52.8) (see Table 3).

Table 3: Participants of the study

Groups		Female	Male	Total
Experimental Group	*f*	21	15	36
	%	58.3	41.7	100
Control Group	*f*	17	19	36
	%	47.2	52.8	100
Total	*f*	38	34	72
	%	52.8	47.2	100

The researcher as an instructor studied with small groups of three or four children. The length of each lesson was 40-45 minutes in each group. While children studied with daily life photographs of three-dimensional objects, geometric shapes cards as trackers and virtual manipulatives in the experimental group; the children studied with daily life photographs of three-dimensional objects, physical manipulatives in the control group.

In each group, the researcher taught the same content which was designed concerning van Hiele's instructional model. At first, all children tried to explore the properties of geometric shapes. In the experimental group, children tried to classify geometric shapes among virtual visuals from a tablet computer, on the other hand, the children in the control group classified shapes by using shape cards (see Figure 26).

The experimental group   The control group

Figure 26: Classifying geometric shapes

The children in both groups classified geometric shapes. The researcher showed daily life photographs of three-dimensional objects to the both groups (see Appendix J) and asked for different examples to increase their understanding. After that, the researcher gave the terminology about the geometric shapes. While the preschool children in the experimental group were studied with AR application; children in the control group studied with geometric shape cards and wooden blocks (see Figure 27). For each geometric shape, four or five three-dimensional virtual models were provided for the experimental group. The list of the three-dimensional models which were given in the Appendix K).

Moreover, various tasks were given to the both groups. The preschool children in both groups completed handouts such as categorization of geometric shapes or coloring activities during each session (see Figure 28).

The experimental group

The control group

Figure 27: Activities with manipulatives

The experimental group

The control group

Figure 28: Categorizing handouts

At the end of each session, the preschool children in both groups, summarized what they have learned during the lesson and gave more example of geometric shapes. In this way, they had a chance to integrate what they have learned.

3.10 Data Collection Procedure and Instruments

Data was collected in the fall semester of the 2015-2016 academic year via forms, achievement tests and interviews from the 5-6 years old preschool children, their teachers and parents. The details about the data collection process are given below.

Table 4: Data collection procedure, instruments and roles of practitioners

Process	Instruments	Practitioners
Before Treatment	• The parent consent form • Demographic information form • Spatial Ability Tests • Geometric Shape Recognition Task	• Parents • Parents • Preschool children • Preschool children
After Treatment	• Spatial Ability Tests • Geometric Shape Recognition Task • Interview questions	• Preschool children • Preschool children • Teachers, preschool children, parents

Demographic information form was used to gather baseline information about each child at the beginning of the study.

The spatial ability test and geometric shape recognition task were used as pre-test and post-test to discover each child's spatial and geometric skills.

Semi-structured interview questions were asked to the children to gather information regarding their personal experience with the tablet computers and AR application at the end of the study. Also, to learn the thoughts of parents and teachers about the treatment, semi-structured interview questions were asked to them too.

3.10.1 Demographic Information Form

Demographic information form (see Appendix B) was administered to participants at the beginning of the study. Short answer and multiple choice questions were used to gather basic demographic data about the participating children. The parents were asked for descriptive information about their children's genders, ages, preschool background, computer-tablet PC ownership, the purpose of using computers, familiarity with mobile devices and touchable screens, parents' education levels and their job information through the questionnaire.

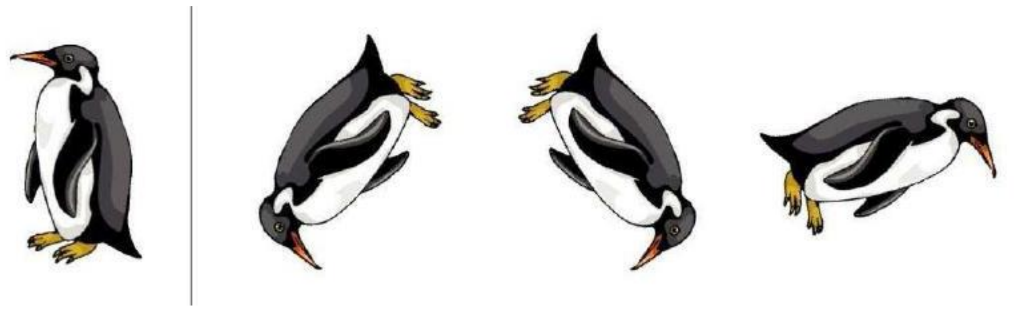
3.10.2 Spatial Ability Tests

Spatial ability was measured with two mental ability tests which are Picture Rotation Test (PRT) and Spatial Perception Scale (SPS). As it was mentioned before, there are several categorizations of spatial abilities. In order to cover these sub-components, more than one spatial ability tests were used. These tests were measuring children's spatial abilities (visualization, orientation, and rotation). PRT measures rotation skills and SPS measures much more visualization and orientation skills. Sample questions from tests were given in the Appendix H and I.

3.10.2.1 Picture Rotation Test (PRT)

This test is a mental rotation test (Quaiser-Pohl, 2003) for pre- and early primary school children (ages 4–6) and it was developed from a similar to another test which is constructed for adults by (Peters et al., 1995; Vandenberg & Kuse, 1978). The test was used to measure the entry level ability in both groups and whether there was a significant improvement in mental rotation ability of preschool children after using the virtual and physical manipulatives.

The PRT consists of figures of colored pictures of humans and animals. There are 16 items (eight human items, eight animal items) and for each item, there is one target figure and three comparison figures (see Figure 29). Preschool children have to compare the first figure on the left (target) to other three similar figure on the right-hand side. For each item, there is only one correct answer; the other two figures are distracters. Therefore, children need to rotate figure mentally to find the right choice on the right-hand side. Before starting PRT, two sample items and demonstration of rotation process were presented to children. There is no time limit, and the maximum score is 16. The reliability of test (Cronbach's α) was measured as 0.75, and split-half reliability was 0.74. The PRT showed high correlations with mental tests (*r*=0.73 with a letter rotation test and 0.57 with a cube-figure rotation test) (Quaiser-Pohl, 2003). The reliability test result of the current study was found as 0.82.



"Here you see the picture of a penguin. It runs in the direction of ... (name an object in the room). One of these three penguins here (point to the pictures behind the line) is the same as the first one. Can you tell me which one?"

Figure 29: Example of item of picture rotation test

3.10.2.2 Spatial Perception Scale (SPS)

The Spatial Perception Scale (SPS) was developed by Tığcı (2003) to measure 6-year-old children's spatial perception. The test covers questions about shape, orientation, spatial position and perspectives of objects. The test was used to measure as pre-test and post-test to measure the entry level abilities and to find out if there was a significant improvement in spatial perception ability of preschool children after using the virtual and physical manipulatives.

The scale items were related to matching of identical or symmetrical rotated objects, finding or showing positions of objects and interpreting perspective of three-dimensional objects (see Figure 30). The internal coherence coefficient of SPS was 0.82 for Cronbach Alpha; 0.79 for Spearman- Brown and 0.79 for Guttman Split half; therefore, this scale is reliable with respect to the level of internal coherence. The SPS showed high correlations (r=0.54) with Raven Progressive Matrice IQ Test (Tığcı, 2003). The reliability test result of the present study was measured as 0.76. The test consists of 51 items. For each correct answer, a child gains one point and no points for the wrong answer. The test takes between 15 to 30 minutes to administer.

"Find the identical figure"

Figure 30: Example items for spatial perception scale

3.10.3 Geometric Shape Recognition Task (GSRT)

The Geometric Shape Recognition Form (Aslan, 2004) was administered in order to reveal the knowledge level of the children about triangle, rectangle, square and circle. This task was developed based on the previous studies of Clements et al., (1999), Hannibal, (1999) and, Satlow and Newcombe (1998).

This form contains typical and confounding shapes of triangle, rectangle, square, and circle (see Figure 31). Each item (triangle, rectangle, square, and circle) has 12 typical and confounding shapes, and totally there are 48 shapes. For each item, children need to find the typical ones firstly then confounding shapes. Each correct answer was worth one point and there was no limited time for answering questions. In order to test the reliability and validity of the task, item and test analysis were conducted and also strength and distinction indices were calculated. Results showed that item strength changed between 0.32-0.99 and none of them had an item distinction below 0.15. The reliability of test was found for four items using formula KR20, which were 0.80 for the triangle, 0.88 for the rectangle, 0.81 for the square and 0.77 for the circle (Aslan, 2004) . The reliability test results for the current study was found as 0.71.

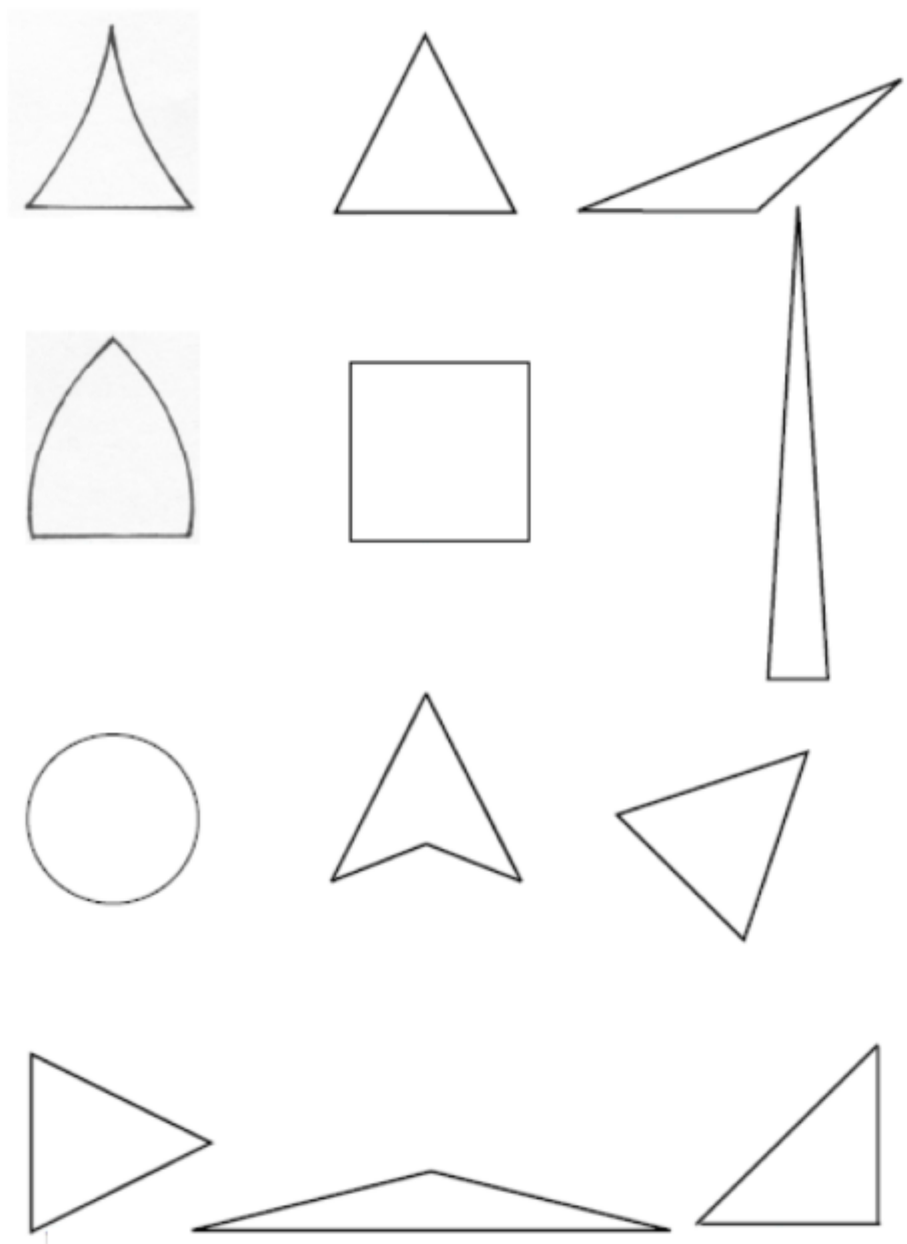


Figure 31: Example of an item of triangle recognition

3.10.4 Interviews

Three sets of semi-structured interview protocols were used for this study. These protocols were used to learn participants' views about the teaching activities. The researcher developed the semi-structured interview protocols concerning the feedbacks from the experts in the fields.

With an aim to determine the opinions of the preschool children about physical and virtual manipulatives, semi-structured interview questions prepared to cover questions on the ideas of children about the treatment. The interview form was composed of some information to be given by the researcher such as the name of the school, name, gender, the date the interview took place, etc. Moreover, there were open and closed ended questions to be answered by the child such as "Do you like using tablet computer (or physical manipulative such as blocks)?", "What do you think about the activities (which are with AR or physical manipulatives) we have done before?" etc to have more detail information about their opinions related to activities and their backgrounds. The questions are prepared according to the level of children's understanding; they are understandable and clear for them.

There was a separate interview form for teachers including questions about their teaching background and their opinions about virtual manipulatives. The question also covered information about teaching experience and technology usage at school (see Appendix D).

Lastly, after treatment, parents were also questioned about their children's experience with manipulatives. The volunteered parents were interviewed to figure out their opinions related to the study by answering a few questions. The questions related to their children's comments about activities were also asked.

The semi-structured interviews were carried out with the participants who were volunteered to investigate their opinions. All the children, parents and teachers were asked if they were willing to participate in the interviews. The researcher interviewed with the participant who accepted to answer questions.

The validity of interview questions was checked by two experts from preschool education. Some of the questions were revised to make them more understandable for participants, especially for children. Before the final version of the semi-structured interview protocol was constructed, five pilot interviews were carried out to evaluate the clarity of the questions. During the pilot study the interview questions were easily understood by children. In order to provide intercoder reliability in this present study, different coders analyzed the interview transcribed data by examining categories and themes (Creswell, 2012). In this way establishing reliable coding could be provided by peer reviewers.

3.11 The Pilot Study

The content of the four-week instruction on geometric shapes was determined and the materials were designed/selected, developed/provided and utilized for both groups. Before they were utilized in the actual experimental setting a pilot study was carried out with five children, one girl and four boys from a public primary school in Istanbul. As in the main study, first the demographic information form and consent form were presented to families to ask for permission and if they agreed to participate voluntarily to fill the form further.

A pilot study was run for validity concerns about the tests and activities provided for the first time with virtual manipulatives. At the beginning of the pilot study, children took the tests (Picture Rotation Test, Spatial Perception Scale, Geometric Shape Recognition Task). The results indicated that the children correctly understood the questions and that they were meaningful to them. The pilot study lasted for two weeks. During the study, children used AR application with tablet computers. After the implementation, in order to receive preschool children's opinions about the manipulatives, they were interviewed. They easily understood and replied semi-structured interview questions.

3.11.1 Observations during Pilot Study

During the pre-test, it was noticed that children had some misconceptions about two-dimensional shapes. For example, they named the shapes below as irregular triangle or not rectangle (see Figure 32).

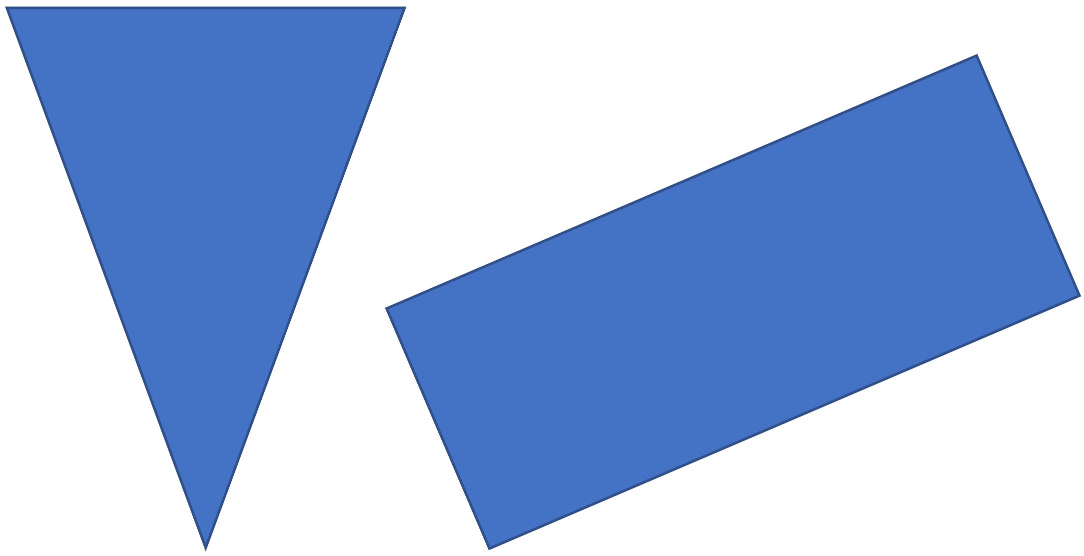


Figure 32: Example for misconceptions

There were three different pre-tests, so it took about 20 minutes to complete them. Since some of the children got bored, in the true experimental study children had a break between the tests. After the pre-tests and each activity, children in both groups were awarded stickers.

For each geometric shape (triangle, square, rectangle, circle, ellipse, cube, sphere, rectangular prism and cylinder); five three-dimensional models were chosen for augmented reality activities that were easily recognizable for preschool children (see Figure 33).

Figure 33: Examples of three-dimensional models

During the study, the researcher observed that the children did not understand some of the three-dimensional models. For example, three-dimensional models such as plates and mirrors were not identified by children, so these were changed before the true experimental study (see Figure 34).

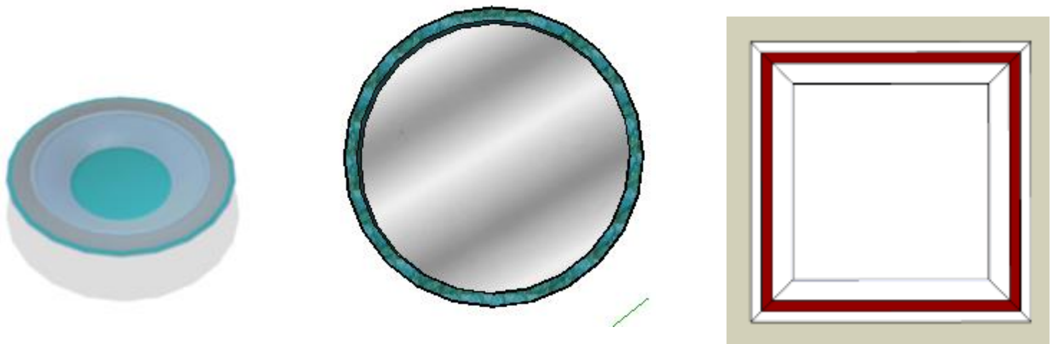


Figure 34: Example of discarded three-dimensional models

During the pilot study, the researcher could communicate and interact with children both individually and collectively. They were familiar with tablet computers, so they did not face any problem in using them. However, the researcher faced technical difficulties about connecting them to the network and the Internet. The mobile modem serving for the broadband connection sometimes did not work correctly or efficiently. In such cases, the researcher shared her own mobile phone's wireless (4G) internet services.

Firstly, tracker cards (which opens three-dimensional models on AR application) for augmented reality activities printed on hard paper, however during the pilot study some of the children could easily fold them. That is why tracker cards were covered by plastic for true experimental study.

3.12 Data Analysis Procedures

The data was collected from preschool children, their family, and teachers and was analyzed in multiple ways. The quantitative data collected from answers given for the demographic information form, the spatial ability tests and geometric shape recognition form were analyzed through statistical techniques. Descriptive statistics were performed on the demographic information (i.e. age, gender, etc…) to present it in means, frequencies and percentiles. Besides, parametric (dependent and independent *t*-test) and the nonparametric statistical test (Mann-Whitney *U* test and Wilcoxon signed-rank test) were used to test the difference between groups and children's scores. The difference in young children's spatial skills and geometry achievement by teaching method was tested by independent *t*-test or Mann-Whitney *U* test, the impacts of virtual and physical manipulatives on spatial skills and geometry achievement over time was tested by dependent *t*-test or Wilcoxon signed-rank test. In order to refine and explain the qualitative findings, qualitative data collection in the form of interviews were utilizes.

In order to investigate the opinions of students, their parents and teachers on the applied instruction, semi-structured interviews were carried out with volunteer students from each group and their teachers and parents. Semi-structured interviews are verbal forms to get answers from respondents to obtain additional specific information (Fraenkel et al., 2011). After completing semi-structured interviews, the researcher transcribed the conversations and analyzed the data through content analysis. During the analysis of interview, besides the researcher, another coder analyzed data to control whether two coders are consistent in evaluating the transcribed data.

3.13 Limitations

There are certain restrictions that every research study may face, and this study also had some limitations. Firstly, sampling was one limitation that should be declared. Convenience non-random sampling method was used to determine the samples of the study. Therefore, the results of this study can not be generalized to a large population but are limited to the current case.

Some of the children's responses during the interview were limited, because of which their replies were brief and incomplete. Moreover, the study was conducted with the preschool children have lasted for four weeks. It would be better if it were done in longer time because four weeks may not be enough to affect preschool children's success.

Furthermore, the translation of the "Picture Rotation Test" into the Turkish was done by the researcher and was not validated by a language expert.

CHAPTER 4

RESULTS

This chapter presents the results of the study which compares the use virtual manipulatives such as AR based applications on a mobile device to real manipulatives in the process of improving the preschool children's spatial skills and geometric recognition level. The treatment involved geometry lesson in which van Hiele's instructional phases were used in activities. To analyze the effects of virtual manipulatives spatial ability tests and geometric shape recognition task were used. Furthermore, children, their parents, and teachers were interviewed using interview protocols to explore the effect of the treatment further. The results of the study are presented with regard to the research questions of the study.

4.1 Descriptive Information about the Data

Before presenting the research questions, first the participants' demographic information is described.

The average age of the preschool children was 5.5 years. The average of control group children was 5.45 and the average of experimental group children 5.65 years. There were 38 girls (52.8%) and 34 boys (47.2%) in the study. In the experimental group, there were 21 girls (58.3%) and 15 boys (41.7%) and in the control group there were 17 girls (47.2%) and 19 boys (52.8%). As the Table 5 indicated, 45.8% of the children continued in pre-kindergarten. 63.9% of the children have sister or brother. 69.4% of the children have their own computer or tablet PC. 87.5% of the children use computers or mobile devices for entertainment. Most of them play digital games, watch a cartoon or listen to music; however, 12.5% of them use devices for educational purpose. Moreover, all the children are familiar with touchable screens.

Table 5: The demographic information of the children participants

		Experimental		Control		Total	
		f	%	*f*	%	*f*	%
Gender	Female	21	58.3	17	47.2	38	52.8
	Male	15	41.7	19	52.8	34	47.2
Attended pre-kindergarten	Yes	18	50	15	41.7	33	45.8
	No	18	50	21	58.3	39	54.2
Having one or more sister(s) or brother(s)	Yes	23	63.9	23	63.9	46	63.9
	No	13	36.1	13	36.1	26	36.1
Computer-Tablet PC ownership	Yes	26	72.2	24	66.7	50	69.4
	No	10	27.8	12	33.3	22	30.6
Purpose of using computers	Entertainment (Game/ Movie/ Music)	33	91.7	30	83.3	63	87.5
	Education	3	8.3	6	16.7	9	12.5
Familiarity with touchable screen	Yes	36	100	36	100	72	100
	No	0	0	0	0	0	0

4.2 The Effect of Manipulatives on Preschool Children's Spatial Ability Test Scores

In order to answer the first research question regarding the effect of virtual manipulatives on preschool children's spatial ability test scores, the data collected from two different tests: Picture Rotation Test and Spatial Perception Scale.

4.2.1 Picture Rotation Test

Picture Rotation Test (PRT) was implemented to both experimental and control groups. The descriptive statistics about the pre-test and post-test scores are given in Table 6.

Table 6: Descriptive statistics of groups for PRT and test of normality

Groups	Tests	*N*	*Mean*	*SD*	*Skewness*	*Kurtosis*	*Shapiro-Wilk*
Experimental	Pre-Test	36	5.44	2.16	1.562	0.183	.148
	Post-Test	36	11. 47	2.60	0.190	-1.351	.156
Control	Pre-Test	36	5.52	1.78	1.391	0.503	.086
	Post-Test	36	7.06	2.48	1.035	-0.367	.348

First, the assumptions of the independent *t*-test which were the level of measurements, random sampling, independence of observation were checked and resulted in satisfaction. According to (Field, 2005) the skewness and the kurtosis values between -1.96 and 1.96 indicated normal distribution so that the PRT score had a normal distribution. To check normality assumption, also Shapiro-Wilk test results were looked into for PRT test. The significant results $W_{(36)\text{Pre-Test}}$=.955 and $W_{(36)\text{Post-Test}}$=.956

for the experimental group and $W_{(36)\text{Pre-Test}}$=.947 and $W_{(36)\text{Post-Test}}$=.967 for the control group indicated normality.

The significance of Shapiro-Wilk tests are greater than 0.05, therefore for both tests the data come from a normally-distributed population (Field, 2005). To determine the homogeneity of variances Levene's test was used. The Levene's test should be non-significant ($p > 0.05$) meet the assumption of equality of variances (Field, 2005). The assumption of equality of variances was assured for both pre-tests and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=1.547, p>0.05, $F_{(1,70)\text{Post-Test}}$=0.638, p>0.05).

Before the comparison of the groups to determine the mean of the differences within groups, paired sample t-test was conducted. The results showed that there was a significant mean difference in spatial ability scores for both groups ($t_{\text{Exp}(35)}$= 12.54, p=0.00; $t_{\text{Ctrl}(35)}$= 3.29, p=0.00).

Table 7: The change in PRT after intervention in both groups

Tests	*Mean*	*SD*	*t*	*df*	*p*
Experimental Group Pre-Test – Post-Test	6. 02	2.88	12.543	35	.000
Control Group Pre-Test – Post-Test	1.58	2.78	3.294	35	.002

Pre-test scores for the PRT are provided in Table 8. The mean score for the experimental group was 5.44 and was 5.50 and for the control group out of 16 points. The results of the independent sample t-test showed that there was no statistically significant difference between the control and experimental group mean scores ($t_{(70)}$= -.179; p>0.05). In other words, there is no significant difference in the mean of PRT score before the intervention.

Table 8: Pre-test results for the PRT

Groups	*Mean*	*SD*	*t*	*df*	*p*
Experimental	5.44	2.86	-.179	70	.859
Control	5.50	1.78			

At the end of the treatment, which based on van Hiele's five phases of learning, the independent *t*-test results showed that virtual manipulatives had statistically significant effect on children's rotation ability scores ($t_{(70)}$= 7.37; p<0.05). The mean score for the experimental group was 11.47 and for the control group was 7.06 out of 16points. To determine the effect size, Cohen's *d*, groups' means difference divided by the *pooled* standard deviation. Cohen's *d* values of .2, .5 and .8 are interpreted as small, medium and large effect size respectively. The effect size (*d*=1.73) represented a large effect, in other words, the experimental group had significantly higher PRT scores than the control group.

Table 9: Post-test results for the PRT

Groups	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental	11.47	2.60	7.367	70	.000	1.73
Control	7.06	2.48				

4.2.2 Spatial Perception Scale

Spatial Perception Scale (SPS) was implemented to both the experimental and control groups. The descriptive statistics about the pre-test and post-test scores were given in Table 10.

Table 10: Descriptive statistics of groups for SPS and test of normality

Groups	Tests	*N*	*Mean*	*SD*	*Skewness*	*Kurtosis*	*Shapiro-Wilk*
Experimental	Pre-Test	36	38.44	4.53	-0.659	-1.25	.084
	Post-Test	36	46.39	2.70	-1.788	0.303	.211
Control	Pre-Test	36	37.22	4.90	-0.361	-1.186	.060
	Post-Test	36	41.47	3.16	-0.867	-1.355	.055

Preliminary analyses were performed to ensure that there was no violation of the assumptions. The level of measurements, random sampling, independence of observation was checked and resulted in satisfaction. The skewness and kurtosis values showed that SPS score had a normal distribution. Moreover, Shapiro-Wilk test results were looked into for SPS test. The significant results $W_{(36)\text{Pre-Test}}$=.947 and $W_{(36)\text{Post-Test}}$=.942 for the experimental group and $W_{(36)\text{Pre-Test}}$=.960 and $W_{(36)\text{Post-Test}}$=.942 for the control group indicated normality (p>0.05). The assumption of equality of variances was assured for both pre-tests and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=.100, p>0.05, $F_{(1,70)\text{Post-Test}}$=2.011, p>0.05).

Before the comparison of the groups, a paired-samples *t*-test was conducted to compare within groups SPS results (see Table 11). The results showed that there was a significant mean difference in spatial ability scores for both groups ($t_{\text{Exp}(35)}$= 10.312, p<0.05; $t_{\text{Ctrl }(35)}$= 4.769, p<0.05).

Table 11: The change in SPS after intervention in both groups

Tests	*Mean*	*SD*	*t*	*df*	*p*
Experimental Group Pre-Test – Post-Test	7.94	4.62	10.312	35	.000
Control Group Pre-Test – Post-Test	4.25	5.34	4.769	35	.000

The independent *t*-test results for the pre-test scores of the SPS (see Table 12) indicated that there was no significant mean difference between the groups at the beginning of the study ($t_{(70)}$=1.099; p>0.05). The mean score for the experimental group was 38.44 and for the control group was 37.36 out of possible 51points.

Table 12: Pre-test results for the SPS

Groups	*Mean*	*SD*	*t*	*df*	*p*
Experimental	38.44	4.53	1.099	70	.276
Control	37.22	4.90			

At the end of the treatment, which based on van Hiele's five phases of learning, the *t*-test results (see Table 13) showed that there was a significant mean difference in young children's spatial ability performance by teaching method (virtual manipulative vs. physical manipulative). The experimental group performed significantly better than the control group ($t_{(70)}$= 7.081; p<0.05; M_{Exp}=46.39and M_{Ctrl}=41.47). The effect size (d=1.67) represented a large effect, in other words, the experimental group had significantly higher SPS scores than the control group.

Table 13: Post-test results for the SPS

Groups	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental	46.39	2.70	7.081	70	.00	1.67
Control	41.47	3.16				

4.3 The Effect of Manipulatives on Preschool Children's Geometric Shape Recognition Task Scores

Geometric Shape Recognition Task (GSRT) was implemented to both experimental and control groups. The descriptive statistics about the pre-test and post-test scores were given in Table 14.

Preliminary analyses were performed to ensure that there was no violation of the assumptions. The level of measurements, random sampling, independence of observation was checked and resulted in satisfaction. However, normality assumption of some of the test was not satisfied completely. Mann-Whitney *U* and Wilcoxon signed-rank test were used as the nonparametric alternative to *t*-test for independent and dependent samples.

The analysis was conducted for GSRT scores and also for each shape (triangle, rectangle, square and circle) separately those were classified under this task.

Table 14: Descriptive statistics of groups for GSRT and test of normality

Groups	Shapes	Tests	*N*	*Mean*	*SD*	*Skewness*	*Kurtosis*	*Shapiro-Wilk*
Experimental	Triangle	Pre-Test	36	7.028	1.57	-0.83	0.68	.029
		Post-Test	36	9.97	1.62	-0.84	-1.39	.005
	Rectangle	Pre-Test	36	9.36	1.66	-2.28	1.29	.009
		Post-Test	36	11.56	.69	-4.67	5.30	.000
	Square	Pre-Test	36	9.19	1.37	-2.38	2.59	.004
		Post-Test	36	11.17	1.18	-3.65	1.64	.000
	Circle	Pre-Test	36	10.50	1.81	-3.53	2.03	.000
		Post-Test	36	11.92	.28	-8.01	10.89	.000
	Total	Pre-Test	36	36.08	3.43	-1.02	0.39	.541
		Post-Test	36	44.61	2.51	-1.70	0.06	.055
Control	Triangle	Pre-Test	36	7.25	1.70	-1.25	1.75	.008
		Post-Test	36	8.75	1.79	-1.86	1.17	.018
	Rectangle	Pre-Test	36	9.83	1.50	-2.37	2.27	.007
		Post-Test	36	10.47	1.56	-3.04	1.18	.000
	Square	Pre-Test	36	9.58	1.70	-0.39	-1.21	.040
		Post-Test	36	10.22	1.97	-2.70	0.60	.000
	Circle	Pre-Test	36	11.14	1.15	-3.46	1.68	.000
		Post-Test	36	11.78	.54	-6.27	6.87	.000
	Total	Pre-Test	36	37.80	3.32	0.03	-0.63	.790
		Post-Test	36	41.22	3.25	-1.66	-0.01	.119

4.3.1 Geometric Shape Recognition Task (GSRT) Scores

The skewness and kurtosis values showed that SPS score had a normal distribution. Moreover, Shapiro-Wilk test results were looked into for SPS test. The significant results $W_{(36)\text{Pre-Test}}$=.974 and $W_{(36)\text{Post-Test}}$=.981for experimental group and $W_{(36)\text{Pre-Test}}$=.941 and $W_{(36)\text{Post-Test}}$=.952 for control group indicated normality (p>0.05). The assumption of equality of variances was assured for both pre-tests and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=.000, p>0.05, $F_{(1,70)\text{Post-Test}}$=1.723, p>0.05).

Before the comparison of the groups, a paired-samples t-test was conducted to compare within groups GSRT results (see Table 15). The results showed that there was a significant mean difference in spatial ability scores for both groups ($t_{\text{Exp}(35)}$= 12.128, p<0.05; $t_{\text{Ctrl }(35)}$= 5.149, p<0.05).

Table 15: The change in GSRT after intervention in both groups

Tests	*Mean*	*SD*	*t*	*df*	*p*
Experimental Group Pre-Test – Post-Test	8.53	4.21	12.128	35	.000
Control Group Pre-Test – Post-Test	3.42	3.98	5.149	35	.000

The independent t-test results for the pre-test scores of the GSRT (see Table 16) indicated that there was a significant mean difference between the groups at the beginning of the study in the favor control group ($t_{(70)}$=-2.164; p<0.05). The mean score for the experimental group was 36.08 and for the control group was 37.80 out of possible 48 points. The effect size (d=.051) represented a medium effect, in other words, the control group had significantly higher GSRT scores than the experimental group.

Table 16: Pre-test results for the GSRT

Groups	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental	36.08	3.43	-2.164	70	.034	0.51
Control	37.80	3.32				

At the end of the treatment, which provided with van Hiele's phases of the learning environment, the *t*-test results (see Table 17) showed that there was a significant mean difference in preschool children's geometric shape recognition level by teaching method (virtual manipulative vs. physical manipulative). The experimental group performed significantly better than the control group ($t_{(70)}$= 4.949; $p<0.05$; M_{Exp}=44.61and M_{Ctrl}=41.22). The effect size (d=1.17) represented a large effect, in other words, the experimental group had significantly higher GSRT scores than the control group.

Table 17: Post-test results for the GSRT

Groups	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental	44.61	2.51	4.949	70	.00	1.17
Control	41.22	3.25				

4.3.1.1 Triangle Recognition Task (TRT) Score

The skewness and kurtosis values showed that TRT score had a normal distribution. However, Shapiro-Wilk test results for both groups did not indicate normality ($p<0.05$). The insignificant results $W_{(36)\text{Pre-Test}}$=.932 and $W_{(36)\text{Post-Test}}$=.906 for the experimental group and $W_{(36)\text{Pre-Test}}$=.914 and $W_{(36)\text{Post-Test}}$=.925 for the control group.

The assumption of equality of variances was assured for both pre-tests and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=.136, p>0.05, $F_{(1,70)\text{Post-Test}}$=.038, p>0.05). Since the scores did not normally distribute non-parametric tests that do not require the assumption of normality were used.

Before the comparison of the groups, the Wilcoxon signed-rank test was conducted to compare within groups TRT results (see Table 18). The test was run and the output indicated that post-test scores were significantly higher than pre-test scores in both groups, z_{Exp}= -4.703, p_{Exp} < .000 and z_{Ctrl}= -3.863, p_{Ctrl}< .000.

Table 18: The change in TRT after intervention in both groups

Tests		*Mean Rank*	*Sum of Ranks*	*z*	*p*
Experimental Group Pre-Test – Post-Test	Negative Ranks	6.17	18.50	-4.703	.000
	Positive Ranks	18.08	542.50		
Control Group Pre-Test – Post-Test	Negative Ranks	13.38	53.50	-3.863	.000
	Positive Ranks	16.39	442.50		

The Mann-Whitney *U* test results indicated that before the treatment triangle recognition levels in the experimental group (*Mdn*=7.00) did not significantly differ from the control group (*Mdn*=7.00), *U*=582.5, *z*=-.765, *p*>0.05. The mean score for the experimental group was 7.02 and for the control group was 7.25 out of possible 12 points (see Table 19).

Table 19: Pre-test results for the TRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*
Experimental	36	34.68	1248.50	582.5	-.765	.445
Control	36	38.32	1379.50			

At the end of the treatment, Mann-Whitney *U* test results (see Table 20) showed that there was a significant mean difference in preschool children's triangle recognition level by teaching method (virtual manipulative vs. physical manipulative) which provided with van Hiele's phases of the learning environment. The experimental group performed significantly better than control group (U= 410.5, z=-2.717, p<0.05; Mdn_{Exp}=10.00 and Mdn_{Ctrl}=9.00). The effect size (r=0.32) represented a medium effect, in other words, the experimental group had significantly higher TRT levels than the control group.

Table 20: Post-test results for the TRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*	*r*
Experimental	36	43.10	1551.50	410.5	-2.717	.007	0.32
Control	36	29.90	1076.50				

4.3.1.2 Rectangle Recognition Task (RRT) Score

The skewness and kurtosis values showed that RRT score had a non-normal distribution. Shapiro-Wilk test results for both groups also did not indicate normality (p<0.05). The insignificant results $W_{(36)\text{Pre-Test}}$=.916 and $W_{(36)\text{Post-Test}}$=.653 for the experimental group and $W_{(36)\text{Pre-Test}}$=.912 and $W_{(36)\text{Post-Test}}$=.842 for the control group.

The assumption of equality of variances was assured for just post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=0.348, p>0.05, $F_{(1,70)\text{Post-Test}}$=15.430, p<0.05). Since the scores did not normally distribute non-parametric tests that do not require the assumption of normality were used.

Before the comparison of the groups, the Wilcoxon signed-rank test was conducted to compare within groups RRT results (see Table 21). The test was run and the output indicated that post-test scores were significantly higher than pre-test scores in both groups, z_{Exp}= -4.791, p_{Exp} < .000 and z_{Ctrl}= -2.410, p_{Ctrl}< .000.

Table 21: The change in RRT after intervention in both groups

Tests		*Mean Rank*	*Sum of Ranks*	*z*	*p*
Experimental Group Pre-Test – Post-Test	Negative Ranks	5.00	5.00	-4.791	.000
	Positive Ranks	16.37	491.00		
Control Group Pre-Test – Post-Test	Negative Ranks	11.06	99.50	-2.410	.016
	Positive Ranks	16.13	306.50		

The Mann-Whitney *U* test results indicated that before the treatment rectangle recognition levels in the experimental group (*Mdn*=10.00) did not significantly differ from the control group (*Mdn*=10.00), *U*=543.00, *z*=-1.210, *p*>0.05. The mean score for the experimental group was 9.36 and for the control group was 9.83 out of possible 12 points.

Table 22: Pre-test results for the RRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*
Experimental	36	33.58	1209.00	543.00	-1.210	.226
Control	36	39.42	1419.00			

At the end of the treatment, Mann-Whitney *U* test results (see Table 23) showed that there was a significant mean difference in preschool children's rectangle recognition level by teaching method (virtual manipulative vs. physical manipulative) which based on van Hiele's five phases of learning. The experimental group performed significantly better than control group (U= 351.50, z=-3.588, p<0.05; Mdn_{Exp}=12.00 and Mdn_{Ctrl}=11.00). The effect size (r=0.42) represented a medium to large effect, in other words, the experimental group had significantly higher RRT levels than the control group.

Table 23: Post-test results for the RRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*	*r*
Experimental	36	44.74	1610.50	351.50	-3.588	.000	0.42
Control	36	28.26	1017.50				

4.3.1.3 Square Recognition Task (SRT) Score

The skewness and kurtosis values showed that SRT score had a non-normal distribution. Shapiro-Wilk test results for both groups also did not indicate normality (p<0.05). The insignificant results $W_{(36)\mathrm{Pre\text{-}Test}}$=.902 and $W_{(36)\mathrm{Post\text{-}Test}}$=.731 for the experimental group and $W_{(36)\mathrm{Pre\text{-}Test}}$=.936 and $W_{(36)\mathrm{Post\text{-}Test}}$=.835 for the control group.

The assumption of equality of variances was not assured for pre and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=4.459, p<0.05, $F_{(1,70)\text{Post-Test}}$=9.150, p<0.05). Since the scores did not normally distribute non-parametric tests that do not require the assumption of normality were used.

Before the comparison of the groups, the Wilcoxon signed-rank test was conducted to compare within groups SRT results (see Table 24). The test was run and the output indicated that post-test scores were significantly higher than pre-test scores in both group, z_{Exp}= -4.869, p_{Exp} < 0.05 and z_{Ctrl}= -1.988, p_{Ctrl}< 0.05.

Table 24: The change in SRT after intervention in both groups

Tests		*Mean Rank*	*Sum of Ranks*	*z*	*p*
Experimental Group Pre-Test – Post-Test	Negative Ranks	10.50	21.00	-4.869	.000
	Positive Ranks	18.45	609.00		
Control Group Pre-Test – Post-Test	Negative Ranks	12.25	98.00	-1.988	.047
	Positive Ranks	14.06	253.00		

The Mann-Whitney *U* test results indicated that before the treatment square recognition levels in the experimental group (*Mdn*=9.00) did not significantly differ from the control group (*Mdn*=10.00), *U*=568.50, *z*=-0.9150, *p*>0.05. The mean score for the experimental group was 9.36 and for the control group was 9.83 out of possible 12 points (see Table 25).

Table 25: Pre-test results for the SRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*
Experimental	36	34.29	1234.50	568.50	-0.915	.360
Control	36	38.71	1393.50			

At the end of the treatment, which based on van Hiele's five phases of learning, Mann-Whitney *U* test results (see Table 26) showed that there was a significant mean difference in preschool children's square recognition level by teaching method (virtual manipulative vs. physical manipulative). The experimental group performed significantly better than the control group (U= 476.00, z=-2.059, p<0.05; Mdn_{Exp}=12.00 and Mdn_{Ctrl}=11.00). The effect size (r=0.24) represented a small effect, in other words, the experimental group had significantly higher SRT levels than the control group.

Table 26: Post-test results for the SRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*	*r*
Experimental	36	41.28	1486.00	476.00	-2.059	.039	0.24
Control	36	31.72	1142.00				

4.3.1.4 Circle Recognition Task (CRT) Score

The skewness and kurtosis values showed that CRT score had a non-normal distribution. Shapiro-Wilk test results for both groups also did not indicate normality (p<0.05). The insignificant results $W_{(36)\text{Pre-Test}}$=.799 and $W_{(36)\text{Post-Test}}$=.312 for the experimental group and $W_{(36)\text{Pre-Test}}$=.753 and $W_{(36)\text{Post-Test}}$=. 466 for the control group.

The assumption of equality of variances was not assured for pre and post-tests with the analysis of Levene's test ($F_{(1,70)\text{Pre-Test}}$=6.400, p<0.05, $F_{(1,70)\text{Post-Test}}$=8.293, p<0.05). Since the scores did not normally distribute non-parametric tests that do not require the assumption of normality were used.

Before the comparison of the groups, the Wilcoxon signed-rank test was conducted to compare within groups CRT results (see Table 27). The test was run and the output indicated that post-test scores were significantly higher than pre-test scores in both groups, z_{Exp}= -3.977, p_{Exp} < 0.05 and z_{Ctrl}= -2.874, p_{Ctrl}< 0.05.

Table 27: The change in CRT after intervention in both groups

Tests		*Mean Rank*	*Sum of Ranks*	*z*	*p*
Experimental Group Pre-Test – Post-Test	Negative Ranks	5.50	5.50	-3.977	.000
	Positive Ranks	11.79	247.50		
Control Group Pre-Test – Post-Test	Negative Ranks	8.50	17.00	-2.874	.004
	Positive Ranks	9.07	136.00		

The Mann-Whitney *U* test results showed that before the treatment circle recognition levels in the experimental group (*Mdn*=11.00) did not significantly differ from the control group (*Mdn*=12.00), *U*=528.50, *z*=-1.430, *p*>0.05. The mean score for the experimental group was 10.50 and for the control group was 11.13 out of possible 12 points.

Table 28: Pre-test results for the CRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*
Experimental	36	33.18	1194.50	528.50	-1.430	.153
Control	36	39.82	1433.50			

At the end of the treatment, Mann-Whitney *U* test results (see Table 29) showed that there was not a significant mean difference in preschool children's circle recognition level by teaching method (U= 591.00, z=-1.119, p>0.05; Mdn_{Exp}=12.00 and Mdn_{Ctrl}=12.00) which based on van Hiele's instructional phases.

Table 29: Post-test results for the CRT

Groups	*N*	*Mean Rank*	*Sum of Ranks*	*U*	*z*	*p*
Experimental	36	38.08	1371.00	591.00	-1.119	0.263
Control	36	34.92	1257.00			

4.4 The Opinions about Manipulatives

To determine the perspectives of respondents' content analysis of semi-structured interview was used. To interpret the findings of semi-structured interviews, a simple category coding procedure was developed. The data gathered from three different groups who participate in the current study; preschool children, their parents, and their teachers.

4.4.1 The Effect of Manipulatives on Preschool Children's Opinions

In order to answer this research question regarding the effect of manipulatives on preschool children's opinions, the data collected by semi-structured interviews. 39

children replied interview questions, 19 from the experimental group, 20 from the control group. On the average, each interview lasted for 5 minutes. The questions also contained data about children's daily lives at home and school.

At first, children asked about their **daily activities at home** (see Table 30). The activities were listed according to their first replies. 35.9% of preschool children are playing with their toys. 28.2% of children are playing games on their tablet PC or computer or parents' smartphones. 20.5% of them are drawing, and the rest of them (15.4%) are watching TV.

Table 30: Children's daily activities at home

Activities	Experimental		Control		Total	
	f	%	*f*	%	*f*	%
Playing with toys	8	42.1	6	30	14	35.9
Computer games	3	15.8	8	40	11	28.2
Drawing	5	26.3	3	15	8	20.5
Watching TV	3	15.8	3	15	6	15.4

Children were also asked about what kind of activities they are doing on computers. 92.3% of children replied that they are playing games and the rest (7.7%) are watching cartoons. Racing games were popular among boys and make up and dress up games were popular among girls.

Children's **favorite activities at school** were also asked (see Table 31). Most of the children (53.8%) stated that their favorite activity at school is playing with toys (car, blocks, balls, etc.) and the rest of them (46.2%) likes school activities such as (painting-drawings, playing with doughs, paper & glue crafts, cutting, etc.).

Table 31: Children's daily activities at school

Activities	Experimental		Control		Total	
	f	%	*f*	%	*f*	%
Playing with toys	11	57.9	10	50	21	53.8
School activities	8	42.1	10	50	18	46.2

All of the children in both groups stated that they enjoyed the activities. Moreover, children in both groups said that **the activities with manipulatives** were generally easy for them.

Children were asked about their favorite part during the activities (see Table 32). Some of experimental groups' responses could be summarized as follows:

> "We can make objects bigger or smaller by touching tablet PC."
>
> "I can move the shapes on the tablet, make them small or big, and rotate them with my fingers."
>
> "It was enjoyable to scan cards with a tablet. I saw building, earth, ball, box, washing machine, etc."
>
> "I liked coloring shapes on a tablet."
>
> "Moving shapes was enjoyable. I made them too small and too big."
>
> "I saw back of refrigerator by touching tablet with my fingers. It was fun."
>
> "The activities were enjoyable but moving a tablet was a little tiring."

Table 32: Children's views about activities

		Experimental		Control		Total	
		f	%	*f*	%	*f*	%
Favorite part	Manipulating objects	13	68.4	0	0	13	33.3
	Scanning cards	3	15.8	0	0	3	7.7
	Wooden blocks/shapes	0	0	16	80	16	41.1
	Coloring	3	15.8	4	20	7	17.9
Hardest part	None	16	84.2	19	95	35	89.7
	Scanning	2	10.5	0	0	2	5.1
	Carrying	1	5.3	0	0	1	2.6
	Coloring	0	0	1	5.3	1	2.6
Studying with manipulatives	Yes	18	94.7	19	95	37	94.9
	No	1	5.3	1	5	2	5.1

Children in control group were also asked about their favorite part during the activities. Some of the responses could be summarized as follows:

> "I liked the shapes, square, rectangle, cube, sphere, ellipse, prisms."

> "Studying with blocks was enjoyable because I like to play with blocks."

"Coloring shapes was fun."

"I like wooden blocks and shapes."

Most of the children replied that they want to make more similar activities.

4.4.2 The Effect of Manipulatives on Parents' Opinions

In order to answer this research question regarding the effect of manipulatives on parents' opinions, the data collected by semi-structured interview questions. The interviews took 2-3 minutes on the average. 35 parents (48%) replied questions, 17 from the experimental group, 18 from the control group. Table 33 gives some descriptive information about parents.

The average age of mothers was 32.9 and fathers was 36.5 years. 57% of the parents (10 from the experimental group, 10 from the control group) let their children play games on their mobile phones.

Table 33: The demographic information about parents

		Mother		Father	
		f	%	*f*	%
Working rate		15	42.8	35	100
Education	Primary school	4	11.4	4	11.4
	Middle school	3	8.6	3	8.6
	High school	13	37.1	17	48.5
	Undergraduate	13	37.1	10	28.6
	Graduate	2	5.8	1	2.9

Parents were asked questions about their children's comments on activities, whether children gave examples from activities and their opinions about the activities they did in the school (see Table 34).

Table 34: The views of parents

		Parents of experimental group		Parents of control group	
		f	%	*f*	%
Children's comments	Positive	12	70.6	15	83.3
	Negative	0	0	0	0
	None	5	29.4	3	16.7
Giving examples	Yes	14	82.4	13	72.2
	No	3	17.6	5	27.8
Views about activities	Positive	14	82.4	11	61.1
	Negative	0	0	0	0
	None	3	17.6	7	38.9

Some of the responses from the experimental group parents could be summarized as follows:

> "My daughter improved her geometric shape knowledge. At home, she was talking about activities and giving examples, such as the earth is a sphere, a table is a rectangle."

“I think these activities are helpful and instructive for my child. He said that he saw some shapes like a cylinder for the first time and tried to draw it. These activities provide more clear learning for children, they can learn without getting bored.”

“I think these activities have contributed to my child's education. He can easily give examples from his room, toys. I think it is useful for him, in the future he can learn other shapes easier.”

“I think these activities were useful for children’s education. Since they learn in an enjoyable way, it may become permanent.”

“I think learning through tablet was effective for my daughter. She could able to name the shapes and draw some of them.”

“My son told me that they were studying while they were playing, it was fun for him. I think it was an interesting and enjoyable way for learning. My son replied all the question related to geometric shapes by himself.”

“I think it is an advantage to learn geometric shapes before primary school. While looking around, my son can observe cause-effect relationship and easily categorize shapes. During activities he had fun, at home he gave examples such as refrigerator as a rectangular prism, box as a cube, jar as a cylinder.”

“My son learned the some of the shapes that he did not know before. At home, he easily named shapes from the items around him. The activities had a positive effect on his learning. He said he had fun during the activities.”

“I think these activities had a positive effect on my daughter; she said that she liked the activities. I guess these activities has improved her visual intelligence.”

> "My son told me that he enjoyed during activities. Since he knows geometric shapes better, he named indoor and outdoor objects. I think the activities were useful, children improved their point of view and reinforced their perception."

> "My son talked about some geometric shapes that he had not known before. He gives examples of a rectangular prism, sphere, cylinder etc. from daily life. I think these activities were helpful for his improvement."

Parents in control group also were asked questions about their children's comments on activities, whether children give examples from activities and their opinions about activities. Some of the responses from parents could be summarized as follows:

> "With these activities, my daughter learned geometric shapes better. She gave examples like a circle, cylinder, rectangle, sphere, ellipse, etc."

> "My daughter liked the activities with wooden blocks. When she came home, she talked about the cylinder and gave examples. She has already known some of the geometrical shapes; however, she started to give examples from objects. You can also use three-dimensional models for teaching."

> "My son enjoyed during activities, he gave examples of geometric shapes especially three-dimensional shapes. I am pleased that my son learned three-dimensional shapes. At the beginning, I was not so sure about letting my son participate the study, but at the end, I am very happy."

> "My daughter said that they were learning shapes with pictures and wooden blocks, and gave examples like a square, triangle, circle, etc. Also, she mentioned about the sticker that you gave her after each lesson. I guess, these activities were effective for children."

> "I think these activities have a positive effect on our children's learning. My son started to ask more questions about geometric shapes especially prisms."

"My son had very good time during activities with you. With the help of you, they learned more geometric shapes. I think this was a very helpful study for them. He gives examples of daily objects.

4.4.3 The Effect of Manipulatives on Teachers' Opinions

In order to answer the research question regarding the effect of manipulatives on teachers' opinions, the data was collected by semi-structured interview questions. Six teachers replied questions. On the average, each interview lasted for 10.5 minutes. The questions also contain data about their experience, opinions about technology usage during lessons, and activities with virtual manipulatives. Table 35 gives some information about teachers.

Table 35: The information about teachers' background and views

Teachers	Experience in teaching	Sample for technology usage	Views about activities
#1	15 years	Internet, interactive stories, chess or tangram games, educational software	Positive impact on learning
#2	25 years	Projection tool for presentations	As an educational game, it is useful/helpful
#3	25 years	Projection tool for presentations and educational software	Useful
#4	25 years	Projection tool for presentations and educational software	Effective and interesting for children
#5	10 years	Projection tool for presentations	Interesting, impressive and enjoyable
#6	11 years	Projection tool for presentations interactive stories	Good and effective

Firstly, teachers were questioned about if they were teaching three-dimensional geometric shapes or not. Some of them answers could be given as follows:

> "I teach main geometric shapes like square, triangle, rectangle, circle."

> "I teach geometrical shapes but not three-dimensional shapes just two dimensional. We relate them to daily objects without giving details."

> "According to the curriculum, I teach, triangle, square, rectangle, ellipse. They able to recognize these shapes."

> "I teach triangle, square, rectangle and circle. Ellipse has just been added to the curriculum. I think the curriculum is simple for children; it can be improved."

> "Besides two-dimensional geometric shapes, I teach cube and cylinder without giving detail. Ellipse also was newly added to the curriculum. Some of the children can understand three-dimensional shapes, some of them cannot."

> "Just two-dimensional shapes, an ellipse was newly added to the curriculum. I do not teach three-dimensional geometric shapes."

Teachers were also asked about if they were faced any problems related to mathematics or geometry while teaching. They were also asked about children's misconceptions about geometric shapes. Some of their answers were given as follows:

> "In general I do not face a problem during my lessons. They love addition and subtraction. The reason behind the misconception could be us. While I am teaching, we relate objects they are similar. For example, we say it looks like triangle or square, but in fact, they are not regular geometric shapes."

> "Children can have difficulty while they are learning geometric shapes. During the lessons, we show them standard shapes as 'equilateral triangles' or 'isosceles triangles'. That why they might have misconceptions about

geometric shapes, I can show more different geometric shapes as 'scalene triangle' or 'right triangle'."

"For children in this age group, it is important to study with concrete examples. They cannot easily imagine when we just say cylinder, we need to show samples. Especially while teaching three-dimensional geometric shapes you need to exemplify."

Technology usage in the classroom was asked teachers and their replies could be given as follows:

"I often use technology in the classroom. I use the Internet for images. I also use Tangram and chess programs, interactive stories. Children like these stories very much."

"I use presentations for reinforcing the subjects. Apart from that, I do not use any other technological tool."

"I use computers during my lessons. Since the Internet connection speed is so slow I usually just use projection tool."

I use projection tool, computer, and the Internet. With the help of them, the lesson becomes more efficient. I use educational sets but do not use educational software. We need to improve ourselves for using programs and software.

"Generally, I use projection tool. Children are using technology in their daily lives so using technological tools is a motivational tool for them. Technology increases children's motivation for school."

"I try to use technology as much as I can, but the Internet connection is so slow in the school. With the help of the Internet, lessons become easier and more enjoyable. Interactive stories are very effective in learning."

Lastly, teachers' opinions about activities with virtual manipulatives were asked. All the teachers were positive about activities. Their answers could be summarized as follows:

> "The activities had a positive impact on children's visual learning. They liked the activities. I think these activities promoted retention of learning. The group of children who attended to study show better performance than their peers at learning geometric shapes."

> "I think these activities were useful for children. They were very eager to participate in the study. They perceived the study as a game; we can say educational game. Children were talking about activities and properties of geometric shapes among themselves. As an educational game, I think the activities were very helpful."

> "I think this study was very useful for children, they not only had fun but also learned."

> "I think this study took the interests of children. The children who attended the study learned three-dimensional shapes and shared their knowledge with classmates; it was very nice. Your study was more advanced than our methods and lessons. I think these activities were very effective and interesting for children."

> "During these activities, I comprehended how effective technology is. While I was teaching geometric shapes, the children who studied with you were able to give more examples than me. Moreover, parents gave me positive feedback about the study. According to my opinion, this study was very interesting, impressive and enjoyable for children. Since children can visualize geometric shapes, they can give more examples."

> "The study was very effective on children. They enjoyed very much. For the first time, I have seen something like that, this is useful for children. Children

face with an environment that we cannot easily construct in the classroom. It was very effective when a child was able to draw a conclusion by himself. It was very good activity and idea for children."

4.5 Summary

In this chapter, the findings of the study which compares the use virtual manipulatives such as tablet computer with AR application to physical manipulatives in the process of improving preschool children's spatial skills and geometric shape recognition level. The treatment process involved geometry lessons in which van Hiele's instructional learning model was used in the activities. To analyze the effects of both virtual and physical manipulatives on children's improvement the "Picture Rotation Tests" and "Spatial Perception Scale" as spatial ability tests and "Geometric Shape Recognition Task" were used. Moreover, the volunteered participants among the preschool children, parents and teachers were interviewed to explore the effect of the treatment further.

Firstly, the quantitative data analyzed. Participants' descriptive information was given. The paired sample *t*-test and Wilcoxon signed-rank test were conducted to compare pre-test and post-test of groups to determine the mean difference within groups. At both groups, the post-test scores statistically significant than the pre-test scores for each spatial skill tests and geometric recognition level task. In other words, the preschool children's test scores in both the experimental and the control group were increased.

Moreover, to compare groups' mean difference after treatment, independent *t*-test and Mann Whitney *U* test were used. The instruments and the test results were shown in Table 36 in detail.

Table 36: The summary of post-test results

Instruments		Tests	Post-Test Results
Picture Rotation Test		Independent *t*-test	The experimental group significantly performed better ($t(70)= 7.37$; $p<0.05$; $d=1.73$)
Spatial Perception Scale		Independent *t*-test	The experimental group significantly performed better ($t(70)= 7.08$; $p<0.05$; $d=1.67$)
Geometric Shape Recognition Task		Independent *t*- test	The experimental group significantly performed better ($t(70)= 4.95$; $p<0.05$; $d=1.17$)
Geometric Shape Recognition Task Sub Categories	Triangle Shape Recognition	Mann-Whitney *U* test	The experimental group significantly performed better ($U(70)= 410.5$; $p<0.05$; $r=0.32$)
	Rectangle Shape Recognition	Mann-Whitney *U* test	The experimental group significantly performed better ($U(70)= 351.5$; $p<0.05$; $r=0.42$)
	Square Shape Recognition	Mann-Whitney *U* test	The experimental group significantly performed better ($U(70)= 476$; $p<0.05$ $r=0.24$)
	Circle Shape Recognition	Mann-Whitney *U* test	There was not a significant difference between groups ($U(70)= 591$ $p>0.05$)

Lastly, in order to determine the opinions of participants, the content analysis of semi-structured interviews was used. Among all the participants, the volunteered ones were completed interviews. With the help of simple category coding procedure, the transcribed views of children, parents, and teachers were grouped under three different title and detailed descriptions were provided to represent preschool children's, parents' and teachers' views about the activities. According to the opinions of participants most of them had a positive thought about manipulatives and activities.

CHAPTER 5

DISCUSSION and CONCLUSION

The purpose of this study was to compare the use of virtual manipulatives such as AR based applications on a mobile device with the use of real manipulatives to aid in the process of improving preschool children's spatial skills. The spatial skills of children were measured by "Picture Rotation Test" and "Spatial Perception Scale"; and geometry skills of children were determined by "Geometric Shape Recognition Task". This chapter includes the discussion of the results, implications derived from the present study, recommendations for practice and further studies. The results are going to be discussed by taking into account of each group of the research questions.

5.1 The Effects on Spatial Abilities

Spatial ability has been studied by several researchers to determine how to improve it. In the present study, the effect of manipulatives on children's spatial abilities was investigated. The interventions with manipulatives based on van Hiele's five phases of learning.

Paired sample *t*-test and independent *t*-test were used to test the effect of manipulatives on children's spatial ability scores. Paired-sample *t*-test results for both PRT and SPS indicated that there was a significant mean difference in spatial ability scores for both groups. In other words, using manipulatives in both groups had an influence on children's spatial ability performance.

Moreover, not only using manipulatives but how they are used with preschoolers might also have affected the results of the study. Studying with small groups might also be effective. Children completed most of the activities individually, in this way they had an opportunity to explore materials by themselves freely.

In both groups, the learning materials were presented with respect to the van Hiele's five phases of instruction. This instruction involved inquiry, objected orientation, explication, free orientation and integration phases. Children experienced manipulatives according to the van Hiele's phases of learning, they explored and learned geometric shapes through observation. With the help of physical and virtual manipulatives, children experienced orientation and visualization of objects from different perspectives that might affect the improvement of their spatial skills. Especially with virtual manipulatives children had a chance to observe various kinds of objects (buildings, oven, refrigerator, wheel, etc.) without leaving a classroom.

At early ages using manipulatives could be very effective in the teaching process. Preschool children might have difficulty in visualizing objects in their minds, therefore, using manipulatives (both physical and virtual) makes easy for children to comprehend subjects. According to the stages of Piaget (1952, 2003), preschool children can see the world from only their perspective and comprehension of abstract concepts is hard for them. Also, van Hiele (1999) stated that children who have lower visual geometric thinking level, have also difficulty in abstraction. In the light of these thoughts, using manipulatives might influence children's spatial skills since they might visualize concepts easily by the help of manipulatives.

Clements and Battista (1992) stated that learning geometry at school plays a major role in developing spatial skills. In both groups, after training, there was a significant difference between pre-test and post-test scores. As it was stated earlier, spatial skills of children could be improved by practice and training. Therefore, in both groups, there was a development in children's spatial ability and this result supported previous studies (Y.-L. Cheng & Mix, 2014; Newman et al., 2016; Sorby, 1999; Tzuriel & Egozi, 2010) which stressed the impact of training on improvement of spatial skills.

Although children in both groups performed better at post-tests, according to the independent *t*-test results, there was a statistically significant difference in favor of experimental groups' spatial ability scores for two tests (PRT and SPS). The studies (Hartman & Bertoline, 2005; Kaufmann & Schmalstieg, 2003; Martín-Gutierrez, Trujillo, & Acosta-Gonzalez, 2013) showed that AR applications have a positive effect on children's improvement in spatial ability. The findings of this present study support the results of the previous studies.

Manipulatives and especially virtual ones (AR application) have been proven as a useful tool in learning geometry and these tools might help to improve spatial skills when integrated with van Hiele's instructional phases. Especially children in the experimental group showed great improvement in their spatial skills.

AR application and tablet computers presented different and enjoyable learning experience for preschool children since it helped to visualize more complex samples that children would not easily encounter in the classroom environment. AR application has a potential to represents lots of different three-dimensional models. In this way, preschool children observe various examples and could enhance their understanding.

Consequently, teachers and educators might use manipulatives (especially virtual manipulatives) in instructions regularly. In this way, children could have a chance to construct useful meaning for abstract mathematical concepts and to improve their spatial skills.

5.2 The Effects on Geometric Shape Recognition

Paired sample *t*-test and independent *t*-test were used to test the effect of manipulatives on children's geometric shape recognition scores. The paired *t*-test results indicated that there was a significant mean difference in test scores for both groups. After four weeks, treatments with manipulatives which based on van Hiele's instructional phases affected both groups' GSRT scores. After treatment, the improvement in children's scores on the geometric shape recognition assessment might show that working with manipulatives supported children's growth in this area.

According to the independent *t*-test results, there was a significant mean difference in preschool children's geometric shape recognition level by teaching method (virtual manipulative vs. physical manipulative) which based on van Hiele's five phases of learning. The GSRT scores of the experimental group were higher than the control group.

Nonparametric tests were conducted to analyze the GSRT scores for each shape (triangle, rectangle, square and circle). According to the Wilcoxon signed-rank test results for each geometrical shape; triangle, rectangle, square, and circle children had performed better after four weeks, treatments with manipulatives.

After treatment, the Mann-Whitney *U* test results showed that there was a statistically significant difference between groups' triangle, rectangle, and square recognition performance. However, there was not a significant mean difference in children's circle recognition scores.

Children first learn simple shapes like a circle. While young children are growing, they might comprehend that objects like a ball or an orange are round and continue to gain experience with the properties of that shape. The circle has no corner or edge; therefore, these properties might be helpful for children to distinguish between circle and polygons. For all children classifying the circle shape was the easiest part. The mean scores were very close in both groups. Although children in the experimental group had slightly better than the control group, children in both groups categorized circles with a high degree of accuracy. This result showed parallelism with the previous studies results (Aslan & Arnas, 2007; Clements, 2004; Clements et al., 1999) which were stated that categorization of circle was the simplest part in geometric shapes recognition.

In the current study, it was seen that children confused squares with rectangles before the treatment. As the position and size changed, children had difficulty in finding squares. After treatment, preschoolers in the experimental group became more successful in classifying squares. On the contrary to the literature (Aslan & Arnas, 2007; Clements, 2004), children in both groups performed better in classifying rectangles than classifying squares. Compared with children's categorization of squares, their accuracy in categorization rectangles was slightly less. Children in the control group were less accurate in grouping rectangles and squares than the experimental group.

In both groups, children scored the lowest in classifying the triangle shape. The results of the present study were consistent with the findings of previous studies (Aslan & Arnas, 2007; Clements, 2004). According to the mean scores of the preschoolers, the experimental group performed better than the control group. Effect size (r=0.32) showed the relative impact of the variable, which was considered as moderate. In general, as the side lengths, angles, and positions of the triangles change, it has been observed that children have difficulty distinguishing these triangles. Also, some of them named figures as a triangle which had no corner or straight edge. Before the treatment children had a specific thought about the triangle and the post-test results showed that the children in the experimental group were more successful in recognizing and naming triangles although their positions, angles, and skewness were changed.

The children were taught according to van Hiele's instructional phases which are the inquiry, objected orientation, explication, free orientation and integration phases. With the help of manipulatives, children explored and discovered various two-dimensional and three-dimensional geometric shapes by observing and learning the properties of these objects. Studying with manipulatives especially virtual ones, gave children a chance to look objects from different perspectives. The children manipulated two-dimensional and three-dimensional objects, in this way they could comprehend the properties of geometric objects more clearly and enhance their geometric recognition levels.

Moyer-Packenham et al., (2005) and Steen et al. (2006), found that children who were used virtual manipulatives performed better than children who used physical manipulatives in the learning process. Similarly, the findings of the present study indicated that children who were taught by virtual manipulatives performed better in learning geometry objects.

The test results revealed that when the visual attributes like size, orientation, ratio or skewness of geometric shapes are changed some of the preschool children had difficulty in identifying the shapes. This results supported the previous study (Aslan & Arnas, 2007). Some of the children categorized triangle, rectangle or square as, non-triangle, non-rectangle or non-square since the objects were attributes were changed. For some of the children, it was hard to identify geometric shapes which were upside-down or rotated. The shapes were not categorized by children who had difficulty in rotating these geometric shapes. To improve children's geometric shape recognition level and avoid misconnections, teachers and educators need to present different forms of geometric shapes to preschoolers. Teachers and educators also should present the variety of samples of geometric shapes by explaining the properties of these shapes. Consequently, to help children to improve comprehensive knowledge about geometric shapes, the number of examples given by teachers should be increased and the samples also should be chosen from the daily life of children.

5.3 The Effects on Opinions

Some of the studies required additional information to flesh out the findings, for this reason, the explanatory mixed method design conducted. To refine the quantitative results the qualitative method was used (Fraenkel et al., 2011). The present study examined children's, parents' and teachers' opinions to elaborate the quantitative results.

In order to learn participants' opinions about the study, the data collected by semi-structured interviews. The gathered data analyzed according to the simple category coding procedure.

At first, children were interviewed about the activities. The gathered data from 39 children yielded three categories related to the research questions. The categories included children’s views: 1) children’s daily life activities at home, 2) children’s daily life activities at school and 3) their views about manipulative activities.

When children’s daily life activities at home are examined, it is understood that majority of children in experimental group spent their time by playing with toys. On the other hand, playing computer game was the popular daily life activity at home. However, in both groups watching TV was the choice of the minority. When children’s daily life activities at school are examined, similarly playing with toys was again the choice of children.

When children’s opinions regarding manipulatives are examined, it is understood that all of the preschool children expressed positive opinions. Children’s favorite parts about the study were manipulating objects, scanning cards, and coloring for the experimental group and wooden blocks /shapes and coloring for the control group. Children in both groups had fun during the activities since they attended eagerly to the study, they might have positive opinions about the study, and this might also affect their scores. These results also supported the previous studies (Dunleavy et al., 2009; Freitas & Campos, 2008; Steen et al., 2006; Wasko, 2013) which also stated that users had positive opinions about virtual manipulatives. These findings also supported the quantitative results of the study. The test scores of the children showed that there was a significant difference after the treatment in both groups. All the children showed improvement in both spatial skills and geometric shape recognition level. As preschool children in both groups mentioned that they enjoyed the activities and had positive opinions about manipulatives, this might have an effect on their learning process.

As children stated before, most of the preschoolers like to play with toys. While they are studying with manipulatives, they said that they had fun and they taught that they were playing games. These manipulative activities might be an engaging way to help children widen their point of views and master their mathematics and geometry skills. Therefore, it might be said that the gaming effect of an AR application as a virtual manipulative might also affect preschool children’s achievement in spatial skills and geometric shape recognition.

After children, parents were interviewed about the activities. The gathered data from 35 parents yielded two categories related to the research questions. The categories included parents' views: 1) their children's comments and given examples of activities and 2) their views about manipulative activities.

When parents' opinions about the activities are examined, it was seen that most of them had positive opinions with respect to these activities. The majority of parents stated that their children liked the activities that is why they were glad that their children attended this study. They also noticed that their children were able to give more and different examples after activities. They stated that their children gave examples of three-dimensional shapes from daily life. Manipulatives helped children for understanding ideas that are abstract. Since the manipulatives represent explicitly and concretely abstract concepts, children were able to comprehend various samples easily and also give their examples from daily life.

Lastly, teachers' ideas about activities especially virtual manipulatives were asked. The data gathered from six preschool teachers and their answers categorized into two subgroups; 1) Their technology experience and 2) their views about virtual manipulative activities.

When teachers' opinions about the study were examined, they all had positive thoughts. This result is in the same line with previous studies (Cascales et al., 2013; Dunleavy et al., 2009; Wasko, 2013) which were stated that teachers had a positive attitude towards AR enhanced learning environments. The teachers said that with this study they had a chance to meet and learn about that kind technologies such as AR applications. Although they were using computers and the Internet in their classrooms, they did not know about AR application. They found these activities fascinating and entertaining for children. Some of them stated that it was very excellent opportunity for children to learn three-dimensional geometric objects with these applications.

As it was mentioned before, the teachers were stranger to AR technology; this situation is also valid for the children. Since AR is a new technology, its motivational effects or novelty effect could cause enhance children's skills.

During the teaching process, teachers generally presented prototype sample forms of geometric shapes and sometimes pay no attention to the other forms (have a different position, size, angles, etc.) of two and three-dimensional geometric shapes. Therefore, children could learn just common samples of geometric figures (Aslan, 2004). The teacher who participated the current study criticized themselves about giving children just prototype samples which might lead children to have misconceptions about geometric shapes.

5.4 Implication for Practice

In early childhood education, subjects of geometry and mathematics are still a lack of attention in Turkey. The topics that are provided preschool children are limited. It can be declared that traditionally the preschool geometry instruction has focused on recognizing geometric shapes such as triangles, squares, rectangles, and circle. As mentioned in the literature, learning mathematics and geometry in the early stages of childhood has an impact on children's future success (Clements & Sarama, 2007; Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001). Moreover, it is recommended that teachers and educators should prepare activities and exercises to promote children's spatial skills and geometry skills. In other words, children should be exposed to a wider range of geometric exercises and activities.

Preschool teachers should develop their creativity and practices to optimize opportunities for children to improve their skills. Teachers should be aware of new theologies and tools and also teaching strategies. As the early childhood is very significant for later learning, the opportunities for the improvement of spatial skills and geometric concepts should be presented in the setting of preschool education. The current curriculum in Turkey appears to present rare opportunities for children's progress in geometry. Therefore, rich learning experiences that increase children's geometry skills should be provided in classrooms through various hands-on materials and exploration such as gaining experience with manipulatives, or daily life objects just as in this study.

During the teaching process, children should not only be given typical samples of geometric shapes, but also different forms of examples which are in different sizes, positions. In this way, children might differentiate geometric shapes more easily and correctly. Teachers and educators should consider enriching their samples.

Observations made during the study showed that children could more easily grasp the samples given through manipulatives and remember them easily afterward. It could be a major step for them to know and provide examples of these abstract concepts at an early age to develop the geometry skills necessary for the next school years. Therefore, teachers and educators should provide rich learning environments for enhancing children's spatial skills, and geometric shape recognition level.

AR system gives educators or teachers lots of opportunities for enriching the instructional environments. There are also many facilities in designing and developing AR based games and guiding learners in creating games. These kinds of game based systems can be challenging for learners and might provide a dynamic learning platforms.

Although using manipulatives in the classroom has lots of advantages it might have some difficulties for teachers and educators. Manipulatives are easily adapted to any lesson and learning environment. Most of the virtual manipulatives are free, and they are helpful for developing skills of children and also present various ways of diverse learning environments for children. However, there are also a few drawbacks of using manipulatives. Teachers should be careful about overuse of manipulatives; sometimes children may disregard the concepts or ideas behind these materials by studying with them too much. At that point, teachers and educators should take into account this problem while they are planning lessons and designing learning environments for their students. Manipulatives should also be used as a part of the lesson, not for the entire lesson. Furthermore, before presenting children with manipulatives, teachers and educators should be familiar with them especially virtual manipulatives.

Educators also should keep in mind that teaching with manipulatives requires advanced planning and materials and setup. Especially for virtual manipulatives technological problems such as interrupted or poor Internet connection or low battery power or slow loading of documents should be considered.

5.5 Suggestions for the Future Research

The present study aimed to improve preschool children's spatial skills and geometry levels with the help of augmented reality as a virtual manipulative. For the further studies, the researchers should take into consideration that AR as a virtual manipulative could also be used in different subjects and fields. For disciplines which require visualization AR might be very useful for modeling, such as in chemistry, architect, geography, etc.

At that age group, children are very willing to learn. With the help of virtual manipulatives, children might learn without getting bored. A further study can be conducted to determine the effects of AR as virtual manipulative emphasizing different age levels.

During the study, AR as a virtual manipulative took the attention of all preschool children. Therefore, to increase motivation and interest of children, virtual manipulative that is embedded in gaming environment could be used in the teaching or learning process. This learning environment might also be an enjoyable and efficient way in the teaching or learning process. The further studies could examine the gaming effects of virtual manipulatives on children's success, motivation, and attitude.

Overall, this present study makes a contribution to see how children's spatial skills and geometric shape recognition levels change with respect to manipulatives. The results of the study suggest that such teaching and learning process should be enriched by offering more attractive and innovative opportunities for children to make new spatial skill experiences in the classroom. The study not only determines the improvement of children but also present deeper insights about preschoolers', their parents' and their teachers' perspectives. Therefore, for the future studies, it is important to take families and educators opinions about activities.

Since the AR technology is fascinating, enjoyable and different for children, its long-term effects on achievement should also be studied by the researchers. The motivational and novelty effect of virtual manipulatives such as AR application could be searched.

Moreover, the treatment duration of this present study was four weeks. For the future studies, it was suggested to determine manipulatives especially virtual ones' long term effects on children's academic success; therefore, the researchers should conduct retention test.

The findings of the current study support not only the idea of using manipulatives especially virtual ones during preschool education but it also the idea that preschoolers could able to learn three-dimensional geometric shapes. In the light of the results, children have the capacity to learn more, but this process should be supported with manipulatives especially virtual ones. Further studies would be conducted to examine preschool children's capacities in different fields.

During the study with manipulatives which based on van Hiele's five phases of learning, children improved their spatial skills instead of learning the concept of the geometric shape itself. The inquiry and guided orientation phases led preschool children to learn and explore new geometric shapes with the help of manipulatives. Manipulating concrete objects and also virtual object help children to figure out the properties of geometric shapes. In other words, these activities also could allow the preschool children to improve knowledge and features of two and three-dimensional geometric shapes and their spatial skills. During the third phase which is the explication phase, children learned to use accurate terminology to name different types of geometric shapes with the guide of the researcher. In the free orientation phase, preschoolers had an opportunity to study on different tasks. Through the handouts, they explored and identified various two and three-dimensional geometric shapes which were hidden. In the final phase, that is the integration phase children were asked to summarize and review what they have learned throughout the study. For the future studies using van Hiele's instructional model could guide researchers to design effective and efficient learning environments.

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Appendix A

The Parent Permission Form

Sayın Veli,

"Orta Doğu Teknik Üniversitesi, Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümünde, Doç. Dr. Ömer Delialioğlu danışmanlığında doktora öğrencisiyim. Doktora tez çalışması kapsamında, gerçek ve sanal manipülatiflerin; 5-6 yaş-grubu çocuklarının geometrik şekilleri anlamalarının ve uzamsal becerilerinin gelişmesi üzerindeki etkileri incelenecektir.

Katılmasına izin verdiğiniz takdirde çocuğunuz ders saatleri içinde haftada 30-45 dakika toplamda 5-8 hafta sürecek etkinliklerimize katılacak, süreç öncesi ve sonrası vereceğimiz ölçekleri cevaplamaları istenecektir. Veli anketleri ise çocuğunuz aracılığıyla ulaştırılacaktır. Size zarf içinde gönderilecek anketleri sizin veya eşinizin doldurması gerekmektedir. Çocuğunuzun cevaplayacağı soruların onun psikolojik gelişimine olumsuz etkisi olmayacağından emin olabilirsiniz. Çalışma süresince çocukların görüntülü kaydı yapılmayacaktır. Çalışma sonunda çocukların etkinlikler ile ilgili görüşleri alınırken sadece ses kaydı yapılacaktır. Sizin ve çocuğunuzun dolduracağı anket ve ölçeklerdeki cevaplarınız kesinlikle gizli tutulacak ve bu cevaplar sadece bilimsel araştırma amacıyla kullanılacaktır. Çalışma sürecince elde edilen veriler güvenli bir ortamda tutulacaktır ve sadece araştırmacıların erişimine açık olacaktır. Bu formu imzaladıktan sonra hem siz hem de çocuğunuz katılımcılıktan ayrılma hakkına sahipsiniz. Araştırma sonuçlarının özeti tarafımızdan okula ulaştırılacaktır.

Anketleri doldurarak bize sağlayacağınız bilgiler çocukların sahip olduğu beceriler ve teknoloji kullanımı hakkında veri toplamamıza katkıda bulunacaktır. Araştırmayla ilgili sorularınızı aşağıdaki e-posta adresini veya telefon numarasını kullanarak bize yöneltebilirsiniz.

Saygılarımızla,

Araştırmacı:
Zeynep Gecü
Yıldız Teknik Üniversitesi, İstanbul
Tel:0212 3834819
zeynep.gecu@metu.edu.tr

Danışman:
Doç Dr. Ömer Delialioğlu,
Orta Doğu Teknik Üniversitesi, Ankara
Tel: 0 312 210 4198
omerd@metu.edu.tr

Yukarıda açıklamasını okuduğum çalışmaya tamamen gönüllü olarak katılıyorum ve çocuğum ....'nın da katılımcı olmasına izin veriyorum. Çalışmayı istediğim zaman yarıda kesip bırakabileceğimi biliyorum ve verdiğim bilgilerin bilimsel amaçlı olarak kullanılmasını kabul ediyorum.

Adı, soyadı: ______________________

Veli Adı, soyadı: __________________ İmzası: _______________________ Tarih: _______________

Çocuğunuzun katılımı ya da haklarının korunmasına yönelik sorularınız varsa ya da çocuğunuz herhangi bir şekilde risk altında olabileceğine, strese maruz kalacağına inanıyorsanız Orta Doğu Teknik Üniversitesi Etik Kuruluna (312) 210-7348 telefon numarasından ulaşabilirsiniz.

Appendix B

Demographic Information Form

Sayın veli aşağıda sizinle ve çocuğunuzla ilgili bilgiler içeren sorular bulunmaktadır. Vereceğiniz cevaplar bilimsel bir araştırmada veri olarak kullanılacak olup başka hiçbir yerde kullanılmayacaktır. Lütfen boş bırakmayınız. Katkılarınız için teşekkürler.

Araştırmacı Zeynep Gecü

1. Çocuğunuzun cinsiyeti: ( ) Kız ( ) Erkek
2. Çocuğunuzun doğum tarihi : gün …………… ay……………… yıl……………
3. Daha önce herhangi bir okulöncesi eğitim kurumuna (kreş, yuva, anaokulu)
   ( ) Gitti ( ) Gitmedi
4. Kardeş Sayısı:……….
5. Çocuğunuzun kendine ait bilgisayarı ya da tablet bilgisayarı var mı?
   ( ) Evet ( ) Hayır
   Evet ise hangisi……………………..…………………………………….…………
6. Çocuğunuz bilgisayarı ne amaçla kullanıyor? (Oyun oynamak, film izlemek, vb.)
   …………………………………………………………………
7. Çocuğunuz tablet bilgisayar ya da akıllı telefon gibi dokunmatik ekranlı cihazları kullanabiliyor mu?
   ( ) Evet ( ) Hayır
   Kullanıyorsa ne kadar zamandır?...
   Haftada ne kadar süreyle kullanıyor?...
8. Anne eğitim durumu
   ( ) Okur-yazar ( ) İlköğretim
   ( ) Ortaokul ( ) Lise
   ( ) Ön lisans ve Lisans ( ) Lisansüstü (yüksek lisans ve üstü)
9. Baba eğitim durumu
   ( ) Okur-yazar ( ) İlköğretim
   ( ) Ortaokul ( ) Lise
   ( ) Ön lisans ve Lisans ( ) Lisansüstü (yüksek lisans ve üstü)
10. Anne çalışıyor mu?
    ( ) Hayır ( ) Evet ise mesleği ……………..
11. Baba çalışıyor mu?
    ( ) Hayır ( ) Evet ise mesleği ……………..
12. Annenin yaşı:……..……
13. Babanın yaşı:………….
14. Çocuğunuzun sizin telefonunuzu oyun amaçlı kullanmasına izin veriyor musunuz?
    ( ) Evet ( ) Hayır
15. Çocuğunuz bilgisayar ya da akıllı telefonla vakit geçirirken siz de onun yanında oluyor musunuz? ( ) Evet ( ) Hayır

Appendix C

Interview Questions for Children

Merhaba …………………, Nasılsın?

Bugün seninle biraz sohbet etmek istiyorum. Biraz konuşabilir miyiz?

- Evde nasıl vakit geçiriyorsun? Neler yapıyorsun?
- Oyun oynar mısın? Ne tür oyunlar?
- Bilgisayarın var mı?
- Bilgisayarda neler yapıyorsun?
- Annenin ya da babanın telefonuyla oynuyor musun?
- Nasıl oyunlar oynamayı seviyorsun?
- Okuldayken neler yapmaktan hoşlanıyorsun?
- En sevdiğin aktivite hangisidir?
- Sevmediğin aktivite hangisidir?
- Birlikte yaptığımız etkinlikleri (gerçek ya da sanal manipülatifler ile yapılan etkinlikler) sevdin mi?
- En çok hangisini sevdin?
- Seni zorlayan etkinlikler (gerçek ya da sanal manipülatifler ile yapılan etkinlikler) oldu mu?
- En çok hangisi seni zorladı?
- Bu tür etkinlikleri (gerçek ya da sanal manipülatifler ile yapılan etkinlikler) sürekli yapmak ister misin?

Sorunlarımı cevapladığın için teşekkürler, şimdi öğretmeninin yanına gidebilirsin.

Appendix D

Interview Questions for Teachers

Merhaba …………………,

- Kaç senedir öğretmenlik yapıyorsunuz?
- Matematik ve geometri eğitiminde karşılaştığınız problemler var mı? Varsa örnek verebilir misiniz?
- Bu problemleri veya zorlukları gidermek için neler yapıyorsunuz? Örnek verebilir misiniz?
- Derslerde teknoloji kullanımı hakkında ne düşünüyorsunuz?
- Derslerde kullandığınız belirli yazılımlar, cihazlar ya da programlar var mı? Varsa hangileridir?
- Okulda internet erişimi var mı?
- Sizce çocuklar yaptığımız etkinlikler hakkında ne düşünüyorlar?
- Sizin etkinlikler hakkındaki düşünceleriniz nelerdir?
- Bu etkinliklerle ilgili sizin tavsiyeleriniz nelerdir?

Vakit ayırıp, sorularımı cevapladığınız için teşekkürler.

Appendix E

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: 28620816/346-752

26.08.2014

Gönderilen : Doç Dr. Ömer Delialioğlu
Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü

Gönderen : Prof. Dr. Canan Özgen
IAK Başkanı

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü öğrencisi Zeynep Gecü'nun "Okul Öncesi Çocuklar İçin Artırılmış Gerçeklik Etkinlikleri: Geometrik Şekilleri Anlamanın ve Uzamsal Becerileri Geliştirmenin Karşılaştırmalı Analizi" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

26/08/2014

Prof.Dr. Canan Özgen
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

Appendix F

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : 59090411/44/5286646 13/11/2014
Konu: Araştırma (Zeynep GECÜ)

ORTADOĞU TEKNİK ÜNİVERSİTESİ
(Eğitim Bilimleri Enstitüsüne)

İlgi: a) 23.10.2014 tarih ve 5496 sayılı yazınız.
b)Valilik Makamının 12.11.2014 tarih ve 5255989 sayılı oluru.

Üniversiteniz Eğitim Bilimleri Enstitüsü doktora programı öğrencisi Zeynep GECÜ'nün ***"Okul Öncesi Çocuklar İçin Artırılmış Gerçeklik Etkinlikleri: Geometrik Şekilleri Anlamanın ve Uzamsal Becerileri Geliştirmenin Karşılaştırılmalı Analizi"*** konulu tezine dair araştırma çalışması hakkındaki ilgi (a) yazınız ilgi (b) valilik onayı ile uygun görülmüştür.

Bilgilerinizi ve ilgi (b) Valilik Onayı doğrultusunda gerekli duyurunun araştırmacı tarafından yapılmasını, işlem bittikten sonra 2 (iki) hafta içinde sonuçtan Müdürlüğümüz Strateji Geliştirme Bölümüne rapor halinde bilgi verilmesini arz ederim.

Murat ADALI
Müdür a.
Şube Müdürü

EK:1- Valilik Onayı
2- Ölçekler

İl Milli Eğitim Müdürlüğü D/Blok Bab-ı Ali Cad. No:13 Cağaloğlu
E-Posta: sgb34@meb.gov.tr

A. BALTA VHKİ
Tel: (0 212) 455 04 00-239
Faks: (0 212)455 06 52

T.C.
İSTANBUL VALİLİĞİ
İl Milli Eğitim Müdürlüğü

Sayı : 59090411/20/5255989 12/11/2014
Konu: Araştırma (Zeynep GECÜ)

VALİLİK MAKAMINA

İlgi:a) 30.10.2014 tarihli dilekçe.
b) MEB. Yen. ve Eğt. Tek. Gn Md. 07.03.2012 tarih ve 316 sayılı 2012/13 nolu genelgesi.
c) Milli Eğitim Araştırma ve Anket Komisyonunun 10.11.2014 tarihli tutanağı.

Orta Doğu Teknik Üniversitesi Eğitim Bilimleri Enstitüsü doktora programı öğrencisi Zeynep GECÜ'nün ***"Okul Öncesi Çocuklar İçin Artırılmış Gerçeklik Etkinlikleri: Geometrik Şekilleri Anlamanın ve Uzamsal Becerileri Geliştirmenin Karşılaştırılmalı Analizi"*** konulu tezine dair araştırma çalışmasını Gaziosmanpaşa ilçesi Bekir Sami Dedeoğlu ilkokulu, Bahçelievler İlçesi Bülent Ecevit İlkokulu, GSD Eğitim Vakfı Bahçelievler ilkokulu ve Yenibosna Fatih Ortaokulunda çocuk görüşme soruları,öğretmen görüşme soruları,kişisel bilgi formu ve geometrik şekilleri tanıma testini uygulama istemi hakkındaki ilgi (a) dilekçe ve ekleri Müdürlüğümüzce incelenmiştir.

Araştırmacının; söz konusu talebi, bilimsel amaç dışında kullanılmaması, veri toplama araçlarının eğitim -öğretimi aksatmayacak şekilde katılımcıların gönüllülük esasına göre seçilmesi, ***veli imzalı onay belgesinin bir örneğinin okulda saklanmak üzere bırakılması,*** araştırma sonuç raporunun müdürlüğümüzden izin alınmadan kamuoyuyla paylaşılmaması koşuluyla, okul idarelerinin denetim, gözetim ve sorumluluğunda ilgi (b) Bakanlık emri esasları dâhilinde uygulanması, sonuçtan Müdürlüğümüze rapor halinde (CD formatında) bilgi verilmesi kaydıyla Müdürlüğümüzce uygun görülmektedir.

Makamlarınızca da uygun görülmesi halinde olurlarınıza arz ederim.

Dr.Muammer YILDIZ
Milli Eğitim Müdürü

OLUR
12/11/2014

Yusuf Ziya KARACAEV
Vali a.
Vali Yardımcısı

İl Milli Eğitim Müdürlüğü D/Blok Bab-ı Ali Cad. No:13 Cağaloğlu
E-Posta: sgb34@meb.gov.tr

A. BALTA VHKİ
Tel: (0 212) 455 04 00-239
Faks: (0 212)455 06 52

Appendix G

Equipment Used in the Research

IPad 2- Technical Specifications

Size and Weigh

- Height: 9.50 inches (241.2 mm)
- Width: 7.31 inches (185.7 mm)
- Depth: 0.34 inch (8.8 mm)
- Weight: 1.33 pounds (601 g)

Wireless

- Wi-Fi (802.11a/b/g/n)
- Bluetooth 2.1 + EDR technology

Display

- 9.7-inch (diagonal) LED-backlit glossy widescreen Multi-Touch display with IPS technology
- 1024-by-768-pixel resolution at 132 pixels per inch (ppi)
- Fingerprint-resistant oleophobic coating
- Support for display of multiple languages and characters simultaneously

Chip

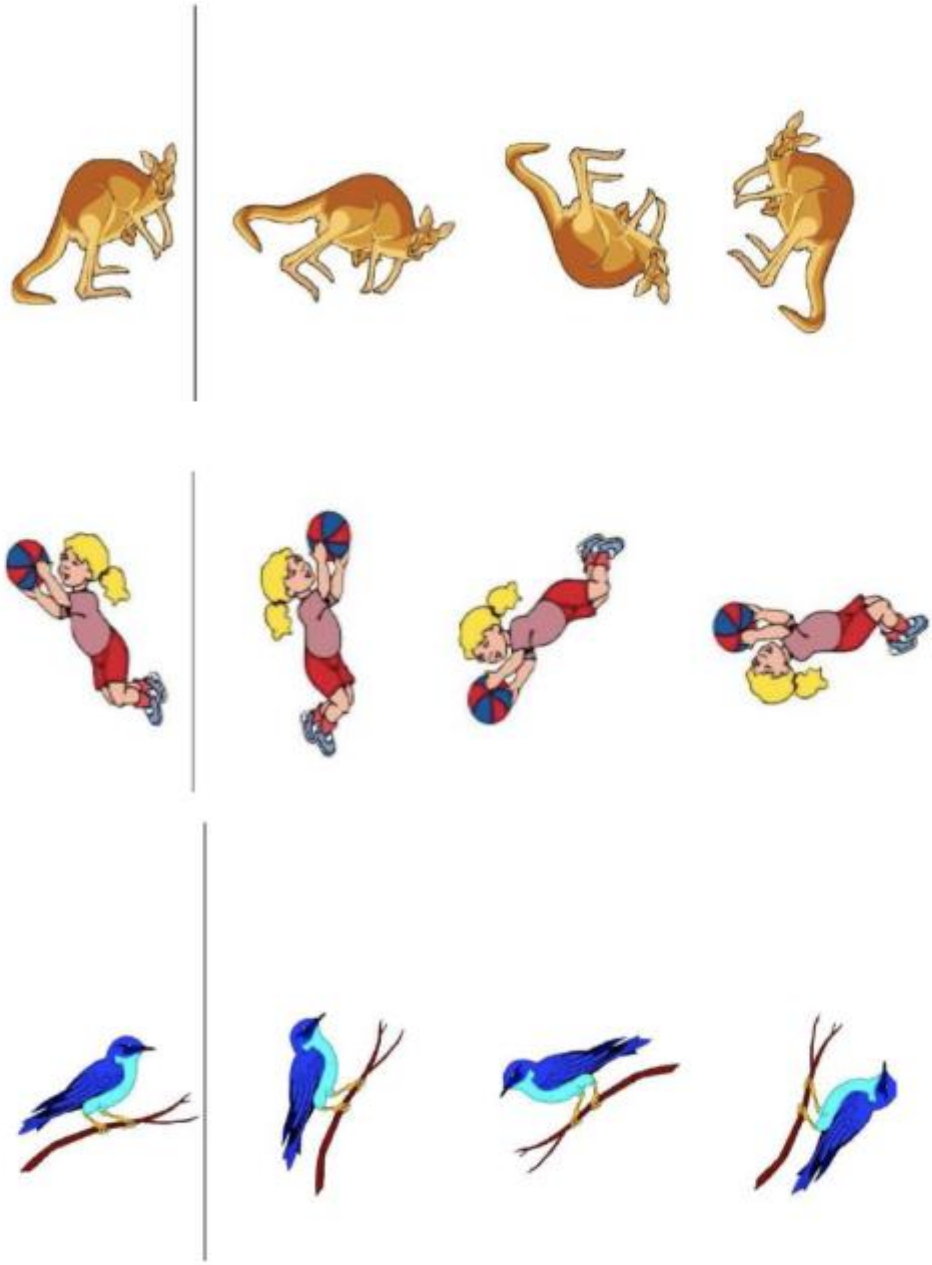
- 1GHz dual-core Apple A5 custom-designed, high-performance, low-power system-on-a-chip

Power and Battery

- Built-in 25-watt-hour rechargeable lithium-polymer battery
- Up to 10 hours of surfing the web on Wi-Fi, watching video, or listening to music
- Charging via power adapter or USB to computer system

Appendix H

Sample Items from Picture Rotation Test



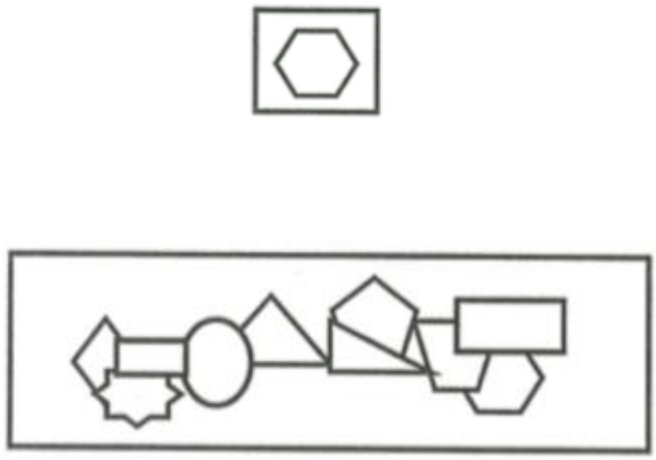
"Here you see the picture of a kangaroo (girl or bird). It runs in the direction of ... (name an object in the room). One of these three kangaroos (girls or birds) here (point to the pictures behind the line) is the same as the first one. Can you tell me which one?"

Appendix I

Sample Items from Spatial Perception Scale

"Find the identical figure"

"Look at the picture and show me this chair"



"Find the identical figure"

Appendix J

Sample Items from Daily Life Photographs of Three-Dimensional Objects

Circle	
Triangle	
Square	
Rectangle	

Ellipse	
Sphere	
Cube	
Prism	
Cylinder	

Appendix K

Sample Items from Three-Dimensional Models for AR Application

Circle		
Triangle		
Square		
Rectangle		

Ellipse		
Sphere		
Cube		

Prism		
Cylinder		

CURRICULUM VITAE

PERSONAL INFORMATION

Name, Surname : Zeynep Gecü -Parmaksız

Birth Date : June 06, 1983

Birth Place : Mannheim, GERMANY

Nationality : Turkish

E-mail Address : zeynepgecu@gmail.com

EDUCATION

- 2011-2017: PhD, Middle East Technical University, Computer Education and Instructional Technology
- 2008-2011:MS, Marmara University, Graduate Program in Computer & Instructional Technologies
- 2002-2007:BS, Boğaziçi University, Undergraduate Program in Primary Mathematics Education

PROFESSIONAL EXPERIENCE

- 2011-Present: Yıldız Technical University, Computer & Instructional Technologies Department, Research Assistant
- June 2013-December 2013: Visiting Scholar, Texas A&M University, Department of Teaching, Learning and Culture
- 2009-2011: Marmara University, Part-Time Lecturer
- 2006-2007: Boğaziçi University, Department of Primary Education, Undergraduate Student Assistant

RESEARCH PROJECTS

- "Improving Effectiveness of Courses Using Classical Lecture Method Through Learning Management Systems and Mobile Tablet PCs"
  Coordinator: Assoc. Prof. Dr. İlhan Varank
- "Development of Electronic Performance Support System for Computer Ethics Education and Ethical Decision Making Process: Ceep Project"
  Coordinator: Assist. Prof. Dr. Serhat Bahadır Kert

PUBLICATIONS

Journals in the Scope of SCI / SCI-Expanded / SSCI / AHCI

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