COMPARING THE EFFECT OF TABLET, DESKTOP, PAPER-PENCIL BASED DRILL PRACTICES ON SPATIAL SKILLS OF VOCATIONAL HIGH SCHOOL STUDENTS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

HÜSEYİN CAN ŞENEL

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
COMPUTER EDUCATION AND INSTRUCTIONAL TECHNOLOGY

AUGUST 2019

Approval of the thesis:

COMPARING THE EFFECT OF TABLET, DESKTOP, PAPER-PENCIL BASED DRILL PRACTICES ON SPATIAL SKILLS OF VOCATIONAL HIGH SCHOOL STUDENTS

submitted by **HÜSEYİN CAN ŞENEL** in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Computer Education and Instructional Technology Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Ömer Delialioğlu
Head of Department, **Comp. Edu. and Inst. Tech.** _____

Prof. Dr. Ömer Delialioğlu
Supervisor, **Comp. Edu. and Inst. Tech., METU** _____

Examining Committee Members:

Assoc. Prof. Dr. Ümmühan Avcı
Comp. Edu. and Inst. Tech., Başkent University _____

Prof. Dr. Ömer Delialioğlu
Comp. Edu. and Inst. Tech., METU _____

Prof. Dr. Zahide Yıldırım
Comp. Edu. and Inst. Tech., METU _____

Assoc. Prof. Dr. Hasan Çakır
Computer Edu. and Inst. Tech., Gazi University _____

Assist. Prof. Dr. Göknur Kaplan
Comp. Edu. and Inst. Tech., METU _____

Date: 20.08.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Hüseyin Can Şenel

Signature:

ABSTRACT

COMPARING THE EFFECT OF TABLET, DESKTOP, PAPER-PENCIL BASED DRILL PRACTICES ON SPATIAL SKILLS OF VOCATIONAL HIGH SCHOOL STUDENTS

Şenel, Hüseyin Can
Doctor of Philosophy, Computer Education and Instructional Technology
Supervisor: Prof. Dr. Ömer Delialioğlu

August 2019, 147 pages

The aim of this study was to compare the effect of using drill and practice applications in tablet computers, desktop computers and traditional paper-pencil booklets for enhancing the spatial skills of vocational high school students. For this purpose, a drill-practice application software compatible with mobile devices and desktop computers was developed. The same content was used in preparing a printed booklet for paper-pencil activities.

For this aim a mixed-method design was used. The quantitative part of the study aimed to provide data about the development of spatial skills of three group, and to compare them. Additionally, the qualitative part aimed to understand how participants perceived the tablet computer-based drill-practice application. A total of 85 vocational high school students were divided into three groups, with 28 in the tablet computer group, 30 in the desktop computer group, and 27 in the paper-pencil group.

Mental rotation test was used as pre-test prior to the interventions. After pre-test, experimental group used the developed application with tablet computers, whilst first control groups used the same content with desktop computers and second control group used paper-pencil booklets, respectively. At the end of the 8-week

treatment period, all of the participants received the same mental rotation test as post-test. For the qualitative part of the study, six students were chosen using maximum variation sampling in accordance with their test scores, and were then interviewed in order to identify the students' perceptions about the use of tablet computers.

The results of the study showed that the spatial skill scores of the vocational high school students were relatively low at the beginning of the study. However, the spatial skill scores of all groups increased significantly after 8 weeks of intervention. When the post-test scores of the tablet, desktop computer, and paper-pencil groups were compared, it was seen that the tablet and desktop computer groups had achieved significantly higher post-test scores than the paper-pencil group. However, there was no significant difference found between the tablet and desktop computer groups. The results of the content analysis on the interview data revealed that the students' perceptions were gathered around five themes; mobile learning tool as facilitator, tablet computers as technological tool, technical properties of tablet computers and software, the content of learning environment, and motivational factors.

Keywords: Spatial skill, drill-practice applications, vocational high school, tablet computers, desktop computers, paper-pencil booklets

ÖZ

UZAMSAL YETENEĞİN GELİŞTİRİLMESİ: MESLEK LİSESİ ÖĞRENCİLERİ İÇİN TABLET, BİLGİSAYAR VE KAĞIT-KALEM UYGULAMALARININ KARŞILAŞTIRILMASI

Şenel, Hüseyin Can
Doktora, Bilgisayar ve Öğretim Teknolojileri Eğitimi
Tez Danışmanı: Prof. Dr. Ömer Delialioğlu

Ağustos 2019, 147 sayfa

Bu çalışmanın temel amacı meslek lisesi öğrencilerinin uzamsal yeteneğinin geliştirilmesinde tablet bilgisayar, masaüstü bilgisayar ve geleneksel kağıt-kalem uygulamalarının kullanımının karşılaştırılmasıdır. Bu amaçla araştırmacı tarafından tablet bilgisayarlar ve masaüstü bilgisayarlara uyumlu bir uzamsal yetenek yazılımı geliştirilmiş, aynı içerik kağıt-kalem uygulaması için basılı materyal olarak da hazırlanmıştır.

Çalışmanın amaçları doğrultusunda karma araştırma yöntemi kullanılmıştır. Araştırmanın nicel bölümü deney ve kontrol gruplarının uzamsal kabiliyetlerindeki gelişimi ve bu grupların karşılaştırılması için veri sağlarken, nitel bölüm katılımcıların tablet bilgisayarla uyumlu uzamsal yetenek yazılımı hakkındaki algılarının belirlenmesini amaçlamaktadır. Meslek lisesinde öğrenim gören 85 katılımcının 28'i tablet bilgisayar grubunda, 30'u masaüstü bilgisayar grubunda ve 27'si de kağıt-kalem buklet grubunda olmak üzere üç grupta yer almıştır.

Katılımcılara ön-test olarak zihinsel döndürme testi uygulanmıştır. Ön-test sonrasında, deney grubu araştırmacı tarafından geliştirilen uygulamayı tablet bilgisayarlar ile, kontrol grupları aynı içeriği masaüstü bilgisayarlar ve basılı kitapçıklar (buklet) ile kullanmışlardır. Sekiz haftalık uygulama süresi sonrasında

tüm katılımcılar aynı zihinsel döndürme testini son-test olarak almışlardır. Araştırmanın nitel bölümü için deney grubu katılımcıları arasından test puanlarına göre maksimum çeşitlilik yöntemiyle altı katılımcı seçilmiştir. Bu öğrencilerle görüşmeler yapılarak tablet bilgisayarla uyumlu uzamsal yetenek yazılımı hakkındaki algıları belirlenmiştir.

Çalışma sonuçları meslek lisesi öğrencilerinin uzamsal yeteneklerinin uygulama öncesinde görece düşük olduğunu ve sekiz haftalık uygulama sonrası kontrol ve deney gruplarının tümünün uzamsal yetenek puanlarının anlamlı olarak yükseldiğini göstermiştir. Tablet, masaüstü bilgisayar ve kağıt-kalem gruplarının son-test puanları karşılaştırıldığında tablet ve masaüstü bilgisayar gruplarının kağıt-kalem grubundan anlamlı olarak daha yüksek son-test puanı aldığı, tablet ve masaüstü bilgisayar grupları arasında ise anlamlı bir puan farkı bulunmadığı görülmüştür. Ayrıca deney grubu ile yapılan görüşmelerde katılımcıların görüşleri öğrenmeyi kolaylaştırıcı özellikler, tablet bilgisayarların teknolojik değeri, tablet bilgisayarlar ve yazılımın teknik özellikleri, öğrenme ortamının içeriği ve motivasyonal faktörler temalarında toplanmıştır.

Anahtar Kelimeler: Uzamsal yetenek, alıştırma uygulamaları, meslek lisesi, tablet bilgisayarlar, masaüstü bilgisayarlar, kağıt-kalem kitapçıkları

To my beloved family

ACKNOWLEDGEMENTS

There are so many people to whom I would like to express my gratitude as I reach the end of my studies. First of all, I am thankful to my supervisor, Prof. Dr. Ömer Delialioğlu for his sincere guidance, interest, valuable comments, as well as endless patience during my study. It would have been impossible to put forward this dissertation without his limitless support.

Moreover, I would like to thank the thesis monitoring committee members, Prof. Dr. Zahide Yıldırım and Assoc. Prof. Dr. Hasan Çakır for their continuous support and guidance, and to the examining committee members, Assoc. Prof. Dr. Ümmühan Avcı and Assist. Prof. Dr. Göknur Kaplan for their helpful comments.

I am very grateful and would like to present my deepest respect to all of my teachers who have guided me through the science, the first of whom would be Mustafa Kemal ATATÜRK.

I also wish to thank my parents, Oktay Şenel and Sevgin Şenel and my brother Caner Şenel from the bottom of my heart. Without your love and endless support, I could not have accomplished this work.

My dear wife, Assist. Prof. Dr. Selma Şenel, you deserve my most special thanks and love. Thank you for your support, your patience, and of course your love. Moreover, I thank you because you are in my life. Asya, our little daughter, our precious gift, you have brought us so much love and happiness. The world is more meaningful with you my princess.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

Technology has transformed our daily routines, it has also had a similar effect on how we teach and how we learn. Universities, institutions and organizations are attaching more importance to technology for the design of instructional events as the usage of communication tools have become more commonplace. The number of distance learning universities and faculties, online courses and registered students are continuing to grow year on year (Allen & Seaman, 2008).

In a similar vein and as a part of a global shift, mobile technologies are pervading the workplace, social life and also education at all levels. In addition to smartphones, mobile computers such as Apple and Android tablets, which offer high-resolution screens and an ever-increasing variety of applications as programs decrease in size, have become popular personal digital devices for daily use. As an effect on educational environments, instructional materials and mediums have become much more portable, individual and socially-communicative (Chen, Kao, & Sheu, 2003).

Numerous research have sought to identify possible effects of mobile technologies on education using familiar handheld devices as the primary delivery tool. Research about mobile devices varies based on investigating student and/or instructor perceptions (Liu, Li, & Carlsson, 2010; Uzunboylu & Ozdamli, 2011; Wang, Wu, & Wang, 2009), ascertaining the effective usage of mobile devices in the classroom (Sung et al., 2005; Wang, Shen, Novak, & Pan, 2009), and examining the different learning contexts of mobile learning (Evans, 2008; Lu, 2008). Today, there is a growing interest to utilize tablet computers in the classroom as a medium for both delivering content and for incorporating interactivity into classroom-based events. Additionally, there have been national projects such as Turkey's FATIH program

("Fırsatları Artırma ve Teknolojiyi İyileştirme Hareketi," or "Movement to Increase Opportunities and Technology") to support instruction by handing out high-tech hardware to both students and schools on a national scale. Today, a new paradigm, STEM (Science, Technology, Engineering, and Math), is changing national level education policies in order to utilize the latest technological tools to teach students, about science, technology, engineering, and math, and to fully integrate these disciplines into educational practices and curricula in order to produce the minds who will create the innovative tools of tomorrows' world.

Spatial skill is an inner construct that basically defines the ability of rotating, designing, and locating objects mentally in two- and three-dimensional environments. Spatial skills are considered as one of the most important skills required by today's students, not only in terms of their academic achievement, but also in the routines of daily life. It is considered as one of the indicators of general student achievement (Guay & McDaniel, 1977; Jordan, Glutting, & Ramineni, 2010; Pallrand & Seeber, 1984; Pribyl & Bodner, 1987), and is regarded as an element of intelligence (Gardner, 1985). Math (Assel, Landry, Swank, Smith, & Steelman, 2003; Casey, Nuttall, Pezaris, & Benbow, 1995; Clements & Battista, 1992; Gallagher, 1989; Reuhkala, 2001; Tracy, 1987), science (Dyche, McClurg, Stepans, & Veath, 1993; Huk, 2006; Lord, 1990; Pallrand & Seeber, 1984; Wu & Shah, 2004 Yang, Andre, Greenbowe, & Tibell, 2003), engineering (Sorby, 2009; Sorby & Baartmans, 2000), and surgery (Brandt & Davies, 2006; Wanzel, Hamstra, Anastakis, Matsumoto, & Cusimano, 2002) are some of the disciplines for which achievement is considered significantly linked to spatial skill.

Mohler (2009) explained spatial skill as one of the basic needs for any technical practice. Additionally, researchers who have extensively studied spatial skill have concluded that spatial skills are directly linked to future professional success for engineering students (Ault & John, 2010; Hsi, Linn, & Bell, 1997; McGee, 1979; Miller, 1996).

Spatial skill was considered as a basic engineering skill up until the late 1970s, when machine parts or other designs were generated by engineering graphics using the

“design-by-drawing” method. After the 1980s, the importance of spatial skill increased as a new design process, 3D software, replaced hand-drawn or 2D sketches. With the help of this new software, 3D objects started being designed using 3D CAD applications such as Solidworks, AutoCad, and Rhino (Contero, Naya, Company, Saorin, & Conesa, 2005).

Additionally, communication and planning in engineering is strictly based on two primary skills. One of these is to be literate in “graphics information processing” which is based on the discovery of data relationships. The second skill is to be able to mentally imagine “graphics communication,” which is strictly based on locating, designing, and rotating 3D objects within 2D environments. According to Ferguson (1992), engineers must possess these skills in order to communicate to others across time and the other person’s mind in order to realize effective designs and drawings.

Considering the importance of identifying, creating, drawing, and integrating 2D and 3D objects, most departments within engineering faculties such as civil engineering, automotive engineering, materials engineering, and mechanical engineering run “technical drawing” or “graphics design” courses in different semesters as compulsory courses. Many of these courses include practical sessions for 2D and 3D drawing with paper-pencil or with computer software. Most of the content and practices of these courses may be defined as enhancing activities for spatial skill. However, the development of spatial skill is not an explicit learning objective for any of these courses.

As a critical skill for many disciplines, enhancing spatial skill has been a research topic for a number of years. Research has proven that high spatial skills may be defined as indicators of future success for many disciplines, but especially for engineering (Hsi et al., 1997). Additionally, contemporary research has proven that children with high spatial skills are very successful in creating, designing, and producing innovative technological tools (Quaiser-Pohl, Neuburger, Heil, Jansen, & Schmelter, 2014) which are the most valuable industrial products for countries’ technological and economic progression.

As previously stated, except for experimental studies, none of the engineering faculties have courses or additional work aimed at enhancing the spatial skills of students. Compulsory courses for drawing or sketching mainly aim to create awareness about 2D and 3D objects, and also for the teaching of one of the software programs (e.g., Autocad, Solidworks) mainly used in industry. This results in the graduation of engineering faculty students who have not developed the necessary spatial skills which can be quite achievable with the application of specific activities.

The second source of industrial and technological workforce is vocational high schools. Vocational high schools, in addition to engineering faculties and vocational colleges, aim to graduate technical staff or qualified labor force for industrial organizations in areas such as machinery, electronics, computer science, and the automotive sector. Students registered to these vocational high schools have to choose one of those discipline areas after their first year. After that, they start to take courses that incorporate hands-on activities which are mainly aimed at the improvement of technical abilities that they will use for life.

Although of critical importance for industry, vocational high schools have experienced major problems like achievement rankings of students in national exams (Millî Eğitim Bakanlığı [Turkish Ministry of National Education], 2018). There have been national projects aimed at increasing student interest and resolving the basic problems associated with these schools, although most have proven unsuccessful.

Vocational high school students have drawing and sketching courses either consisting of paper-pencil activities or with computer software such as AutoCad or SolidWorks. These courses are intended to teach students the fundamental basics of technical drawing, 2D perspectives, properties of 3D objects and generating 3D objects from 2D perspectives. Most vocational high schools utilize computer software for the course content and plan to teach one of these software as part of the course.

As a result of the data analyses on pre-interviews conducted as part of the current study, it was seen that none of the students interviewed had knowledge about the

importance or role of spatial skill. As with engineering faculties, there are no explicit objectives in the curricula of vocational high schools about spatial skill. The only option open to students of vocational high schools is to enhance their spatial skill through "drawing courses." As previously mentioned, these courses contain activities such as identifying 2D perspectives and drawing/sketching basic 3D objects.

Enhancing spatial skill is a notable aim for researchers from different disciplines such as mathematics, physics, geometry, geology, education, and surgery (Clements & Battista, 1992; Olkun, Altun, & Smith, 2005; Pallrand & Seeber, 1984; Sorby & Baartmans, 2000; Wanzel et al., 2002), as it is considered critical to both academic achievement and overall life skills. The literature shows that researchers have designed various instructional events in order to support the acquisition of spatial skill. Using concrete materials (physical manipulatives) is seen as one way of supporting spatial skill (Alias, Gray, & Black, 2002), with design drawing and sketching practices defined as another approach to enhance spatial skill (Olkun, 2003). Additionally, the use of readily prepared software (packet software) is also common in some research for the same objective (Martin-Dorta, Saorín, & Contero, 2008), whilst in one study, researchers designed a complete course design (Sorby & Baartmans, 2000) so as to improve students' skills in spatial skill.

In studies that utilize packet software, researchers prefer the use of well-known 3D software for the development of learners' spatial skills. Geometer's SketchPad, Google Sketchup (Martin-Dorta et al., 2008) and GeoGebra are some of the geometric- and mathematically-based software which permits students to make calculations, equations, and to create drawings and sketches. Numerous research studies have tried to find the potential effects of these tools, or try to integrate these tools into student courses (Dixon, 1997; Erkoç, Gecü, & Erkoç, 2013; Leong & Lim-Teo, 2003). On the other hand, none of these tools were primarily designed to generate solutions for problematic issues posed within educational courses, or specifically designed as instructional material for enhancing spatial skill. Although it is possible to integrate some part or some specifications of these tools into courses or

instructional designs, the objectives and properties of these tools do not exactly match with the aims of the research community.

In the current study, a drill and practice-based mobile learning environment was designed in order to attempt to enhance the spatial skills of vocational high school students in Turkey through comparison of the same content on desktop computers and paper-pencil booklets, and the subsequent elicitation of students' thoughts about their experiences.

1.2. Statement of the Problem

Spatial skills are critical in math, science, engineering, technology development and industry. Literature proved that these skills can be developed by systemic studies. Contemporary attempts to develop these skills are mainly based on use of technology like computers and software. On the other hand, most of these studies use readily prepared drawing software. The main aim of these tools is to make geometric draws, calculations, creating 3D objects and make designs. However developing skills needs systemic studies with well-designed materials.

Besides lack of systemic and well-designed instructional software for developing spatial skills, there is limited comparison studies in the literature. Use of latest technology products are common and there is tendency to use them as soon as they are released but there is need to compare them in experiment conditions since they have major differences like input differences, usability issues and mobility.

Third, spatial skill research is mainly focused on engineering faculties. However, work-force in technology and industry is not mainly on engineers but also technicians. There is not enough experimental research that focus on vocational high schools though these schools are one of the main work-force source for industry and technology based production.

1.3. Purpose of the Study

Considering the importance of spatial skills on science, engineering and overall job-success in technical professions, researcher aimed to design a drill-practice based learning environment that can be easily used in tablet computers and desktop computers and a conventional paper-pencil booklet and to compare these tools to develop spatial skills of vocational high school students. In development of the content, researcher used simplifying conditions method (Reigeluth, 1999) to help students to progress in this moderate to complex skill (spatial skill).

Literature seeking attempts to enhance these skills are mainly focused on engineering faculties and university students (Mohler, 2009; Ault & John, 2010; Strong & Smith, 2002). On the other hand, vocational high schools and vocational colleges in Turkey have critical role to generate technically skilled work-power for industry. Additionally, vocational high schools have a considerable amount of registration rate among high schools (Millî Eğitim Bakanlığı [Turkish Ministry of National Education], 2018). Regarding their critical mission and student rate, researcher decided to focus on these schools and attempted to enhance their spatial skills.

Considering these in mind, the purpose of this study is to compare the effect of using drill and practice applications in tablet computers, desktop computers and traditional paper-pencil booklets for enhancing the spatial skill of vocational high school students and to reveal students' perceptions about use of learning software in tablet computers.

1.4. Research Questions

This study seeks to answer the following research questions and related sub-questions:

Research Question 1: Is there any significant difference in spatial skill scores of within groups before and after interventions?

Sub-question 1.a: Is there any significant difference in spatial skill scores of paper-pencil group before and after intervention?

Sub-question 1.b: Is there any significant difference in spatial skill scores of desktop computer group before and after intervention?

Sub-question 1.c: Is there any significant difference in spatial skill scores of tablet computer group before and after intervention?

Research Question 2: Is there any significant difference between three intervention groups according to their post-test scores?

Research Question 3: What are the perceptions of participants about mobile learning environment?

1.5. Significance of the Study

Developing learning environments to enhance spatial skills of vocational high school students, comparing effects of these environments on spatial skills and taking perceptions of students about use of learning software with tablet computers is critical in different aspects.

In the literature of spatial skills, there is limited research that use specific learning tools to enhance spatial skills. Most of the studies that seek enhancement of spatial skills are using readily prepared drawing or calculation software whose main focus is to make industrial design and production. There is a lack of empirical data that provide instructional design issues to enhance these skills. In this respect, present study is expected to be pioneer in the spatial skill research and would contribute the literature by offering simplifying conditions method as an instructional design framework.

Literature has not concluded in exact definition of spatial skill or components of it. However, literature proved that spatial skill can be enhanced through systemic studies. Real objects, drawing lessons, computers and computer aided drawing software, block games, latest technological tools like tablets or virtual reality applications are all tools that are used to enhance spatial ability. On the other hand,

we do not have enough evidence if any one of these tools is superior to the others or which specific property of these tools provide effective ways to enhance spatial skill. This study will be significant providing design considerations for different media and comparing them (tablet computers, desktop computers and paper-pencil booklets) in controlled experiment conditions.

Since spatial skills are directly linked to success in math, science and engineering fields, there is growing attention on these very critical skills. Although there are numerous research that seek ways to enhance spatial skills, none of them were targeted vocational high schools, which have critical role to grew up technical work-force for industry. This study is significant since it proposes new and specifically developed instructional tools (learning software adaptive with tablet and desktop computers and paper-pencil booklets) for vocational high school students. Teachers and students of vocational high schools may benefit from these tools in-class activities to enhance spatial skills of the participants.

To conclude, to enhance spatial skills, offering empirical data based on instructionally designed tools and content is very crucial. In other words, it is needed to have well-designed and specifically developed tools rather than using readily prepared tools different tools to improve these skills. Besides, comparing three different tools, tablets, desktops and paper-pencil booklets, which have different features like input differences and mobility may give us idea about their possible effects on spatial skills. In addition, vocational high schools, as a source for industrial and technical labor force, are the focus and this study is offering them tools that may be easily used in-class activities.

1.6. Definition of Terms

The aim of this part of the study is to provide definition of terms, which are used throughout the study.

Spatial Skill: “the ability to generate, retain, retrieve, and transform well-structured visual images” (Lohman, 1996, p. 188).

Spatial Visualization: A component of spatial ability that relates to manipulating, rotating or twisting pictorially given objects.

Spatial Orientation: A perceiving environmental scenarios as a reflexive movement without thinking or predicting the correct sides of movements.

Simplifying Conditions Method: It is defined as "a practical guideline to make a simple-to-complex sequence for tasks of at least moderate complexity" (Reigeluth, 1999, p. 442).

1.7. Organization of the Study

The study is arranged in five chapters; Introduction, Literature Review, Methodology, Results, and Discussion and Conclusion.

The background of the study, problem statement, the purpose of the study, significance of the study, research questions and organization of the study are reported in the current chapter (Chapter 1, Introduction).

In Chapter 2, the related literature and current studies are reviewed and summarized based on three main areas of significance; the definition and importance of spatial skill, the role of spatial skill on STEM disciplines, and latest studies that aim to develop spatial skill.

In Chapter 3, the methodology is explained; with an introduction, the design of the study, and information about variable sampling, the participants, data collection instruments and procedures, a description of the mobile learning environment application, implementation, and procedures being reported.

The results and findings of the study are presented in Chapter 4; and includes demographic information of the participants, effects of the interventions on participants' spatial skills, and the experiences and thoughts of the participants about the mobile learning environment.

Finally, a discussion and conclusion to the study is presented in Chapter 5, in which the researcher discusses the results of the research with consideration to the related

literature. Additionally, suggestions are put forward for future academic research in this area.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1. Review of the Literature

In this chapter, literature related to the current study is reviewed. Considering the content and primary objectives of the study, the literature review is comprised of four main sections. First, the definition and importance of spatial skill is presented; second, studies related to engineering and technology disciplines and the role of spatial skill are detailed, third, studies designed to enhance spatial skill are reported and lastly media comparison studies and effects of different input modalities were presented.

2.1.1. Spatial skill

2.1.1.1. Definition of Spatial skill

Argument about the definition of spatial skill has continued from the 1920s until today. In the early stages, there was controversy about whether spatial skill is a separate construct or just a measure of general intelligence (Bodner & Guay, 1997). After some reliable studies were published, it was accepted that spatial skill is a separate construct comprised of three main factors; mental rotation, spatial visualization, and spatial perception (French, 1951; Thurstone, 1950).

In the developmental history of spatial skill research, Sir Francis Galton (1911) may be considered as the pioneer since he was the first researcher that reported about "mental imagery." Afterwards, Thorndike (1921) identified a three point classification of abstract, mechanical, and social intelligence. Since then, researchers have been trying to separate spatial skill from general ability by defining it in various ways and also by searching for various methods to measure its component elements (Mohler, 2009). However, it is still not possible to find a complete or definitive

definition for spatial skill. Additionally, there is also ongoing debate about the components or factors of spatial skill.

2.1.1.2. Historical Development

Mohler (2009) reviewed the published research about spatial skill through a four stage chronology. In this classification, studies of spatial skill started with the aim of separating spatial skill from general intelligence through psychometric measurements. In the second stage, researchers tried to make a concrete definition of spatial skill. Another objective was to figure out the components and factors of spatial skill. As a result of these studies, certain incompatible definitions and factors of spatial skill emerged due to the wide range of spatial skill tests used in the measurement of spatial skill. By the end of this period, it was confirmed that spatial skill is not a unitary construct and may be evaluated by varied measurement tools. During the subsequent stage, knowledge about spatial skill matured along with gender and development studies. While some researchers tried to figure out the differences between individuals across gender, others tried to observe its development through the years. Currently, studies are ongoing about enhancing spatial skill by means of various instructional events.

Although there is an established historical research background and general agreement about the significance of spatial skill, today there is still no single definitive definition for spatial skill (Yıldız & Tüzün, 2011). Additionally the term, spatial skill, is synonymously used with some other terms like spatial perception, spatial cognition, spatial intelligence, spatial reasoning, spatial skills, and spatial sense (Bishop, 1983; Rafi, Anuar, Samad, Hayati, & Mahadzir, 2005; Wheatley, 1990).

However, in more recent studies (Ferguson, Maloney, Fugelsang, & Risko, 2015; Maeda & Yoon, 2016), researchers have tended to use the term “spatial skill” as a general concept. For this reason, the researcher in the current study also elected to use the term “spatial skill” throughout this study. In this part of the literature review, the most cited definitions of spatial skill are reported.

2.1.1.3. Spatial skill and Intelligence

McGee (1979, p. 896) defined spatial skill as "to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects." Gardner (1985), in his multiple intelligence theory, considered intelligence not as a single general ability but as "specific modalities," and defined visual-spatial (spatial intelligence) ability as a type of intelligence. "Central to spatial intelligence are the capabilities to perceive the visual world accurately, to perform transformations and modifications upon one's visual experience, even in the absence of physical stimulation" (Gardner, 1985, p. 173).

Lohman (1996) termed spatial skill "as the ability to generate, retain, retrieve, and transform well-structured visual images" (p. 188) and emphasized the importance of spatial skill in science and mathematics achievement, since it is critical for producing and understanding figures and graphics. Linn and Petersen (1985) published well-known meta-analytical research about gender differences in spatial skill, and declared spatial skill as "*representing, transforming, generating, and recalling symbolic, nonlinguistic information*" (p. 1482).

Mayer and Sims (1994) defined spatial skill as rotating objects mentally in two or three dimensions and visualizing the different patterns of objects that would result from such rotations or localizations. Activities like perception of horizontality, mental rotation of objects, and location of simple figures within complex figures have all been referred to as measures of spatial skill (Linn & Petersen, 1985).

On the other hand, it is possible to encounter contemporary definitions of spatial skill in recent studies. Rafi et al. (2005) defined spatial skill as a critical mindful set of actions to evaluate the effectiveness in learning, practicing, and working and also in daily routines. This definition stresses the importance of spatial skill on daily life. It is the ability to rotate, locate and visualize objects mentally in two and three dimensions. Similarly, Martin-Dorta et al. (2013) considered spatial skill as an important mental skill in how individuals sense, comprehend, plan, and interact with their environment. As can be observed from these proposed definitions, there are

major similarities, especially in the actions of spatial skill such as “generating, retrieving, rotating, and manipulating.”

In consideration of special ability as a separate construct from general intelligence, interest towards spatial skill has increased gradually. Researchers began to lean more towards spatial skill in presenting possible outcomes and how it may affect both academic performance in both academic disciplines and in daily life.

2.1.1.4. Components of Spatial skill

There are on-going debates about the factors or components of spatial skill. Psychometric perspectives, especially factor analysis, are the main tools used for categorizing spatial skill. As the measurements tools have varied, the components or factors of spatial skill have also varied and with various names attached. Maccoby and Jacklin (1974) stated that spatial skill consists of two major factors, “analytic” and “non-analytic.” McGee (1979) offered a different taxonomy with two components as “spatial visualization” and “spatial orientation.” Linn and Petersen (1985) argued there being three factors of spatial skill, as “spatial visualization,” “spatial orientation,” and “spatial relations.”

According to Maccoby and Jacklin (1974), “analytic processes” are more difficult and more complex than “non-analytic,” including actions like designing or imaging a closed state of a given open object. Conversely, non-analytic processes include the rotating or relocating of specific objects. In McGee’s (1979) taxonomy, “spatial visualization” relates to manipulating, rotating or twisting pictorially given objects, whilst “spatial orientation” is defined as perceiving environmental scenarios as a reflexive movement without thinking or predicting the correct sides of movements. Linn and Petersen (1985) aimed to focus on the processes that respondents use for individual items in order to classify the factors of spatial skill. They identified three main categories of spatial skill as “spatial perception,” “mental rotation,” and “spatial visualization.” Spatial perception is the first component and is significantly related with deciding on spatial relationships with regards to adjustment to the surroundings of oneself in spite of distracting information. The second category,

mental rotation, emphasizes how to turn a two- or three-dimensional figure rapidly and accurately. The third category, spatial visualization, is the ability to solve complicated spatial skill tasks that require multi-step manipulations.

Although further experimental research about the possible effects and conceptual definitions of spatial skills is still needed (Mohler, 2009), it has been validated that spatial skill is a significant construct for learning outcomes on science (Dyche et al., 1993; Huk, 2006; Lord, 1990; Pallrand & Seeber, 1984; Wu & Shah, 2004; Yang et al., 2003), math (Assel et al., 2003; Casey et al., 1995; Clements & Battista, 1992; Gallagher, 1989; Reuhkala, 2001; Tracy, 1987), language learning (Pearson & Ferguson, 1989), and also in disciplines such as engineering (Sorby, 2009; Sorby & Baartmans, 2000), architecture, surgery (Brandt & Davies, 2006; Wanzel et al., 2002), and technology (Rafi, Samsudin, & Ismail, 2006). Spatial skill may be considered as an inner construct effecting especially arithmetic and logical processes (Laski et al., 2013). The National Research Council's Committee on Support for Thinking Spatially (2006) stated that, "Spatial thinking is at the heart of many great discoveries in science, that it underpins many of the activities of the modern workforce, and that it pervades the everyday activities of modern life" (p. 1).

2.1.2. Spatial skill and Engineering and Technology Disciplines

The literature contains significant argument about the possible relationship between spatial skills and engineering disciplines. Over the past 50 years, some high-quality studies have been conducted that indicate spatial skills to be of critical importance to math and science performance (Lubinski, 2010; Newcombe, 2010). One of the more widely known works was called Project Talent (Wai et al., 2009), which was a study that observed approximately 400,000 people from the late 1950s (their high school years) right through to 2010. It was found that people with high spatial skill scores at the high school level were much more likely to major in engineering and technology based disciplines and then continue on to develop technology related careers than those with lower scores.

2.1.2.1. Spatial skill and Math

The literature contains a range of research about the possible relationship between spatial skill and mathematics in terms of student outcomes. There is notable evidence for the positive correlation between spatial skill and math achievement, and also with other disciplines such as the sciences (Battista, 1990; Higgins, 2006; Olkun, 2003).

One of the most cited research in this area is by Guay and McDaniel (1977), who investigated the relationship between spatial skills of younger children and their mathematics achievement. The outcomes of the study pointed to a positive relationship between spatial skills and the mathematics achievement of elementary school students. According to their study's results, students who performed better in spatial skill also performed better in mathematics, whilst low spatially-skilled students achieved lower results in mathematics. Similar results emerged in Battista's (1990) research, who revealed a positive correlation between the learning of conceptual topics and spatial skill.

In a largescale study, Pearson and Ferguson (1989) explored relationships among the measures of spatial skill and both mathematics and English language achievement with 168 female and 114 male undergraduate students. Their results reported that females' math and English language achievement scores were both found to be predictive of spatial skill, while for the males, only math achievement was predictive of spatial skill.

In another study that used structural equation modeling to research the estimators of math competence in 8-year-old students, visuospatial skills were considered to be a significant precursor (Assel et al., 2003). Reuhkala (2001) found similar results when researching the relationship between spatial skills (visuospatial working memory and the ability to mentally rotate three-dimensional objects) and mathematical skills. The study reported on the ability of subjects to mentally rotate abstract figures as being related to mathematical skills, and that performances in static visuospatial tasks and mental rotation related to math test scores.

Research studies have indicated that spatial skills are also critical for problem-solving ability in addition to mathematics achievement. Alias et al. (2002) studied a group of engineering students' problem-solving skills with regards to whether or not spatial visualization had any effect on these skills. The study's results offered that spatial skill was indeed crucial to problem-solving skills in structural design applications.

2.1.2.2. Spatial skill and Science

In a large scale study, Carter, LaRussa, and Bodner (1987) examined spatial skill as a predicator to success in different levels of a general chemistry course. Considering literature that pointed to a relation between spatial skill and achievement in chemistry courses for engineering departments, the researchers examined in detail to see if there exists a relationship between spatial skill and performance in introductory chemistry courses. For this purpose, two different samples ($N1 = 1648$ science and engineering students, and $N2 = 850$ nursing and agriculture students) were applied two spatial skill tests. The results indicated that students classified as having "high spatial skill" on the spatial skill tests significantly performed higher than those with "low spatial skill" in their general chemistry course exams. Additionally, the researchers found significant correlations between spatial skill and the students' performance in general chemistry, but only for questions that required high-level problem-solving skills.

In another widely known study, Pribyl and Bodner (1987) researched the potential relationship between spatial skill and performance in organic chemistry. Their study focused on four organic chemistry courses that were designed for students enrolled to various science and engineering departments such as agriculture, biology, health sciences, pharmacy, and chemical engineering. In four different classes, the results showed a small but positive relationship between spatial skill and achievement in organic chemistry, with spatial skill scores explaining as much as 15% of the variance found in students' organic chemistry course scores. Another result of the study was that spatial skill was found to be significantly meaningful when the exam questions were sub-grouped. Where the students were required to mentally

manipulate two-dimensional representations of molecules, and/or exams focused on higher-order cognitive processes, the students with high-level spatial skill performed better than those with low-level spatial skill.

Similar results were found in Carter et al.'s (1987) research, who found that spatial skill significantly affected the achievement scores of students in entry-level general chemistry classes. Yang et al. (2003) also studied spatial skill and the impact of visualization/animation on learning electrochemistry, and reported that spatial abilities were found to be related to performance in chemistry.

2.1.2.3. Spatial skill and Other Disciplines

In another area of science, geology, Black (2005) examined the relationship between spatial skill and the conceptual understanding of earth science. Researcher studied a group of 97 college students who were enrolled across six different courses in the disciplines of geoscience, chemistry, physics, and biology. According to the results of the study, the researcher found a moderately significant positive relationship between the scores of earth science conceptual understanding and scores on each of the three factors of spatial skill; spatial perception, mental rotation, and spatial visualization. Additionally, mental rotation was found to be the best predictor of earth science conceptual understanding scores within all variables.

Similarly, Delialioğlu and Aşkar, (1999) sought to establish the potential impacts of math and spatial skills on high school students' physics achievement. Their study's results proved that spatial skills and math ability together significantly affected the students' physics achievement.

Furthermore, Tai, Yu, Lai, & Lin (2003) examined the logical thinking abilities of students in a computer programming language lesson, and researched if spatial skill predicted this ability. The results proved that students with high-level spatial skill performed better in logical thinking and computer programming than students with low-level spatial skill. Additionally, students with high-level spatial skill had more positive attitudes towards computer-assisted learning that those with a lower level.

2.1.3. Enhancing Spatial skill

Although there have been debates about the possibility of enhancing spatial skill (Sexton, 1992; Zavotka, 1987), contemporary studies have shown that spatial skill can indeed be improved through additional instruction (Kurtulus, 2013; Martin-Dorta et al., 2013; Sorby, 2009; Sorby & Baartmans, 2000). Sorby (1999) summarized that eye-to-hand coordinated activities can play a supportive role in the enhancement of spatial skills. Playing with construction toys such as Lego in early childhood, taking part in drafting, attending sketching or mechanic-type courses, playing three-dimensional video games, or undertaking sporting activities are just some of the activities that pointed to the enhancement of spatial skills.

Various interventions can be found in the literature, with specifically designed software used to support spatial skill (Hauptman, 2010), 3D software for geometrical drawing (Martin-Dorta et al., 2013), and special introductory courses (Sorby, 2009) or real objects (Baki, Kosa, & Guven, 2011) all used to support spatial skill development. In all of these studies, increases in the spatial skills of students were found in favor of the experimental groups.

2.1.3.1. Course Design for Enhancing Spatial skill

Spatial skills are highly interrelated with many types of everyday human reasoning, as well as being fundamental to fields such as mathematics, engineering and the natural sciences, there has also been research on how to increase spatial skill. Much of the recent research incorporates the latest computer technologies, with new software, the Internet and new hardware devices. On the other hand, first studies of spatial skills began with paper-pencil drawing activities.

In a 6 year study, Sorby (2009) developed a course design primarily aimed at enhancing the spatial skills of female engineering students enrolled at Michigan Technological University in the US. From 1993 through to 1998, Sorby used PSVT-R as a measurement tool in order to evaluate the spatial skills levels of first-year engineering college students just prior to them beginning their major engineering courses. Failing students were encouraged to take a 10-week spatial skills course,

which included 2D and 3D transformations, sketching multi-view drawings, and object transformation as some of the basic contents of the course. Each week, the students attended a two-hour lecture and a two-hour in-laboratory class. Following the course, PSVT-R was applied as part of the course final exam, and the reported results were found to be quite impressive. In the 6 year duration, a total of 186 students attended the course, and their second score was shown to have a 26.4 point significant increase over their first scores. Additionally, it was noted that those students who showed low-level spatial skills but attended the spatial training course achieved higher grades in a number of courses such as Introduction to Engineering, Mathematics, and Science when compared to students with low-level spatial skills who did not participate in the spatial training course.

In a similar study, Martin-Dorta et al. (2008) designed a three-week remedial course in order to enhance the spatial abilities of students by utilizing a 3D CAD modeling software (Google SketchUp) and a set of 24 aluminum physical items parts. The researchers used MRT (Mental Rotation Test) (Vandenberg & Kuse, 1978) for spatial relations factor and DAT:SR (Differential Aptitude Test: Space Relations) as the spatial visualization factor of spatial skill. A total of 40 civil engineering students (25 males, 15 females) voluntarily participated in a study of 12 hours over a three week period. The participants were all aged between 18 and 20 years old. The intervention consisted of three different exercises that were designed to be easy through to complex. The first exercise was about identifying the software and drawing some daily objects. The second exercise was related to drawing certain machine parts by their axonometric projection. In the third exercise of the intervention, the participant students were asked to generate 3D parts represented by their orthographic views. After the three week intervention period (one practice for each part), MRT and DAT:SR were applied as a post-test. Paired *t*-test results indicated that the remedial course using Google SketchUp had a positive impact on the spatial skill of the students, both in the MRT and DAT:SR tests. However, the research did not include a control or second experimental group to compare the results to a different kind of intervention, and is therefore unsurprising that a positive effect on spatial skill was reported after any kind of additional intervention.

Additionally, Google SketchUp is not a course material known to be especially designed to improve the spatial skills of students.

2.1.3.2. Games for Enhancing Spatial skill

De Lisi and Wolford (2002) researched the effects of computer games on the spatial skills of elementary school students. In a pre-test-post-test design research, participants (experimental group) played a computer game for total 330 minutes for a period of 11 weeks. The measurement tool for the study was a mental rotation test in which the experimental participant group performed better at post-test, while there was no difference in their pre-test. The results indicated that a significant increase in the students' mental rotation performance after having played the assigned computer games. However, it must be noted that the comparison group had no intervention while the experimental group received an 11-week treatment.

In another study that aimed to enhance spatial skill (Feng, Spence & Pratt, 2007) researchers used video games to explore if playing action-based video games was significant to the enhancement of spatial skill, especially for females. In the study, an experimental group played a non-action video game. Then, in a different experiment, the researcher showed that action-based video games significantly affected the spatial skills of learners, with females seeing a more significant improvement than males in both "useful field of view" and "mental rotation" tasks.

In a similar aimed study, Hun, Hwang, Lee & Su (2012) explored if a game-based spatial learning tool enhanced the spatial sense of elementary school students and would positively affect their math ability performance. Using cognitive component analysis, the researchers tried to create a spatial learning tool according to the results of computerized authentic spatial sense tests. In the first stage of the study, a total of 867 students participated by evaluating the questions of CASST (a Computer Aided Sketching Software). In the second stage, 99 participants were divided into three groups, with two experimental groups and one control group. One of the experimental groups were applied the intervention as a spatial learning tool, whilst the second experimental group used physical operations, and the control group

received no intervention. The study's results indicated that the math learning performance of all three groups showed a meaningful difference. Additionally, Experiment Group 1 (spatial learning tool) and Experiment Group 2 (physical operation) achieved significantly higher scores on their post-tests.

In another study, Martin-Dorta et al. (2013) also developed a game aimed at increasing the spatial skills of university students. A 3D mobile game application, called "Virtual Blocks," was developed in order to provide a 3D virtual environment to build models with cubes that helped students to perform visualization tasks so as to promote the development of their spatial skill during a short remedial course. As a validation study with 26 freshman engineering students at La Laguna University (Spain), the researchers concluded that the training had a measurable and positive impact on the students' spatial skill. In addition, the results from a satisfaction questionnaire that was administered showed that the Virtual Block game was considered by the participant respondents to be easy to use and a stimulating application.

2.1.3.3. Software for Enhancing Spatial skill

Software use in developing spatial skills are very popular and there is numerous research that uses drawing software. Rafi et al. (2005) examined if it was possible to enhance the spatial skills of preservice teachers' spatial skills. The study's participants were 98 preservice teachers registered to a Computer Aided-Design (CAD) course. Mental rotation and spatial visualization tests were administrated to the participants as a pre-test at the beginning of the semester. After the pre-test, a desktop-based software (Web-based Virtual Environment-WbVE) was used for a period of 5 weeks in a computer laboratory as an experimental group treatment. As expected, there was a significant difference seen between the pre-test and post-test scores of the participants in favor of the post-test scores.

Ault and John (2010) designed a single group pre-test-post-test design study with 41 civil, electronic, electrical, mechanical, and mining engineering students. Four modules of the web-based EnVISIONS software (Isometric Sketching, Orthographic

Projection: Normal Surfaces, Flat Patterns Rotation of Objects about a Single Axis) were used as the primary course material, along with workbooks. The students were presented with face-to-face lectures, followed by laboratory work in which students could use the related software. PSVT-R (Guay & McDaniel, 1977) was used as the measurement tool for spatial skills, both as a pre-test and as a post-test. The results of the study revealed that the participants gained significant improvement in their spatial skills.

Hauptman (2010) designed a software called "Virtual Spaces" in order to enhance the 3D geometric skills of students. The researcher worked with four groups of students, of which three were experimental groups and a control group who received no intervention. The researcher also attempted to see if self-regulating questions had any impact on spatial thinking. The participants were 192 high school (10th grade) students. The first experimental group used software and answered self-regulating questions, whilst the second experimental group used only the software, and the third experimental group only received the self-regulating questions. The fourth (control) group received no treatment. The study's results indicated that spatial thinking was improved by the use of the software and by the asking of self-regulating questions, since there was a significant difference found between the first and third experimental groups and the fourth (control) group in MRT (Mental Rotation Test) (Vandenberg & Kuse, 1978) and APTS-E (Spatial-Visual Reasoning test of the Aptitude Profile Series-Educational). Also, the second group (software only) achieved higher scores in the MRT and APTS-E tests when compared to the non-treatment (control) group. The results revealed that studying with Virtual Spaces 1.0 proved to be effective in the improvement of the participants' spatial thinking.

In their study, Martin-Dorta, Saorin & Contero (2011) applied a web-based training to 38 university students from the departments of Civil, Electronic and Mechanical Engineering. Additionally, a control group of 30 students received no additional training during the study. All of the participants completed the MRT (Mental Rotation Test) (Vandenberg & Kuse, 1978) as a measurement tool. The results revealed significant improvement in the average spatial visualization scores among

the experimental group in comparison to the control group. The students also positively valued the course accomplishments; expressing their preference for such multimedia content over the conventional pencil and paper formats, and for online learning over face-to-face lectures.

In a recent study, the possible effects of Augmented Reality (AR) based virtual manipulatives are examined in comparison with physical manipulatives (Gecu-Parmaksiz & Delialioğlu, 2018). The aim was to investigate the development of spatial skills of preschool children with teaching them geometric shapes. Researcher used a quasi-experimental research design in order to examine the effects of AR and real objects. Participants were 72 preschool children, ranging from age five to six. Experimental group used AR applications with tablet computers and the control group used physical manipulatives for four-week experiment period. Both groups performed similar tasks with two different tools (AR-real objects). Two data collection tolls for spatial ability were conducted as pre-test and post-test. The results proved that AR group significantly had increasing spatial ability test scores.

In a similar study Virtual Reality learning activities were used develop their spatial ability (Molina-Carmona et al., 2018). Researchers have designed an experimental study using an on-purpose learning activity based on a virtual reality application. The intervention includes a virtual environment where geometric shapes are shown and manipulated by moving, rotating and scaling them. Participants were divided two groups. Control group with a traditional computer with screen, keyboard and mouse and experiment group with virtual reality goggles with a smartphone. Participants completed Purdue Spatial Visualization Test—Rotation (PSVT-R) as pre-test and after 4 weeks of intervention as post-test. The results indicated that there is significantly increasing test scores for both groups and the VR group significantly higher post-test scores than control group.

2.1.3.4. Physical Manipulatives for Enhancing Spatial skill

Various physical manipulatives are used in math and geometry instruction. These real objects are often used in classrooms environments to help students to understand

abstract concepts by examining real ones. By this, students can understand the abstract concepts like volume and surface area of 3D shapes. Teachers often use real objects to teach these terms. This method helps students to visualize the volume and surface area of each object. The use of physical manipulatives can facilitate the acquisition of math and geometry in classroom environment (Baki et al., 2011).

Literature presents research that use real objects to enhance spatial ability. Drawing and sketching real 3D objects like cubes, pyramids and other geometric shapes is a method to enhance spatial ability. On the other hand, using real objects may be more effective for youngers who are not able to make abstract operations and it is more helpful for terms like volume and surface area.

In an experimental research, Yıldız (2009) examined the effect of three-dimensional learning software and physical manipulatives on spatial skill (spatial visualization and mental rotation) of primary school students. The researcher designed a learning simulation which had three-dimensional virtual unit blocks as well as physical manipulatives. The learning simulation was applied to the experimental group, whilst the blocks were applied to the control group. The results of the study proved that whilst there was a significant difference seen between the pre-test and post-test scores of both groups for spatial visualization, mental rotation ability test scores showed a significant difference only for the control group. Additionally, the total spatial skill scores of the participants did not point to a significant difference among the experimental groups.

In a similar research, Baki et al. (2011) studied the enhancement of spatial visualization skills of preservice mathematic teachers using a dynamic geometry software and physical manipulative. The researchers used two experimental groups, as well as one control group for the purposes of results comparison. In the first experimental group, the participants (n = 32) used Cabri 3D as a virtual manipulative for 2 hours per week over a 10-week period of a solid geometry course. The second experimental group (n = 30) used real objects over the same time period, and the control group (n = 30) used no additional materials and continued with the traditional course design. All three groups had worksheets which the experimental

groups' prepared based on 3D software and physical objects. Before and after the intervention, PSVT-R (Purdue Spatial Visualization Test:Rotations) (Guay & McDaniel, 1977) was used as the measurement tool for spatial visualization skills. The results proved that the spatial skill scores of the students in the experimental groups were significantly higher at the end of the semester compared to the beginning, but not for the control group. Additionally, it was found that the dynamic geometry software and physical manipulative groups showed higher performances in their spatial visualization skills than the control group. Also the Cabri 3D group performed better than the physical manipulative group only on the "views" section of PSVT-R. On the other hand, it may be noted that positive results in favor of the experimental groups could be termed as "expected results," since the experimental groups received additional practice time, whereas the traditional classroom (control) did not. Notably, there was no significant difference seen between the two experimental groups, with the exception of the "views" section of the PSVT-R.

2.1.3.5. Developing Mobile Learning Environment

Common usage of mobile tools like smartphones, PDA's (Personal Digital Assistants), and tablet personal computers have globally shifted today's instruction. Instructional events today include complicated sets of actions that employ high-tech material for the interaction of peers and instructors (Tallent-Runnels et al., 2006). However, this new direction of instruction has also been accompanied by certain problems. The effective use of classroom-based instruction together with new technologies such as mobile tools and social networks are still arguable (Kukulska-Hulme, 2010). Most studies in the early literature of mobile learning were concerned with the use of mobile devices to just present or carry learning materials (content) to these small portable screens (Thornton & Houser, 2001). The usage of mobile devices in education cannot be defined as simply providing content on small portable devices.

In today's education, it is insufficient for instructors or researchers to provide learners with content for mobile screens without creating a level of interaction for learners through content and community (student-student, student-instructor,

instructor-students). Commonplace usage of mobile devices in education can only be sustained through effective instructional designs efficiently integrated within these still relatively new mobile devices.

The variety of tools used for developing spatial skill has been heavily based on the emergence of new technologies, with a desire and interest of researchers to utilize these new technologies within educational contexts. Student motivational factors may be another reason, since new tools are always seen as more attractive to younger generation users. Easy access to the Internet, the power of multimedia, as well as their mobility are other reasons for researchers to have selected the latest technological tools.

On the other hand, there is limited evidence given in the literature about the instructional design or framework of these methods, and little information about why researchers have preferred to utilize games, web-based instruction or drawing software. A brief summary of how researchers have used such tools for supporting spatial skill is provided in Table 2.1.

Table 2.1. *Literature about Data Collection, Instruments and Datasets*

Author/ Journal	Tool	Time period	Participants	Instructional Design	Measurement Tool	Result
Kurtulus (2013) Computers & Education	Internet access pc	4 weeks	60 university students (preservice teachers)	Virtual Tours of museums, Drawing floor plan	PSVT-R (Guay & McDaniel, 1977)	+
Martin-Dorta et al. (2013) Multimedia Tools & Applications	Touchscreen handheld devices	1 week	26 university students (engineering)	Virtual Blocks (3D mobile game app)	MRT (Vanderberg & Kuse, 1978)	+ Easy to use
Martin-Dorta et al. (2008) Journal of Engineering Education	Desktop computers, real objects	3 weeks	40 university students (engineering)	Google SketchUp	MRT (Vanderberg & Kuse, 1978) DAT:SR (Bennett, Seashore, & Wesman, 1973)	+
Martin-Dorta et al. (2013) Multimedia Tools and Applications	Mobile devices	3 weeks	68 university students (engineering)	Web-based online software	MRT (Vanderberg & Kuse, 1978) Satisfaction survey	+ Preference for multimedia

Additionally, instructional designers and theorists present powerful arguments for various different instructional methods, as can be seen in Figure 2.1. While lecture and presentations have strong sides like being standardized and structured, demonstration and modeling present realistic showing and easier to apply. On the other hand drill and practice method lets learners to study for mastery and automization.

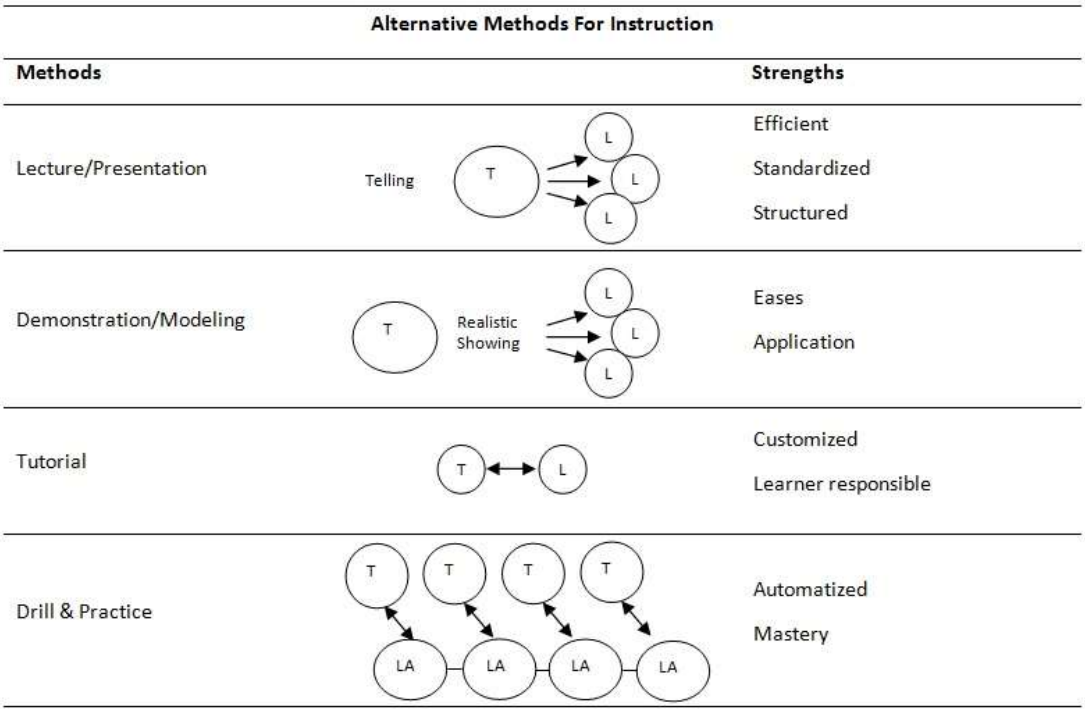


Figure 2.1. Alternative Methods for Instruction (Reigeluth, 1999, p. 23)

McGee (1979) defined spatial skill as an important human skill which shows critical importance in how individuals perceive, organize, and interact with their environment. Additionally, there are similar definitions of spatial skill that prove it is highly related to the retrieval, retention and transformation of visual information in two- and three-dimensional environments.

There are significant clues about spatial skill as a strong predicator of students' general achievement and also of its strong effect on math and science achievement (Batista, Wheatley, & Talsma, 1982; Smith, 1992; Sorby, 1999). Spatial skills are also shown as predictors for the future success of engineering students in their professional life (Lieu & Sorby, 2008; Sorby, 2009; Thornton, Ernst, & Clark, 2012). Additionally, there have been studies published that link spatial skill to architecture and some other science-based disciplines (Mohler, 2006).

On the other hand, spatial skills may be defined as a prerequisite skill since students do not use these skills directly in life, but they can benefit more if they are able to

apply these skills without conscious effort (Roblyer, 2004). Gagne (1982) and Bloom (1986) referred to this as “automaticity of skills.” Gaining automaticity of skills differs from student to student. While some students acquire automaticity through repeated use of skills in practical situations, others acquire this automatic recall more efficiently through isolated practice. Drill and practice, instructional gaming and certain simulation courseware can provide the ideal means of practice when tailored to individual skills needs and learning pace (Roblyer, 2004).

Reigeluth (1999) suggested “demonstration of skills,” “explanations or generalities about how to do it” and “practice with feedback” as means to support or enhance the learning of skills. As it can be seen in Figure 3.5 drill and practice is a useful method for automatization and mastery. Roblyer (2004) also offered technology-based solutions to specific learning problems. Simulation software, math tools (e.g., Geometer’s Sketchpad, GeoGebra), and specific software are suggested for difficult topics that include abstract and complex issues, or where manual skills are being learned. These technologies offer relative advantages as they are more visual with graphic displays that help make abstract concepts more concrete and easy to manipulate. Additionally, these technologies give students the chance to perform significant skills practice.

The current study supports the combination of drill and practice applications with tablet and desktop computers in order to provide students with opportunities for the development of spatial skills. This approach is aimed at improving the learning conditions of students, as well as helping them in the improvement and automatization of spatial skills.

Since the current study aimed at vocational high school students undertaking complex cognitive tasks (e.g., mental rotation, 2D and 3D mental imagery, identifying poorly structured 3D parts) through focusing on specific skills (i.e., spatial skills), the design and sequencing of the learning material is a key element. In the industrial age paradigm, sequencing was defined as breaking content down into smaller parts and presenting each piece separately, one at a time. Today,

there is a more holistic approach as it may be based on order of performance, especially if the objective involves the delivery of training (Reigeluth, 1999).

In sequencing, the need for instruction is critical, especially for complex tasks, where the relationship between topics is of significant importance (where a strong relationship exists), and when the size of the content is significant (where extensive content exists). Similarly, spatial skill entails a very complex set of events in areas such as surgery though to engineering, with the easiest form of action, mental rotation, being very much related to complex mental imagery such as, in the case of engineering, the mounting or assembly of multiple different parts.

With these in mind, researcher decided to design a drill and practice application that can be easily used in mobile devices, tablet computers and desktop computers. Design issues and development phases of the tool are detailed in methodology part of this thesis.

2.1.4. Media Comparison Studies and Effects of Input Devices

As technology develops, new tools emerge in educational settings. Comparison of latest tools (televisions, multimedia, web-based tools, computers and mobile devices) played important role in history of instructional technology field. Clark (1983) published a meta-analysis that examined the influence of media on learning where he reported that media do not influence learning under any circumstances. Clark (1983) defends that medium is not the message but it is just a vehicle helps to delivered instruction and does not influence instruction. Additionally he offered to researchers to end exploring the relationship between media and learning unless new theories are suggested (Clark, 1983).

As a reply to Clark (1983), Kozma (1991) put forward the relationship between media, content, and the interaction of the learner with that environment. Additionally Kozma (1991) concluded that various media have specific systems and processing capabilities that can address to learner and produce a unique experience. In this study, there are three different tools (tablet, desktop and booklets) which have different input styles (finger, mouse and pencil) and different modality (videos, 3D

objects, still pictures). Besides, some of these tools may create additional motivation or may present mobility for students. In this part, comparison studies related with spatial skills were reported.

Literature presents studies that compare different media or techniques to enhance spatial skill. Rafi et al. (2006) investigated whether drawing instruction using three different methods improved spatial visualization and mental rotation with 138 undergraduate students placed in three groups. The first experimental group used EDwgT (Engineering Drawing Trainer) in the computer laboratory with preinstalled multimedia software, while a second experimental group used conventional instruction with printed material and digital video clips, and the control group used just printed materials only. The results proved that students using EDwgT received significantly higher scores in spatial visualization, whilst the video-enhanced group were also reported to have had higher scores than the conventional (control) group. Additionally, similar results were found in the mental rotation accuracy scores of the participant students. While the computer-mediated experimental group received the highest scores, the video-enhanced experimental group also received higher scores than the conventional (control) group. On the other hand, the groups were not found to differ significantly in terms of their mental rotation speed rates.

Samsudin, Rafi, and Hanif (2011) conducted an experimental research to enhance the spatial skills of students and to measure its impact on their orthographic drawing performances. The researchers employed a sample comprised of 98 secondary school students who were randomly assigned into two experimental groups and one control group. The first experimental group were administered an interaction-enabled intervention, whilst the second experimental group were administered an animation-enhanced intervention, and the control group were trained using conventional printed materials. The research instruments employed were computerized versions of the Mental Rotation and Spatial Visualization tests. The results indicated a significant increase was found in the spatial visualization and mental rotation accuracy scores of experiment group. Additionally, technology-

based training methods appeared to be more efficient, with both experimental groups having performed better than the control group in terms of mental rotation accuracy.

Wang, Chang, & Li, (2007) compared the possible effects of 2D- versus 3D-based media tools on the spatial skill. With a pre-test/post-test comparison group design experiment was conducted with two groups and 23 participants. Learning materials delivered the same content to both groups with different media representations (2D and 3D web based HTM pages). Two versions of media, 2D-based and 3D-based ones, both include seven HTML pages delivering the same content. Results of the study have proved that comparison and experiment groups did not have significant difference in post-test scores. Researchers focused the sample size of the research and emphasized that a larger sample size may give significant results. However, type of instruction (web based instruction), design of the media and content are some other critical aspects for enhancing spatial skill.

There are studies that may give researchers clues about use of different input devices, especially for electronic devices. Using tablets with fingers as input tools, or a mouse with desktop computers may create varied results. In their research, Zabramski, Gkouskos, & Lind, (2011) compared line-tracing performances of three different input tools; mouse, stylus and finger. Results proved that for at least moderately complex drawing tasks, touch input (finger) is much more efficient than mouse or stylus. Researchers advised to use finger in graphics design applications. This result may give us idea to use touchable tools for enhancing spatial because they may produce effective results in compared to desktop computers. Additionally, participants of the study preferred finger as the most user-friendly input tools while, they were putting pen second and mouse input last.

In another input research, Findlater et al. (2013) compared four different tasks for touchable screens and desktop computers: pointing, dragging, crossing and steering. In all of the tasks, participants that used finger as input (touchable screens) outperformed desktop computers group. Additionally, results proved that the touchable screens (finger input) reduced the performance gap between older and younger adults. More, the touchable screen resulted in a significant movement time

reduction of 35% over the mouse for older adults, compared to 16% for younger adults. This result supports the idea of using tablet computers to enhance spatial skills of students since they presents more faster and efficient input when they are compared to mouse and stylus.

2.2. Summary

As can be understood from the literature, most research attempts to identify the possible effects of mobile devices and their software on spatial skill. The participants of these studies are university students in nearly all of these studies. Since spatial skills are significantly related to science and math-based disciplines, the research study groups are mostly representative of math, chemistry, geology, surgery or engineering courses. Additionally, it may be stated that most of the studies aimed to identify possible increases in spatial skill targeting engineering faculties.

For the case of Turkey, it may be reported that vocational high schools are a significant source for the industrial and technology-based workforce. However, to the best of the knowledge of the current study's researcher, there has been no single research published in the literature in this research area that has targeted vocational high school students.

Current conditions and achievement rates of vocational high schools in Turkey are acknowledged to be significantly problematic (Ayas & Pişkin, 2011; Çapulcuoğlu & Gündüz, 2013; Sönmez, 2010), and therefore additional consideration needs to be applied to the education delivered within this type of Turkish high school.

Second, Geometer's SketchPad, Google Sketchup (Martin-Dorta et al., 2008) and GeoGebra are some of the geometric- and mathematically-based software which permits students to make calculations, equations, and to create drawings and sketches. Numerous research studies have tried to find the potential effects of these tools, or try to integrate these tools into student courses (Dixon, 1997; Erkoç, Gecü, & Erkoç, 2013; Leong & Lim-Teo, 2003). On the other hand, none of these tools were primarily designed to generate solutions for problematic issues posed within educational courses, or specifically designed as instructional material for enhancing

spatial skill. Although it is possible to integrate some part or some specifications of these tools into courses or instructional designs, the objectives and properties of these tools do not exactly match with the aims of the research community.

Additionally, in most of the research that seeks to establish the potential effects of web-based software, games or other mobile tools on spatial skill, the studies are based on administering test applications to experimental groups, with a control group for comparative purposes only (i.e., no interventions were applied to the control groups in most studies). Positive results of these studies in favor of experimental groups may therefore be sourced from the intense effects of administering new interventions.

In light of this literature review, in designing and developing a new instructional tool and identifying the significant gap for vocational high school students in the case of Turkey, the researcher of the current study decided to create a drill and practice based mobile learning environment (adaptive for mobile devices, tablet computers and desktop computers). While experiment group uses drill and practice application on tablet computers, comparison groups use the same content, but through different mediums; those being desktop computers and paper-pencil booklets. It is expected that the current study will be significant offering a new instructional tool for enhancing spatial skill and a first step towards increased emphasis placed on vocational high school students' spatial skills, and therefore a pioneering study for future research in this area.

CHAPTER 3

METHODOLOGY

3.1. Introduction

This chapter presents the methodology of the research. The design of the study, its variables, participants, data collection instruments and procedures, mobile learning environment are all reported within sections of this chapter.

3.2. Research Questions

This study seeks to answer the following research questions and related sub-questions:

Research Question 1: Is there any significant difference in spatial skill scores of within groups before and after interventions?

Sub-question 1.a: Is there any significant difference in spatial skill scores of paper-pencil group before and after intervention?

Sub-question 1.b: Is there any significant difference in spatial skill scores of desktop computer group before and after intervention?

Sub-question 1.c: Is there any significant difference in spatial skill scores of tablet computer group before and after intervention?

Research Question 2: Is there any significant difference between three intervention groups according to their post-test scores?

Research Question 3: What are the perceptions of participants about mobile learning environment?

3.3. Design of the Study

The study followed a mixed-methods research methodology in order to compare the effects of use of three different media, tablet computers, desktop computers and paper-pencil material on spatial skills of vocational high school students. In addition, semi-structured interviews were conducted to obtain qualitative data regarding the participants' perceptions about the mobile learning environment.

3.3.1. Embedded Mixed Method Design

Mixed method research represents an opportunity to take advantage of the strengths of both quantitative and qualitative data (Miles & Huberman, 1994). While the quantitative method provides researchers with the opportunity to monitor and evaluate the scores of instruments such as questionnaires, surveys and polls, which are commonly used to describe frequencies and trends for large numbers of people; qualitative methods have the potential to reveal different perspectives of complex problem situations through the acquisition and assessment of in-depth data utilizing data collection tools such as interviews of varying types (Creswell, 2012).

The embedded design, a type of mixed method research, is mainly aimed at supporting the primary data with a second form of supplementary data. In the embedded design, data collection phases may be designed as either simultaneous or sequential. Embedded design involves the collection of a second form of data to support and aid the analysis of the primary data. Although the second set of data may be in either forms, qualitative or quantitative, researchers generally employ quantitative data as the primary source and qualitative data as the supportive. While collecting qualitative data prior to the intervention helps the researcher to tailor the design more specifically to the selected participants, collecting qualitative data following on from an application may reveal detailed ideas about how the participants experienced the intervention (Creswell, 2012).

The difference between the embedded design and the explanatory sequential design is that the embedded design tries to respond to different research questions. The researcher therefore collects different sets of data during the study, and then analyses

them separately in order to address two different research questions or sets of questions, whilst the explanatory mixed method attempts to elaborate upon and inform the first set of data with the second and generally qualitative dataset. The researcher may use the embedded design for analyzing the possible impact of an intervention (as the first research question), and then reporting on how the participants experienced the intervention (as the second research question) (Creswell, 2012).

Since there are three different research questions in the current study and the researcher collected two different kinds of data in order to answer them, the embedded mixed method design was selected as the most appropriate research design for the current study.

The embedded design enables researchers to collect two kinds of data simultaneously or sequentially, but to then analyze them separately in order to addresses the different research questions of a study (Creswell, 2012). For the first two research question ("1. Is there any significant difference in spatial skill scores of participants before and after interventions? 2. Is there any significant difference between three intervention groups according to their post-test scores?"), the researcher collected quantitative data both prior to and immediately following the intervention. Researcher collected qualitative data after completing the 8 weeks of intervention for the last research question (3. What are the perceptions of participants about mobile learning environment?).

In the current study, quantitative data was used to address whether or not the intervention (mobile learning environments) had an impact on the outcome (spatial skills of students), and if there was any significant difference between the three different experimental groups; whereas, the qualitative data was used in order to assess how the participants experienced the intervention by collecting their thoughts about their mobile learning experience. In this form of mixed method design, the qualitative data also provides additional information for the first phase (Creswell, 2012). Figure 3.1 illustrates the research steps of the embedded mixed-method design (Creswell, 2012).

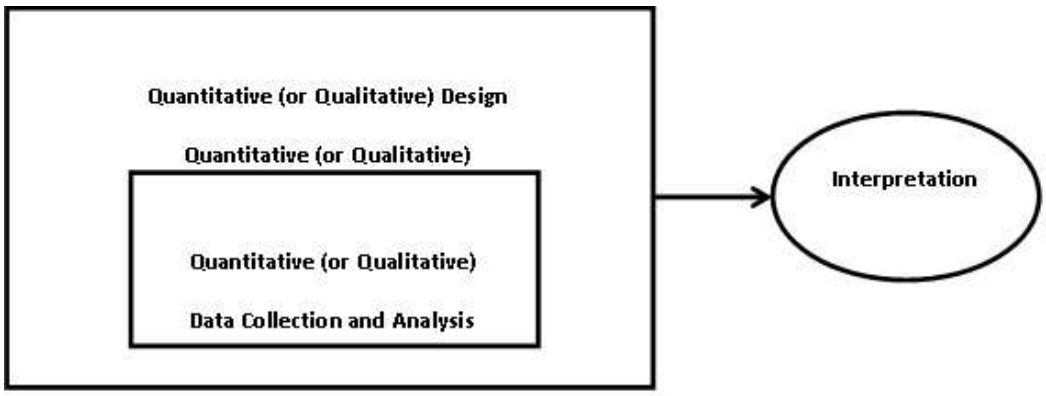


Figure 3.1. Research Design of the Study (Creswell, 2012, p. 541)

3.4. Variables

The spatial skills of the participating students, which are tested by way of the Mental Rotation Test adapted for the Turkish context (Vandenberg & Kuse, 1978), is the dependent variable of the current study. While there is ongoing debate about the components of spatial skill and its measurement, many contemporary research studies utilize MRT scores (Vandenburg & Kuse, 1978) as an indicator of spatial skills. The independent variables of the study are the interventions, with tablets, desktops and printed material studied throughout the eight-week intervention.

3.5. Participants and Sampling

Since there are two different kinds of research questions in the study, two groups of participants were included. As a sampling strategy, convenience sampling was used for the first part of the study. Maximum variation sampling was selected as the second sampling methodology for identifying the interview participants for the qualitative phase of the study.

Table 3.1. *Participants*

	Tablet Group	Desktop Group	Paper-Pencil Group	Total
	n	*n*	*n*	*N*
Participants	28	30	27	85

Although there are several vocational high schools in research site, the researcher decided to use the two schools that were geographically closest. One of those schools was used to retest the validity and reliability of the MRT, whilst the other was used for the experimental application of the study.

Since the experimental design required three groups of participants, the researcher decided to use three distinct groups of students without changing the existing learning environment. As the interventions lasted for 5-10 minutes of each classroom hour, the school principal offered to use classes as intact groups without need for random assignment. The pre-test scores of the participants proved that the existing class configurations were appropriate for use them as intact groups since there was no significant difference found between them in terms of their pre-test scores (see Appendix F).

There were a total of 85 participants aged 14 to 16 years old in the three groups, with all of them enrolled in the 9th grade of vocational high school. Most of the participants are coming from the countryside every day with school services. The rest of the students are coming from suburban side of the city. Socio-economic status of these students is not high and there is high rate of absenteeism as the teachers reported.

Additionally, as it is reported in results, nearly half of the participants' fathers do not have a full time job. Working rate is very low in mother. The rate of having full-time job is 10%. This is similar when the parents' graduation schools are examined. More than half of the participants' mother did not continue to high school. Similar to mother graduation, less than half of the fathers' of the participants are graduated from high school or higher education organizations. This presents additional clues of the socio-economic status of the participants.

All of the participants of the study were male, since no females had registered to the departments of mechanics, automotive, or electricity at the vocational high schools. The reasons behind this phenomenon have been detailed in various sections of this

study. Similarly, all of the participants of this study are from mechanics department of vocational high school.

Six participants were selected by way of purposeful sampling for the qualitative phase of the study. Considering their pre-test and post-test scores, maximum variation sampling was applied in order to identify the participants. Six of participants who made progress through the intervention and who are not able to increase his score are selected to reach a maximum variety. All of the participants were selected from the tablet computer experimental group, since the research question is aimed at eliciting the experiences of the tablet computer group.

3.6. Data Collection Tools

Three data collection tools were used by the researcher for the establishment of the datasets to test the study's research questions. The first tool was the demographic information form which was primarily based on physical and socioeconomic information about the participants. The second data collection tool was an adaptation of the Mental Rotation Test or MRT (Vandenberg & Kuse, 1978), which was utilized in the evaluation of the students' spatial skills. The third tool employed in the study was a semi-structured interview form, which was used to gather the interviewed participants' experiences about the intervention. Details about each of the tools are provided in the following subsections.

3.6.1. Demographic Information Form

The demographic information form was a tool specifically prepared by the researcher for the current study. The form consists of 10 questions about the participants' age, socioeconomic status, and parental information etc. In the current study, demographic information means more than descriptive and frequency data since the dependent variable, spatial skill, is highly affected by the subjects' maturity. Additionally, the tool contains questions about the participants' computer literacy, the computer-based games they frequently play, and the mobile computing devices they own or have access to. The literature states that the use of mobile devices, computers and the playing of computer-based games can positively affect

spatial skill. Each of these aspects was considered in the formation of the demographic tool, which can be found in Appendix A.

3.6.2. Mental Rotation Test

There are ongoing arguments about how to measure spatial skill sourced from the various and arguably inaccurate definitions in the literature (Linn & Petersen, 1985; Martin-Dorta et al., 2008). It is therefore possible to note that different approaches and definitions have been proposed for both the definition and the factors of spatial skill. These differences are presented in Chapter 2, which is the Literature Review of the current study. Additionally, the literature offers frequently used quantitative measurement tools for spatial skill studies. One of the mostly used measurement tools is Mental Rotation Test (Vandenberg & Kuse, 1978).

In this study, the researcher used MRT as a measure of spatial skill. However, we must consider that MRT is basically focused on one of the components of spatial skill, "spatial visualization." Readers should note that McGee (1979) identified the components of spatial skill as "spatial visualization" and "spatial orientation" while "spatial visualization" relates to manipulating, rotating or twisting pictorially given objects, "spatial orientation" is defined as perceiving environmental scenarios.

The internal consistency coefficient of the MRT was reported to be .88 and its test-retest reliability as .83 (Vandenberg & Kuse, 1978). Developers calculated these values with a sample of 3,268 adults and adolescents of age 14 years or older. The MRT is widely used in studies as a measurement tool to investigate the possible effects or relations of spatial skill (Mäntylä, 2013; Meneghetti, Gyselinck, Pazzaglia, & De Beni, 2009; Peters, 2005).

The researcher retested the validity and reliability of MRT with 244 students prior to using it. Results of the Exploratory Factor Analysis (EFA) indicated that the first component has the highest eigenvalue and that the following components have very low values (see Figure 3.2.). This result proves that the measurement tool is a one-dimensional tool.

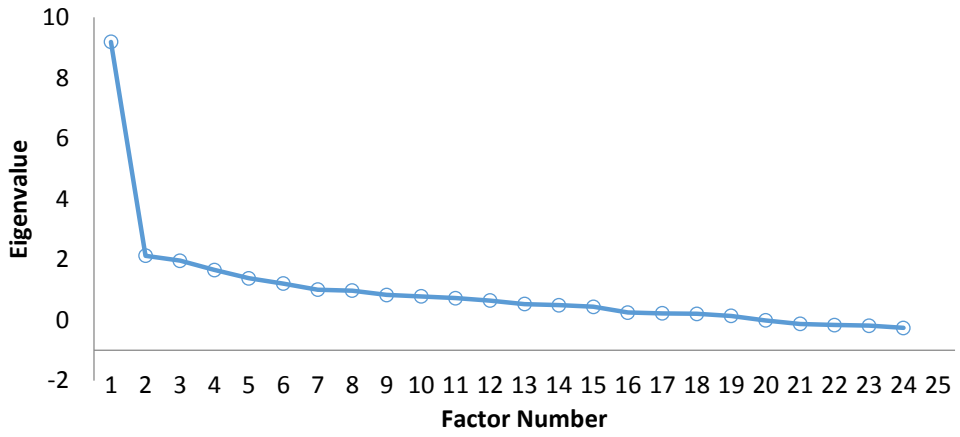


Figure 3.2. Scree Plot Graph

As a result of the EFA, factor loadings of the items were examined and the lowest factor load value was observed to be .32 (see Table 3.2.). This result presents evidence for the construct validity of the tool. The alpha coefficient for the 24 items was found to be .82, suggesting that the items have relatively high internal consistency. A reliability coefficient of .70 or higher is considered "acceptable" in most social science research situations (Santos, 1999). As a result, it can be stated that the scale measures the spatial visualization component of the spatial skills of vocational high school students in a valid and reliable way.

Table 3.2. *Items and Factor Loads*

Item Number	*Factor Load*	*Item Number*	*Factor Load*	*Item Number*	*Factor Load*	*Item Number*	*Factor Load*
M1	.59	M13	.51	M7	.32	M19	.34
M2	.68	M14	.75	M8	.61	M20	.43
M3	.43	M15	.68	M9	.72	M21	.71
M4	.44	M16	.79	M10	.49	M22	.40
M5	.58	M17	.47	M11	.52	M23	*.73*
M6	.76	M18	.44	M12	.55	M24	.67

MRT is a multiple-choice test which has two correct answers for each item. Each item has a target figure shown on the left and four stimulus figures (multiple-choices) on the right. Two of these stimulus figures are rotated versions of the target figure, and two cannot be matched to the target figure. There are 24 items in MRT and participants received one point if both of the stimulus figures that matched the target figure were identified correctly. No credit was given for a single correct answer. This means that the maximum score obtainable from the MRT is 24. An example item from MRT is given in Figure 3.3.

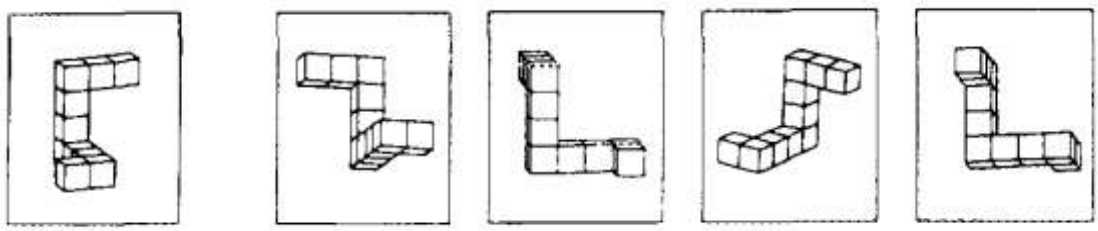


Figure 3.3. Example item from Mental Rotation Test (Vandenburg & Kuse, 1978)

3.6.3. Interviews

In this study, there are two kinds of data (quantitative and qualitative) and interviews were the data collection instrument of the qualitative part of the study to explain the perceptions of the participants about mobile learning environment. Interviews are one of the most important data sources for qualitative research (Yin, 2009).

In this part of thesis, researcher explained the all interview forms that he used for this research. The first three interview forms were used to make a clear analysis for the need of research and for the results of the pilot study. The fourth interview form is the data collection tool and it was used in order to reply third research question.

The researcher initially created three different interview forms in order to gather the participants' thoughts, and also of their teachers during the pilot implementation. The first two interview forms were used at the outset of the study in order to conduct

a “pre-analysis.” The researcher conducted interviews with three different students (Appendix D) and two teachers (Appendix E). These initial forms were semi-structured and designed to gather information about the need for a possible learning environment. The third interview form the researcher created was used to gather information about the experiences of the pilot study’s participants (Appendix C.). This form included controls and checklists about the technical capabilities of the mobile learning environment assessed in the pilot study. The form additionally included questions that sought the advice and criticism of the pilot study’s participants.

The fourth interview form was the semi-structured interview form that was applied in the main application of study (Appendix B.) to reply third research question. It was used in order to gather the experiences of the study’s participants about the mobile learning environment and therefore to gather data so as to respond to the third research question.

The form was semi-structured in its design so as to elicit details about how the participants perceived about their learning experience. Since the mother tongue of students is Turkish, the semi-structure interview form was prepared in Turkish. This first draft of the interview questions was prepared based on the related literature and considering the pilot study results. This form was sent to three experts, one of them is a Turkish language instructor in a state university, second is a measurement and evaluation expert who is lecturing in a state university and third one is an instructor in computer technology department, to be controlled in terms of clarity and appropriateness to the aim of the research question.

After getting critics and suggestions of experts, former questions of the form were reconsidered and some new questions were added. For example, one of the experts suggested adding questions about length of the session (intervention). Latest version of the interview form was sent to same experts for final check and the interview form preparation process was finalized.

The latest form of interview has nine questions. Questions mainly aimed to gather data about use of tablet computers in learning environments, the specifications of the software, experiences about the eight week intervention and positive and negative sides of the experience.

Researcher conducted interviews after 8 weeks of intervention. All of the interviews were conducted in classroom settings and each interview took between 5 and 10 minutes. All interviews were sound recorded with the permission of the interviewees.

3.7. Data Analysis

The researcher collected three types of data for this study. The first dataset was sourced from the demographic information form, and contained demographic information and other variables like "playing computer games," "having tablet computer" etc. that the literature suggested may affect the dependent variable, spatial skill. The second dataset was sourced using the MRT and consisted of scores that were used as measurements of the participants' spatial skills. The third dataset was formed from the transcribed semi-structured interviews conducted with the participants in order to learn about their experiences (see Table 3.3).

After receiving the permission of the school principals and the parents of the volunteer student participants, each of the participants completed the demographic information form. As a second step, the MRT was conducted as a pre-test exercise in order to analyze if there was any significant difference between the three classes. Fraenkel, Wallen, and Hyun (2011) stated that researchers may use intact groups without changing the existing learning environment and classroom setting.

Table 3.3. *Data Collection Procedure, Instruments and Datasets*

	Instrument	*Aim*	*Practitioners*
Before intervention	Demographic Inf. Tool Mental Rotation Test	Demographic Inf. Pre-test	Participants Participants
After intervention	Mental Rotation Test Interview form	Post-test Perceptions	Participants Participants

Since the pre-test proved there to be no significant difference between the three groups (classes), the researcher randomly chose one of the classes as the experimental group and the two other as the control groups. The experimental group used the mobile learning environment for a period of 8 weeks, first control group used the same material with desktop computers, and the second control group used paper-pencil materials. All three groups' applications ran concurrently. After 8 weeks of intervention, participants completed the MRT a second time as a post-test.

After analyzing the post-test results, the researcher applied purposeful sampling to select prospective interviewees for the qualitative phase of the study. Semi-structured interviews were then conducted with six selected participants. Results were reported after transcribing the qualitative data and thematic coding was completed.

The data collection and analysis process flow is illustrated in Figure 3.4.

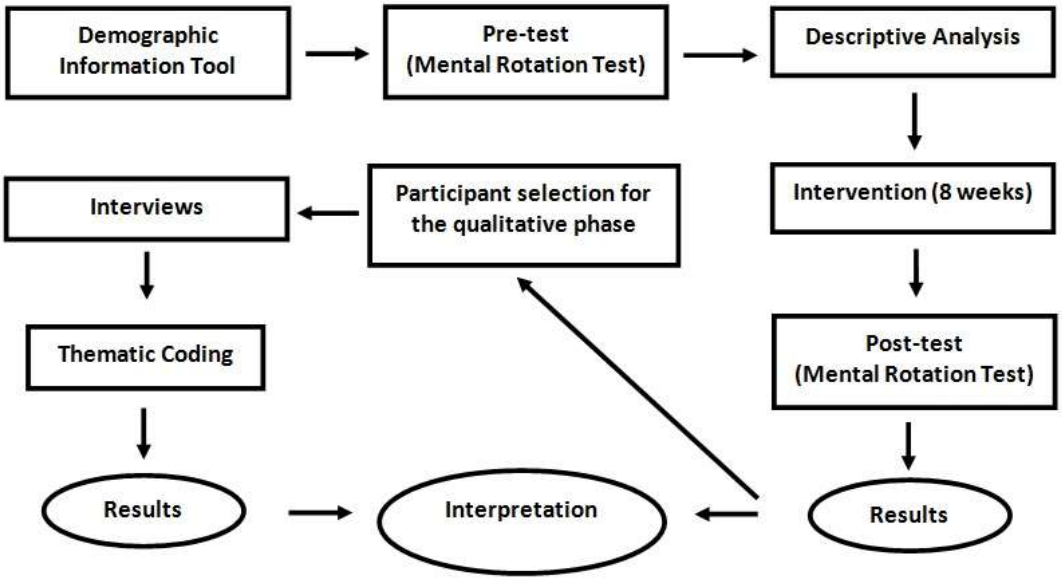


Figure 3.4. Data Collection and Analysis Process Flow

3.8. Trustworthiness

While the researchers use terms validity and reliability for accuracy of quantitative research, trustworthiness have the same meaning for qualitative study (Lincoln & Guba, 1985). To provide trustworthiness of a qualitative research, there are some strategies that must be taken like inter-coders agreement, peer review, debriefing, rich description and triangulation (Marshall & Rossman, 2011). Researcher used inter-coder agreement, triangulation and rich description.

Researcher used two other coders for inter-coder agreement of this study. One of the coders is an assistant professor in the Department of Educational Sciences. She has Ph.D. degree in measurement and evaluation. She conducted numerous research using qualitative methods and experienced in qualitative study. The other coder is an instructor the Department of Computer Technology. He is a Ph.D. student and got her B.S. degree from CEIT. He got courses on instructional technology, educational research and statistics and used qualitative methods in some of his research. Before coding starts, three coders came together and discussed the procedure of the study. Then, they coded one the transcription of the interviews. Researcher and coders compared their findings (codes) in terms of their differences and similarities just completed coding. Researcher and coders negotiated on differences and agreed on

codes. After that researcher and coders coded all data (six transcriptions). Inter-coder agreement is found as .94 between three coders as Miles and Huberman (1994) pointed out .80 inter-coder reliability score is sufficient. Coders meet again to provide full agreement and they negotiate on differences till full agreement was provided.

As a second strategy for trustworthiness, the researcher used triangulation. Researcher attended all the class hours to make a clear observation of interventions and too see natural context of the research and to gain insight about the phenomenon, there is no use of an observation form.

The last strategy that researcher used for the trustworthiness of qualitative part is rich description. Researchers must present detailed information about the procedure and steps of the qualitative research for readers. The aim of detailed explanation is easy understanding of phases and results of the research (Marshall & Rossman, 2011). The researcher gave details of each phase to provide rich description about the study. By this, those who wish to benefit from this research may easily have understanding about the procedure, phases and findings.

3.9. Role of the Researcher

In this study, researcher has a number of roles. First of all, researcher made the design and development of the software used in the tablet and desktop computers, and booklets that paper-pencil group used.

Second, researcher is the lecturer for the paper-pencil group. Since tablet and desktop groups have briefing videos in software and paper-pencil group does not have a chance to have videos on their booklets, researcher made small lectures before each intervention.

Third, researcher was in the experiment site through all intervention weeks. Researcher was in laboratories and in classes with the teachers and replied the questions of the participants throughout the experiment.

3.10. Mobile Learning Environment

In this part of the study, design and development phases of the tablet and desktop computer adaptive mobile learning environment has been explained. Simplifying conditions method, steps taken in design and development were detailed. Content and organization of the tool were presented with storyboards and screenshots. Lastly pilot study was reported.

3.10.1. Simplifying Conditions Method

The aim behind designing a mobile learning environment was to enhance or support the spatial skills of the participants as the development of spatial skills is directly linked to the future success of their professional life (McGee, 1979; Sorby, 1999). Previous studies that aimed to enhance spatial skill have employed various tools and methods. Web-based tools (Kurtulus, 2013), off-line computer software (Martin-Dorta et al., 2008) and real objects (Alias et al., 2002) are some of the tools used to enhance spatial skill. Additionally, graphic courses (Lord, 1985), playing with two- or three-dimensional objects on computer screens (Duesbury, 1996), drawing pictures of these objects and measuring their sizes are some of the instructional events used to support spatial skill development (Martin-Dorta et al., 2008; Olkun & Altun, 2003).

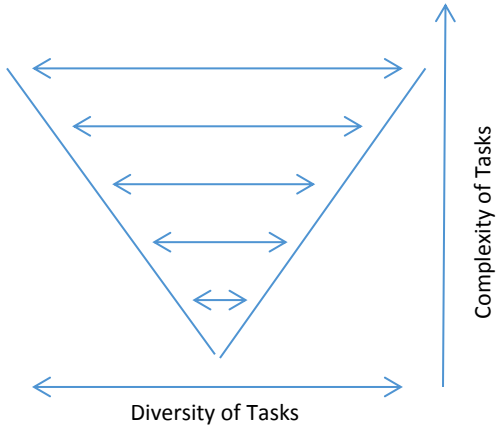
The current study's literature review revealed that most of these tools have had reportedly significant effects on spatial skill. While there have been numerous studies that have used these various tools and methods, only a limited number provided detailed information about how instructional design theories were applied in creating the tools.

The researcher of the current study selected to use the "Simplifying Conditions Method" (Reigeluth, 1999), or SCM, in the designing of the mobile learning tool. Since the spatial skills of the participants were initially very low (see Appendix F. for pre-test scores) and spatial skill is a complex component of the cognitive domain, any design must be strictly sequenced and begin with the simplest of tasks. SCM offers "*practical guideline to make a simple-to-complex sequence*" (Reigeluth, 1999,

p. 442) for tasks of at least moderate complexity. SCM works by starting with a simpler version of a task that is representative of all tasks before tackling the more complex (Reigeluth, 1999). Additionally, in the case of the current study, SCM may help facilitate the acquisition of spatial skills used for real-world tasks from the first learning episode of the mobile application.

SCM offers the use of real-world performance elements for each version of a task. The researcher therefore decided to utilize real-world objects (machinery parts) that the vocational high school students would likely use in their drawing, machining, and mounting courses. Another proposal of SCM is the teaching of prerequisites as a first step. Just as spatial skill is a prerequisite to most areas of engineering, mental rotation, visualization and locating/relocating are prerequisite actions in most daily routines of industrial employees. Task analysis and sequencing with SCM are summarized in Table 3.4. and each step that were taken by the researcher in design and development were reported.

Table 3.4. *Offerings of SCM and Practice in Learning Episodes*

	Task Analysis and Sequencing with SCM (Elaboration Theory)	Learning Episodes
Conceptual Map		Eight learning episodes, each with 10-16 questions ordered based on complexity. Learning episodes differ according to content, and include different subskill types defined as actions of spatial skill. First learning episode involves counting cubes (task of rotating, viewing); second episode (finding the top view) requires both rotating and imaging of 2D surfaces/views.
Underlying Logic	Simple to complex (simple task to complex task)	Eight different learning episodes designed with most basic requirements first. First learning episode needs only rotation and viewing, but seventh episode needs rotation, imaging and identification. Practices in each episode presented from simplest question first (object without additional structures), to most complex last (object containing more cubes and many additional sides).
Design	Simultaneous task analysis and sequencing - rapid development of prototype	Learning episodes designed based on literature, plus input from vocational high school teachers. Prototype generated and presented to students and teachers. Final form created based on feedback.
For Learners	Provides - flavor of the whole task - simple but applicable skills - enhanced motivation	Study aim: to improve spatial skills of vocational high school students (later working as technicians). Spatial skill is proven as a critical skill, especially for engineering, and highly related to math and science achievement. An applicable skill since all technical work requires some kind of spatial skill to design, create, and repair 3D real-world objects.

The researcher designed the mobile learning environment considering Reigeluth's (1999) three-phase model of designing with SCM (see Figure 3.5). Each of the phases and steps that were followed are then explained in detail.

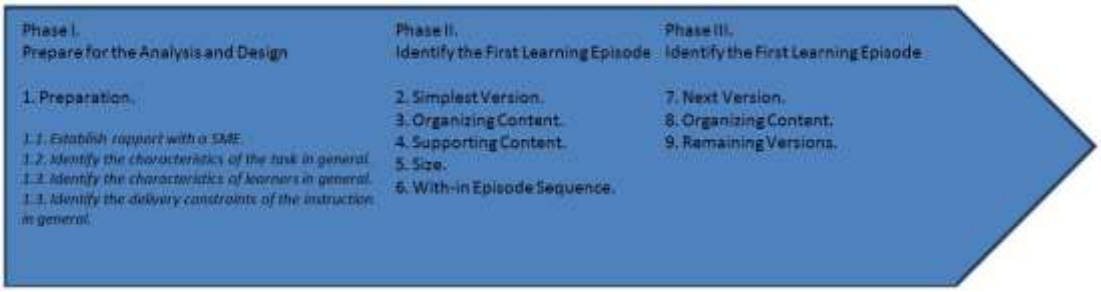


Figure 3.5. SCM-Phases and Steps (Reigeluth, 1999)

3.10.2. Using SCM for Design

3.10.2.1. SCM Design Phase One: Prepare for Analysis and Design

1. Laying the groundwork for analysis and design

1.1. *Establish rapport with a SME*

The researcher arranged meetings with vocational high school teachers from the departments of Technical Drawing, Machinery, and Automotive, and with instructors of a vocational college, as subject-matter experts (SMEs). The teachers and instructors showed significant interest at the initial meeting, reporting that their students were in significant need for such a project and practical work sessions. They also reported that usage of the proposed technology-based tool may provide extrinsic motivation for the development of students' spatial skills.

1.2. *Identify the characteristics of the task in general*

In several meetings, it was recognized that a specific problem existed that related to the students' 3D imaging skills. It was said that the students experienced difficulties in converting and transforming 2D views to 3D previews, and with rotating, locating and designing 3D objects. It was concluded that it would be beneficial to create a tool that addressed 2D and 3D objects, and to facilitate student interaction with such a tool in order to enhance their spatial skills. The SMEs reported that they did not

have the time for additional courses, but that such a tool could be utilized outside of class hours with the help of mobile devices.

1.3. *Identified the characteristics of the learners in general*

The literature reports evidence that vocational high school students experience low-level academic achievement and self-efficacy. They have a perception of having low-academic success and are not very interested or motivated in their academic courses. The SMEs all reported similar stories and added that mostly the vocational high school students had not adequately succeeded in their high school entrance exams, and thereby attended vocational high school as almost an obligatory or last resort option. Additionally, the SMEs concluded that most of the students came from rural or semirural areas.

1.4. *Identify the delivery constraints*

The SMEs informed the researcher that there were a limited number of course hours in which to give prerequisites about 2D viewing, drawing and sketching, and also that no additional practices, materials or course hours for enhancing students' abilities in linking 2D views with 3D real objects. They added that there was no perceived way to add additional lessons or sessions to the teaching schedule.

3.10.2.2. SCM Design Phase Two: Identifying the first learning episode

2. What is the simplest version of the task that is representative to the task as a whole and to describe the conditions?

The researcher and the SMEs decided to design a simple rotation and imaging task, having reviewed the literature and in considering the simplicity and relation of the task with spatial skill. Based on the advice of one SME (vocational college technical drawing instructor), it was intended to use 1x1 cubes in order to construct 3D objects as a simplifying condition. All of the SMEs stated that rather than presenting holistic 3D objects, the use of objects that consist of 1x1 cubes would better help the students to identify and apply their imaging skills for the first experience.

As the first, and therefore the simplest, episode of the mobile application, it was considered to ask students the number of 1x1 cubes that a given 3D object consisted of. This was deemed to be a simple and holistic practice since it included two main subskills of spatial skill; rotating and viewing.

3. Organizing content

All other content of the learning episodes were designed along with the SMEs and in accordance with the literature, based on the actions of spatial skill that the students are required to develop. A summary of the content, actions of spatial skill, and questions in the mobile learning app are shown in Table 3.5.

Table 3.5. *Content of the mobile learning environment.*

Episode	*Name*	*Tasks*	*Scope*
Episode 1: *Counting Cubes*	How many cubes?	- Rotating and viewing 3D objects	- Briefing video - 16 questions - Easy to complex - 10-15 minutes
Episode 2: *Finding the top view*	Look from top	- Rotating and viewing 3D objects - Imagining and identifying 2D views of 3D objects (one side of 3D object)	- Briefing video - 12 questions - Easy to complex - 5-10 minutes
Episode 3: *Finding the wrong view*	Wrong side	- Rotating and viewing 3D objects - Imagining and identifying 2D views of 3D objects (all sides of 3D object)	- Briefing video - 10 questions - Easy to complex - 10-15 minutes
Episode 4: *Matching the real object*	Find the real object	- Transforming 3D objects from 2D view - Identifying true 3D object viewing 2D views	- Briefing video - 10 questions - Easy to complex - 10-15 minutes
Episode 5: *True view of 3D*	True view	- Rotating and viewing 3D objects - Identifying 3D objects Note: 3D objects are not 1x1 cubes from this point on	- Briefing video - 10 questions - Easy to complex - 5-10 minutes

Episode	*Name*	*Tasks*	*Scope*
Episode 6: *Finding the colored side*	Find the color side	- Imaging the rotated side - Identifying 2D view - Matching the true colored side of 3D object with 2D image	- Briefing video - 12 questions - Easy to complex - 10-15 minutes
Episode 7: *Rotating in different angles*	Let's rotate	- Rotating objects in specific angles and planes	- Briefing video - 10 questions - Easy to complex - 10-15 minutes
Episode 8: *Retest of all episodes*	Again and again	- Practice of all tasks	- 14 questions - Easy to complex - 10-15 minutes

4. Supporting content

The researcher and the SMEs planned briefing videos for each episode, based on advice received from the researcher's thesis monitoring committee. The required subskills that each related episode attempted to improve were explained in the corresponding videos (identifying information of skills and how it relates to other courses and used in the real world).

Some clues (e.g., creating an origin point/plane and trying to rotate a 3D object around it or simply fixing a 3D object constant and imaging navigation around the object) are provided in order to help the students' knowledge progression so that they may practice the related subskills more easily in the subsequent questions. Additionally, example and non-example questions are resolved at the end of the videos in order to simplify each task.

5. Size: Making sure the amount of learning required for this version of the task fits the size of the episode for your course.

The researcher and the SMEs decided to plan each episodes lasting 15-20 minutes for two main reasons. First, the school principal agreed for the researcher to use interventions in the first 15-20 minutes of each lesson. Second, the students may not

remain actively engaged over episodes of extensive duration, and may therefore lose interest. Each episode of the mobile application contains a 1-2 minute briefing video as well as 10-16 questions.

6. Within-episode sequence

- Explaining the required subskill/s (prerequisite skill/s)
- Providing clues about the related subskill/s (e.g., creating an origin point/ plane and trying to rotate a 3D object around it, or simply fixing a 3D object constant and imaging is being navigated around)
- Solving an example and non-example
- Ordering questions from simple to complex
- Motivational factors
    - Scoring after each question

3.10.2.3. SCM Design Phase Three: Identify the Next learning episode

A total of seven other episodes were planned in order to address the major actions and/or subskills (rotating, viewing, imaging, identifying, relocating, transforming). Each episode was designed in order to include different kinds of actions (e.g., first episode requires rotating, sixth episode requires rotating, imaging and identifying) based on the simple-complex continuum and variation of tasks.

As reported in detail, SCM presented an instructional design framework for the content. Table 3.6. summarizes the relevance of offerings SCM with the possible learning outcomes.

Table 3.6. *Table of Specification of SCM, Tasks and Learning Outcomes*

Task Analysis and Sequencing with SCM	*Tasks*	*Learning Outcomes*
Diversity of Tasks	Is there a task diversity as content progresses?	* Learning episode-1 starts with rotating and viewing. * Learning episode-8 ends with recognizing angles and planes.
	Do tasks have the required activities to gain aimed skill?	* Drill and practice activities are strictly advised for developing mastery
Complexity of Tasks	Is there a sequence in complexity of tasks for the aimed skill?	* There are 8 learning episodes * First episode starts with easiest tasks (rotating) * Latest episode is the most complex one with recognizing angles and planes.
	Is there a sequence in complexity within each task?	* Each learning episode have 10-16 questions. * First question is the easiest and the last one is the most complex.
Simple to Complex	Is there a underlying logic in sequencing tasks?	* Simple objects and 1*1 cubes were used (without additional structures) at first. * Complex objects and real parts (real parts with many additional sides) were used at the end.
Rapid Development of Prototype	Is there a task analysis? Is there any rapid development for prototyping?	* All tasks were designed and sequenced with subject-matter experts. * Beta versions were piloted with students.
Simple and Applicable Skills	Can students gain the aimed skill through systemic study?	* Spatial skills were proved to be enhanced by systemic practices
Enhanced Motivation	Are there any intrinsic motivation sources? Are there any extrinsic motivation sources?	* Importance of spatial skills were introduced to participants. * Movie tickets were presented as rewards for highest scores.

3.10.3. Learning Software

The learning software (mobile application) was developed using Unity, a 3D development software. Screenshots of the developed mobile application are given in Figures 3.10 to 3.12. Unity allows users to render products for different operating systems so learning software is compatible for Android and IOS based mobile tools and Windows-based computers.

The researcher generated storyboards for each mobile learning app screen after deciding upon the content. Examples of the storyboards are shown in Figures 3.6, 3.7, and 3.8. All of the links, objects and texts located on the screen are explained in detail on each storyboard. As can be seen, buttons for each of the eight episodes are shown of the left- and right-hand side of the main screen. Two buttons were added to the lower part of the screen for users to access briefing information about spatial skill and the mobile application. Figure 3.6 presents an image of the main screen of the mobile application as a storyboard.

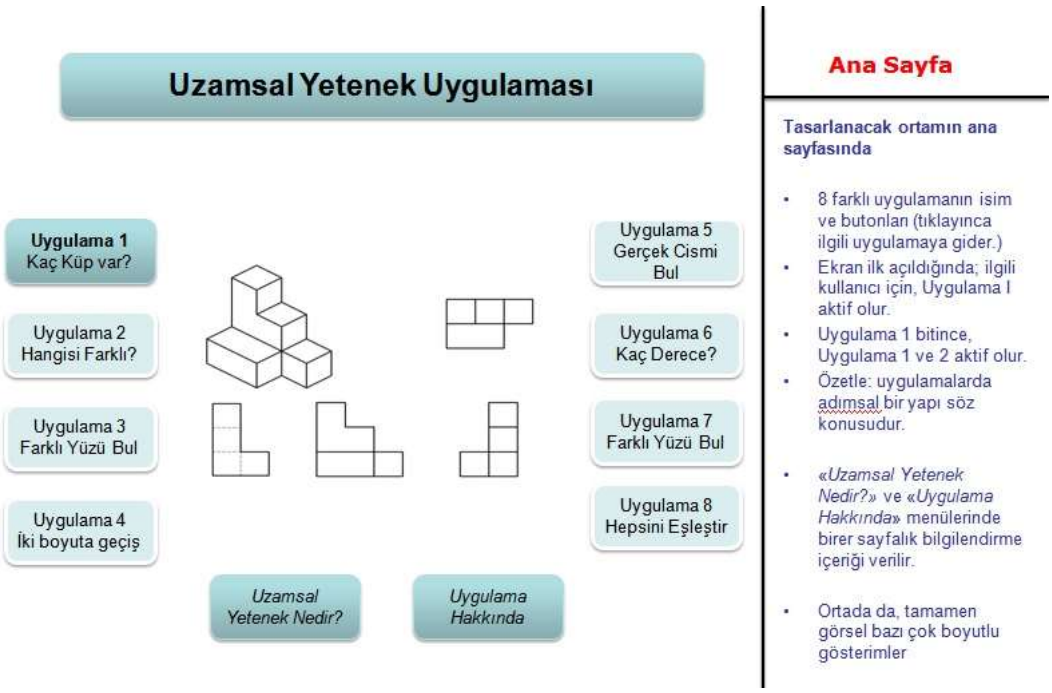


Figure 3.6. Storyboard of Mobile Learning App Main Page

An introductory screen was prepared for each learning episode of the mobile application (see Figure 3.7). A briefing video provided students with information about the subskill/s required to be practiced in the episode. Certain clues that may help the students were emphasized and an example/non-example question was included and resolved in each video.

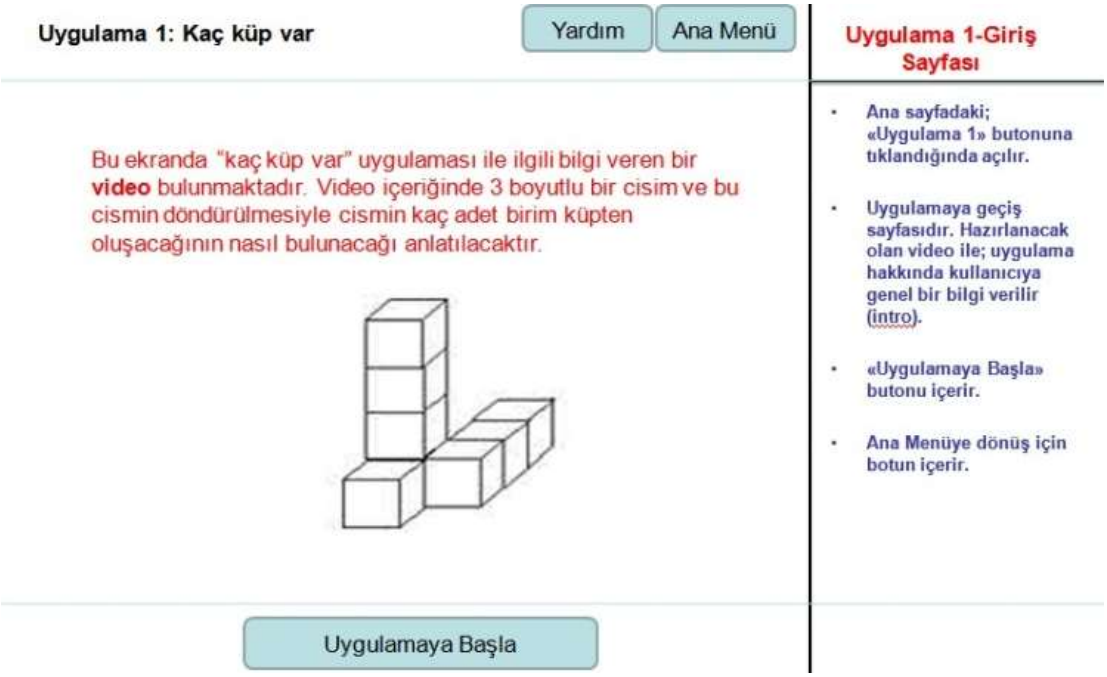


Figure 3.7. Storyboard of a Learning Episode First Page

The first question of each episode appears following the briefing video. Each screen shows a 3D object or 2D graph which is controllable and rotatable by the user (finger or mouse, based on the device type). The user may also focus, maximize and minimize and rotate the object or graph. The student then answers questions by selecting their chosen answer option. Figure 3.8 provides an example of a question together with its choices from which the user can choose the one they believe to be correct.

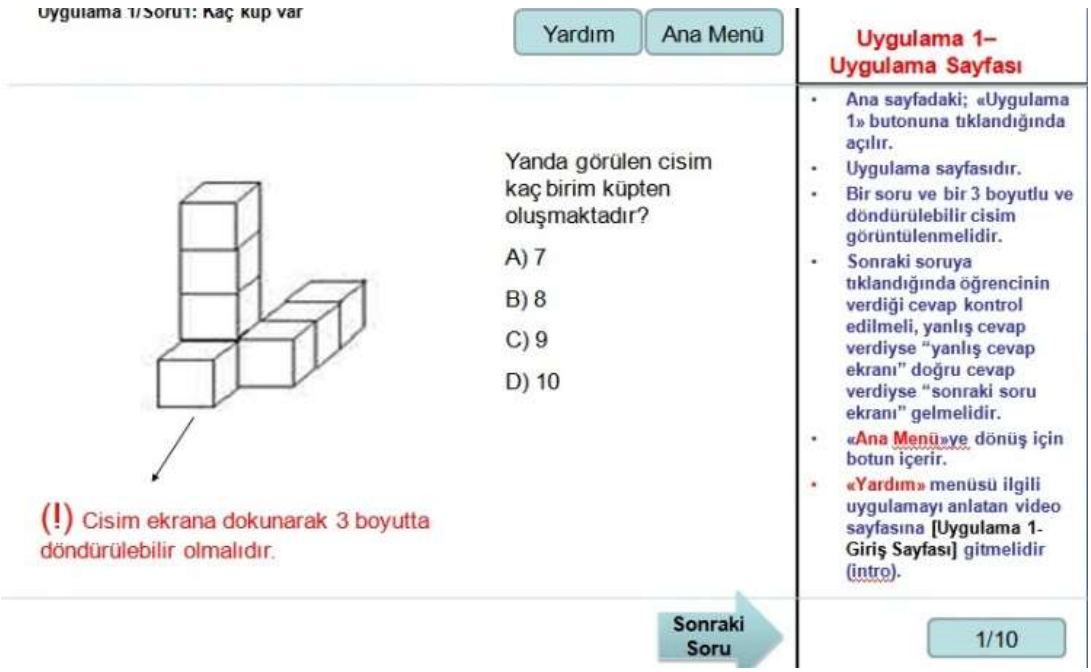


Figure 3.8. Storyboard of a Drill and Practice Page

Flowcharts were prepared for each screen and these were later used in the software development phase. Each of the episodes used the same page layout, with just minor differences according to the drill practice type.

After planning each learning episode (tasks, content and duration) with the SMEs (teachers) and creating the storyboards, the researcher generated 3D objects and 2D graphs for each of these objects. The researcher drew and developed a total of 180 different 3D objects in the development phase, of which 140 were then used in the eight episodes. 2D graphs of all 180 3D objects are also generated. SolidWorks 3D modeling software was used in the development of the 3D objects and the 2D graphs. Figure 3.9 presents a screenshot of the development phase of the 3D objects and Figure 3.10 gives the screenshot of a briefing video.

The researcher and SMEs studied each drill practice question carefully in order to design based on the simple-to-complex model. Prerequisite tasks such as rotating and identifying were added first to the drills and then practiced throughout the episodes. The method followed in the development of the episodes was based on

SCM's approach to learning moderate-to-complex level cognitive skills (Reigeluth, 1999).

Based on the literature, the pre-test results proved that the spatial skill scores of the participants were found to be very low. With this in mind, the researcher and the SMEs sought ways to simplify the complexity of the spatial skill activities. During a meeting held with the SMEs, one of the teachers suggested the use of 1x1 volume cubes while developing 3D objects. Most of the teachers agreed that such a view would simplify some of the tasks for the students such as viewing, identifying and matching. In order to follow this idea, some of the 3D objects were redrawn using 1x1 cubes. The difference between the holistic objects and the 1x1 volume cubes are shown in Figure 3.9.

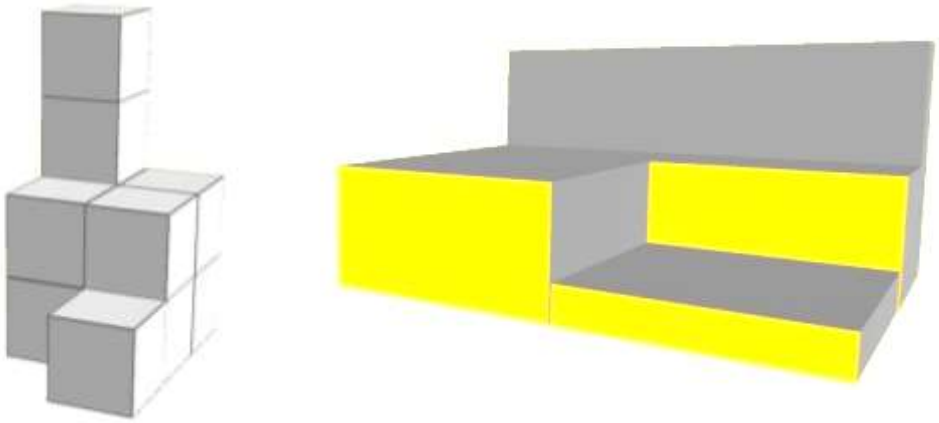


Figure 3.9. Development of 3D objects

(a) 1x1 cube view; (b) Holistic object view

Another principle of SCM is supporting the enhanced motivation of learners. The researcher and SMEs decided to score the participants' correct and incorrect question answers, and then to show the result on the screen following each attempt by the participant. As a scoring algorithm, it was decided to award 100 points for each correct answer and deduct 50 points for incorrect answers. For the highest score achieved in each episode, the winning participant was rewarded with a free movie ticket (All of the winning participants in three groups were rewarded with free movie

tickets). The guiding principle behind this algorithm and the corresponding motivational award scheme was to encourage the full concentration and detailed effort of the participants within the mobile learning environment, since spatial skill is a complex cognitive skill and the drill practice questions were designed to become increasingly more complex as the episodes progressed. Screenshots of the answer results (correct or incorrect) and their feedback are presented as Figures 3.11 and 3.12 respectively.

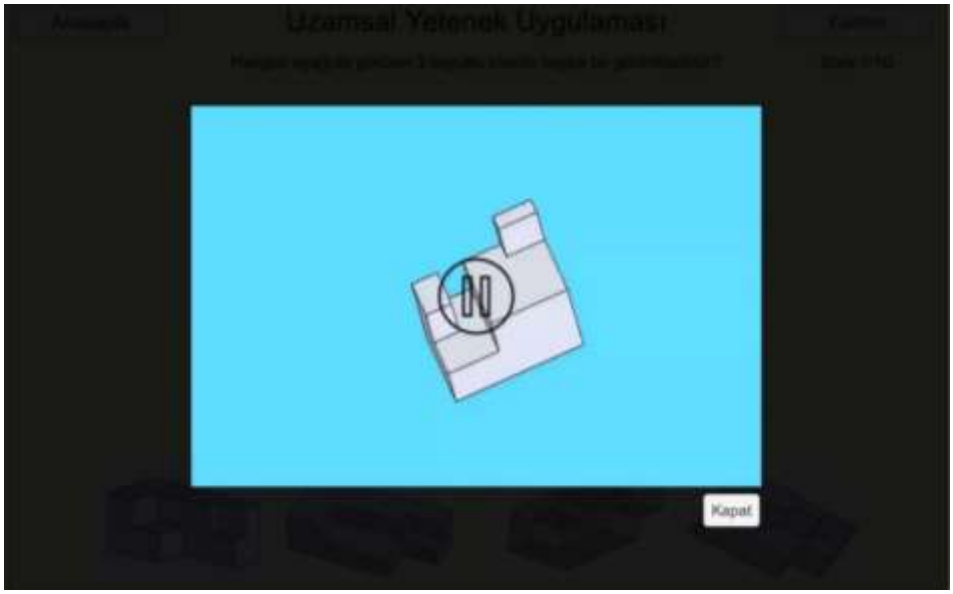


Figure 3.10. Briefing Videos of a Learning Episode

Figure 3.11. Scoring of Learning Episodes – Correct Answer

Figure 3.12. Scoring of Learning Episodes – Incorrect Answer

3.11. Paper-Pencil Booklets

As stated in design of the study, there are three groups in this research. While experiment group used learning software with tablet computers, first control group used the learning software in desktop computers. The specifications and content of

the software is the same for both groups. Both groups included a briefing video provided students with information about the subskill/s required to be practiced in the episode. Certain clues that may help the students were emphasized and an example/non-example question was included and resolved in each video.

The second control group used paper-pencil booklets with same content for 8 weeks. Researcher did not use a different design consideration for content of the paper-pencil booklets. Same visuals, questions and learning episodes were used for paper-pencil booklets. On the other hand, there are two main differences between learning software and booklets.

Since there is no chance to include videos on booklets, researcher lectured to paper-pencil group before each intervention session. The lectures included the description of the task (e.g., rotating and viewing 3D objects), hints and tips to solve drill-practice questions and solving example, non-example question. Additionally feedbacks were given to participants after checking their answers.

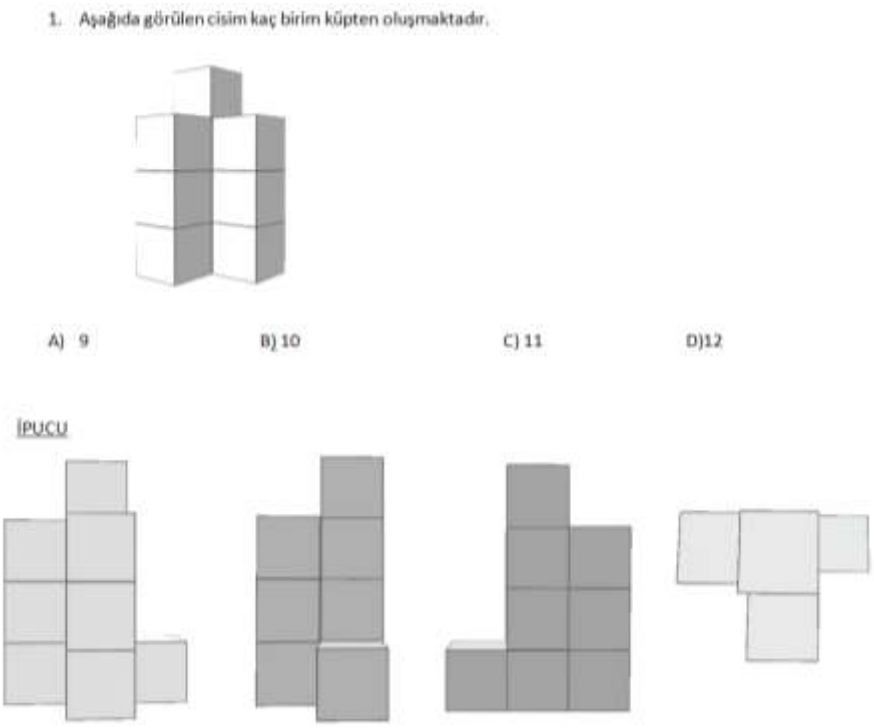


Figure 3.13. Example question from booklet

Second, paper-pencil group do not have the opportunity to interact with the content. In other words, while software lets tablet computer and desktop computer groups to rotate, minimize, maximize or focusing the content, paper-pencil group does not have these options. On the other hand, researcher provided still pictures for paper-pencil group that lets participants to see the visuals from different angles and sides. Example questions from booklets were given in Figure 3.13. and 3.14.

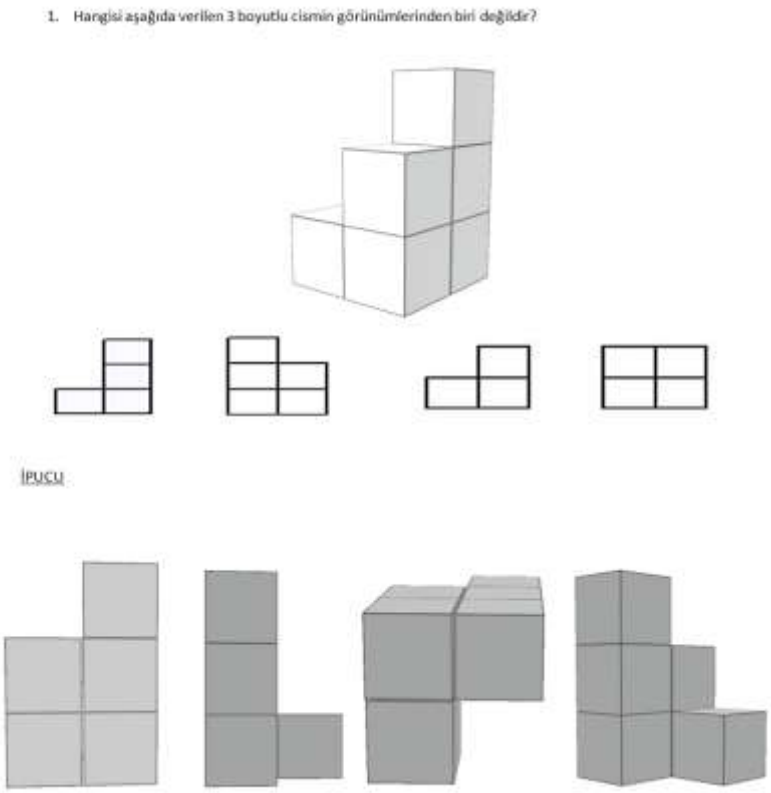


Figure 3.14. Example question from booklet

As given in limitations part, researcher did not make a pilot study for paper-pencil group. However, the content of the learning software and booklets is the same and researcher made a pilot study using learning software.

3.12. Pilot Study

Following the development of the software, a pilot study was conducted with six volunteer vocational high school students (from the same school used for retesting the Turkish adaptation of the MRT). Each were randomly chosen among the students that completed the retest of the MRT. As with the primary experimental environment, parental permission was sought for each prospective pilot participant and signed consent forms collected accordingly. The pilot students also completed the demographic information form.

The pilot study lasted for a period of 8 weeks, with the students completing two episodes each week. The researcher observed the pilot students using tablet computers and the developed mobile learning application. After completion of the pilot study, semi-structured interviews were held with each of the students. The Semi-structured Interview Form was used to guide the interviews, and critique regarding the technical aspects of the software and its content were gathered.

Most of the pilot students were critical about the background color of the software and the high sensitivity of the touchscreen of their mobile devices to the developed mobile learning app. The students reported a perceived need for more questions in certain episodes. While some of them found the questions complex, others demanded more complex 3D objects. The students provided positive feedback for the scoring protocol and being able to compare their scores with that of their peers. Observations made by the researcher during the pilot study showed that the scope of the content was found to be compatible with the designated time constraint.

The researcher applied certain changes to the software based on the critique gathered during the pilot study. For example, the background color of the screen was changed. New 3D objects were then developed and used in the questions. The biggest issue that was raised during the pilot study related to the sensitivity of mobile device touchscreens when using the developed app. After detailed examination, the researcher located the source of the problem as being software-related, and the screen sensitivity issue was then resolved following a programming change as well

as changes to the 3D options. Figures 3.15 and 3.16 represent the latest version of the software.

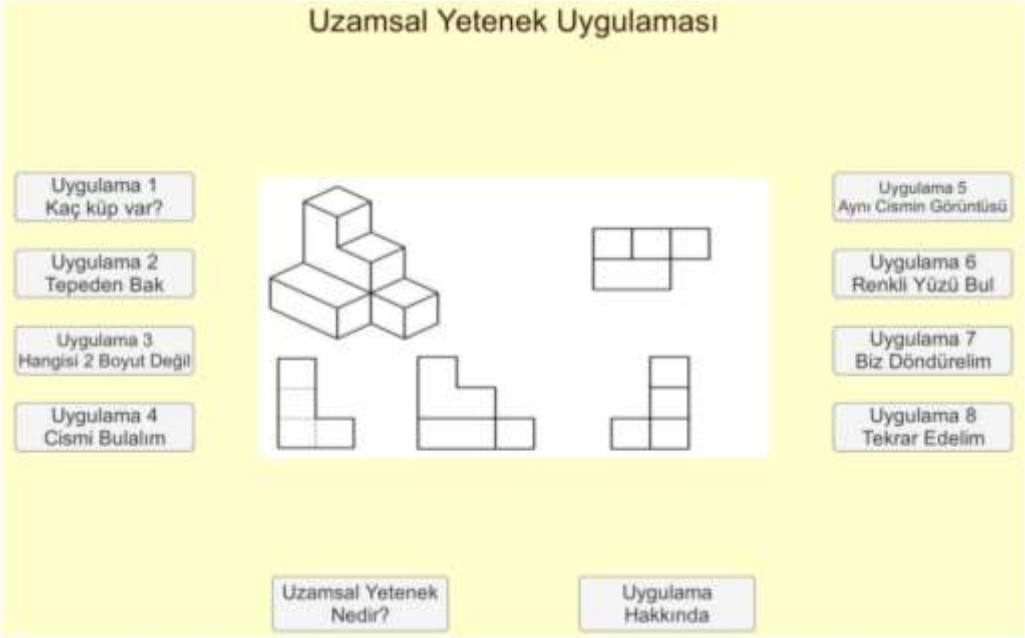


Figure 3.15. Main screen of software

Figure 3.16. Example item form learning episode

3.13. Procedure

Two vocational high schools in research site were chosen by the researcher for the study group due to their geographic location and number of enrolled students. The researcher also knew one of the teachers who is working at one of these schools. Due to having an insider, the researcher selected one of the schools for the intervention of the experimental study and the other in order to retest the validity of the MRT and for the pilot study. The teacher known to the researcher was one of the vocational high school teachers, who provided invaluable support to the researcher throughout the study. Bogdan and Biklen (2007) stated the potential benefits of having an "insider" in terms of the application of qualitative research.

The researcher visited both vocational high schools, with the help of the insider, and there met with the teachers and principals as an initial first step. The researcher provided detailed information about the proposed study and the possible outcomes that were envisaged. The principals and the teachers of both schools reacted positively and invited the researcher to see the learning environment first-hand and to meet with some of the students.

As a first step researcher retested the validity of the MRT with the first vocational high school students. Second, beta version of the software was used by six students to get feedback. After 4 weeks of experience, opinions and advices of the participants collected through semi-structured interviews (Appendix C). Latest version of the software was developed considering results of pilot study.

The researcher and the teachers planned dedicated visiting hours in order to inform the students about the real experiment study. After being provided with brief information about the study, all of the students (85 students in three classes) voluntarily accepted to participate in the study. Since all of the students were younger than 18 years of age, the students were each asked to return a signed "Parent Permission Form" (see Appendix B). All of the participants, their teachers, and the schools' principals were informed about the privacy of the study's data. The

researcher also reported that the real names of the participants would not be used in the reporting of the study.

The Demographic Information Form (Appendix A) was handed to each of the participants to begin the collecting of research data. After a period of one week, the Mental Rotation Test (MRT) (Vandenberg & Kuse, 1978) was conducted in order to collect quantitative data, and also to determine if there was any meaningful difference between the selected three classes.

All three groups were applied the MRT to the same standards and on the same day. The MRT was conducted within the classroom environment by the researcher with the help of the classroom teachers. The students were given 4 minutes for the first 12 questions, and then after a couple of minutes break, they were given another 4 minutes to complete the last 12 questions. The results (Appendix F) showed that the three different classes may be defined as intact groups (Fraenkel, Wallen & Hyun, 2011).

The computer laboratory of the school was used for the desktop computers to run the software for the experiment phase. The developed paper-pencil booklets for the study were completed within the classroom environment, too. Role of the researcher and qualifications of learning material are summarized in Table 3.7. and sub-heading 3.9.

Each of the intervention sessions (24 sessions in total, with eight for each study group) were administered by the researcher with the help of the class teachers. Each session lasted for approximately 20 minutes, which was in accordance with the school principal's directive. After 8 weeks of intervention and with each student having completed the software or the booklet, according to their study group, the participants then completed the MRT once again as a post-test.

Table 3.7. *Role of Researcher and Qualifications of Learning Material*

Intervention type	*Content*	*Input Device*	*Role of the Researcher*	*Actions of researcher*	*Episode Content*
Tablet Computers	Briefing videos, Interactive 3D objects	Touchable Screen-Finger	Guiding through intervention	Replying student questions, giving clues and support for practices	Rotating and viewing 3D objects Imaging and identifying 2D views Transforming 3D objects from 2D view Identifying true 3D object viewing 2D views Rotating objects in specific angles and planes
Desktop Computers	Briefing videos, Interactive 3D objects	LCD screens-mouse	Guiding through intervention	Replying student questions, giving clues and support for practices	Rotating and viewing 3D objects Imaging and identifying 2D views Transforming 3D objects from 2D view Identifying true 3D object viewing 2D views Rotating objects in specific angles and planes
Paper-pencil Booklets	Explanations of researcher, Still pictures of 3D objects	Booklets-pencil	Giving briefing explanations and guiding through intervention	Presenting content related with tasks, Solving examples, Giving information about tasks, Replying student questions, giving clues and support for practices	Rotating and viewing 3D objects Imaging and identifying 2D views Transforming 3D objects from 2D view Identifying true 3D object viewing 2D views Rotating objects in specific angles and planes

For the second phase of the study, qualitative data was collected via semi-structured interviews that followed the experimental study groups' usage of the mobile learning environment.

Maximum variation sampling was used as the sampling method to decide which participants would be interviewed. The researcher decided to employ maximum variation sampling since a wide range of participants may realize more significant and more useful data related to their experiences during the treatment implementation. Patton (1990, p. 173) also defined the aim of maximum variation sampling as "*capturing and describing the central themes or principle outcomes that cut across a great deal of participant or program variation.*" Since the researcher primarily wanted to define the experiences and thoughts of the participant about the mobile application, the data was required to be gathered from a variety of participants who may each have different thoughts or feelings. Data saturation (Bogdan & Biklen, 2007; Marshall & Rossman, 2011) was considered as the key concept related with the data collection phase of the qualitative phased of the study.

3.14. Limitations

As all research have, this study has limitations too. First, sampling is a limitation in this study. Researcher used convenience sampling as a sampling strategy for the first part of the study. Considering its location and ease of entrance (having an insider at the site), a specific vocational high school is selected as research site.

Second limitation is about data collection. All qualitative data were collected by the researcher himself. Transcribe and analyses of qualitative data were done by the researcher again. This means findings of the study are mainly based on researcher viewpoint of the phenomenon.

Third, participants of this research are all male. Vocational high schools are male dominant schools for departments like machinery, automotive, electrics. These departments have high rates of male students and in some cases all of the students are male. In this study, all participants are male and readers must consider that this research was conducted with male participants.

Fourth, this study has three groups of participants and two of them used the same software. One group used software with tablet computers and the other group used with desktop computers. The third group used same content with paper-pencil booklets. Researcher made a pilot study for specifications of software for tablet and desktop computers but did not make a pilot study for paper-pencil booklets.

CHAPTER 4

RESULTS

4.1. Descriptive Statistics

In this part of the chapter, detailed descriptive information about the participants is provided. In addition to their gender, age and grade level variables like parent graduation and occupation and “having computers,” “using computers” and “playing computer games” were collected. Considering the literature, the researcher decided to also collect data about these variables.

The study was formed with a total of 85 participants in three intervention groups. There were 28 participants in an experimental group (using tablet computers), 30 participants in the first control group (using desktop computers), and 27 participants in the second control group (using paper-pencil booklets). All of the students were enrolled in the first grade (ninth grade in K-12 terms) of a vocational high school in a medium scale province of Turkey. The average age of the participants was 14.64 years old, and all of the participants were male. The average age for the experimental group was 14.79 years, whereas for the first control group it was 14.47 years, and 14.67 years for the second control group.

As can be seen in Appendix F., all of the participants were male. Many parents in Turkey prefer not to register their children to specific departments of vocational high schools. As previously reported in this study, due to social, cultural, and academic reasons germane to the Turkish context, there are limited numbers of female students enrolled to vocational high schools in general, whilst certain departments within these schools such as mechanics, automotive, mechatronics, aircraft maintenance, and electrics have very limited numbers or even no female students. Similarly, there were no female students enrolled in any of the three classes that formed the study groups (experimental or control) of this study.

Researcher collected data about graduation information about parents to gain insight about socio-economic status of the participants. Father graduation results indicated nearly half (45.88%) of the participants' fathers (*n* = 39) are graduated from middle school, whilst 16.47% (*n* = 14) of them are graduated from primary school, 32.94% (*n* = 28) of them are graduated from high school and 4.70% (*n* = 4) of them are graduated from higher education institutions. Similarly, mother graduation results indicated 35.29% of the participants' (*n* = 30) mother are graduated from primary school, whilst 42.35% (*n* = 36) of them graduated from middle school, and 22.35% (*n* = 19) of them graduated from high school.

Another data that researcher collected is parent occupation. Results showed that more than half (52.94%) of the participants' father (*n* = 45) have a full-time job, whilst 27.06% (*n* = 23) of them have half-time job, 11.77% (*n* = 10) are retired and 8.23% (*n* = 7) of them do not working. Occupation rates are lower in mothers' side. According to results, more than half (63.35%) of the participants' mother (*n* = 53) do not have a job, whilst 28.24% (*n* = 24) of them have half-time job, and just 9.41% (*n* = 8) of them have a continuous job.

The participants were asked if they had smart phones, computers, and/or tablet computer, and about their previous experience using these tools. While most of the participants stated that they had smart phones, nearly half of the participants had desktop computers. All of the participants stated that they had prior experience with computers, tablets, and smart phones. Additionally, the researcher collected data in order to analyze the ratio of having a tablet, desktop computer or a smart phone. The data indicated that nearly half (45.88%) of the participants (*n* = 39) have computers in their home, whilst 63.52% have a smart phone (*n* = 54), but having a tablet pc showed the lowest rate with only 15.29% (*n* = 13).

The other data item collected by the researcher was about the playing of computer-based games by the participants, which was another variable reported in the literature that may have a relation to spatial skill. Of the 85 participants, 59 (69.41%) indicated that they played computers games.

Table 4.1. *Other Variables that may Affect Spatial skill*

		Group			
		Tablet Group	Desktop Group	Paper-Pencil Group	Total
		f	*f*	*f*	*f*
Having a computer	Yes	14	17	8	39
	No	14	13	19	36
Having a tablet pc	Yes	5	4	4	13
	No	23	26	23	72
Having a smart phone	Yes	23	27	24	74
	No	5	3	3	11
Using a computer (in a week)	0-1 hour	3	4	5	12
	2-4 hours	12	5	6	23
	5-7 hours	6	10	7	23
	8 hours or above	7	11	9	27
Using a tablet pc (in a week)	0-1 hour	22	30	22	74
	2-4 hours	1	0	1	2
	5-7 hours	2	0	3	5
	8 hours or above	3	0	1	4
Using a smart phone (in a week)	0-1 hour	0	0	0	0
	2-4 hours	0	0	0	0
	5-7 hours	0	0	0	0
	8 hours or above	28	30	27	85
Playing computer games (in a week)	0-1 hour	7	8	8	23
	2-4 hours	10	7	9	26
	5-7 hours	4	7	7	18
	8 hours or above	7	8	3	18

4.2. Effect of Three Different Intervention Types

This part relates to Research Question 1, which also consists of three sub-questions. In this section, each sub-question is reported on with the participants' pre-test and post-test results.

Research Question 1: Is there any significant difference in spatial skill scores of participants before and after interventions?

4.2.1. Difference of Spatial Skill Scores of Paper-Pencil Group

One of the two control groups used paper-pencil booklets during the eight-week intervention. The content of the booklet was same as used by the two other groups (using tablet pc, and using desktop pc), but for this group the participants only used the paper booklets for their drill and practice sessions. In order to identify the differences in spatial skill scores of the participants, MRT was employed as both a pre-test and post-test to the intervention. Information about the descriptives is given in Table 4.2 for the pre-test and post-test results of the paper-pencil booklet control group.

Table 4.2. *Descriptives of Pre-test and Post-test of Paper-Pencil Group*

	n	*M*	*SD*	*Var*	*Skewness*	*Kurtosis*	*Min*	*Max*
Pre-test	27	3.96	1.990	3.960	.213	-.858	1	8
Post-test	27	4.41	2.223	4.934	.348	-.766	1	9

Paired sample *t*-test was used in order to compare the pre-test and post-test results of the paper-pencil control group participants. The results indicated that there was a significant difference found between the pre-test and post-test scores of the participants. In other words, the participants of the paper-pencil control group achieved significantly higher scores on the MRT applied after the eight-week intervention period. The post-test scores (M = 4.41; SD = 2.223) were significantly

higher than the pre-test results (*M* = 3.96; *SD* = 1.990). Table 4.3 presents the results of the paired sample *t*-test for the paper-pencil control group.

Table 4.3. *Results of Paired Sample t-test for Paper-Pencil Group*

	M	*SD*	*SEM*	*95% CI*		*t*	*df*	*Sig. (2-tailed)*
				Lower	*Upper*			
Pre-test Post-test	-.445	.974	.188	-.830	-.059	-2.371	26	.025*

**The mean difference is significant at the .05 level.*

As can be seen in Table 4.3. paper-pencil group has significantly higher scores in post-test. Additionally Cohen's d effect size was found as .46 which means moderate effect size.

4.2.2. Difference of Spatial Skill Scores of Desktop Computer Group

The second control group used desktop computers for the eight-week intervention. The content they used was same as with the other two groups (using tablet pc, and using paper-pencil booklets), except that the participants used desktop computers for their drill and practice sessions. MRT was used as both a pre-test and post-test in order to identify the differences in their special ability before and after the intervention. A summary of the descriptive information is presented in Table 4.4 for the pre-test and post-test results of the desktop computer group.

Table 4.4. *Descriptives of Pre-test and Post-test of Desktop Computer Group*

	n	*M*	*SD*	*Var*	*Skewness*	*Kurtosis*	*Min*	*Max*
Pre-test	30	4,13	1,676	2,809	,105	-,079	1	8

Post-test	30	5,93	2,243	5,030	,305	-,381	2	11

Paired sample *t*-test was used to compare the pre-test and post-test results of the desktop computer control group's participants. The results provided sufficient evidence to conclude that a significant mean difference existed between the pre-test and post-test scores of the desktop computer group's participants. The participants scored significantly higher in the post-test (*M* = 5.93; *SD* = 2.243) compared to the pre-test (*M* = 4.13; *SD* = 1.676) in terms of their spatial skill scores. Table 4.5 presents the results of the paired sample *t*-test for the desktop computer group.

Table 4.5. *Results of Paired Sample t-test for Desktop Computer Group*

	M	*SD*	*SEM*	*95% CI*		*t*	*df*	*Sig. (2-tailed)*
				Lower	Upper			
Pre-test Post-test	-1.80	1.750	.320	-2.453	-1.147	-5.634	29	.000*

**The mean difference is significant at the .05 level.*

As can be seen in Table 4.5. desktop computer group significantly has higher scores in post-test. Additionally Cohen's *d* effect size was found as 1.03 which means high effect size. This means difference between the two means is larger than one standard deviation. This high effect size coefficient may be sourced from lower pre-test scores.

4.2.3. Difference of Spatial Skill Scores of Tablet Computer Group

Participants of the experimental group of the study used tablet computers for the eight-week intervention. The content they used was the same as with the other two groups (using desktop pc, and using paper-pencil booklets), but the experimental

group participants used tablet computers with touchscreens instead for their drill and practice sessions. MRT was used as a pre-test and post-test in order to identify the differences in their special ability scores before and after the intervention. A summary of the descriptive information is presented in Table 4.6 for the pre-test and post-test results of the tablet computer (experimental) group.

Table 4.6. *Descriptives of Pre-test and Post-test of Tablet Computer Group*

	n	*M*	*SD*	*Var*	*Skewness*	*Kurtosis*	*Min*	*Max*
Pre-test	28	4.04	1.836	3.369	.292	-.528	1	8
Post-test	28	6.07	2.227	4.958	.250	-.311	2	11

Paired sample *t*-test was used to compare the pre-test and post-test results of the participants. The test result provided sufficient evidence to conclude that there was a significant mean difference found between the pre-test and post-test scores of the tablet computer group's participants. The participants scored significantly higher in the post-test (M = 6.07; SD = 2.227) than they did in the pre-test (M = 4.04 SD = 1.836) in terms of their spatial skill scores. Table 4.7 presents the results of the paired *t*-test for the tablet computer group.

Table 4.7. *Results of Paired Sample t-test for Tablet Computer Group*

	M	*SD*	*SEM*	*95% CI*		*t*	*df*	*Sig. (2-tailed)*
				Lower	Upper			
Pre-test Post-test	-2.03	1.478	.280	-2.609	-1.463	-7.289	27	.000*

**The mean difference is significant at the .05 level.*

As can be seen in Table 4.7. tablet computer group significantly has higher scores in post-test. Additionally Cohen's *d* effect size was found as 1.37 which means high effect size. This means difference between the two means is larger than one standard deviation. This high effect size coefficient may be sourced from lower pre-test scores.

4.3. Difference Between Three Groups According to Post-test Scores

The final sub-question of the first research question, which focused on the quantitative phase of the study, was aimed at evaluating the differences in spatial skill scores of the three study groups' participants after the eight-week intervention. In the previous sub-questions, the results showed that each of the groups separately made academic progress during the eight-week intervention. This fifth sub-question (of the first research question) aimed to identify if there was any significant difference post-intervention at the group level, based on their different method of application (using tablet pc, using desktop pc, or using paper-pencil booklets) during the intervention.

A summary of the groups' descriptive statistics for the post-test are provided in Table 4.8. As can be seen, the overall combined group mean score of the post-test was found to be 5.49, while the minimum score was 1 and the maximum was 11. Standard deviation was found to be 2.328 for the whole study group (i.e., all three groups).

Table 4.8. *Results of Mental Rotation Test as Post-test (all Groups)*

	n	*M*	*SD*	*Min*	*Max*
Tablet Group	28	6.07	2.227	1	8
Desktop Group	30	5.93	2.243	2	11
Paper Pencil Group	27	4.41	2.223	2	11
Total	85	5.49	2.328	1	11

Two critical assumptions were tested prior to conducting One-way ANOVA to compare the post-test scores of the three groups. The first assumption was about the normality of distribution of the test scores, and the second assumption was about the variances between the groups. One-way ANOVA requires normal distribution of the scores. Skewness and kurtosis values were used in order to determine the first assumption. As can be seen in Table 4.9, skewness and kurtosis values were found to be .225 and -.491, respectively. Field (2009) stated that skewness and kurtosis values between -1.96 and 1.96 are indicators of normal distribution.

Table 4.9. *Skewness and Kurtosis Values of Mental Rotation Test (Post-test)*

	n	*M*	*SD*	*S*	*Skewness*	*Kurtosis*	*Min*	*Max*
MRT scores (Post-test)	85	5.49	2.328	5.420	.225	-.491	1	11

Levene's test of homogeneity of variances was then used for the second assumption. The results proved that the three groups came from the same population and that they had equal variances. Table 4.10 provides a summary of the test results.

Table 4.10. *Test of Homogeneity of Variances (Post-test)*

Levene Statistic	*df1*	*df2*	*Sig.*
.081	2	82	.922

After providing both assumptions, analysis of variance (One-way ANOVA) was used in order to determine the difference of post-test scores of the participants after intervention. Results indicated that there was a statistically significant difference found between the three groups according to their spatial skill scores. In other words,

there was sufficient evidence to conclude that at least one of the means of the spatial skill scores of the participants differed significantly ($p < .05$; $F(2.82) = 4.721$). Results of the One-way ANOVA test are presented in Table 4.11. The effect size ($\eta^2 = .01$) according to the criteria of effect size proposed by Cohen (1988, p. 286) is a small effect size.

Table 4.11. *Results of ANOVA (Post-test)*

	SS	*df*	*MS*	*F*	*Sig.*
Between Groups	47.005	2	23.502	4.721	.011*
Within Groups	408.242	82	4.979		
Total	455.247	84			

**The mean difference is significant at the .05 level.*

Since the analysis of variance proved that there was a significant difference found in the post-test scores of the participants and that there are three study groups, Bonferroni test was then used in order to examine the differences between each of the groups. Bonferroni test compares intervention groups in sets of two, and then establishes if the mean scores of the groups differ significantly or not. Table 4.12 presents the results of the Bonferroni test.

Analysis results of the Bonferroni test proved that a significant mean difference exists between the tablet computer (experimental) group and the paper-pencil booklet (control) group. The tablet computer (experimental) group ($M = 6.07$; $SD = 2.227$) had significantly higher spatial skill scores than the paper-pencil booklet (control) group ($M = 4.41$; $SD = 2.223$). Similarly, the desktop computer (control) group had significantly better post-test scores ($M = 5.93$; $SD = 2.243$) than the paper-pencil booklet (control) group ($M = 4.41$; $SD = 2.223$). On the other hand, the results indicated that no significant difference in mean scores was found between

the desktop computer (control) group (*M* = 5.93; *SD* = 2.243) and the tablet computer (experimental) group (*M* = 6.07; *SD* = 2.227).

Table 4.12. *Results of Bonferroni Test (Post-test)*

(I) Group	*(J) Group*	*M Diff (I-J)*	*SE*	*Sig.*	*95% CI*	
					Lower Bound	*Upper Bound*
Tablet Computer	Desktop Computer	.138	.586	1.000	-1.29	1.57
	Paper Pencil Booklet	1.664*	.602	.021	.19	3.13
Desktop Computer	Tablet Computer	-.138	.586	1.000	-1.57	1.29
	Paper Pencil Booklet	1.526*	.592	.035	.08	2.97
Paper Pencil Booklet	Tablet Computer	-1.664*	.602	.021	-3.13	-.19
	Desktop Computer	-1.526*	.592	.035	-2.97	-.08

**The mean difference is significant at the .05 level.*

4.4. Perceptions of Participants about Mobile Learning Environment

This section relates to the results of the qualitative phase of the study, which addressed Research Question 3.

Research Question 3: What are perceptions of participants related to the mobile learning environment?

The qualitative phase of the study aimed to understand the experiences of the experimental (tablet computer) group's participants regarding the mobile learning environment. To this aim, qualitative data was collected following conclusion of the eight-week intervention period.

Content analysis was then applied so as to elicit detailed information about the phenomenon. Researcher himself collected all the data, transcribed them and made the analysis. Just after the interviews have been completed, researcher transcribed all the recordings. Transcriptions were transferred to MS Word program and reorganized. Researcher coded the interviews. Coding data is analyzing raw data by separating it into minor but meaningful pieces without slipping the connection between them. Researchers may form their own codes as well as using predetermined ones with new codes. In this study, the researcher created his own codes and generated subthemes and themes (Miles & Huberman, 1994).

Results of the content analysis indicated that the experiences of the participants could be grouped around five themes; which were "mobile learning tool as facilitator," "tablet computers as a technological tool," "technical properties," "learning content" and "motivational factors." The themes and categories are presented in Table 4.13. In the following subsections, each themes is explained in detail and exemplified with direct quotations from the interviews with the researcher.

Table 4.13. *Themes and Categories*

Themes	*Categories*
Mobile Learning Tool as Facilitator	Creating awareness
	Being supportive
	Effective instructional use
Tablet Computers as a Technological Tool	Tablet usage preferences
	Demand for technology
Technical Properties	Specifications of hardware
	Specifications of software
Learning Content	Variety of content
	Covered content
	Complexity of content
Motivational Factors	Active participation in courses
	Enhancing motivation
	Feeling challenging and successful

4.4.1. Theme: Mobile Learning Tool as Facilitator

The most referred to theme that was identified from the participants' interviews was about the supportive side and instructional use of the mobile learning tool. The participants' experiences revealed that the mobile learning tool was informing, highly supportive and helpful in facilitating the enhancement of their spatial skill. Three categories and 19 codes were gathered under this theme. The researcher named the categories as "creating awareness," "being supportive," and "effective instructional use." Table 4.14 provides detail about the theme. Each of the categories were interpreted with the aid of direct quotations of the participants.

Table 4.14. *Categories and Codes of Mobile Learning Tool as Facilitator*

Theme	*Categories*	*Codes*	*f*
Mobile Learning Tool as Facilitator	Creating awareness	importance of spatial skill	4
		creating interest	3
		useful practices	4
		mechanics	2
		work-life	4
	Being supportive	hints and tips	4
		explanatory video	5
		example questions	4
		positive feedback	3
		easy to complex	3
		ordered episodes	4
		using simple components	2
	Effective instructional use	new method	5
		enables practicing	4
		self-study	2
		gamification	2
		helps other courses	2
		implicit learning	3
		helps work-life	4

4.4.1.1. Category: Creating Awareness

Since spatial skill was largely a new term for the participants, there were many questions and significant interest shown towards the intervention. The students noted the significance of spatial skill with the help of the mobile learning environment. The participants demanded further information about spatial skill as they progressed through the learning episodes. The participants' interviews supported that using mobile learning tool, giving real-life examples, and emphasizing its importance

attracted the participants and helped them create awareness about this critical construct. Direct quotations of some of the participants are as follows:

> *I had no idea about the definition of intelligence, but I am sure I know it now. This is the type of intelligence that we use in our job, and I would like to develop it more.* (P001)

> *Explanations of the researcher helped me a lot to understand spatial skill. I know that I am very weak in this subject, but even I can see how I have developed.* (P002)

> *I had never heard of spatial skill before this project, but it does appeal to me now after using the tablet computers. I did some Internet research and now l see how important it is for us, and how it really is related to our jobs.* (P003)

Another point about which the participants highly referred was the positive effect of the mobile environment on their hands-on practices and school lessons, especially those related to mechanics. All of the participants were from the mechanics department, and most reported that using machinery parts through touchscreens afforded them the opportunity to identify all the details. Additionally, some of the students declared that using familiar tools and enhancing their spatial skill may have possible outcomes for their subsequent working life. Some of the participants' direct quotations were as follows:

> *We are using lots of machines, hand tools and devices. Now I believe that spatial skill plays a role in using them. It is also important in our school lessons; for example, in drawing, designing and mounting classes.* (P003)

> *We continuously use machinery parts and devices in our work. Spatial skill and this mobile application are related to the qualified usage of these tools. Therefore, l felt that this project was very important.* (P005)

> *This ability is important to understanding and designing how to draw a part. You may draw anything, a machinery part, or even an engine. This ability will help me in my design and development work.* (P006)

4.4.1.2. Category: Being Supportive

The participants frequently reported positive experiences in that the mobile learning tool played a supportive role in their 8 weeks of practice. The briefing videos shown at the beginning of each episode, example and non-example questions solved in the videos, and the hints and tips given both at the beginning of the videos and following incorrectly answered questions were significantly reported by the participants. All of the participants commented positively about the supporting role of the mobile learning environment.

> *I was not very good at the questions at first, but then I watched the videos over and over again. I tried to solve the questions like in the video, and found after one or two questions I was getting them right. The videos helped me a lot.* (P001)

> *The questions were not easy and it was very hard for me to make progress at first. But then I decided to pay more attention to the problems that were explained in the videos. The videos include one or two example questions and they were similar with the questions we saw. But I still think more examples were needed.* (P003)

> *The software gave me feedback after I got the answers wrong. I saw my latest score and a message told me about how I should respond. For example, in one of them it said 'Try to think that you are wandering about the 3D object. Try it again.' That was good advice and helped me to remember the basic rules.* (P002)

Another point that was significantly referred to was the supportive role of the mobile learning tool in sequencing and segmenting the content. The participants stated their positive thoughts about the presented order of the content and in using simplified units. Providing examples from widely-used 3D objects supported the students to become actively engaged with the content and to understand the relations of spatial skill through real-life examples. Direct quotations from some of the participants were as follows:

Designing the 3D objects using little cubes was very helpful. (P002)

I was not very good with 3D, but this software helped me a lot because it's arranged with simple things through to quite complex. In the first episodes, there were questions about viewing and afterwards questions about rotating and imaging. It goes from simple to complex, which is good. (P003)

There was an arrangement to what we saw in the software, and it was quite challenging. The episodes were all related somehow, and while the first questions were simpler, the latter questions were much harder. Once I knew this, I was more careful and focused. (P004)

The realistic objects and simple cubes were examples of real life, and so now l know what spatial skill means to us. (P005)

4.4.1.3. Category: Effective Instructional Use

The participants stated that using specifically designed software for activities connected to their working life was a unique experience for them. Most of the participants expressed that this method proved to be an invaluable experience in academic terms. According to the participants, this new method afforded them unlimited practice options, as well as the opportunity for self-study. Quotations from some of the participants were as follows:

This was the first time that I had used software like this. It was both enjoyable and instructional. We usually just learn in classes and labs, but this was a new kind of activity, and now I prefer this new way. (P003)

I liked the practicing very much. This was really important to me because it was quite different to drawing or mounting objects. This software allowed us to rotate, view, and image lots of times, and we also collected points as we did it. (P005)

I could study with the Android tablet alone, and didn't need anybody to help me because it was easy, and the videos helped a lot. I need help when

drawing or using the computer, but this Android app gave me the opportunity to study alone. (P002)

Other codes mentioned under this theme were about how the mobile tool helped the students implicitly, and how they perceived the effects of the mobile tool in their courses and daily work. The participants stated that the drills and practices were not only supportive for specific courses such as "technical drawing," but also for courses such as "maintenance" and "welding." Some of the participants reported that the mobile tool helped to develop some of their skills that they use automatically such as locating, rotating, and imaging mentally. However, fewer participants mentioned that these skills were of significant importance for their profession. Some of the participants' direct quotations were as follows:

I believe that the app was helpful for our course and also for some other courses, because we use similar objects with similar contexts. For example, I draw parts on a computer and handle it on CNC (computer numeric control) in another course. (P006)

I feel better in most of the courses now because I am more confident with 3D objects. (P001)

Now I find imaging parts is easier for me. I can now imagine 2D views automatically when I see a machinery part. (P002)

I work with my dad on a production-line that produces caterpillar track parts. Developing 3D and 2D skills is very important in my working life, and now I find that I am faster. (P005)

To conclude, the participants frequently emphasized the supportive role of the mobile learning tool, and also reported on the effectiveness of the instruction in developing their skills. The briefing videos that included hints and tips, as well as examples and non-examples, were reported to be very supportive features and perceived as being helpful by the participants.

Feedback was emphasized as another supportive element of the mobile app, and helped the participants to remember the basic rules as well as giving advice with regard to solutions to certain drills. Additionally, the participants found the sequencing and segmenting to be particularly beneficial. Presenting simple questions at the beginning of each episode and then supporting them with complex questions later on was another design feature that the participants frequently mentioned. The use of small units in building 3D objects attracted the attention and approval of the participants.

All of the participants described the mobile environment as a new experience for them. The participants reportedly liked the opportunities presented through the practicing and self-study that the mobile learning tool afforded, and that they found this new type of instruction to be like playing a game because of its scoring feature, the separate episodes, and the achievement-based rewards on offer. While all of the participant interviewees expressed the positive effect of the tool on their technical drawing course, some stated that the software also helped them with other courses too. The participants who had previous job experience stated that 2D and 3D skills were crucial to their working life.

4.4.2. Theme: Tablet Computers as a Technological Tool

In addition to the instructional and effective use of the mobile learning environment, the participants expressed opinions about the use of tablet computers as a technological tool. The researcher noted that not only the software, but also that the tablet computers themselves were of particular interest to the participants. Both the unofficial observations during the experimental phase and the semi-structured interviews demonstrated that this unique research also addressed the technology understanding of the participants since the use of tablet computers was quite new to them.

Under this theme, the researcher formed two categories. One was related to the “tablet usage preferences” of the participants, in which the participants mentioned Internet access, communication, playing games, and using familiar software. The

second category was defined as “technology era,” since the participants significantly emphasized the importance of technology usage in their daily routines. Under this category, the participants mentioned mobility, usage of a new technological device, and learning technology. Table 4.15 provides detail about the theme. Each of the categories were interpreted with the aid of direct quotations of the participants.

Table 4.15. *Categories and Codes of Tablet Computers as a Technological Tool*

Theme	*Categories*	*Codes*	*f*
Tablet Computers as a Technological Tool	Tablet usage preferences	Internet access	4
		communication	4
		playing games	3
		using familiar software	2
	Demand for technology	mobility	4
		new technological device	6
		learning technology	4

4.4.2.1. Category: Tablet Usage Preferences

The participants significantly described their tablet computer usage preferences in some detail, as well as some potential benefits to their usage. According to the participants, the use of tablet computers may help them to conduct their research, to communicate, and to play and study freely. Internet access emerged as one of the benefits that the tablet computers can provide. Second, communication was emphasized as a tablet usage option by the participants. Third, the playing of computer-based games was seen as another preference by the participants, as well as the use of educational software. Some of the participants’ direct quotations related to this category were as follows:

> *Using the tablet computer was so easy and helpful. I was so relaxed in using them because l had access to the Internet and could search for everything I needed.* (P004)

I love using tablet computers because there are lots of mobile games for the Android market and most of them are free. Also, most of the games are just for tablet computers. (P002)

If we had the chance to use tablet computers again, I may use similar software. There are lots of applications in Google Play; for example, English-teaching ones. I wish I had one. (P006)

4.4.2.2. Category: Demand for Technology

The other category for this theme relates to the demand of technology that we feel in most of technology-based jobs. The participants were reportedly quite aware of the importance of today's digital lifestyle and communication tools, and interpreted that the tablet computers were just the latest technological device. The participants stated that the tablet computers fulfilled a critical role in today's technology and also for their profession. The participants were also eager to learn to use these devices and were very curious about their technical properties.

Tablet computers are the latest computers and I believe that everybody will soon use tablet computers in their work. (P004)

We had tablet computers when I was working in the car-service and trying to analyze the faults on cars using these computers. They are really fantastic devices and we can use them for almost every task. (P006)

I believe that learning about these devices and their abilities is very important, because all of us will use these devices in the future. (P001)

As a result, the participants were positive in their thoughts about the usage of tablet computers as a new technological tool. Mobility, ease of access to the Internet, gaming options, and educational software makes these devices efficient technological tools. The participants seemed eager to learn about these tools, and to use them for every single task.

4.4.3. Theme: Technical Properties

Another theme that the participants significantly mentioned regarded the technical properties of the tablet computers (both hardware and software). In contrast with the previous themes, the participants also negatively commented about certain technical properties of both the hardware and software of the Android tablet computers used in the exercise. The researcher gathered the codes under two categories as "hardware" and "software." Screen size, touchscreens, and control options were the most frequently used codes that the participants emphasized in terms of the hardware. Although these codes were related to the hardware, they should be evaluated with consideration to the software and operating system of the tablet computers used during the intervention. Graphics, links, rotating, and focusing were the most cited specifications of the software. Table 4.16 provides detail about the theme. Each of the categories were interpreted with the aid of direct quotations of the participants.

Table 4.16. *Categories and Codes of Technical Properties*

Theme	*Categories*	*Codes*	*f*
Technical Properties	Specifications of hardware	screen size	5
		touchscreens/ control options	3
	Specifications of software	graphics	3
		links	3
		rotating/focusing	5

4.4.3.1. Category: Specifications of Hardware

Most of the participants commented on the technical properties of the tablet computers. Screen size was the most referred to hardware-related technical property. The interviewees mostly commented negatively, emphasizing the relatively small screen size of the tablet computers, and stated that they would have preferred using larger screens. There were also comments made that using larger screen sizes during

the intervention would have been more efficient. Direct quotations of some of the participants were as follows:

> *I think we needed bigger screens. They were really small. I would like to have had the chance to focus on some of the images and objects in more detail.* (P003)

> *The only negative thing about the tablet was its small screen. I could maybe have used it more efficiently and easily rotated objects it if it was a little bigger. I had a hard time when rotating some of the objects.* (P004)

> *It would be more enjoyable if there were bigger* [tablet] *computers. We may then have been able to use the application more easily. I would like to have watched the videos on a bigger screen size. I believe that this application may be more helpful too with a bigger screen.* (P006)

The participants were positive about the control options of the tablet computers. Most vocational high schools in Turkey use desktop computers in a laboratory or classroom setting, and therefore there is limited utilization of tablet computers or smart screens in these schools. The participants mentioned having positive experiences with regards to the tablet computers' touchscreens and control options (i.e., use of a finger rather than a mouse or stylus). Most of the participants compared mouse and finger-based control, whilst all of the participants commented positively about finger-based touchscreen controlling of the hardware. The participants stated using the tablet computers more easily with touchscreens and finger-based control. Some of the participants' direct quotations were as follows:

> *I'm experienced in using a desktop computer, but had rarely used a tablet computer. I found it easy to use and relaxing because of using finger-based control and therefore didn't need a mouse. I liked the tablet computers much more.* (P004)

> *I liked the sensitivity of the touchscreen. It was very sensitive and it recognized all of my intended moves. Its screen was a little small though, but its sensitivity was quite good.* (P006)

There were many rotating and focusing drills, but it was very simple to make these movements with finger-based control. Touchscreens and finger-based control was easy to use. (P001)

4.4.3.2. Category: Specifications of Software

In addition to the experiences and thoughts of the participants about the content, design and motivational factors of the mobile application, they also offered valuable feedback about the technical qualifications of the software. The participants stated that the graphics of the 3D objects were realistic, and that this helped them to feel like they were using real objects. Although there were numerous 3D objects, rotating, focusing, minimizing and maximizing controls, the application succeeded to show all the details of the objects, graphs and colors. Direct quotations about the technical properties of the application by some of the participants were as follows:

The software was successful for the maximizing, focusing and rotating tasks without experiencing any problems. There was no freezing. Our laboratory [desktop] *computers keep need to be restarted for similar tasks.* (P001)

The graphs, visual details, and the colors of the 3D objects were so realistic. Rotating, maximizing, and minimizing tasks were all very fast. (P004)

All the links were active and there was no freezing or slow links. 3D software generally has freezing problems, but this one was very good at handling the 3D objects. (P006)

As can be seen from the direct quotations, the participants mostly provided positive feedback about the technical aspects of the hardware and software. Touchscreens and finger-based control were the most frequently coded hardware-based specifications. Similarly, for the software, visuals, graphics, links and rotating/maximizing/minimizing performance received the most positive comments from the participants. The only criticism noted was about the small screen size of the tablet computers. However, there were no negative comments received from the pilot study on this issue, with most

students having negative thoughts about the size of the tablet computers in real experiment.

4.4.4. Theme: Learning Content

How the participants perceived and evaluated the content of the mobile learning environment emerged as the fourth and one of the most referred to themes. The learning content's design, instructional usage, technology-based usage, and technical qualifications of the environment drew the attention of the participants.

The participants provided some invaluable feedback about the variety, size, and complexity of the learning content. The participants provided criticism, advice, and approval with regard to the content. Most of the feedback related to the length of the intervention, the time allocated for each learning episode, and the complexity of the drill and practice questions. The researcher formed three categories for this theme, which were "variety of content," "size of content," and "complexity of content." Table 4.17 provides detail about the theme. Each of the categories were interpreted with the aid of direct quotations of the participants.

Table 4.17. *Categories and Codes of Learning Content*

Theme	*Categories*	*Codes*	*f*
Learning Content	Variety of content	2D perspective	4
		3D objects	5
		exam preparation	2
		mental process	2
	Covered Content	number of episodes	4
		number of questions	6
		additional activities	3
		time limitation	6
	Complexity of content	abstract	3
		confusing	2
		difficult	2
		time consuming	2

4.4.4.1. Category: Variety of Content

Most of the participants stated that the mobile application included different types of drill and practice activities, and that these varied practices enabled them to identify the 2D graphs and 3D objects in detail. There were seven different drill types used in the application, and each of them was unique and aimed at different abilities. However, some of the participants suggested new question types and content.

Some of the participants reported needing more questions in some of the learning episodes such as on 2D perspectives or 3D rotation. The 2D perspective practices and rotating exercises were the most popular drill type among all episodes. Although there were daily-use 3D objects in the learning episodes, the participants requested objects such as real machinery parts such as bolts, nuts, screws etc.

> *I would suggest the adding of new objects. Nuts, bolts and some other parts are the basic and most used in our courses. I believe they would make a great addition.* (P006)

> *I liked all the episodes. Each was different and I realized that they each started with counting and rotating, and ended with relocating.* (P001)

> *It helped me to pass from 2D to 3D. There were different question types and l liked to solve each of them.* (P002)

4.4.4.2. Category: Covered Content

All of the participants agreed that the mobile application and each learning episode needed to contain more questions. They suggested having more learning episodes and longer episodes (with more questions in each episode). This may suggest that the participants enjoyed the application and they wanted to spend more time using it.

> *I needed more questions. It was too short and l completed each episode in nearly 10 minutes. More questions would make more of a contribution.* (P004)

The learning episodes were very detailed and well-designed, but more episodes may help us to interact that bit more. (P006)

Other suggestions offered by the participants concerned presenting unlimited options for tablet computers and the mobile learning application. There was no time limit set for completion of the learning episodes, but each episode was designed to last 15-20 minutes. The students requested that more time be set aside to using tablet computers and the learning software. Most of them reported that using tablet computers and the application would be more efficient and convenient than time spent attending normal course hours.

We did not have enough time to interact with the tablet computers and the app. The time was too short with only 15 minutes. Yes I could complete the episodes, but I would have preferred to use the tablet for longer. (P003)

I would like to have used the app more and more. Time was too short and we had to complete the exercises in 20 minutes. More questions and more time would have been helpful. (P001)

4.4.4.3. Category: Complexity of Content

As defined in Chapter 2, the literature review of this study, spatial skill is an inner construct and presents a set of mindful actions such as imaging, locating, and rotating 2D graphs or 3D objects. Each of these actions and tasks demand high-level cognitive processes. In other words, actions related with spatial skill need higher-level skills. Some of the participants stated that the application contained complex questions and drills, and that they were unable to complete all of them correctly. Although the content was segmented and sequenced, some of the episodes were criticized for being too complex to solve. Actually, this was considered an expected outcome of the study, since the pre-test scores implied the participants having low spatial skill scores. According to their pre-test scores, seven of the 85 participants answered just one question correctly, and 12 of the participants answered just two of the 24 items correctly. Direct quotations of some of the participants were as follows:

It was too hard for me, and l always made wrong decisions. I wish it had been a little bit easier. (P003)

The first episodes were ok, but the latter ones were too complex for me to solve. (P001)

l liked the app very much, but some of the episodes were difficult. I only answered the questions with the help of you [the researcher] *and my friends.* (P002)

4.4.5. Theme: Motivational Factors

Motivational factors were listed as one of the most referred to categories. The participants commented a great deal about how the learning environment and the usage of the tablet computers increased their motivation towards the lessons and school. Some of the students defined the experimental process as a reason for attending school. Most of the participants reported that it was perceived to be an enjoyable activity, and that their primary aim was to use the tablet computers and the software. Table 4.18 provides detail about the theme. Each of the categories were interpreted with the aid of direct quotations of the participants.

Table 4.18. *Categories and Codes of Motivational Factors*

Theme	*Categories*	*Codes*	*f*
Motivational Factors	Active participation in courses	attendance to courses	5
		additional interest	6
		expectation for lesson	5
	Enhancing motivation	new method	6
		unique experience	5
		enjoyable activities	6
	Feeling challenging and successful	scoring	4
		comparing scores	4
		challenge with friends	3
		completing tasks	2
		taking rewards	4

The first category that emerged for the theme of “Motivational Factors” was the opportunity afforded to the students to actively participate in the mobile learning environment provided. Motivation was the second category, and attracted the most citations by the participants. The third category related to the feeling of being successful and challenging, since the students reportedly felt highly committed to working in the mobile learning environment.

4.4.5.1. Category: Active Participation in Courses

This new method of instruction was described as a unique experience for the participants, and positively reacted to the usage of the tablet computers and the drill and practice application. Most of the participants reported that it had a positive effect on their school attendance and that they attended all of the class hours and completed each learning episode. However, they also suggested wanting or needing more time to use the tablet computers and the mobile learning application. Direct quotations from some of the participants were as follows:

> *I am not usually interested in the drawing lessons, but I attended all the lessons* [during the experimental intervention] *because l loved to use the tablet computer and the app.* (P001)

> *l have a tablet computer and l love to play games on it. This app and using the tablet really appealed to me, and l began to show more interest in the lesson. I did some Internet research for more detailed information about it because the app got me interested.* (P006)

> *I kept feeling really curious about the next lesson, and was very excited to be using the tablet. I expected to use it a bit more, but the time was too short.* (P002)

4.4.5.2. Category: Enhancing Motivation

One of the most coded categories was enhancing motivation, with the participants having showed significant interest towards using the tablet computers and the mobile

learning application. The students expressed that they were using tablet computers for the first time. Similarly, they declared that they had never used a mobile learning application prior to the intervention. Integration of the latest hardware and the new method of instruction was seen as a unique experience for the students. The participants stated that the activities were enjoyable, and that the new method of instruction and the uniqueness of the experience were the primary motivating factors for them throughout the exercise.

> *We are used to working on computers, but had never used tablets in our lessons before. Additionally, this was the first time that I had used software that was especially designed for us.* (P002)

> *The drill and applications were entertaining. I loved to progress through the application; each episode had a different style of questions and it was quite enjoyable.* (P003)

> *It was such a valuable experience for us that I wanted to use the tablet and practice more and more. I loved the lessons, and came to school with a feeling of great excitement and motivation.* (P001)

4.4.5.3. Category: Feeling Successful and Challenging

The students declared positive thoughts about the scoring feature of the mobile learning application. The performances of the participants were scored according to the answers they gave, as correct or incorrect. While they were awarded 100 points for each correct answer, each incorrect answer saw their total score decreased by 50 points. All of participants received a score at the end of each learning episode. The students were positive about the opportunity to compare their scores against each other, and to their previous weeks' scores.

> *The scoring was very interesting because it was punishing when we gave incorrect answers. Since there was a big price for each of our decisions, we had to stop and think twice.* (P006)

> *I compared my scores with my best friend, and we challenged each other every week. It was like a game to us, and I really enjoyed it.* (P005)

The researcher rewarded the highest scoring student in each episode with a complimentary movie ticket. The award was seen as a useful motivational source for the students, with the researcher having observed a high level of challenge between the students within the laboratory setting. Completion of the tasks (learning episodes) with the scoring feature, as well as being able to compare scores and receive awards, were named as external motivational factors by the participants. Some of the students thought of the application as a game.

> *I got the highest score two times and it was a wonderful feeling. Now I have two movie tickets to use and I earned them in the final weeks. I worked really hard for them, and I succeeded!* (P004)

> *Finishing the episodes and getting separate scores for each episode was so exciting. I was the winner in the first episode, but I couldn't achieve any more. But it was very challenging and everybody was very enthusiastic about the lessons.* (P006)

CHAPTER 5

DISCUSSION

The aim of this study is to compare the usage of tablets computers, desktop computers, and conventional paper-pencil booklets to enhance the spatial skills of vocational high school students, and then examining the participants' perceptions about a well-designed mobile learning environment. The research findings offer valuable data about the spatial skills of vocational high school students, the effects of different instructional tools applied, design issues about the mobile learning environment, and students' experiences with regard to this as a unique educational practice. Considering these aspects, the results are considered to be significant for students, researchers, instructional designers, and teachers.

Considering the objectives of the current study, the researcher decided to use mixed-method research as the methodology in order to respond to the two distinct types of research questions. Embedded design, one of the mixed-method research designs, aims to reply to different and supportive kinds of research questions within a single experiment using different datasets. Three research questions were used in the current study in order to analyze the enhancement of spatial skill, and to reveal any hidden outcomes about the mobile learning environment developed and utilized in the study, and the tablet computers in terms of enhancing participants' spatial skill.

The first two research questions were addressed through the analysis of quantitative data, while the third question used qualitative data. After designing and conducting the experimental phase and collecting the quantitative data, the experiences of the participants were collected and unidentified variables revealed by way of qualitative research methods.

The researcher developed a drill-practice based software compatible with mobile learning environments such as mobile smartphones, tablet computers, and desktop computers using Reigeluth's (1999) simplifying conditions method (SCM). Afterwards, the researcher tested the effects of the tablet computers, desktop

computers and paper-pencil booklets on the spatial skills of Turkish vocational high school students and then compared the results. Additionally, the perceptions of the participants were collected through semi-structured interviews in order to gain a deeper understanding of the phenomenon.

After identifying the research site, designing and developing the software, and the completion of a pilot study, the participants took the Mental Rotation Test (Vandenberg & Kuse, 1978) as a pre-test and three study groups were formed for the experiment settings. After 8 weeks of intervention, the Mental Rotation Test was used again as a post-test for three groups. After completion of the quantitative phase of the study, the researcher interviewed six of the participants from the tablet computer study group in order to collect the qualitative data.

To conclude, the quantitative results showed that: (1) the participants (first grade vocational high school students, or ninth grade in K-12 terms) had relatively low spatial skill scores according to their pre-test scores; (2) all three study groups, mobile learning tablet computer (experimental) group, desktop computer (control) group, and the paper-pencil booklet (control) group achieved significantly higher scores on their post-test (Mental Rotation Test) compared to their pre-test; (3) both the tablet computer (experimental) group and the desktop computer (control) group achieved significantly higher scores on their post-test than the paper-pencil booklet (control) group; and, (4) no significant difference was found between the tablet computer (experimental) group and the desktop computer (control) group, according to their post-test scores. In terms of the study's qualitative results; (5) the participant vocational high school students from the experimental (tablet computer) group were highly interested and reacted positively to the mobile learning environment (usage of tablet computers). Their feedback focused on five themes as: (a) mobile learning tool as facilitator; (b) tablet computers as technological tools; (c) technical properties; (d) learning content; and, (e) motivational factors.

This chapter presents detailed discussion of both the quantitative and qualitative results of this study, the participants' experiences revealed from the study,

implications for practice, and also recommendations for future studies. The results are presented and discussed based on the research questions of the study.

5.1. Spatial skill scores of each group before and after interventions

Researchers have defined spatial skill as an inner construct that is critical to many disciplines, but more especially for success in math and science (Lubinski, 2010). Numerous studies have proven that spatial skill may predict achievement in science and technology based careers (Miller & Halpern, 2013; Taylor & Hutton, 2013). In addition, the identification of and training for spatial skills have become major research topics based on its well-known effects on overall success (Shea, Lubinski, & Benbow, 2001) in working life.

In the current study, the researcher used three different types of intervention with three study groups. Two groups (using tablet computers, and using desktop computers) used purposefully designed software and one group used paper-pencil booklets containing the same content. The researcher then explored the potential effects of the training in order to develop this very critical inner construct.

All three study groups received the same drill and practice learning episodes with same content, but employing different media, with tablet computers, desktop computers, and paper-pencil booklets. MRT (Mental rotation test) (Vandenburg & Kuse, 1978) was used as a pre-test and to evaluate similarities between the three groups.

Following an eight-week intervention period, the MRT was reapplied as a post-test. The researcher used the post-test scores to compare each group against their pre-test scores. Paired samples *t*-test was used in order to compare the pre-test and post-test scores of each group (within groups).

Comparison of the pre-test and post-test results proved that all three groups performed better in their post-test. In other words, the interventions had a positive effect on the spatial skill scores of the three groups of participants. This result draws parallel with the literature and supports the idea of spatial skill being a skill that can

be acquired or developed through training (Hegarty, 2018; Olkun, 2003; Sorby & Baartmans, 2000).

As reported in Chapter 1 (Introduction) of this study, there is still ongoing debate as to the definition of spatial skill. Similarly, the components of spatial skill and the measurement of these components is still a matter of academic argument. On the other hand, the literature seemed to reach a consensus about the enhancing of spatial skills (Hauptman, 2010).

Numerous studies have proven that spatial skill can be improved through systemic studies. Paper-pencil work, additional drawing classes, and specifically designed courses are some examples of early studies in this area (Sorby & Baartmans, 2000). These studies reported positive results on the use of paper-pencil sketching practices. Using computer-aided drawing software (Shavalier, 2004) is another training method used in order to enhance spatial skills. Likewise, using handheld devices with games (Martin-Dorta et al., 2013) has reported positive outcomes for the enhancement of spatial skills. Similar with these studies, all three intervention groups in the current study made progress in terms of the participants' spatial skill, having achieved higher post-test scores compared to the pre-test. Additionally, the literature proposes positive results to the enhancement of spatial skill through drawing or sketching exercises and in-class activities (Mohler & Miller, 2009). Sketching flipped or rotated versions of objects, drawing tangible objects and hands-on problem solving are just some of the methods that can be employed using a paper-pencil approach. Initial studies on spatial skill employed booklets and specifically designed college courses (Rafi et al., 2006). In these studies, the students were encouraged to draw 3D objects and to attend sketching sessions. In most of these research studies, there were limited descriptions given of printed materials, just a mention that students used drawing materials already in use in lessons such as "technical drawing" or "engineering drawing".

On the other hand, the researcher in the current study designed content for three mediums (tablet computers, desktop computers, paper-pencil booklets) using the simplifying conditions method (SCM) which aims to simplify and sequence content

through seeking the help of subject-matter experts (SME) and using a three-phase model. Since spatial skills require automaticity and the subconscious use of these skills in daily work-life, drill and practice sessions are pointed to being one of the most effective methods to increase these skills (Reigeluth, 1999). All three groups received the same drill-practices which were purposively developed to advance the sub-skills of the participants' spatial skills. For the paper-pencil booklet group, the researcher used still pictures, additional lectures, and the provision of one-on-one feedback instead of audiovisual media as provided to the other two groups (tablet and desktop computers) have. The use of well-designed (simplifying conditions method) paper-pencil booklets may have helped the paper-pencil group to achieve higher post-test scores.

Similar to the paper-pencil group, the desktop computer group also used drill practices. The software used by the desktop computer group was specifically designed and developed by the researcher for the current study. The software is adaptive for desktop computers, and was reported to be used easily by the participants of the desktop (control) group in unofficial discussions held with the participants.

Similar to the conventional paper-pencil booklet group, the other control group, the desktop computer group, also showed increased spatial skill post-test scores. There has been numerous research that has utilized computers and drawing software in order to enhance spatial skill (e.g., Baki et al., 2011; Martín-Dorta et al., 2008). Most of these studies have reported positive outcomes in increasing participants' spatial skill scores and have also received positive feedback from participants. On the other hand, the literature does not present any research that clearly explains the design issues of software used in the experimental setting. CAD software and 3D modeling software are some of the dynamic software utilized in spatial skill studies. However, none were designed specifically to enhance spatial skills, just for the purposes of drawing, design and production. Using well-designed drill-practice episodes in accordance with the simplifying conditions method may have helped students to enhance sub-skills like viewing, rotating, identifying, matching and transforming.

Similar to the paper-pencil and desktop computer groups, the tablet computer group also performed better in their post-test, achieving significantly higher scores. The literature reports positive results of the use of tablet computers (Chang, Wu, Lai, & Sung, 2016; Wang, Wu, & Hsu; 2017) to enhance spatial skills. In the current study too, the use of tablet computers and learning software may have helped the study's participants to achieve increased post-test scores.

As previously mentioned, the researcher used the Simplifying Conditions Method (SCM) (Reigeluth, 1999) in order to develop content for the mobile learning software and for the paper-pencil booklets. The same content was used for the tablet computer, desktop computer, and paper-pencil booklet groups. In other words, the current study included a specific content design and development phase that was intended to positively affect the development of the participants' spatial skills.

To conclude, the results of the current study drew parallels with the literature, in that it supports that spatial skills can be enhanced through systemic instruction. The 8 weeks of drill-practice sessions aided the students' enhancement of their spatial skills. In other words, the results proved that all three study groups positively responded to the interventions, and succeeded in achieving higher mental rotation test scores in their post-test when compared to their pre-test scores.

5.2. Difference between three groups

One-way ANOVA was used in order to determine the difference between the post-test scores of the three participant groups. The results indicated that there was a statistically significant difference between the three groups, according to their post-test (MRT) scores.

Further analysis examined the differences between the three participant groups (tablet, desktop computer, and paper-pencil groups). Bonferroni test was also applied in order to compare the intervention in three groups of two. The results indicated that the tablet computer group and the desktop computer group both had significantly higher scores when compared to the paper-pencil booklet group, while no significant

difference was found between the tablet computer group and the desktop computer group.

Higher post-test scores of the tablet computer and desktop computer groups may have been sourced from the use of different mediums (software and paper-pencil booklets). As reported in previous chapters, the learning software that the tablet and desktop computer groups used included briefing videos. Since the paper-pencil group did not watch any videos, the researcher presented short lectures to the paper-pencil group prior to before each intervention session instead of briefing videos of software. Second, tablet and desktop computer may focus on 3D objects in drill-practices, maximizing, minimizing, and rotating of 3D objects. The researcher used still pictures in the booklets in order to provide similar opportunities to the paper-pencil study group. Third, while the software itself provided a form of feedback to the tablet and desktop computer group participants, the researcher instead provided one-to-one feedback to the participants of the paper-pencil group.

As Kozma (1991) claimed, different media have specific features and processing capabilities that can address learners and thereby produce a unique experience within that environment. There is subsequently a powerful relationship between media, content, and learner interaction. Although the content used by the three different groups was the same, there were significant differences in the presentation of the content, and these differences may supported the foundation of positive results seen in the tablet and desktop computer groups.

Second, since the computers are considered “new” technology products, and the participants’ first experience of using learning software, extrinsic motivation may have also been a factor in why the desktop computer (control) and tablet computer (experimental) groups both outperformed the paper-pencil booklet (control) group on post-test scores.

Third, the difference between the tablet and desktop groups and the paper-pencil group may be sourced from the perspective of novelty. The novelty effect, or Hawthorne effect, may help to explain the difference between the technologically

supported groups (tablet and desktop) and the conventional group (paper-pencil). A novelty effect can develop when learners are stimulated to greater efforts because of the novelty of the tools being used. In other words, participants may exhibit greater efforts if they meet with a new learning experience (Kulik & Kulik, 1991). First of all, the participants in the current research had not previously used tablet computers in their lessons before. Second, they had not previously used any similar form of learning software before. They did, however, have prior experience in drawing and sketching so that they were used to drawing objects or making sketches, but it was their first time that they had practiced using computer-based software and tablet computers. As a result, the differences seen between the computer-based groups and the conventional group may be due in part to the novelty effect.

Research on the use of different media to develop spatial skill varies. Desktop computers, mobile phones, real object, paper-pencil booklets, tablet computers and also virtual reality applications have all been used to enhance the spatial skills of learners. On the other hand, two related basic questions should be considered in order to make comparisons of these media: “Is one tool superior to the others?” and “Which specific property of these tools provides effective enhancement of spatial skills?”

Research on use of stylus, mouse, or finger-based control as input tools may provide clues about the appropriate usage of tablet computers for enhancing spatial skill. Research has proven that finger-based control rather than mouse-based or stylus-based is the quicker tool (Findlater, Froehlich, Fattal, Wobbrock, & Dastyar, 2013). Additionally, the use of finger-based control has been shown to provide more reliable results for the drawing of lines and shapes (Zabramski, Gkouskos, & Lind, (2011).

With these issues in mind, the use of finger-based control with tablet computers may be considered advantageous in helping students to rotate and investigate 3D objects in a quick and easy manner. Additionally, students may more easily and reliably maximize, minimize, and focus related drawings or objects using finger-based control, as opposed to using a mouse on desktop computers.

These ideas may provide clues as to the usage of real-time objects, rather than software, to enhance spatial skills. Research on spatial skills started with using specific course design for engineering students and using books, booklets, drawing assets or real-world objects. On the other hand, designing and producing real-world objects is both costly and time consuming, and it may not be even viable for students to acquire numerous items from their home or school. Drawing software within computer-aided drawing (CAD) applications provides the opportunity to produce unlimited numbers of objects and designs.

Considering the issues of mobility, unlimited practice options, reliability, and the pace of the input tool (e.g., finger-based), it can be said that the mobile learning environment (i.e., tablet computer with software) offers certain advantages over conventional tools.

However, in the current study, the post-test results proved that the tablet computer (experimental) group did not score significantly higher than the desktop computer (control) group. Although finger-based control has been shown to have certain advantages, this alone may not have resulted in a positive effect on the development of the participants' spatial skills, but just ease of use of the device and the software. A prolonged and more inclusive experiment may be required in order to reveal the possible effects of finger-based control over mouse-based or stylus-based devices.

Another reason may be over-enthusiasm (increased motivation), on behalf of the participants, towards the use of tablet computers. While the desktop computer group used computers within a computer laboratory (a well-known tool and place for the participants), the tablet group were using tablet computers for the first time (for most of the participants). The resultant likely over-enthusiasm and dedication of some of the session time to the basic operation of the tablet computers themselves may have distracted the participants' focus away from the intervention.

Although tablet computers incorporate touchscreen technology and are considered highly mobile, they do, however, use much smaller screens than desktop computers. As reported in the qualitative results, the participants were highly critical of the of

tablet computers' smaller screens and most demanded larger screens. This difference in screen size may have created more positive results for the desktop computer group because they had a larger space in which to maximize, minimize, and rotate their 3D objects.

5.3. Experiences of Participants

Embedded design aims to answer two different kinds of research questions within a single study. Different research questions support and provide additional information for each other within the embedded design. After analyzing the quantitative dataset and deciding how different interventions affected spatial skill, the aim of the second research question was to reveal how the tablet computer (experimental) group's participants experienced the intervention, and which latent variables may add value to the first research question. In other words, the qualitative part of the study aims to provide information from the perspective of the students, and how their experience can be enriched.

Since this intervention was the participants' first experience with a mobile learning environment, they showed considerable interest towards both the use of the tablet computers and the developed software. After 8 weeks of intervention and the subsequent post-test, the researcher conducted semi-structured interviews with six participants of the tablet computer (experimental) group in order to learn about their experiences. A semi-structured interview form was used for the interviews. Each interview lasted from 5 to 10 minutes, and all of the qualitative audio content was transcribed verbatim, and then coded and recoded according to thematic coding.

Five themes, 13 categories, and 54 codes emerged through the coding. The five themes were named as: (a) mobile learning tool as facilitator; (b) tablet computers as technological tools; (c) technical properties; (d) learning content; and, (e) motivational factors.

First, the students reported how the mobile learning tool helped them throughout the intervention. The participants stated how the intervention helped them to create awareness about spatial skill, and its significance to their work-life. Additionally, the

participants provided invaluable feedback about the supportive role of the software design in their emphasis of the example questions, the explanatory videos, and the segmenting. Additionally, the participants found the experience to be both unique and very effective.

Second, the participants reported their opinions as to how they perceived tablet computers as a technological tool, and how this kind of technological tool is unavoidable in today's technology era. However, the usage aim of tablet computers varies. The participants reported alternative usage preferences such as for the playing of computer games, for communication, and for access to the Internet.

Third, the participants provided critique about the technical properties of the tablet computers in terms of both hardware and software usability. The screen size of the tablet computers, as well as the screen sensitivity and control options were the most mentioned topics during the participants' interviews. While the participants positively commented on the touchscreen sensitivity and control options of the tablet computers, they negatively reacted about its screen size. Most of the participants emphasized that a larger tablet computer screen size would have helped them to more easily use the learning software.

Fourth, the participants focused on the learning content in terms of its size, variety, and complexity. The participants found that the learning episodes varied and they provided positive feedback on the varied drill-practice types. The size of the content was another issue that the participants focused upon. The participants were mostly satisfied with the number of questions and number of episodes, but most complained about time-based constraints.

Lastly, the participants emphasized the motivational factors that they experienced through usage of the software and from use of the tablet computers. The students reported that using the tablet computers and the specifically designed software helped them to actively engage and participate in the lessons. This unique case encouraged them to attend courses and increased their interest level towards the course. Additionally, the participants stated that they would excitedly anticipate their

upcoming lessons. Some of the participants provided clues as to how the design of the learning tool helped them to feel challenged and also successful. The participants reported their positive thoughts about the scoring and rewarding features of the learning tool, and how they enjoyed challenging their friends.

The results of the current study proved that spatial skills may have developed through drill-practice interventions and through different types of media. The results of the qualitative analysis showed that the students found the tablet computers to be quite helpful to them in their lessons, and that they evaluated the tablets as being quite instructive.

5.4. Implication for Practice

Spatial skill, which has been shown as one of the indicators of overall achievement in math, science, and technology, is an inner construct which plays a critical role in the visualization of 3D objects, rotating objects mentally, as well as relocating and designing them (Black, 2005; Mbano & Nolan; 2017; Milgram, 2011). Numerous studies have proven that spatial skill can be improved (De Lisi & Wolford, 2002; Martin-Dorta, Soarin, & Contero, 2008; Miller & Halpern, 2010). Teaching through specifically designed courses, using computer-supported material, using physical manipulatives and virtual reality tools are some of the techniques that can be employed in order to enhance the spatial skills of students. As previously stated, the current study aimed to compare three different interventions exploring the effects of them on the spatial skills of vocational high school students, and to reveal the perceptions of the experimental group's experiences during this unique practice.

The results proved that the 8-week intervention with three different media types showed positive results, and that the interventions significantly increased the spatial skills of the participants. In order to reveal the participants' experiences, and to understand their perceptions about the design of the software, its integrity with tablet computers, and the use of such new technologies for in-class activities, the researcher collected qualitative data through semi-structured interviews. The results indicated that the participants positively reacted to the unique experience, were

satisfied with the content, showed interest in using the tablet computers and software, and attended the courses with a significant sense of motivation.

Considering the overall aim of the current research and its results, there are specific implications for practice that can be drawn from the study's results. First, well-designed paper-pencil and computer based drill-practice applications are effective to enhance spatial skills of vocational high school students. Researchers and designers may use and re-investigate the effects of these tools in future research on spatial skill.

Second, the simplifying conditions method (SCM) was the instructional design framework used for the design of the content. The current study's results proved that SCM is an effective strategy for enhancing moderate to complex cognitive skills such as spatial skills. Designers, researchers and teachers may therefore make use of SCM to develop similar tools for enhancing spatial skills or other skills that require simplification and sequencing.

As a result of the qualitative part of the current study, the participants highly criticized the dimensions of the tablet computer touchscreens. Tablet computers with larger sized screens may help students to take better advantage of the content for this specific type of learning material. Since the learning material in the current study contained rotating, counting, and imaging activities, larger tablet computer screen sizes may have helped the learners to progress further.

Research results have proven that tablet computers are one of the latest technological tools available and that students are very interested to utilize these tools in their lessons if the software is instructionally well-designed. Use of these tools with proper content may create more effective learning environments.

To conclude, the researcher designed a learning software and paper-pencil booklet using SCM, and then compared results based on usage of the three different media. Researchers, designers, and also teachers may therefore design new material using SCM and then use them along with the latest technological tools with improved specifications.

5.5. Suggestions for Future Research

The current research aimed to compare the effects of three different media, with similar content developed for spatial skills learning by Turkish vocational high school students, and to learn about their perceptions about this unique experience. The study's results proved that well-designed spatial training can positively affect the spatial skills of vocational high school students. All three intervention types were found to have helped the students to improve their spatial skills.

The current study included the development of learning software in which the researcher used SCM as the instructional design framework. SCM can help researchers to simplify and sequence content for a complex cognitive skill such as spatial skill. Designers, researchers, and teachers may therefore use SCM for the development of similar software and to retest its effects on spatial ability.

The current study aimed to enhance the spatial skills of Turkish vocational high schools. Future studies could focus on students from other types of high school with similar tools. Research with different school types (participants) may generate varied results since different school types may have certain and therefore varied characteristics. Similarly, the current study was conducted with only male participants due to the specific characteristics of the research site. Future studies that include female as well as male participants may therefore yield more inclusive results.

The literature offers that maturation is a predictor of spatial skills. While some research suggests that the young will likely benefit more from training than adults in terms of spatial skill enhancement, others report no significant difference realized from spatial trainings (Linn & Petersen, 1985). The current study focused on first grade students (ninth grade in K-12 terms) of a Turkish vocational high school. Future research could address different student grades or earlier level schools in order to observe the maturation effect in spatial skills development.

In the current study, it was the participants' first experience with using tablet computers in a classroom setting. Similarly, the participants used learning software

for the first time in their learning life. A novelty effect may therefore have occurred for the experimental participant group in the current study. Future research could focus on studies where all of the participants have similar prior experiences in order to exclude the novelty effect.

In the qualitative phase of the current study, the participants commented significantly about the screen size of the tablet computers employed in the intervention. Considering such feedback, future research studies may consider the use of larger-sized screens. The use of larger screens, updated technological tools, and enabling students to have additional free time to use the tablet computers may increase the students' motivation towards the learning environment and to their courses.

REFERENCES

Alias, M., Gray, D. E., & Black, T. R. (2002). Attitudes towards sketching and drawing and the relationship with spatial visualisation ability in engineering students. *International Education Journal, 3*(3), 165-175.

Allen, I. E., & Seaman, J. (2008). *Staying the course*. Needham, MA: The Sloan Consortium.

Andersen, L. (2014). Visual–spatial skill: Important in STEM, ignored in gifted education. *Roeper Review, 36*(2), 114-121.

Assel, M. A., Landry, S. H., Swank, P., Smith, K. E., & Steelman, L. M. (2003). Precursors to mathematical skills: Examining the roles of visual-spatial skills, executive processes, and parenting factors. *Applied Developmental Science, 7*(1), 27-38.

Ault, H. K., & John, S. (2010). Assessing and Enhancing Visualization Skills of Engineering Students in Africa: A Comprehensive Study. *Engineering Design Graphics Journal, 74*(2), 12-20.

Ayas, T., & Pişkin, M. (2011). Lise Öğrencileri Arasındaki Zorbalık Olaylarının Cinsiyet, Sınıf Düzeyi ve Okul Türü Bakımından İncelenmesi. *Ilkogretim Online, 10*(2), 550-568.

Baki, A., Kosa, T., & Guven, B. (2011). A comparative study of the effects of using dynamic geometry software and physical manipulatives on the spatial visualisation skills of pre-service mathematics teachers. *British Journal of Educational Technology, 42*(2), 291-310.

Battista, M. T. (1990). Spatial visualization and gender differences in high school geometry. *Journal for Research in Mathematics Education, 21*(1), 47-60.

Bennett, G. K., Seashore, H. G, & Wesman, A. G. (1973). *Differential aptitude tests, forms S and T.* New York: The Psychological Corporation.

Bishop, A. J. (1983). Space and geometry. In R. Lesh & M. Landau (Eds.), *Acquisition of mathematics concepts and process* (pp. 175-203). New York: Academic Press.

Black, A. A. (2005). Spatial skill and earth science conceptual understanding. *Journal of Geoscience Education, 53*(4), 402-414.

Bloom, B. S. (1986). Automaticity: The Hands and Feet of Genius. *Educational Leadership, 43*(5), 70-77.

Bodner, G. M., & Guay, R. B. (1997). The Purdue visualization of rotations test. *The Chemical Educator, 2*(4), 1-17.

Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An Introduction to Theory and Methods* (5th ed.). Boston: Allyn and Bacon.

Brandt, M. G., & Davies, E. T. (2006). Visual-spatial skill, learning modality and surgical knot tying. *Canadian Journal of Surgery, 49*(6), 412-416.

Carter, C. S., LaRussa, M. A., & Bodner, G. M. (1987). A study of two measures of spatial skill as predictors of success in different levels of general chemistry. *Journal of Research in Science Teaching, 24*(7), 645-657.

Casey, M. B., Nuttall, R. L., Pezaris, E., & Benbow, C. P. (1995). The influence of spatial skill on gender differences in mathematics college entrance test scores across diverse samples. *Developmental Psychology, 31*(4), 697-705.

Chang, K. E., Wu, L. J., Lai, S. C., & Sung, Y. T. (2016). Using mobile devices to enhance the interactive learning for spatial geometry. *Interactive Learning Environments, 24*(4), 916-934.

Chen, Y.-S., Kao, T. C., & Sheu, J. P. (2003). A mobile learning system for scaffolding bird watching learning. *Journal of Computer Assisted Learning, 19*(3), 347-359.

Clark, R. E. (1983). Reconsidering Research on Learning from Media. *Review of Educational Research, 53*(4), 445-459.

Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 420-464). New York: Macmillan.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Contero, M., Naya, F., Company, P., Saorin, J. L., & Conesa, J. (2005). Improving visualization skills in engineering education. *Computer Graphics and Applications, IEEE, 25*(5), 24-31.

Creswell, J. W. (2012). *Educational research: Planning, Conducting, and Evaluating Quantitative and Qualitative research* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Çapulcuoğlu, U., & Gündüz, B. (2013). Lise öğrencilerinde tükenmişliğin cinsiyet, sınıf düzeyi, okul türü ve algılanan akademik başarı değişkenlerine göre incelenmesi. *Trakya Üniversitesi Eğitim Fakültesi Dergisi*, *3*(1), 12-24.

De Lisi, R., & Wolford, J. L. (2002). Improving children's mental rotation accuracy with computer game playing. *The Journal of genetic psychology*, *163*(3), 272-282.

Delialioğlu, Ö., & Aşkar, P. (1999). Contribution of students' mathematical skills and spatial skill of achievement in secondary school physics. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *16*(17), 34-39.

Devon, R., Engel, R., & Turner, G. (1998). The effects of spatial visualization skill training on gender and retention in engineering. *Journal of Women and Minorities in Science and Engineering*, *4*(4).

Dixon, J. K. (1997). Computer use and visualization in students' construction of reflection and rotation concepts. *School Science and Mathematics*, *97*(7), 352-358.

Duesbury, R. T. (1996). Effect of type of practice in a computer-aided design environment in visualizing three-dimensional objects from two-dimensional orthographic projections. *Journal of Applied Psychology*, *81*(3), 249-260.

Dyche, S., McClurg, P., Stepans, J., & Veath, M. L. (1993). Questions and conjectures concerning models, misconceptions, and spatial skill. *School Science and Mathematics*, *93*(4), 191-197.

Ekici, G. (2006). Meslek Lisesi Öğretmenlerinin Öğretmen Öz-Yeterlik İnançlari Üzerine Bir Araştirma. *Eurasian Journal of Educational Research (EJER)*, (24), 87-96.

Erkoç, M. F., Gecü, Z., & Erkoç, Ç. (2013). The effects of using Google SketchUp on the mental rotation skills of eighth grade students. *Educational Sciences: Theory & Practice*, *13*(2), 1285-1294.

Evans, C. (2008). The effectiveness of m-learning in the form of podcast revision lectures in higher education. *Computers & education*, *50*(2), 491-498.

Fabian, K., & MacLean, D. (2014). Keep taking the tablets? Assessing the use of tablet devices in learning and teaching activities in the Further Education sector. *Research in Learning Technology*, *22*, 22648.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science*, *18*(10), 850-855.

Ferguson, A. M., Maloney, E. A., Fugelsang, J., & Risko, E. F. (2015). On the relation between math and spatial skill: The case of math anxiety. *Learning and Individual Differences, 39*, 1-12.

Ferguson, E. S. (1992). *Engineering and the Mind's Eye*. Chicago: MIT press.

Fındık, L. Y., & Kavak, Y. (2013). *Türkiye'deki sosyo-ekonomik açıdan dezaavantajlı öğrencilerin PISA 2009 başarılarının değerlendirilmesi. Kuram ve Uygulamada Eğitim Yönetimi, 19*(2), 249-273

Field, A. (2009). *Discovering statistics using SPSS*. Sage publications.

Findlater, L., Froehlich, J. E., Fattal, K., Wobbrock, J. O., & Dastyar, T. (2013). Age-related differences in performance with touchscreens compared to traditional mouse input. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 343-346). New York, NY: ACM.

Fraenkel, J., Wallen, N., & Hyun, H. (2011). *How to Design and Evaluate Research in Education* (8th ed.). New York, NY: McGraw-Hill.

French, J. W. (1951). *The Description of Aptitude and Achievement Tests in Terms of Rotated Factors*. Chicago, IL: University of Chicago Press.

Gagne, R. (1982). Developments in learning psychology: Implications for instructional design. *Educational Technology, 22*(6), 11-15.

Gallagher, S. A. (1989). Predictors of SAT mathematics scores of gifted male and gifted female adolescents. *Psychology of Women Quarterly, 13*(2), 191-203.

Galton, F. (1911). *Inquiries into human faculty and its development*. London: Dent.

Gardner, H. (1985). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basic books.

Geary, D. C., Saults, S. J., Liu, F., & Hoard, M. K. (2000). Sex differences in spatial cognition, computational fluency, and arithmetical reasoning. *Journal of Experimental Child Psychology, 77*(4), 337-353.

Gecu-Parmaksiz, Z., & Delialioğlu, Ö. (2018). The effect of augmented reality activities on improving preschool children's spatial skills. *Interactive Learning Environments*, 1-14.

Goldstein, D., Haldane, D., & Mitchell, C. (1990). Sex differences in visual-spatial skill: The role of performance factors. *Memory & Cognition, 18*(5), 546-550.

Guay, R. B., & McDaniel, E. D. (1977). The relationship between mathematics achievement and spatial abilities among elementary school children. *Journal for Research in Mathematics Education, 8*(3), 211-215.

Hauptman, H. (2010). Enhancement of spatial thinking with Virtual Spaces 1.0. *Computers & Education*, *54*(1), 123-135.

Hegarty, M. (2018). Ability and sex differences in spatial thinking: What does the mental rotation test really measure?. *Psychonomic Bulletin & Review*, *25*(3), 1212-1219.

Higgins, H. J. (2006). *The relationship of sixth-grade students' mental rotation ability to spatial experience and problem-solving strategies by socioeconomic status and gender* (Unpublished Doctoral Dissertation). University of Nevada, Reno.

Hsi, S., Linn, M. C., & Bell, J. E. (1997). The Role of Spatial Reasoning in Engineering and the Design of Spatial Instruction. *Journal of Engineering Education*, *86*(2), 151-158.

Hung, P. H., Hwang, G. J., Lee, Y. H., & Su, I. H. (2012). A cognitive component analysis approach for developing game-based spatial learning tools. *Computers & Education*, *59*(2), 762-773.

Hunt, J. (2016). Why do women leave science and engineering?. *ILR Review*, *69*(1), 199-226.

Huk, T. (2006). Who benefits from learning with 3D models? The case of spatial skill. *Journal of Computer Assisted Learning*, *22*(6), 392-404.

Jones, S., & Burnett, G. (2008). Spatial skill and learning to program. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *4*(1), 47-61.

Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences*, *20*(2), 82-88.

Kell, H. J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2013). Creativity and Technical Innovation Spatial skill's Unique Role. *Psychological Science*, *24*(9), 1831-1836.

Kozhevnikov, M., Motes, M. A., & Hegarty, M. (2007). Spatial visualization in physics problem solving. *Cognitive science*, *31*(4), 549-579.

Kozma, R. B. (1991). Learning with Media. *Review of Educational Research*, *61*(2), 179-211.

Kukulska-Hulme, A. (2010). Mobile learning as a catalyst for change. *Open Learning*, *25*(3), 181-185.

Kulik, C. L. C., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in human behavior, 7(*1-2), 75-94.

Kurtulus, A. (2013). The effects of web-based interactive virtual tours on the development of prospective mathematics teachers' spatial skills. *Computers & Education, 63,* 141-150.

Laski, E. V., Casey, B. M., Yu, Q., Dulaney, A., Heyman, M., & Dearing, E. (2013). Spatial skills as a predictor of first grade girls' use of higher level arithmetic strategies. *Learning and Individual Differences, 23,* 123-130.

Leong, Y. H., & Lim-Teo, S. K. (2003). Effects of geometer's sketchpad on spatial skill and achievement in transformation geometry among secondary two students in Singapore. *The Mathematics Educator, 7*(1), 32-48.

Lieu, D. K., & Sorby, S. A. (2008). *Visualization, Modeling, and Graphics for Engineering Design*. Delmar: Cengage Learning.

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry. Evaluation and Program Planning.* Newbury Park, CA: Sage. http://doi.org/10.1016/0149-7189(87)90056-5

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterisation of sex differences in spatial skill: A meta-analysis. *Child Development, 56*(6), 1479-1498.

Liu, Y., Li, H., & Carlsson, C. (2010). Factors driving the adoption of m-learning: An empirical study. *Computers & Education, 55*(3), 1211-1219.

Lohman, D. F. (1996). Spatial skill and G. In I. Dennis & P. Tapsfield (Eds.), *Human abilities: Their nature and assessment* (pp. 97-116). NJ: Erlbaum: Hillsdale.

Lord, T. R. (1985). Enhancing the visuo-spatial aptitude of students. *Journal of Research in Science Teaching, 22*(5), 395-405.

Lord, T. R. (1990). Enhancing learning in the life sciences through spatial perception. *Innovative Higher Education, 15*(1), 5-16.

Lu, M. (2008). Effectiveness of vocabulary learning via mobile phone. *Journal of Computer Assisted Learning, 24*(6), 515-525.

Lubinski, D. (2010). Spatial skill and STEM: A sleeping giant for talent identification and development. *Personality and Individual Differences, 49*(4), 344-351.

Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press.

Maeda, Y., & Yoon, S. Y. (2016). Are gender differences in spatial skill real or an artifact? Evaluation of measurement invariance on the Revised PSVT: R. *Journal of Psychoeducational Assessment, 34*(4), 397-403.

Marshall, C., & Rossman, G. B. (2011). *Designing qualitative research* (5th ed.). Thousand Oaks, CA: Sage.

Martin-Dorta, N., Sanchez-Berriel, I., Bravo, M., Hernandez, J., Saorin, J. L., & Contero, M. (2013). Virtual Blocks: a serious game for spatial skill improvement on mobile devices. *Multimedia Tools and Applications, 73*(3), 1575-1595.

Martín-Dorta, N., Saorín, J. L., & Contero, M. (2008). Development of a fast remedial course to improve the spatial abilities of engineering students. *Journal of Engineering Education, 97*(4), 505-513.

Martin-Dorta, N., Saorin, J. L., & Contero, M. (2011). Web-based spatial training using handheld touch screen devices. *Journal of Educational Technology & Society, 14*(3), 163-177.

Mäntylä, T. (2013). Gender differences in multitasking reflect spatial skill. *Psychological Science, 24*(4), 514-520.

Mayer, R. E., & Sims, V. K. (1994). From whom is a picture worth a thousand words? Extensions of a Dualcoding theory of multimedia learning. *Journal of Educational Psychology, 86*(3), 389-401.

Mbano, N., & Nolan, K. (2017). Increasing Access of Female Students in Science Technology, Engineering and Mathematics (STEM), in the University of Malawi (UNIMA). *Science Education International, 28*(1), 53-77.

McGee, M. G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin,* 86(5), 889-918.

McLean, J. E., & Ernest, J. M. (1998). The role of statistical significance testing in educational research. *Research in the Schools, 5*(2), 15–22.

Meneghetti, C., Gyselinck, V., Pazzaglia, F., & De Beni, R. (2009). Individual differences in spatial text processing: High spatial skill can compensate for spatial working memory interference. *Learning and Individual Differences, 19*(4), 577-589.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Milgram, D. (2011). How to recruit women and girls to the science, technology, engineering, and math (STEM) classroom. *Technology and Engineering Teacher*, *71*(3), 4-11.

Miller, C. (1996). A Historical review of applied and theoretical spatial visualization publications in engineering graphics. *Engineering Design Graphics Journal*, *60*(3), 12-33.

Miller, D. I., & Halpern, D. F. (2013). Can spatial training improve long-term outcomes for gifted STEM undergraduates? *Learning and Individual Differences*, *26*, 141-152.

Mohler, J. L. (2006). *Examining the spatial skill phenomenon from the student's perspective*. West Lafayette, IN: Purdue University.

Mohler, J. L. (2009). A review of spatial skill research. *Engineering Design Graphics Journal*, *72*(3), 19-30.

Mohler, J. L., & Miller, C. L. (2009). Improving spatial skill with mentored sketching. *Engineering Design Graphics Journal*, *72*(1), 19-27.

Molina-Carmona, R., Pertegal-Felices, M., Jimeno-Morenilla, A., & Mora-Mora, H. (2018). Virtual reality learning activities for multimedia students to enhance spatial ability. *Sustainability*, *10*(4), 1074.

Mumcu, H. Y., Mumcu, İ., & Aktaş, M. C. (2012). Meslek lisesi öğrencileri için matematik. *Amasya Üniversitesi Eğitim Fakültesi Dergisi*, *1*(2), 180-195.

National Research Council. Committee on Support for Thinking Spatially. (2006). *Learning to think spatially: GIS as a support system in the K-12 curriculum.* Washington, DC: National Academies Press.

Newcombe, N. S. (2010). Picture This: Increasing Math and Science Learning by Improving Spatial Thinking. *American Educator*, *34*(2), 29-35.

Newcombe, N. S., Bandura, M. M., & Taylor, D. G. (1983). Sex differences in spatial skill and spatial activities. *Sex Roles*, *9*(3), 377-386.

Olkun, S. (2003) Making Connections: Improving Spatial Abilities with Engineering Drawing Activities, *International Journal of Mathematics Teaching and Learning*, 1-10.

Olkun, S., & Altun, A. (2003). İlköğretim öğrencilerinin bilgisayar deneyimleri ile uzamsal düşünme ve geometri başarıları arasındaki ilişki. *Turkish Online Journal of Educational Technology*, *2*(4), 86-91.

Olkun, S., Altun, A., & Smith, G. (2005). Computers and 2D Geometric Learning of Turkish Fourth and Fifth Graders. *British Journal of Educational Technology, 36*(2), 317-326

Pallrand, G. J., & Seeber, F. (1984). Spatial skill and achievement in introductory physics. *Journal of Research in Science Teaching*, *21*(5), 507-516.

Pearson, J. L., & Ferguson, L. R. (1989). Gender differences in patterns of spatial skill, environmental cognition, and math and English achievement in late adolescence. *Adolescence, 24*(94), 421-431.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications.

Peters, M. (2005). Sex differences and the factor of time in solving Vandenberg and Kuse mental rotation problems. *Brain and Cognition*, *57*(2), 176-184.

Peters, M., Chisholm, P., & Laeng, B. (1995). Spatial skill, student gender, and academic performance. *Journal of Engineering Education*, *84*(1), 69-73.

Pribyl, J. R., & Bodner, G. M. (1987). Spatial skill and its role in organic chemistry: A study of four organic courses. *Journal of Research in Science Teaching*, *24*(3), 229-240.

Quaiser-Pohl, C., Neuburger, S., Heil, M., Jansen, P., & Schmelter, A. (2014). Is the Male Advantage in Mental-Rotation Performance Task Independent? On the Usability of Chronometric Tests and Paper-and-Pencil Tests in Children. *International Journal of Testing, 14*(2), 122-142.

Rafi, A., Anuar, K., Samad, A., Hayati, M., & Mahadzir, M. (2005). Improving spatial skill using a Web-based Virtual Environment (WbVE). *Automation in Construction*, *14*(6), 707-715.

Rafi, A., Samsudin, K. A., & Ismail, A. (2006). On Improving Spatial skill Through Computer-Mediated Engineering Drawing Instruction. *Educational Technology & Society*, 9(3), 149-159.

Reigeluth, C. M. (1999). *Instructional-design theories and models, Volume II: A new paradigm of instructional theory.* Hillsdale, NJ: Erlbaum.

Reuhkala, M. (2001). Mathematical skills in ninth-graders: Relationship with visuo-spatial abilities and working memory. *Educational Psychology*, *21*(4), 387-399.

Roblyer, M. D. (2004). *2004 Update Integrating educational technology into teaching.* Prentice Hall.

Samsudin, K., Rafi, A., & Hanif, A. S. (2011). Training in Mental Rotation and Spatial Visualization and Its Impact on Orthographic Drawing Performance. *Educational Technology & Society, 14*(1), 179-186.

Santos, J. R. A. (1999). Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of Extension, 37*(2), 1-5.

Sexton, T. J. (1992). Effect on spatial visualization: introducing basic engineering graphics concepts using CAD technology. *Engineering Design Graphics Journal, 56*(3), 36-43.

Shavalier, M. (2004). The effects of CAD-like software on the spatial skill of middle school students. *Journal of Educational Computing Research, 31*(1), 37-49.

Shea, D. L., Lubinski, D., & Benbow, C. P. (2001). Importance of assessing spatial skill in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology, 93*(3), 604-614.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*(3972), 701-703.

Smith, I. M. (1964). *Spatial skill. Its Educational and Social Significance* (1st ed.). London, UK: University of London.

Smith, P. (1992). Spatial skill and its role in United Kingdom education. *The Vocational Aspect of Education, 44*(1), 103-106.

Sorby, S., Casey, B., Veurink, N., & Dulaney, A. (2013). The role of spatial training in improving spatial and calculus performance in engineering students. *Learning and Individual Differences, 26*, 20-29.

Sorby, S., Veurink, N., & Streiner, S. (2018). Does spatial skills instruction improve STEM outcomes? The answer is 'yes'. *Learning and Individual Differences, 67*, 209-222.

Sorby, S. A. (1999). Developing 3-D spatial visualization skills. *Engineering Design Graphics Journal, 63*(2), 21-32.

Sorby, S. A. (2009). Educational Research in Developing 3-D Spatial Skills for Engineering Students. *International Journal of Science Education, 31*(3), 459-480.

Sorby, S. A., & Baartmans, B. J. (2000). The development and assessment of a course for enhancing the 3-D spatial visualization skills of first year engineering students. *Journal of Engineering Education, 89*(3), 301-307.

Sönmez, M. (2010). Türkiye'de mesleki ve teknik örgün öğretimin sorunları ve yeniden yapılandırılma zorunluluğu. *Eğitim ve Bilim, 33*(147), 71-84.

Stieff, M., & Uttal, D. (2015). How much can spatial training improve STEM achievement?. *Educational Psychology Review*, *27*(4), 607-615.

Strong, S., & Smith, R. (2002), Spatial visualization: Fundamentals and trends in engineering graphics, *Journal of Industrial Technology, 18*(1), 1-5.

Tai, D. W., Yu, C. H., Lai, L. C., & Lin, S. J. (2003). A study on the effects of spatial skill in promoting the logical thinking abilities of students with regard to programming language. *World Transactions on Engineering and Technology Education UICEE*, *2*(2), 251-26.

Tallent-Runnels, M. K., Thomas, J. A., Lan, W. Y., Cooper, S., Ahern, T. C., Shaw, S. M., & Liu, X. (2006). Teaching courses online: A review of the research. *Review of Educational Research, 76*(1), 93-135.

Taylor, H. A., & Hutton, A. (2013). Think3d!: Training spatial thinking fundamental to STEM education. *Cognition and Instruction*, *31*(4), 434-455.

Thorndike, E. L. (1921). On the organization of the intellect. *Psychological Review, 28*(2), 141-151.

Thornton, P., & Houser, C. (2001). Learning on the Move: Foreign language vocabulary via SMS. In C. Montgomerie & J. Viteli (Eds.), *Proceedings of ED-Media 2001, World Conference on Educational Multimedia, Hypermedia & Telecommunications* (pp. 1896-1897). Waynesville, NC: AACE.

Thornton, T., Ernst, J. V., & Clark, A. C. (2012). Augmented Reality as a Visual and Spatial Learning Tool in Technology Education. *Technology and Engineering Teacher*, *71*(8), 18-21.

Thurstone, L. I. (1950). Some Primary Abilities in Visual Thinking. *Proceedings of the American Philosophical Society, 94*(6), 517-521.

Tracy, D. M. (1987). Toys, spatial skill, and science and mathematics achievement: Are they related? *Sex roles*, *17*(3-4), 115-138.

Ullman, D. G., Wood, S., & Craig, D. (1990). The importance of drawing in the mechanical design process. *Computers & Graphics*, *14*(2), 263-274.

Uzunboylu, H., & Ozdamli, F. (2011). Teacher perception for m-learning: scale development and teachers' perceptions. *Journal of Computer Assisted Learning*, *27*(6), 544-556.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, *47*(2), 599-604.

Waber, D. P. (1979). Neuropsychological aspects of Turner's Syndrome. *Developmental Medicine and Child Neurology, 21*, 58-70.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial skill for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817-835.

Wang, H. C., Chang, C. Y., & Li, T. Y. (2007). The comparative efficacy of 2D-versus 3D-based media design for influencing spatial visualization skills. *Computers in Human Behavior*, *23*(4), 1943-1957.

Wang, J. Y., Wu, H. K., & Hsu, Y. S. (2017). Using mobile applications for learning: Effects of simulation design, visual-motor integration, and spatial skill on high school students' conceptual understanding. *Computers in Human Behavior*, *66*, 103-113.

Wang, M., Shen, R., Novak, D., & Pan, X. (2009). The impact of mobile learning on students' learning behaviours and performance: Report from a large blended classroom. *British Journal of Educational Technology*, *40*(4), 673-695.

Wang, Y.-S., Wu, M.-C., & Wang, H.-Y. (2009). Investigating the determinants and age and gender differences in the acceptance of mobile learning. *British Journal of Educational Technology*, *40*(1), 92-118.

Wanzel, K. R., Hamstra, S. J., Anastakis, D. J., Matsumoto, E. D., & Cusimano, M. D. (2002). Effect of visual-spatial skill on learning of spatially-complex surgical skills. *The Lancet*, *359*(9302), 230-231.

Wei, W., Chen, C., & Zhou, X. (2016). Spatial skill explains the male advantage in approximate arithmetic. *Frontiers in Psychology*, *7*, 306.

Wheatley, G. H. (1990). Spatial sense and mathematics learning. *Arithmetic Teacher*, *37*(6), 10-11.

Wu, H.-K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education*, *88*(3), 465-492.

Yang, E.-M., Andre, T., Greenbowe, T. J., & Tibell, L. (2003). Spatial skill and the impact of visualization/animation on learning electrochemistry. *International Journal of Science Education*, *25*(3), 329-349.

Yıldız, B. (2009). *Üç-boyutlu sanal ortam ve somut materyal kullanımının uzamsal görselleştirme ve zihinsel döndürme becerilerine etkileri*. Master's Thesis. Hacettepe Üniversitesi, Ankara.

Yıldız, B., & Tüzün, H. (2011). Üç-Boyutlu Sanal Ortam ve Somut Materyal Kullanımının Uzamsal Yeteneğe Etkileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *41*, 498-508.

Yin, R. K. (2009). *Case Study Research Design and Methods*. Thousand Oaks: Sage.

Yolcu, B., & Kurtuluş, A. (2010). 6. sınıf öğrencilerinin uzamsal görselleştirme yeteneklerini geliştirme üzerine bir çalışma. *İlköğretim Online, 9*(1), 256-274.

Zabramski, S., Gkouskos, D., & Lind, M. (2011). A comparative evaluation of mouse, stylus and finger input in shape tracing. In C. Georgios, Z. Panayiotis, & L.-C. E. Law (Eds.), *Proceedings of 1st European Workshop on HCI Design and Evaluation* (pp. 57-61). IRIT Press.

Zavotka, S. L. (1987). Three-dimensional computer animated graphics: a tool for spatial skill instruction. *Educational Communication and Technological Journal, 35*(3), 133-144.

APPENDICES

A. Demographic Information Form

Değerli Öğrenciler,

"Mobil uygulamalar ile uzamsal kabiliyetin desteklenmesi" konulu bir tez çalışması yürütmekteyim. Aşağıda yer alan sorular uzamsal kabiliyeti etkileyebilecek diğer faktörlerin belirlenmesi amacıyla hazırlanmıştır. Çalışmadan elde edilen sonuçların doğruluğu, sorulara içten ve samimi cevaplar vermenize bağlıdır. Sonuçlar yalnızca bu araştırma için kullanılacak ve bilgiler gizli tutulacaktır. Çalışmaya verdiğiniz destek için çok teşekkür ederim.

Hüseyin Can ŞENEL
Orta Doğu Teknik Üniversitesi
Bilg. ve Öğretim Teknolojileri Eğitimi Bölümü
Doktora Öğrencisi

1. Yaşınız:

( )14 ( )15 ( )16 ( )17 ( )18 ( )19

2. Cinsiyetiniz:

( )Kadın ( )Erkek

3. İlk dönemki not ortalamanız:

4. İlk dönemki matematik dersi başarı notunuz:

5. Annenizin ve babanızın öğrenim düzeyi nedir?

Anne	Baba
( ) Okuryazar değil	( ) Okuryazar değil
( ) İlkokul mezunu	( ) İlkokul mezunu
( ) Ortaokul mezunu	( ) Ortaokul mezunu
( ) Ortaöğretim (lise) mezunu	( ) Ortaöğretim (lise) mezunu
( ) Yükseköğretim mezunu	( ) Yükseköğretim mezunu

6. Annenizin ve babanızın çalışma durumu nedir?

Anne	Baba
( ) Çalışmıyor (işsiz).	( ) Çalışmıyor (işsiz).
( ) Tam günlü bir işte çalışıyor.	( ) Tam günlü bir işte çalışıyor.
( ) Yarı zamanlı bir işte çalışıyor.	( ) Yarı zamanlı bir işte çalışıyor.
( ) Haftanın bazı günleri çalışıyor.	( ) Haftanın bazı günleri çalışıyor.
( ) İş buldukça çalışıyor.	( ) İş buldukça çalışıyor.
( ) Diğer.	( ) Diğer. . . . .

7. Aşağıdakilerden hangi/hangilerine kendi ait sahipsin ve ne kadar süredir kullanıyorsun?

Masaüstü Bilgisayar	Laptop (dizüstü) bilgisayar	Akıllı Telefon	Tablet Bilgisayar
( ) Masaüstü bilg. yok	( ) Dizüstü bilg. yok	( ) Akıllı tel. yok	( ) Tablet Bilg. yok
( ) 3 aydan az	( ) 3 aydan az	( ) 3 aydan az	( ) 3 aydan az
( ) 3-6 ay arası	( ) 3-6 ay arası	( ) 3-6 ay arası	( ) 3-6 ay arası
( ) 6 ay-1 yıl arası	( ) 6 ay-1 yıl arası	( ) 6 ay-1 yıl arası	( ) 6 ay-1 yıl arası
( ) 1-2 yıl arası	( ) 1-2 yıl arası	( ) 1-2 yıl arası	( ) 1-2 yıl arası
( ) 2-3 yıl arası	( ) 2-3 yıl arası	( ) 2-3 yıl arası	( ) 2-3 yıl arası
( ) 3 yıl ve üstü	( ) 3 yıl ve üstü	( ) 3 yıl ve üstü	( ) 3 yıl ve üstü

8. Haftada kaç saat bilgisayar/dizüstü bilgisayar/akıllı telefon/tablet bilgisayar kullanıyorsunuz?

Bilgisayar	Tablet	Akıllı Telefon
( ) 0-1saat arası	( ) 0-1saat arası	( ) 0-1saat arası
( ) 2-4 saat arası	( ) 2-4 saat arası	( ) 2-4 saat arası
( ) 5-7 saat arası	( ) 5-7 saat arası	( ) 5-7 saat arası
( ) 8 saat ve üstü	( ) 8 saat ve üstü	( ) 8 saat ve üstü

9. Haftada kaç saat bilgisayar oyunu oynuyorsun?

( ) 0-1saat arası
( ) 2-4 saat arası
( ) 5-7 saat arası
( ) 8 saat ve üstü

10. Ne kadar süredir bilgisayar oyunu oynuyorsun?

( ) Bilgisayar oyunu oynamam
( ) 3 aydan az
( ) 3-6 ay
( ) 6 ay-1 yıl
( ) 1-2 yıl
( ) 2-3 yıl
( ) 3 yıl ve üstü

B. Interview Form (Main Study)

Hüseyin Can ŞENEL
Araştırmanın Amacı:
Meslek lisesi öğrencilerinin uzamsal kabiliyetleri mobil öğrenme ortamlarıyla artırılması

Merhaba;

Adım Hüseyin Can ŞENEL. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi bölümünde doktora öğrencisiyim. Yaklaşık 8 hafta boyunca sizlerle bir çalışma yaptık ve tablet bilgisayarlar ile yardımcı bir yazılım kullandın. Şimdi seninle bu 8 haftalık çalışma hakkında bir görüşme yapmak istiyorum. Bu nedenle;

- Öncelikle görüşmeyi kaydetmek için izninizi istiyorum. Bu, hem görüşmemizin akışı hem de konuşulanların analizi açısından önem taşımaktadır.
- İsminiz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı olarak kullanılacak ve sonrasında imha edilecektir.
- Tuttuğum kayıt isterseniz size okutulacak ve değiştirmek istediğiniz bir ifade var ise istediğiniz değişiklikler yapılacaktır. Görüşmemiz ortalama 10-15 dakika sürecektir.

Görüşme Soruları

1. Tablet bilgisayarların ders içerisinde kullanılması hakkında ne düşünüyorsun? Ne gibi faydaları olduğunu gördün?
2. Kullandığın yazılım hakkında ne düşünüyorsun?
3. 8 haftalık süre nasıl geçti? Keyifli ya da zor muydu? Daha uzun, daha kısa olmasını ister misin?
4. Diğer derslerinde de bu bilgisayarları kullanmak ister misin? Tablet bilgisayarları derslerde ne şekilde kullanmak hoşuna gider (derste internete girmek, oyun oynamak, özel bir yazılım kullanmak)?
5. Uzamsal yetenek diye bir kavramla karşılaştın. Sence önemli bir konu mu?
6. Tablet ve içindeki özel yazılım uzamsal yeteneğine etki etti mi? Kendinde gelişme hissettin mi?
7. Benzer bir uygulamayı (oyun, eğitimsel web sitesi, vb) tekrar kullanmayı ister misin? Ders dışı zamanlarda da kullanmayı düşünür müsün?
8. Sence 8 haftalık çalışma sürecinde neler iyiydi ve neler kötüydü? (tablet bilgisayarlar, yazılım, süre, öğretmenler)
9. Bu sürecin daha etkili olabilmesi için (bu uygulamayı geliştirmek için) neler yapılabilir?

C. Interview Form (Pilot Study)

Hüseyin Can ŞENEL
Araştırmanın Amacı:
Meslek lisesi öğrencilerinin uzamsal kabiliyetleri mobil öğrenme ortamlarıyla artırılması

Merhaba;

Adım Hüseyin Can ŞENEL. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi bölümünde doktora öğrencisiyim. Öğrencilerin uzamsal kabiliyetlerinin artırılması yönünde bir doktora tezi hazırlamaktayım. Bu maksatla okulunuzda bir çalışma yaptık. Dört hafta boyunca tablet bilgisayarlar ve bir yazılım kullandınız. Bu süreçle ilgili eleştiri ve önerilerini öğrenmek istiyorum

- Öncelikle görüşmeyi kaydetmek için izninizi istiyorum. Bu, hem görüşmemizin akışı hem de konuşulanların analizi açısından önem taşımaktadır.
- İsminiz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı olarak kullanılacak ve sonrasında imha edilecektir.
- Tuttuğum kayıt isterseniz size okutulacak ve değiştirmek istediğiniz bir ifade var ise istediğiniz değişiklikler yapılacaktır. Görüşmemiz ortalama 10-15 dakika sürecektir.

Görüşme Soruları

1. Tablet bilgisayarlar hakkında ne düşünüyorsun? İyi yanları nelerdi?
2. Tablet bilgisayarların sevmediğin ya da kullanırken hoşuna gitmediğin özellikleri var mıydı? Nelerdi?
3. Yazılım hakkında ne düşünüyorsun? İyi yanlarını söyleyebilir misiz?
4. Yazılımda iyi olmayan yerler var mıydı? Nelerdi?
5. Sen olsan başka bir tablet kullanır mıydın? Nasıl bir bilgisayar seçerdin?
6. Yazılımda neler farklı olmalıydı? Sence nasıl olursa arkadaşlarına daha faydalı olur?

D. Interview Form (Pre Analysis-Students)

Hüseyin Can ŞENEL
Araştırmanın Amacı:
Meslek lisesi öğrencilerinin uzamsal kabiliyetleri mobil öğrenme ortamlarıyla artırılması

Merhaba;

Adım Hüseyin Can ŞENEL. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi bölümünde doktora öğrencisiyim. Öğrencilerin uzamsal kabiliyetlerinin artırılması yönünde bir doktora tezi hazırlamaktayım. Bu maksatla okulunuzda bir çalışma yapmayı planlıyorum.

Bu çalışmada 6-8 haftalık süre boyunca sizlere tablet bilgisayarlar, masaüstü bilgisayarlar ve kâğıt-kalem uygulamaları yaptırılacaktır. Uygulama sürecinde öğrenci ve öğretmenlerle görüşmeler (yazılı-sözlü röportajlar) yapılacaktır. Öncelikle sizlerin uzamsal kabiliyetlerinin ölçülmesi için Vanderberg ve Kuse (1978) zihinsel döndürme testi uygulanacaktır. 6-8 haftalık uygulamanın ardından test tekrar uygulanarak nasıl bir gelişim gösterdiğiniz incelenecektir.

Şimdi de sizlerin daha önce tablet bilgisayar ve mobil yazılımlar kullanıp kullanmadığınız, uzamsal yetenek hakkındaki görüşleriniz hakkında kısa bir görüşme yapmak istiyorum. Bu nedenle;

- Öncelikle görüşmeyi kaydetmek için izninizi istiyorum. Bu, hem görüşmemizin akışı hem de konuşulanların analizi açısından önem taşımaktadır.
- İsminiz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı olarak kullanılacak ve sonrasında imha edilecektir.
- Tuttuğum kayıt isterseniz size okutulacak ve değiştirmek istediğiniz bir ifade var ise istediğiniz değişiklikler yapılacaktır. Görüşmemiz ortalama 10-15 dakika sürecektir.

Görüşme Soruları

1. Tablet bilgisayarlar hakkında ne düşünüyorsun? Daha önce kullandın mı? Hangi amaçlar için kullandın?
2. Derslerin için tablet bilgisayar kullandın mı? Tablet bilgisayarların sana bir faydası olduğunu düşünüyor musun?
3. Derslerde tablet bilgisayar kullanmayı faydalı buluyor musun? Böyle bir imkânın olsun ister misin?
4. Cisimlerin iki boyutlu olarak hayal etmede zorluk yaşıyor musun? Derslerinde cisimlerin iki boyutlu ve üç boyutlu durumlarını, görsellerini canlandırmada zorluk yaşıyor musun?
5. Bu yeteneğinin gelişmesi gerektiğini düşünüyor musun? Bu yeteneği geliştirmek için hiçbir çabada bulundun mu?
6. Okulunda/derslerinde bu yeteneğin geliştirilmesi için bir uygulama yapıldı mı? Yapılmasını ister misin? Sana nasıl bir fayda sağlayacağını düşünüyorsun?
7. Hazırlanacak bir bilgisayar yazılımının/tablet bilgisayarların senin ya da diğer öğrencilerin ilgilerini çekeceğini düşünüyor musun? Öğrencilerin böyle bir yazılıma ihtiyaçları var mı? Böyle bir yazılım ile cisimler ile ilgili hayal etme/görselleştirme kabiliyetiniz artabilir mi?

E. Interview Form (Pre Analysis-Teachers)

Hüseyin Can ŞENEL
Araştırmanın Amacı:
Meslek lisesi öğrencilerinin uzamsal kabiliyetleri mobil öğrenme ortamlarıyla artırılması ve mobil öğrenme ortamı tasarım ilkelerinin belirlenmesi?

Merhaba;

Adım Hüseyin Can ŞENEL. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi bölümünde doktora öğrencisiyim. Öğrencilerin uzamsal kabiliyetlerinin artırılması yönünde bir doktora tezi hazırlamaktayım. Bu maksatla okulunuzda bir çalışma yapmayı planlıyorum.

Bu çalışmada tablet bilgisayarlar ve bu bilgisayarlarda bulunan yazılımlarla sizlere (15 öğrenci) 4-6 haftalık bir uygulama yaptırılacaktır. Uygulama sürecinde öğrenci ve öğretmenlerle yazılımın geliştirilmesi ve tasarım ilkelerinin belirlenmesi için sürekli olarak görüşmeler (yazılı-sözlü röportajlar) yapılacaktır.

Öncelikle sizlerin uzamsal kabiliyetlerinin ölçülmesi için Vanderberg ve Kuse (1978) zihinsel döndürme kâğıt kalem testi uygulanacaktır. Daha sonra öğrencilerin yarısı (15 öğrenci olduğu varsayılmaktadır) ile 6-8 hafta boyunca okul saatleri sonrası ya da öğrencilerin kabul ettiği saatlerde 1 ders saatini geçmeyecek şekilde öğrencilerin tablet üzerinden uygulamayla çalışma yapmaları sağlanacaktır.

- Öncelikle görüşmeyi kaydetmek için izninizi istiyorum. Bu, hem görüşmemizin akışı hem de konuşulanların analizi açısından önem taşımaktadır.
- İsminiz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı olarak kullanılacak ve sonrasında imha edilecektir.
- Tuttuğum kayıt isterseniz size okutulacak ve değiştirmek istediğiniz bir ifade var ise istediğiniz değişiklikler yapılacaktır. Görüşmemiz ortalama 10-15 dakika sürecektir.

Görüşme Soruları

1-Uzamsal kabiliyet/zekâ diye bir kavram duydunuz mu? Kavramla ilgili neler biliyorsunuz?

2-Öğrencilerin bir görseli mental olarak yerleştirme, döndürme ya da yeniden boyutlandırma gibi özellikleri hakkında neler düşünüyorsunuz?

3-Araştırmalar uzamsal kabiliyetin özellikle mühendislikle ilgili branşlarda başarı için bir yordayıcı olduğunu bildirmektedir. Bu konudaki görüşlerinizi alabilir miyim?

4-Uzamsal kabiliyetin geliştirilmesinin öğrenci başarısını etkileyeceğini düşünüyor musunuz? Bu konuyla ilgili bir çalışmanız/uygulamanız oldu mu?

5-Hazırlanacak bir bilgisayar yazılımının/tablet bilgisayarların öğrencilerin ilgilerini çekeceğini düşünüyor musunuz? Öğrencilerin böyle bir yazılıma ihtiyaçları var mı? Böyle bir yazılım ile uzamsal kabiliyet artırılabilir mi?

F. Participants

Demographic Information of the Participants

		Group							
		Tablet Group		Desktop Group		Paper-Pencil Group		Total	
		f	*M*	*f*	*M*	*f*	*M*	*f*	*M*
Gender	Male	28		30		27		85	
	Female	0		0		0			
Age (years)			14.79		14.47		14.67		14.64

Results of Mental Rotation Test as Pre-test

	n	*M*	*SD*	*Min*	*Max*
Tablet Group	28	4.04	1.835	1	8
Desktop Group	30	4.13	1.676	1	8
Paper Pencil Group	27	3.96	1.990	1	8
Total	85	4.05	1.812	1	8

Skewness and Kurtosis Values of Mental Rotation Test (Pre-test)

	N	*M*	*SD*	*S*	*Skewness*	*Kurtosis*	*Min*	*Max*
MRT scores (Pre-test)	85	4.05	1.812	3.283	.187	-.602	1	8

Test of Homogeneity of Variances (Pre-test)

Levene Statistic	*df1*	*df2*	*Sig.*
.581	2	82	.562

Results of ANOVA (Pre-test)

	SS	*df*	*MS*	*F*	*Sig.*
Between Groups	.418	2	.209	.062	.940
Within Groups	275.394	82	3.358		
Total	275.812	84			

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	: Şenel, Hüseyin Can
Nationality	: Turkish (TC)
Date and Place of Birth	: 29 June, 1985, Amasya, Turkey
Phone	: +90 312 210 22 92
E-mail	: can.senel@metu.edu.tr

EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	Hacettepe Uni., Comp. Edu. and Inst. Tech.	2010
B.Sc.	Hacettepe Uni., Comp. Edu. and Inst. Tech.	2008
High School	Maltepe Military High School, İzmir	2004

WORK EXPERIENCE

Year	Place	Enrolment
2008-Present	National Defense University	Instructor

FOREIGN LANGUAGES

English

HOBBIES

Football, Swimming, Movies.