DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

UTILIZATION OF VIRTUAL REALITY ENVIRONMENT AS AN INTERACTIVE VISUAL LEARNING TOOL IN PRIMARY SCHOOL EDUCATION SYSTEM

by

Hüseyin Aşkın ERDEM

August, 2013

İZMİR

UTILIZATION OF VIRTUAL REALITY ENVIRONMENT AS AN INTERACTIVE VISUAL LEARNING TOOL IN PRIMARY SCHOOL EDUCATION SYSTEM

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Computer Engineering, Computer Engineering Program

by

Hüseyin Aşkın ERDEM

August, 2013
İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"UTILIZATION OF VIRTUAL REALITY ENVIRONMENT AS AN INTERACTIVE VISUAL LEARNING TOOL IN PRIMARY SCHOOL EDUCATION SYSTEM"** completed by **HÜSEYİN AŞKIN ERDEM** under supervision of **ASSIST. PROF. DR. ŞEN ÇAKIR** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Şen ÇAKIR

Supervisor

Assoc. Prof. Dr. Aylin Kantarcı

(Jury Member)

Asst. Prof. Dr. Semih UTKU

(Jury Member)

Prof.Dr. Ayşe OKUR
Director
Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENTS

I would like to thank to my advisor Assist. Prof. Dr. Şen ÇAKIR for her continuous help, excellent suggestions, encouragements, patience, guidance and support throughout the stages of this thesis.

A special thanks to my father, my mother and my sister Civil Engineer (M.Sc) Işıl ERDEM, the most valuable assets of my life; for all their support and for believing in me and being always by my side.

I wish to express my deepest appreciation and gratitude in my acknowledgments to Assist. Prof. Dr. Semih UTKU and Assist. Prof. Dr. Timur KÖSE for their help to create this thesis. Also, thank to Research Assistant Psychologist (MA) Tülay YILDIRIM for the support while preparing the survey questions.

And special thanks to the headmaster Servet ERMİN, the teachers and the students of the T.R. İzmir Dokuz Eylül University Özel 75. Yıl Primary School where the virtual programme was tested.

Hüseyin Aşkın ERDEM

UTILIZATION OF VIRTUAL REALITY ENVIRONMENT AS AN INTERACTIVE VISUAL LEARNING TOOL IN PRIMARY SCHOOL EDUCATION SYSTEM

ABSTRACT

In the world, computer technology is always in progress and every system which contains this technology makes human life easier. The interaction necessary for entering data into these systems were and are now provided generally by mouse and keyboard. Besides, voice commands and touch screens offer alternatives in terms of ease of use. At this point, interactivity method of used system is of great importance. The success of the designed system is determined by how easy the user can use the programme.

In this study, "interaction without touching" method which aims to give feedback according to the user's movements was preferred as the interaction method. This method enables users to control the programme without physically touching the computer. This control is established by a system that depends on merging the user's real images with virtual objects. The system creates a virtual reality environment via video capture. In this way, the system enables people who have just started using computer and who cannot use computer to control the system.

A virtual reality environment containing "Mathematics", "Science of Life" / "Science and Technology" and "English" courses which will be used as an interactive visual learning tool in primary school education system was created. With the designed application, the primary purpose was to build an environment in which students can interact with virtual images. Beside this, facilitating students' perception of three dimensional objects with the help of three dimensional virtual models and eliminating the need for additional equipment during teaching were also aimed.

Keywords: Virtual reality, interactive learning, video capture, primary school education.

SANAL GERÇEKLİK ORTAMININ - ETKİLEŞİMLİ GÖRSEL EĞİTİM ARACI OLARAK - İLKOKUL EĞİTİMİNDE KULLANILMASI

ÖZ

Dünyada bilgisayar teknolojisi sürekli olarak gelişmekte ve içerisinde kullanıldığı her sistem insan hayatını biraz daha kolaylaştırmaktadır. Bu sistemlere veri girişi için gereken etkileşim, başlangıçta ve halen yaygın olarak fare ve klavyeyle sağlanmaktadır. Bunun yanında, sesli komutlar veya dokunmatik ekranlar günümüzde rahat kullanım açısından alternatif sunmaktadır. Bu noktada, kullanılan sistemin etkileşim yöntemi önem teşkil etmektedir. Çünkü tasarlanan sistemin başarısını, kullanıcının programı ne kadar rahat kullanabildiği belirlemektedir.

Bu çalışmada, etkileşim yöntemi olarak, kullanıcının hareketlerinin algılanmasına göre geri bildirimler uygulanmasını amaçlayan, dokunmadan etkileşim yöntemi tercih edilmiştir. Yöntem, kullanıcıların bilgisayara fiziksel (gerçek) anlamda dokunmalarına gerek kalmadan programı kontrol edebilmelerini sağlamaktadır. Bu kontrol, kullanıcının gerçek görüntüleriyle sanal nesnelerin birleştirilmesine dayanan bir sistem ile sağlanmaktadır. Sistem, görüntü yakalama ile sanal gerçeklik ortamı oluşturmaktadır. Böylelikle, bilgisayar kullanımına yeni başlayan veya bilgisayar kullanamayan kişiler için sistem kontrol edilebilir duruma getirilmektedir.

İlkokul eğitim sistemindeki “Matematik”, “Hayat Bilgisi” / “Fen ve Teknoloji” ve “İngilizce” derslerini kapsayan, etkileşimli görsel eğitim aracı olarak kullanılacak bir sanal gerçeklik ortamı tasarlanmıştır. Tasarlanan uygulama ile öncelikle, öğrencilerin sanal nesnelerle etkileşimde bulunabilecekleri bir ortam oluşturulması amaçlanmıştır. Bunun yanında, üç boyutlu sanal modellemelerin yardımıyla öğrencilerin üç boyutlu cisimleri algılamalarının kolaylaştırılması ve ders esnasında kullanılacak ek materyal ihtiyacının ortadan kaldırılması hedeflenmiştir.

Anahtar Kelimeler: Sanal gerçeklik, etkileşimli öğretim, video yakalama, ilkokul eğitimi.

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER ONE
INTRODUCTION

In developing societies, people should keep pace with various technologies. Information is in a continuously changing situation for societies in the information age, so modern societies do scientific researches to find new methods and techniques in terms of learning and teaching. Old methods and techniques rapidly lose their efficiency in the education area. When it was seen that the traditional approaches were unsufficient to resolve the problems within this area, Virtual Reality (VR) which brings a new perspective to education methods is used to benefit from technological possibilities.

Imagine going for a short walk only wearing daily clothes without using any space suit or devices in the open air of the Planet Mars of which atmosphere contains carbondioxide at the rate of 90 %. The Mars stones can be investigated in detail; the soil composed mainly of iron can be touched or one can even be surrounded by a nascent dust storm while walking on the surface of the Red Planet. Without leaving the Earth and using neither space suit nor oxygen supply, the Mars can be experienced closely by VR that is considered as a promising future technology.

VR in general meaning is replicating or modelling a real world case on computer. In this sense, it is especially related with visual models. To use this technology, one should interact with models. Anything can be designed virtually, because the modelled objects, environments and applications that use these models are computer-generated, which means designs are limited only by designer's imagination. This kind of approach shows that VR can offer application possibilities in numerous fields from military to medicine, from entertainment to trade. Nowadays, the most popular one among these areas is education.

By using VR as computer-assisted education technology, in the future, it is predicted that VR can take the place of today's education technologies and methods (Kayabaşı, 2005).

1.1 Literature Review

Today, computer technologies constitute the spine of human life because they make life easier. This technology addresses people of all ages in every area. It can be a theme park for a child, a centre of financial transactions for a bank employee or a centre of calculations where scientific studies are conducted by an academician. Computer systems are utilized in every area starting from service industry. It becomes impossible to get service when these systems are out of order. School enrolments and hospital appointments are virtually taken and credit card payments are done by connecting to these systems. In addition to these opportunities, one does not have to be in a specific place like home or office to connect to the internet. By using tablet personal computers or smart phones with the internet accessibility property, payments can be done, e-mails can be checked or the intended song in that moment can be listened to on bus, in metro or on street.

In daily life, like the given examples, virtual contents can be interacted continuously in an easy and rapid way via computer based systems like smart phones or tablet personal computers. Lately, this interaction is accomplished only with fingertips due to minimized usage of keypad. Traditional laptops, cell phones or even refrigerators and washing machines started to have the speciality of touch screen control panel after the touch screen's fast integration with every technological device. The ease of use of touch screen shows itself even in taking a queue number from a machine in a bank.

Although, touch screens are indispensable as the latest technology for all kinds of electronic devices, from now on newly technological easiness shows its face as future's controlling mechanism *interaction without touching*.

In short, a specific area of the real world is constantly scanned with various methods (colour tracking, skeleton position or motion detection) in interaction without touching method. By using the retrieved results from scanned images, the programme/simulation is directed and controlled.

As the most up-to-date example, “interaction without touching” controlling mechanism can be met in the latest version of three dimensional (3D) televisions. In these systems, the user’s hand movements are detected via camera or motion detection sensor. By this way, the user can change the channel or turn on the sound without using a remote controller.

In this work, the main purpose of the system is to design an interactive visual learning tool programme. Besides, it creates a visual environment which facilitates learning 3D concepts at primary school level. Also, by bringing ease of use to students, this system aims to avoid loss of attention of primary school students and to make them focus on course contents without necessitating keyboard, mouse or touch screen. For achieving this kind of ease of use, interaction without touching method was preferred in this work.

VR applications can be met sometimes as a building model investigated via 3D glasses, as virtual touristic tours only visited via computer screen and as a rehabilitation work which is used by haptic robot arms. VR applications that can be used in education lead the most intensified studies in academic area.

Minogue, Jones, Broadwell, & Oppewall (2006) developed a VR application employing desktop VR programme designed by using PHANTOM® (Phantom Premium, 2013) haptic desktop device to teach middle school students the structure and function of an animal cell.

In their web-based VR work designed by Virtual Reality Modeling Language (VRML), Indrusiak & Reis (2001) transformed two dimensional (2D) integrated circuits into 3D VRML model by adding a depth factor to these 2D circuits to examine from various perspectives on the Web.

Other work which uses depth perception on the Web is C. S. Lányi, Z. Lányi & Tilinger’s (2003) VR environment. This environment was created by designing a hyper text markup language (HTML) based web page that uses VRML with the aim

of seeing VR usability in the school curriculum in order to provide space and depth perception for elementary and high school students.

Kerawalla, Luckin, Seljeflot, & Woolard (2006) aimed to teach 10-year-old students the day and night formation concept employing the 3D mobile Earth model enlightened by the Sun's beams in the Augmented Reality (AR) environment via only web camera (webcam) and AR tile/marker (2D geometric black shape drawn on white background) use.

A computer game based 3D system was designed in Tüzün, Soylu, Karakuş, İnal, & Kızılkaya's (2009) work to give support to geographical learning in primary fourth and fifth grades. This system aims to teach the seven continents and twenty four countries to students.

When making a comparison between video-capture VR and Head-Mounted Display (HMD) in terms of used devices; Rand, Kizony, Feintuch, Katz, Josman, Rizzo, & Weiss (2005) tried various virtual environments (VEs) by these two VR platforms and evaluated them in terms of systems that will be used in VR therapeutic application.

In her progressing work, Murtagh (2011) created a virtual human model (avatar) and in order for the model to be used more efficiently in Irish Sign Language (ISL) simulations for the deaf, she detailed it to include face and body movements.

This thesis study presents VR based visual learning tool application for primary school education system. VR learning applications designed with low-cost systems are basis of this study. The main purpose of the system which can be executed only by a personal computer (PC) with a webcam is to create an interactive VE. Also, visualising third dimension concept by using 3D models and course menus which include geometric objects facilitates teaching and students' understanding of concepts that have three dimensions. Beside these aims, by virtually designing the

models such as geometric objects or solar system, this programme omits additional material needs in traditional teaching.

"Pre/post test" method was used to scientifically underpin and observe the performance level of this study. For this reason, the evaluation forms and surveys were prepared for the four grades in accordance with the course menu contents in VR environment designed as interactive learning tool. Before and after the programme was tested in each classroom, the forms containing the same questions were handed out to the students. Different from the pre-test, post-test includes a survey with seven questions. These pre/post tests were compared and analysed statistically and then the performance of the VE was investigated. Consequently, the VE designed as interactive visual learning tool can be utilized for teaching 3D concepts especially like internal organs or for teaching English words at primary school.

This study was designed in six chapters. Later on the first (introduction) chapter, a general introduction about VR concepts and a brief literature review of VR applications generated for education area are given. The second (virtual reality) chapter defines basic concepts about VR at first and then considers its historical process. Also, VR systems, their evaluation methods and necessary devices to use these systems are mentioned in this chapter. At the end of this chapter, VR application areas are explained with detailed examples. The third (method) chapter covers the VR environment designed as an interactive visual learning tool. Programming language, graphic and image processing libraries and 3D modelling tool whereby the VE was created are also contained here. Furthermore, the mode of operation of the interactive environment and its interaction method is included in this chapter. The fourth (application) chapter addresses the virtual environment as an interactive application and focuses on its intended use and the course menus with their contents backed up with detailed screenshots. The fifth (analysis results) chapter delves into the results acquired from the evaluation forms and surveys that were conducted at T.R. İzmir Dokuz Eylül University, Özel 75.Yıl Primary School. Afterwards, the results were evaluated by utilizing statistical methods and they were described in detail according to grades by using the tables and graphics. In the sixth

and last (conclusions) chapter, the advantages that the virtual system has brought to the education area and the conducted statistical analyses were observed from a general view.

CHAPTER TWO
VIRTUAL REALITY

VR is a multidisciplinary area employing insights, concepts, principles and techniques from engineering, communications, physics, mathematics, computer graphics, performing arts, simulation and modelling (Vandergrift, 1996).

There is no general definition of VR concept. For this reason, researchers interested in VR try to define this concept according to the virtual systems they design, interaction methods or devices they use. In this chapter, a dictionary method frequently used in the literature is followed to form a basis for VR by defining primarily *virtual*, *real*, and *reality*.

Virtual: "Describes something that can be done or seen using a computer and therefore without going anywhere or talking to anyone" (Real Dictionary, 2013).

Anything designed on computer can be considered as virtual in terms of computer terminology.

Real: **"**Actually existing as a thing or occurring in fact; not imagined or supposed" (Oxford Dictionaries, 2013).

Reality: **"**The state of things as they are, rather than as they are imagined to be" (Cambridge Dictionaries online, 2013).

By following the dictionary definitions, VR can be shortly defined as a generated environment or technology which is three dimensionally formed with all sorts of existing/non-existent creatures, objects or places designed in computer environment similar to their origins and which is perceived as if it was real.

To have a clearer understanding of VR concept from different perspectives, it can be defined as an environment and according to its intended purposes.

VR as an environment: Environment comprising of interactive computer simulations which detect participant's position and actions by reversing feedback to one or more senses give the feeling of being mentally immersed in the simulation (Sherman & Craig, 2003).

The intended purpose of VR: Creating the illusion of being in an environment which can be perceived by user as a believable place with enough interactivity to handle required tasks efficiently and comfortably (Gutiérrez, Vexo, & Thalmann, 2008).

VR is considered as the latest technology which provides interaction between computer systems and the users (Kantarcı & Çakır, 1998).

At first, when the VR term came into use, it generated great expectations. It was thought that this technology could create virtual worlds indistinguishable from the real worlds. Even today, technology is not ready to build computer-generated environments as believable as reality. For this reason, it is considered that VR creates "acceptable" reproductions of real objects or worlds for training, designing and entertaining (Gutiérrez, Vexo, & Thalmann, 2008).

Reproductions of the real world can be achieved by VR through creating some details such as movement, visual effects and audio in the cyberspace (Kantarcı & Çakır, 1998).

2.1 Basic Concepts of Virtual Reality

The factors that provide the designed VE to be perceived sensually as real are explained as the following.

Immersion can be utilized in two ways as the physical and mental immersion. Physical immersion is the state of being physically in devices that create VE where user's various senses can be fooled. The user who uses the virtual application

physically feels himself/herself in these devices. In mental immersion, the user is highly engaged with the virtual materials/environments within the created alternate reality (Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

Sense of Presence is the possibility of the user to be represented virtually in a real place where he/she does not physically exist. When performing tasks by interactions, the user acts and thinks as he/she was in a real world and although he/she knows that it is VE, he/she psychologically acts as if it was real (Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

Interactivity provides the stages wherein the user performs tasks such as moving, shifting and rotating objects with or without additional device and/or data suit and sensual (such as see, hear, etc.) feedback given to these stages (Ko & Cheng, 2009).

Real-Time creates the feeling of reality by increasing the plausibility of VE through interactions with the users and feedback given to these interactions which are simultaneous to the real world (Ko & Cheng, 2009).

The concepts of immersion, presence, interactivity and real-time are directly related with creating a reality perception in the user to provide VR experience. These four factors should be provided to create minimum reality perception in a good and efficient virtual-real application. First of them is immersion. The more the environment can isolate the user physically and physicologically from the real world, the more the users can adapt themselves to the VE and focus on the tasks within this environment. After the user is enoughly immersed, as the second and third factors making the VR take one more step closer to reality are interaction in the application and its timing. Multisensory (see, hear, smell, and feel) interactions should give real-time feedback. In this way, reality atmosphere can be created. The fourth and last factor is presence. When the user perceives the VE he/she interacts with as real; he/she directs his/her movements and ideas accordingly. As a result, he/she thinks as if the created simulation was real.

The definitions of avatar and cyberspace which are related to VR are given as follows.

Avatar is an icon or image that represents a participant or physical object in VE like computer games, internet forums etc. and that the participant can move around the screen (Cambridge Dictionaries online, 2013; Oxford Dictionaries, 2013; Sherman & Craig, 2003).

Cyberspace is the vast space existing in computer network where the denizens of this space are physically located in disparate physical locations can meet and share ideas and socialize as if they were physically proximate (Craig, Sherman, & Will, 2009; Sherman & Craig, 2003).

2.2 Historical Content of Virtual Reality

Like most technological advances, VR found places initially in science fiction books.

VR showed itself firstly as fictitious virtual Africa in Ray Bradbury's 1950 dated story, The Veldt. In 1984, William Gibson put forward a definition of "cyberspace" in his novel named Neuromancer and put his name among the VR pioneers (Kurbanoğlu, 1996; Sherman & Craig, 2003).

VR was gradually started to be used with interaction devices or/and displays from 1960s onwards in various areas like informatics companies, in research and development works and at universities. Works, researches and applications that can be viewed as milestones of VR can be summerised below by years.

1962: "Sensorama" was a multisensory vehicle simulator designed by Morton Heilig. It is known as one of the first VR applications. In this simulator, the user sits in front of a screen and chooses from different ride options prerecorded employing bcycles, motorcycles etc. and watches this ride as 3D images without any interaction.

Besides, sense of reality is increased by using features such as smell and sound (Gutiérrez, Vexo, & Thalmann, 2008).

1968: Ivan Sutherland built a HMD as VR Helmet which enabled users to have right and left views of 3D images created on computer by small cathode ray tubes (CRT). In this system, the user's head movements are tracked in order to update the virtual images accordingly. As a result, the illusion of being in a VE is created (Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

1976: In Myron Krueger's "Videoplace" named work, the user's images recorded via camera are combined with virtual images or objects in computer environment and projected onto screen / projection screen by projector. He also defined "Videoplace" as "Artificial Reality". As the user moves, the reflection (silhouette) seen on the screen also moves. The user can interact with the virtual objects by touching them via his/her projected reflection. This method is called as video-capture VR technique (Federick, 2010; Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

1985: "VPL Research" was the first company interested in developing hardware and software regarding VR. Within the scope of the studies, "Dataglove", glove-based input device which detects the user's hand position was developed (Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

1992: A VR interface named The CAVE Automatic Virtual Environment (CAVE) was developed by the Electronic Visualization Laboratory, University of Illinois in Chicago. CAVE, is a cube shaped VR room where users can move and walk. The walls of CAVE are designed as monitors onto which various virtual images are rear-projected by projectors. The user can observe the 3D content by utilizing lightweight stereo glasses. Although the system aims immersion of one user, more than one person up to ten people can find an opportunity to see virtual contents at the same time (Gutiérrez, Vexo, & Thalmann, 2008; Sherman & Craig, 2003).

1993: The first desktop haptic device "PHANTOM®" which provides 3D navigation and haptic force-feedback was introduced into the market by SenseAble Devices. PHANTOM® robot arm detects the user's hand position and its coordinates and gives tactile feedback to the user (Phantom Premium, 2013; Sherman & Craig, 2003).

1994: VRML is a type of file with .wrl extension which enables computer based 3D objects and applications to be defined on the Web. By using VRML, virtual worlds are networked via the internet (Ko & Cheng, 2009; Whyte, 2002).

2.3 Virtual Reality Systems

It was seen in the following years that this technology could not meet its promise. Either requirement of high-cost devices or inaccurate estimation of the advantages it will bring to the areas that use this system caused this technology to find application areas only in military and entertainment sector with high-cost. By the reducing prices of the used devices with time and by the possibility of creating different VEs using alternative devices, this technology was considered as being inexpensive and started to be used in academic field (education).

Basically, VR systems give sensory feedback to the user in order to create "being there" perception.

A general VR system designing includes; software that creates 3D VE and hardware which supports this software, input and output devices to establish the interaction and lastly, the user(s) controlling the system by directives (Whyte, 2002).

These systems are classified in three groups according to the immersion degrees established by the used devices and how much the user perceives (see, touch, hear) the real world while experiencing the simulation (Gutiérrez, Vexo, & Thalmann, 2008).

Fully-immersive systems completely surround the user's field of vision. They are designed by using the helmets like HMDs to completely isolate the users from the real world. By creating real/virtual sounds and by using headphones, sense of hearing can be closed to the real world (Gutiérrez, Vexo, & Thalmann, 2008).

Semi-immersive systems are created by projecting the VE to large screens (wall-mounted display, large projection screens). The users are not fully surrounded by the VE; they can still see their hands, feet and so on. 3D images change according to the user interaction. These systems have a chance of implementation in cubic rooms as in the CAVE example where the walls of a cubic room onto which the virtual world is projected. In general, for educational purposes as pilot and captain training simulations or driving course simulations are used by multiple user groups to pave the way for collaborative work (Gutiérrez, Vexo, & Thalmann, 2008; Ko & Cheng, 2009).

Non-immersive systems are also called desktop-based VR systems. VR is presented only by a PC screen with a little nearly no immersion. This VR system has the lowest cost. Since they have low cost, VR applications are achieved a lot using these systems. Web-based VR applications are also based on non-immersive system (Gutiérrez, Vexo, & Thalmann, 2008; Ko & Cheng, 2009).

2.4 Evaluation Methods of Virtual Reality

Although VR systems can be classified according to immersion levels, they can also be classified and evaluated according to the used devices, display or feedback ratios that are given to the users. Apart from the above-mentioned, virtual and real material ratios used in the system allow the evaluation of these systems in different reality perspectives. VR evaluation methods can be examined in two categories. The first one is the Zeltzer's Cube that examines advance level of VR system. The latter is Milgram's Reality-Virtuality continuum which specifies system's conceptual position on the real-virtual line.

2.4.1 Advance Level of Virtual Reality Systems: The Zeltzer's Cube

Different evaluation methods can be used to determine how close the VR system stands to reality. One of them is the Zeltzer's Cube as shown in Figure 2.1. In order to represent the simulated world, this cube evaluates the VR system in three parameters as interaction and presence which are related to user's perception and autonomy. According to Zeltzer, every virtual system should include certain amounts of autonomy, presence and interactivity. Variables in this cube can have values ranging from 0 to 1. If the VR system has the value of 1 for each variable, this system is accepted to form a complete and advanced level of VR. The cube is basically used for determining the VR system's advance level (Mazuryk & Gervautz, 1996).

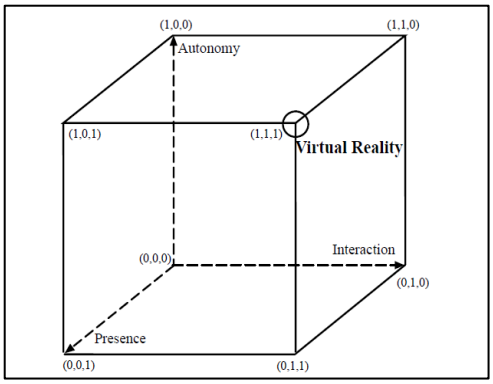


Figure 2.1 The Zeltzer's cube (Mazuryk & Gervautz, 1996)

2.4.2 Real-Virtual Transformation

In some VR systems, both virtual and real material usage is in question. In a VR system designed in this way, how much virtual or real the system is cannot be determined explicitly. To solve this complexity, Reality-Virtuality Continuum graphic which classifies the system as a display technology can be used while passing from virtual to real and visa versa as shown in Figure 2.2. A designed virtual system is classified according to how much virtual and real materials it includes by a scaling in Milgram's Reality-Virtuality Continuum graphic (Gutiérrez, Vexo, & Thalmann, 2008).

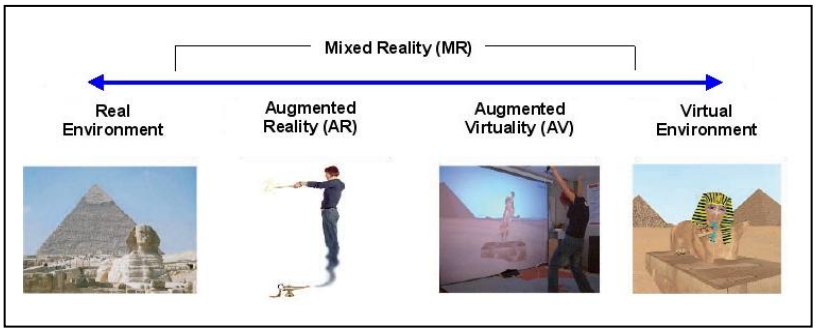


Figure 2.2 Real-virtual environments in Milgram's reality-virtuality continuum (Gutiérrez, Vexo, & Thalmann, 2008)

Concepts that are between a hundred percent VE and a hundred percent Real Environment (RE) defined in Reality-Virtuality Contiuum are given below. In some sources, Mixed Reality (MR) is an expansive version of VR.

Virtual World (Virtual Environment) is a 3D graphical computer-created environment which has/has not correspondence in real world and has specific rules and relationships such as weather condition, gravity that increase reality perception. It can also be named as "Virtual Environment" (Sherman & Craig, 2003).

According to Sherman and Craig (2003), virtual world is the fourth key element which creates VR experience in addition to immersion, interactivity and sensory feedback given to user input.

Because of the hype and unrealistic expectations of VR technology, many researchers employ the term "virtual environment" instead of "virtual reality" (Mazuryk & Gervautz, 1996).

Real Environment, as understood from its name, is a Reality-Virtuality continuum stage which has a hundred percent real content without any computer based content. It's also known as "Real Reality" (Gutiérrez, Vexo, & Thalmann, 2008).

Mixed Reality, a more expansive concept of VR, is a transition zone between VE and RE with the purpose of creating a more effective and useful environment by merging computer-generated virtual graphics with real world images/objects at specific ratios. According to merging ratios of virtual and real contents, MR is divided into two titles as *Augmented Reality* (AR) which contains more real images than virtual ones and *Augmented Virtuality* (AV) which includes more virtual images than real ones. AV can be thought as the opposite of AR. (Gutiérrez, Vexo, & Thalmann, 2008; Ko & Cheng, 2009).

In AR example faced in advertisement sector, AR tile printed on paper is viewed by connecting to the webpage of the product by using webcam. By this way, the product appears as 3D virtual object in the same location with AR tile on computer screen. This method is frequently used by film companies. For instance, a virtually created 2D/3D creature or object can be added to an actor's real world video camera image.

AV method is usually utilized by weather forecasters in weather presentations. Weather forecaster is real and the map onto which weather condition is projected has virtual content covering the background of the weather forecaster (Gutiérrez, Vexo, & Thalmann, 2008).

2.5 Virtual Reality System Devices

With the aim of the VE used in VR systems generate more sense of reality in the user for sending stimulus to various sense organs of the user and for immerging the user at high levels in physical and psychologic terms, more developed devices are used in addition to traditional data input (mouse, keyboard) / output (monitor) methods and devices. These devices both help classify the system according to the degree of immersion and provide the VE to present a more effective VR experience.

In a VR system, input devices provide interaction, output devices provide the feeling of immersion and software provides proper control and synchronization of the entire environment (Mazuryk & Gervautz, 1996).

In a standard immersive VR system, a basic interaction environment is built by three important devices. These are a display (HMD) enabling the user to see the created VE, a tracker which tracks the user movement simultaneously and detects when the user changes his/her point of view (e.g., turning right/left, walking etc.) and a manipulation device (e.g., data glove, 3D mouse, joystick). As the user moves himself/herself or employs manipulation device, the changes occured in the VE are sent in real-time from computer to the user's display (HMD) and this process continues as a cycle throughout the utilization of the environment. This kind of system is classified as fully immersive VR, because the user cannot see the real (outer) world (Mazuryk & Gervautz, 1996).

2.5.1 Input Devices of the Virtual Reality System

These devices are used for entering data into computer by the user. In the systems which provide VR, more developed and high cost devices are preferred instead of traditional data entering method using mouse and keyboard. The basic input devices used in VR systems are introduced below.

Tracking devices are input devices that capture the user's movements via tracking by various methods (sound, optic etc.) and detect his/her position and also measure orientation (Mazuryk & Gervautz, 1996).

In order to detect the user's location, there are various types of trackers; acoustic (ultrasonic) trackers using sound waves, optical trackers using LED or laser light, magnetic trackers generating magnetic fields by using either alternating current (AC) or direct current (DC), and mechanical trackers using a mechanical linkage of rigid arms which have joints between them (Mazuryk & Gervautz, 1996).

3D input devices are generally in the shape of glove or are hand-held in order to touch, select or modify the virtual objects in the VE (Mazuryk & Gervautz, 1996).

Data gloves are the most used 3D input devices. Position and orientation are measured by the sensors attached to specific points on the glove(s). A more precise result can be obtained by sensors attached to the joint angles of fingers. Apart from the worn data gloves with sensors, data suits with sensors are also frequently used in VR applications to track the whole body (Mazuryk & Gervautz, 1996).

Another 3D input device is called the Space Ball. When the user moves the ball, data input is taken by measuring translation forces and rotation torques of the ball (Mazuryk & Gervautz, 1996).

2.5.2 Output Devices of the Virtual Reality System

These are the devices which show or make the users feel the change in the VE or the measurements done according to the obtained data. Output devices used in VR systems are given below.

Personally wearable 3D glasses present the VE created by combining two different images shown as right and left from two different perspectives. In this way, the designed VE can be shown to the user in 3D (Mazuryk & Gervautz, 1996).

HMD was first invented by Ivan Sutherland and consists of a motion capture placed on the user's head and two small monitors like glasses that are placed in front of the user's eyes. As the user moves, information of position are transferred to computer by motion capture and VE images updated according to this information are shown to the user by monitors. They can be divided into two groups as See-through HMD and Opaque HMD. See-through HMDs are generally used in virtual applications like AR applications where the real (outer) world is wanted to be shown to the user. The field of view of the user who employs Opaque HMD is completely covered with virtual materials and the user cannot see the real (outer) world.

Therefore, the systems using Opaque HMD can be classified as fully immersive VR systems (Mazuryk & Gervautz, 1996).

Display Room is a VR room wherein large projection screens are located as walls. The environment in which three, four or six walls (including ceiling and floor) are covered with back-projected virtual materials is shown to the user from different perspectives with the help of 3D glasses or HMDs. The user can wander in the room. Because of its potential for use on projects with multi-user access, it provides an advantage for collaborative work. It is generally used experimentally at universities or in entertainment sector. The system can be evaluated as "semi-immersive VR system", because when the user wearing only glasses investigates the system without using HMD, he/she can see the real (outer) environment (Mazuryk & Gervautz, 1996).

Beside output's visual display, haptic display devices addressing haptic sensations are also used in VE applications. For haptic displays, two types of feedback devices as tactile and kinestetic (force) can be mentioned. Tactile feedback devices aim to make the user feel as if he/she was touching the surface of the virtual object, whereas kinestetic (force) feedback devices create the feeling which represents muscular force when placing the object (combining virtual model pieces) or moving it. Therefore, these devices provide the virtual application to be felt more real (Mazuryk & Gervautz, 1996).

2.6 Application Areas of Virtual Reality

VR gives an opportunity to develop any application in every area such as education, medicine, arts, sports, entertainment, trade, and manufacturing. Today, non-immersive based low-cost VR opened the door to implement VR applications not only by specific companies or VR laboratories at universities but also by anyone who interests in this area.

In this section, previous studies about VR area are covered in four titles as education, military & security, medicine and entertainment & trade.

2.6.1 Virtual Reality in Education

At present, VR is one of the most used methods in education area. Experiments that can be hazardous for students in classrooms or high-cost devices which are used by pilots or astronauts can be simulated and trainings can be done using these simulations. By this way, either the user's life safety or protection of the devices can be maintained. For instance, an astronaut is expected to succeed in flight simulation tests before using the real space-shuttle.

Mikropoulos & Natsis (2011) reviewed empirical research on the educational applications of VR during 10 years (1999-2009). In this work, after studies done in two stages according to six keywords: "educational virtual environment", "virtual learning environment", "virtual environment", "virtual reality", "education", "learning", 53 research studies scientifically supported through tests and surveys were mentioned. The investigated studies are evaluated under specific topic titles. Developed VEs generally included science, technology and mathematics topics. Beside these, studies related to historical and cultural topics were also faced. These studies were developed by interdisciplinary groups consisting mostly of scientists, teachers and educators. 16 of the applications used immersive or semi-immersive systems, four used CAVE, and the rest used desktop VR systems. As data collection methods, questionnaries (open/close tests, multiple choice questions), observations, interviews and task completions in EVEs were benefited from. As the target audience, the investigated EVE systems include students from elementary school to university. Although visual representations were used in all systems, some of them contained auditory and haptic systems. As interaction method and devices, mouse and keyboard were mostly preferred but it was seen in one of the studies that dataglove was used as navigation and manipulation of virtual objects. Although the benefits of VE in education were investigated in all studies, only 17 of them stated the benefits as enjoyment, usability enthusiasm, motivation, interest and willigness to

use. As a result, both students and teachers supported the utilization of VR in education.

In their study, Yang, Chen, & Jeng (2010) tried to create a "physically interactive learning environment (PILE)". PILE system was established by using video-capture based VR technology with the help of PC, webcam and projector. PILE application was employed in English lessons at a middle school in Taiwan. The designed VE includes 6 staged education application consisting of introducing English letters, understanding phrases, talking about phrases, listening to phrases, matching words and pictures and also listening to and writing the words. For testing the application, two separate groups, each comprising of 30 students were employed. During three weeks in total, the experiment group consisting of the first 30 students took English lessons via PILE system for a period of 40 minutes each week. Other 30 students were taught lessons by using slides via a classical presentation technique. In conclusion, the students in the PILE group found this system more interesting and funnier, direct contact with the virtual objects (without using avatar) increased their feeling of "being in the VE" and after completing the mission stages, their sense of achievement increased. By this way, it was observed that learning performance of the test group was improved. In addition, since the system set by webcam does not necessitate wearable VR clothes (data suits) or helmet, it established comfort in motion.

One of the most frequently used methods to generate VR in education area is web based VR applications. Most of the people who develop this kind of application prefer VRML. In this way, user can interact with 3D simulations through VRML web pages which contain 3D objects and environments. In some studies, Extensible 3D (X3D) which is a new version of VRML based on Extensible Markup Language (XML) and which can support complex VR applications was and is used (Ko & Cheng, 2009).

In their web based work, Indrusiak & Reis (2001) generated 3D layout of integrated circuits with a depth factor by using VRML. For this, integrated circuit

layout files with Caltech Intermediate Format (CIF) file extension drawn as regular 2D were transformed into 3D VRML model containing user defined depth by CIF to VRML (CIF2VRML) conversion tool. Finally, voltage levels in circuit elements were partly modelled according to colour variations. Besides, 3D models created for microelectronics education and IC design were advantagous compared to 2D drawings in terms of transparancy between 3D model layers and different point of views.

In another study for VR utilization in education area, chemistry and foreign language laboratories were simulated by e-learning application provided via the Net.

In Hatem's (2011) "e-learning systems in virtual environment" themed work, benefits of web based VE that uses X3D file format in e-learning area were shown. X3D is the most commonly used tool in e-learning systems to create 3D viewing and browsing. In this study, two different web based VE e-learning systems were used. The first of them is "on-line virtual chemistry laboratory system" that provided the students to perform experiments accurately depending on the curriculum. For this, observing methane and oxygen (O_2) gas atoms' interactions before and after reaction and comparing the experiments of interactions of two different elements (Mg and C) with oxygen were simulated. As being the second learning system, "on-line English language education system" facilitates learning language audile and visual through on-line interactive system. This system was supported by two applications as the uppercase/lowercase application and the word/figure matching application. With these simulations, on-line e-learning method let the students in distant locations join the chemistry experiments. By adding voice records to the foreign language laboratory environment, the users were able to listen to the right spelling of the foreign words. Besides, it was shown that X3D based VR can be used as an effective method to facilitate distance learning by experiencing and the VR technology.

In their study, Sun & Cheng (2009) three dimensionally simulated the Anping Fort in Taiwan which has historic features based on webcam input-interface technology via interface that has Chineese and English language options. Four sub-

scenes which belong to the Anping Fort were generated as the periphery, the showroom, the tower and the tunnel. Three major functions (browsing, digital content describing and question responding) were designed for these four sub-scenes. In the browsing mold, the user directs and controls the system via avatar. The digital content describing mold shows the randomly chosen historic events about the Anping Fort as written to the user. Finally, in the question responding mold, the user is expected to respond to the shown closed/ended questions. The user directs avatar in virtual scene through webcam. Consecutive frames taken from webcam are divided into nine fields and each field corresponds to the command of the user's motion. According to the results of the research survey that was applied to the thirty undergraduate students who tried this 3D virtual system, it was seen that webcam input-interface and 3D VR encouraged the users to understand and learn historic spot and that interface style provided ease of use.

Monahan, McArdle, & Bertolotto (2008) built a web based VR environment. A VR university was simulated where students online learn, collaborate on projects and be social by Collaborative Learning Environment with VR (CLEV-R) system. In the study, not a pedagogical analysis (learning concepts and contents) but 3D interface design for online learning, socialising and communication and its usability were investigated. Web based multi-user 3D environment designed for real time teaching is displayed as personalized webpage which mimics a real university with its lecture room and meeting rooms and which consists of two distinct sections for each student. In the upper section of the webpage, the VR environment which includes lecture theatre, library, meeting rooms and social areas is shown in 3D, while in the lower section Graphical User Interface (GUI) which contains communication tools (user information, connected users info, text chat, live voice, notepad applications) exists. CLEV-R system was also transferred to Personal Digital Assistants (PDA) environment for "anytime-anywhere" access. Therefore, as mobile learning (m-Learning) application example with the name of mCLEV-R targeting mobile device utilization in education is continued to be designed as webpages containing only specific functions of CLEV-R. It is aimed that the students can see course announcements, communicate and download course notes by using mCLEV-R. The

results obtained from the tests and questionnaires which were applied to students show that this system can be beneficial in e-Learning area.

In their study, Hsieh & Lee (2008) created AR English Learning System (ARLIS) to be helpful for pre-school students when learning English. To decrease complexity during the design of AR tile/marker and to increase their capacity, they benefited from permutation and combination concepts in mathematics. In order to receive real images, webcam as video and computer monitor as display device were employed in the study. Finally, since the system designed only with webcam and PC has low-cost, it was foreseen that it can be a new trend in education.

As another AR application, Karewalla et. al. (2006) explained the virtually simulated day-and-night formation concept by using both traditional teaching method and AR method. Afterwards, these two methods were compared experimentally. In the programme, to indicate day and night time, a child animation was generated on the Earth model. When it is day time, the child's awaken state and when it is night time, the child's sleeping state is displayed by the support of digital image. Similar to the video-capture VR technique, the user images are taken via webcam. Nevertheless, the interested part of the real images in this study is 2D figure named as AR tile/marker onto which 3D virtual model will be added in computer environment. Adding process is displayed to the user by computer screen. When the student moves the paper (AR tile), the Earth model in real-virtual image will move simultaneously. In this way, it is provided that the students can view the Earth model from different perspectives. This system can simulate VE only by computer with webcam and AR tile at affordable prices not necessitating additional devices like HMD. At last, AR tile method was determined to be more effective than the traditional teaching method for 10-year-old children to interactively learn sunrise and sunset and day-and-night formation in 3D environment.

In Murthagh's (2011) progressing work, she has developed an application for the deaf. In this work, creating a linguistically motivated avatar which will be used for ISL visualisation was aimed. VR human model (avatar) which will be created by

taking into consideration that ISL is not only supported by hands, but also by face and body movements is modelled down to the last detail such as hair and eyebrows using MakeHuman (MakeHuman, 2013) and Blender (Blender, 2013) programmes.

In their developed work, Minogue et. al. (2006) built a desktop VR programme for middle school science instructions by haptic feedback device. It was aimed that the middle school students test the structure and functions of animal cell theoretically and sensually. The effectiveness of the work was determined by pre/post test method using the experimental and control groups. At a middle school in North Carolina, the half of the eighty students (experimental group) who used The Cell Exploration VR programme received bi-modal (visual + haptic) feedback, the other half (control group) received uni-modal (visual) feedback. All of the students used the programme with PHANTOM® desktop device that provides haptic feedback during their exploration. The modelled cell can be zoomed in/out and rotated via this device. Nevertheless, while the control group was using the programme, haptic feedback feature was turned off and it was provided that the students could follow the programme only visual. At the end of the work, conseptual-cognitive asessment items showed that haptic feedback addition did not make a difference statistically. However, in general, it was seen that Cell Exploration programme enhanced students' understanding of cell concept, that its graphics in the design and haptic device are highly engaging and that it increases the interest of the students to cell concept.

Tüzün et. al. (2009) used a 3D computer game for geography learning in primary schools and investigated its effect on geography education (when learning the names and locations of the continents and countries) of the primary school students. Besides, the advantages of game based learning environments and their application types in the curriculum were investigated. The programme was used by twenty four students in the fourth and fifth grade in a private school in Ankara for a period of three weeks (as three stages). For this study, an educational computer game named Quest Atlantis (QA) was selected and the students' connection was established by the mail system named Q-mail within this game. In the game, April 23 National

Sovereignty and Children's Day was taken as basis and in order for the children who will come from 24 different countries on 7 different continents on the Earth to join the activity, the students were expected to help these lost children in the VE find their directions. According to the results of the test analysis applied to 13 students who could complete all stages, the students found the programme funny because it enabled them to explore and chat and also it was seen that computer games can be used for supporting "formal learning environments" in geography learning.

In their work, Lanyi et. al. (2003) designed an animation-aided VR test programme as multimedia for enhancing depth perception of the students. The programme was prepared as HTML based VRML application to be used by students in elementary school (10/14 year-old) and in high school (15-year-old) in Hungary. Analyses were done by the support of paper-tests. The questions similar to that of the tests prepared as pre/post test were used in the VR test programme to make the students pay their attention to the programme and to increase space and depth perception. The student can see various 3D geometric objects in virtual test environment and can choose from multiple-choice answers. Finally, it was stated that this kind of computer programme can help children gain better space perception and it is usable for 12-15 year old students' education curriculum.

This thesis study facilitates primary school students' perception of three dimension concept and processes of envisioning by VR based visual education application that contains 3D geometric object examples such as cube and pyramid. Besides, clearer and understandable learning environment was thought to be designed via the VR method by arranging 3D virtual representations of additional materials used in classical teaching in order to teach movements of the Sun-Earth-Moon, the day and night formation or the open/closed forms of geometric objects. In addition, the VE was considered to be useful since it directs the students' attention to the programme by capturing their attention.

Some of the VR applications done in many other fields except the field of education are investigated in the following titles.

2.6.2 Virtual Reality in Military & Security

Intended purpose of VR technology in military and security field is to save lives as in other fields, but VR also indirectly presents an environment based on user training. VR applications used in military and security field are designed as necessary training simulations for training generally soldiers, policemen, security personnels or astronauts. Various search and rescue operations in natural disasters, hostage-rescue operations or tank utilization methods can be created as VE. Additionally, in military operations in which VR technology is used, the users are prevented from being damaged (Craig, Sherman, & Will, 2009).

VR environments are also benefited from when sending satellites to space and in maintenance/repair works of these satellites. Since a manned space mission with multiple extravehicular activities (EVAs) including space walks were necessitated to repair breakdown of The Hubble Space Telescope (HST) launched in 1990, the National Aeuronautic and Space Administration (NASA) used VR technology as mission rehearsal tool. The EVA/RMS VR Simulator used by two EVA astronauts and the Intervehicular activity (IVA) astronaut who controls the Remote Manipulator System (RMS) simulates the circumstances that might arise during the HST repair operations as well as the procedures to be used in the mission. It also provides communication between astronauts. In the virtual system as the hardware part, HMDs and for interaction data glove and robot arms were used (Craig, Sherman, & Will, 2009).

A simulation system called VR Assault Planning Training or Rehearsal (VRaptor) was created by a study conducted at Sandia National Laboratories. By this system, people who work in security sector are practically taught how to behave in a possible hostage-rescue mission by the VE. The goal here according to virtually created scenario is to enable the user to protect himself/herself and not to get shot while rescuing the hostage. The user can see the VE and the virtual shape of gun replica he/she is holding from a perspective of first person shooter (FPS) with the help of HMD. To build a more real VR, both head tracking data obtained from HMD and

position tracking data received from the gun replica are employed (Craig, Sherman, & Will, 2009).

An operation of navigating a submarine safely into port which can seldom be rehearsed by junior submarine officers in the real world is created as training application in the VE. The Officer of the Deck (OOD) VR application which aims training of naval officiers prevents possible fatal manoeuvre failures that can be faced in the real world. The user can see the VE which contains port and navigational markers via HMD and can navigate the virtual submarine (Craig, Sherman, & Will, 2009).

2.6.3 Virtual Reality in Medicine

VR has various usages in health sector. There are various methods where VR is used to provide people to handle their fears by determining fear of spider, height and darkness and so on.

Applying a virtual therapy by "SpiderWorld" named simulation at Human Interface Technology Lab., Washington University, people who fear of spiders try to conquer their fears using fake fuzzy spider that provides tactile stimulation under psychologist supervision (University of Washington spider world, 2013).

Primal Pictures founded in 1991 presented an interactive project model named as "Primal Human" which gives an opportunity to investigate structures and organs such as muscle, vessel and bone three dimensionally especially for medical students and their educators by modelling the 3D human anatomy in a complete and medically accurate way (Primal Pictures 3D human anatomy software, 2013).

In order to find appropriate VR therapeutic application, Rand et. al. (2005) made comparison in terms of sense of presence, incides of side effects, perceived extertion and performance and investigated two different VR platforms that coworked with one of the four VEs (3 Games VE and 1 Office VE) which the healthy participant

used. The study aimed evaluation of Projected Video-Capture VR Platform (GX-Monitor) and Head-Mounted Display Platform (GX-HMD). Therefore, the “Games” VE which contains three games and the “Office” VE were utilized. The First one is “Birds & Balls game” wherein the user sees himself standing in a pastoral view where different coloured balls emerge and fly toward the user. Depending on the intensity of contact by the user body, the balls within the game will burst or transform into doves and then fly away. The second one is called “Soccer game” in which the user sees his reflection as the goalkeeper in a soccer game. The balls are shot at him from different angles, and he is expected to hit the balls with different parts of his reflected body to prevent them from entering the goal area. The third one is “Snowboard game” wherein the user sees back view of himself mounted on a snowboard. He needs to avoid obstacles by moving his body or by leaning from side to side while skiing downhill. Except these games as the fourth VE, a “virtual office” application was used in which a classical office is visualised. Here, the user visually scans the office environment at least 2 min and no longer than 5 min. The user is expected to name 16 different items in this office. This study was tried by two groups comprising of 40 and 49 people, respectively. The first group used game VEs via video-capture VR and HMD. The second group was divided into two groups as young and elderly. The young used virtual office by video-capture VR or HMD; the elderly used it by both video-capture VR and HMD. Results of the tests show that the users who experienced the virtual games had higher sense of presence via video-capture VR system, that side effects (nausea, oculomotor and disorientation) were felt more in HMD and that the utilized VR platform can affect the key characteristics of the system.

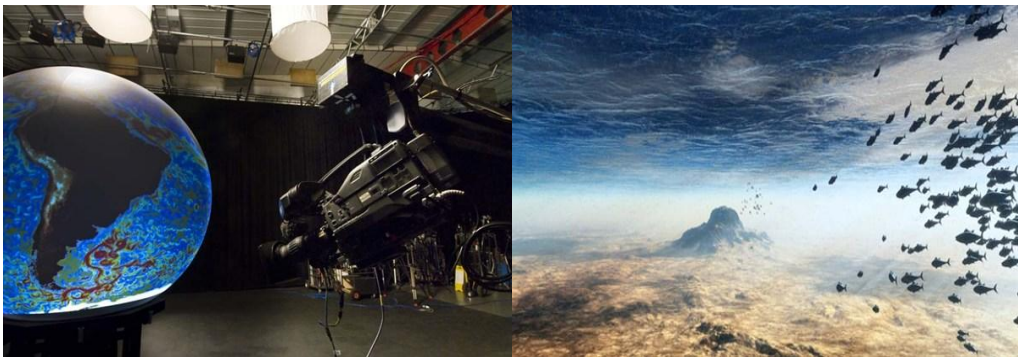
In her work, Sezer (2009) designed a web based game system by using VR environment for rehabilitation patients at Hacettepe University, Physical Therapy and Rehabilitation Center. By this means, by playing the game, the muscles (e.g hand muscles) of the patient that need to be strengthened are improved and healed in a short period. Video-capture VR technique in which the user’s real images are taken via camera and interaction is established by projecting these images via projector was used as the method for the study. With the help of low-cost system designed by

using webcam and PC, the patients were able to perform physical activities without getting bored in a funny environment. After the tests done using this system, physical therapy resulted in a shorter period.

In his study, Nar (2008) developed a virtual animation tool which integrates motion capture data with 3D model. Personal bone transformations were extracted via motion data containing 3D marker positions which are obtained from the markers on the user body. The obtained motion capture data was transferred to 3D animation model and in this way, by monitoring the user's walking types; facilitation of diagnosing process was aimed whether the user has gait disorder or not.

2.6.4 Virtual Reality in Entertainment & Trade

VR plays an important role at the product development stage of commercial companies or in entertainment sector. Products which will be mass-produced can be designed as models or developments and additions can be tested on released products. Besides, especially cinema and advertising sectors address the audience and attract their attention by using virtual materials.



(a) (b)

Figure 2.3 Pictures from "Light the Ocean" documentary (a) 3D real world model (b) 3D virtual scene (Light the Ocean photo gallery, 2013)

In National Geography signatured and 2011 dated "Light the Ocean" (Nicholls, 2011) documentary, "illuminating" ocean water by masterfully using the virtual materials built through specially developed computer animation software,

geographical formations, mountains and creatures under the ocean water are visualised as shown in Figure 2.3. Within the period of the documentary, a simulation of Gulf Stream and Humboldt which take thousand years to complete the full trip within the oceans round the world are shown to the audience (Light the Ocean, 2011).

In the movie called Avatar (Cameron, 2009), the actors were told to act while having the sensors on their faces to animate the virtual 3D alien copies created in computer environment in a real-like way. The received real images were combined with the alien copies in computer environment and many details including mimic movements were reflected to the audience. Actors' movements are received by the data suits which contain the sensors and by the other sensors that are put on their faces and then the movements are transferred to computer environment.

AR method was used in another commercial virtual application. At present, AR gives opportunity to develop an application on mobile and wireless devices.

In Nokia's Live View application (Nokia live view, 2013), with the help of cell phone with camera, one has the chance to see the nearest structures such as hospital, bank, and school or the nearest places like library and theatre according to his/her hobby and to get information from the screen of cell phone.

By a digital cosmetic mirror which is a project of a Japanese cosmetic company named Shiseido (Shiseido: Skincare, makeup & fragrance, 2013), customers' images without make-up are scanned by webcam and transferred to the screen. The customer can choose among the make-up equipment such as different coloured eye shadow or lipstick from the catalogue on the touchscreen and can see her face after make-up on the screen. By seeing the result before having make-up, the customers can have better decisions about the make-up processes they want (Andrews, 2010).

Similar methods to the cosmetic mirror method have opportunity to be used also in clothes companies and in haircuts.

Another area which uses VR application is tourism. In order to create models and images as real-like as possible in virtual tourism applications, very intensive data are used. Therefore, the computer systems that will process these data are more complicated and have high cost (Kantarcı & Çakır, 1998).

Figure 2.4 shows a screenshot of the Smithsonian National Museum of Natural History in Washington where the visitors can visit through a panoramic virtual tour via PC or mobile phone. The visitors can find their way on a map showing 3 floors of the museum and can see microscopic organisms, first humans, animals at present, and can even have a chance to see dinosaurs that lived 65 million years ago by "time travel" which are exhibited in different rooms (Smithsonian virtual tour, 2013).

Figure 2.4 Screenshot from virtual tour of Smithsonian National Museum (Smithsonian National Museum of Natural History panaromic virtual tour, 2013)

A Korean 4D (3D as VR + 1D as user) media and entertainment company named as d'strict (d'strict, 2013) created "the live park" application that is a 4D high-tech theme park by combining virtual material and digital technology as shown in Figure 2.5. In this application, an MR environment was built wherein the user is represented as avatar. It uses the input taken from the user through various sensors and interaction by touching / without touching methods. The system containing both 360 degree 3D theatre which provides field of vision for multi user and the 4D Hologram

stage which includes AR applications can be used for education, too (4D virtual reality theme park, 2013; d'strict: The live park, 2013).

Figure 2.5 “The Live Park” virtual content and user (4D virtual reality theme park, 2013)

In the light of the above-mentioned studies and virtual applications, it can be seen that applications which will be built by using VR have no limit in all fields varying from military to medicine, from tourism to cinema.

CHAPTER THREE
METHOD

This chapter firstly covers design stages of VR environment used as an interactive visual learning tool in two parts as hardware and software. After giving information about the design stages, working methods and interaction technique of this VR learning tool are explained.

3.1 Hardware Part of the Virtual Learning Tool

In this work, a webcam and a projector were used as additional hardware devices. Aim of this hardware device choice is to generate a VR environment with devices as low-cost as possible. In all primary schools, this system will be useful since there is no need for additional devices.

Students who use this system can already see the RE while interacting with the VE. Programme can be displayed in two ways, only with computer screen or with projector. When the system runs by using monitor, it can be classified as non-immersive VR system. When the projector is used optionally, the system can turn into semi-immersive system because virtual material covers more field of view. The VR system employed in this study was designed by using video-capture VR technique.

In video-capture VR, the user's image is taken to a single plane and movement tracking is achieved by using webcam and software without placing markers (sensors) on the user body. Therefore, user's image is embedded in VE. The user can see his/her reflected live image on the screen and user movements are taken as the system input. In this way, user's interaction with VE is established. Although the origins of video-capture VR date back to the middle of 80s, it found places in scientific researches mostly in the last years. Krueger, Gionfriddo, & Hinrichsen (1985) are one of the first users of this technique by their innovative Videoplace system. Videoplace is one of the first video-capture VR studies in which the user can

interact with virtual objects via his/her own movements (Weiss, Rand, Katz, & Kizony, 2004).

Videoplace is a computer generated graphics environment which projects the user's live images and virtual objects/creatures onto a video screen. In this environment, there can be only one user's image or images of other users in different locations. In short, more than one user are allowed to use this programme. Beside the user images, various graphics and animations can be included in this environment. Videoplace was first emerged as a telecommunications environment which enables users in different locations to share video experience simultaneously (Krueger, Gionfriddo, & Hinrichsen, 1985).

By providing user interaction with graphics in the environment and with the addition of other users, a collaborative work environment can be established. This kind of implementation can form the basis for many studies supporting group work and can increase the benefit gained from group work.

3.2 Software Part of the Virtual Learning Tool

This thesis study was written in C++ programming language. The structure of the VR environment which can be used as an interactive visual learning tool was designed in three basic units as shown in Figure 3.1. This section covers these three units from the bottom to the top; "Computer Graphics Unit", "Computer Vision Unit" and "3D-Modelling Unit", respectively.

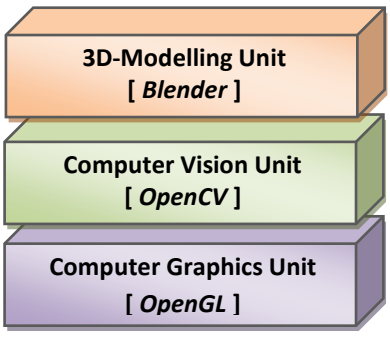


Figure 3.1 Three design structure units of the interactive visual learning tool

3.2.1 Computer Graphics Unit: OpenGL

The first unit of the structure is computer graphics unit. This unit was coded with "Open Graphics Library (OpenGL)" (OpenGL, 2013). OpenGL 3.7 version was used in this work.

OpenGL is a software library that provides an interface to graphical hardware. It includes more than 700 different instructions in which objects and figures are defined in order to be used in interactive 2D/3D applications. 670 of these instructions belong to OpenGL and the other 50 belong to "OpenGL Utility Library (GLU)" which contains additional modelling properties and figures (Shreiner, 2010).

Any kind of graphical application especially computer games, animations and engineering drawings can be implemented by utilization of open source OpenGL library which started to be used in the first graphic applications in 1992. It can run under Linux, Windows and MAC OS X operating systems. In order to provide this OpenGL property, OpenGL Utility Toolkit (GLUT) is used to open/close window in which OpenGL figures are drawn or to take user input via input devices (keyboard etc.). By employing GLUT, platform independent working environment is established (Hawkins & Astle, 2001).

Main reasons for the selection of OpenGL in this study are that it is open source and it supports platform independent working. For the window need to display VE, OpenGL library and GLUT toolkit were utilized. Besides, the colouring and illumination processes of 2D figures which were drawn with OpenGL and 3D models which were imported from Blender to OpenGL ensured the use of OpenGL.

3.2.2 Computer Vision Unit: OpenCV

The second unit of the design structure is the computer vision unit. "Open Source Computer Vision Library (OpenCV)" (OpenCV, 2013) was used in this section. Open CV 2.4.3 version was used in this work.

Computer Vision is used for recognising an object that is within the image, for changing colour and light of the picture or for detecting the travel direction of a car in video camera image by accomplishing computations or processes using various algorithms on a picture or mobile images obtained from video camera (Bradski & Kaehler, 2008).

OpenCV utilized in computer vision field is an open source library written in C and C++ of which development process started in 1999 under the leadership of Intel. Like OpenGL, OpenCV can also run under Windows, Linux, MAC OS operating systems as platform independent. OpenCV which contains more than 500 image and video analysis functions provides ease of use and allows real-time implementations run by multiple operators (Bradski & Kaehler, 2008).

The primary reasons for the utilization of OpenCV in this study are that it is open source and platform independent. Another reason for choosing OpenCV is that, it supports the necessity for the applications which create real-time feedback in order to increase the reality perception within the VE. This property of OpenCV gives a vital advantage to process images which will be received continuously from webcam. Also, platform independency of this library can clear the way for the generated VE to run under other operating systems.

3.2.3 3D-Modelling Unit: Blender

The third and last unit of this structure is the 3D modelling unit. In this part, "Blender 3D modelling programme" was used. This work utilized Blender 2.64.0 version.

Blender is a 3D modelling and animation studio package which was released as open source under the GNU General Public License (GPL) from 2002 onwards. Generally, it is used for creating high quality images and models in television commercials and on Open-Movie animation projects such as "Big Buck Bunny", "Sintel" (Flavell, 2010).

Like OpenCV and OpenGL libraries, Blender programme is platform independent. Blender can be used under Windows, Linux, Mac OS X, Iris and Solaris operating systems (Flavell, 2010).

For Blender utilization, the basic reason as mentioned in the first and second units is that it is an open source application. Other reasons for Blender utilization are that the created 3D models can be easily imported to OpenGL and that model creation is an easier process compared to OpenGL and that Blender has a practical user interface.

3.3 Mode of Operation of the Virtual Learning Tool

General mode of operation of the VR environment that is used as an interactive visual learning tool obtained by combining hardware and software tools are shown in Figure 3.2.

Drawings and models created with OpenGL and Blender are merged with user images taken from webcam by using OpenCV. By this way, real and virtual image consisting of the user's real images and virtual models is obtained. These obtained real and virtual images can be directly shown on computer screen or projected to projection screen via projector. The user sees his/her own image and virtual animations at the same time in the reflection within the VE window. By the user movements in order to interact with these virtual objects and by contacting with these objects "without touching them", real-time virtual modifications (object's movement, changing or opening next/previous steps) are accomplished. Therefore, as the user images taken from webcam change continuously, reality perception is created by establishing interaction with environment.

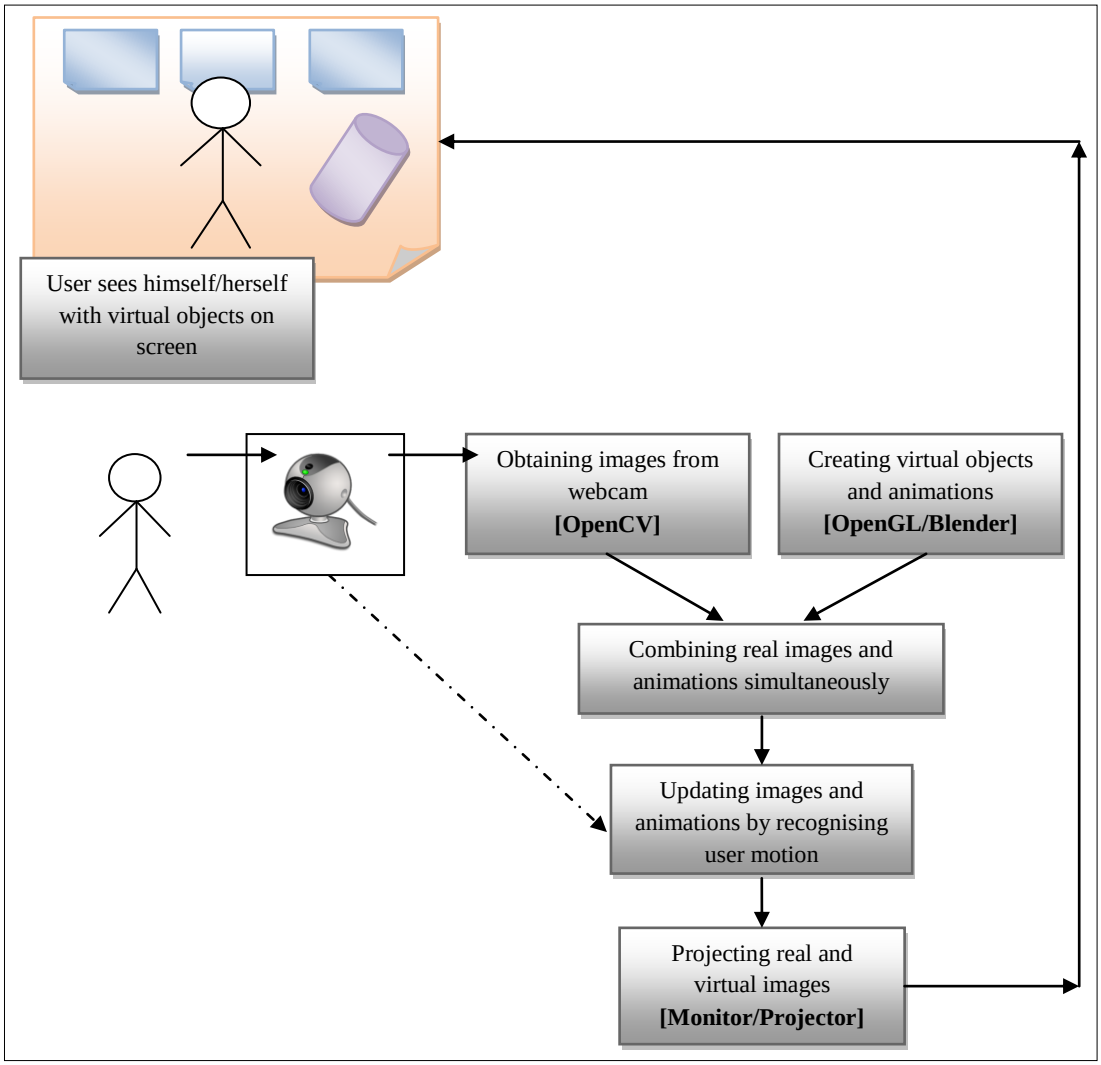


Figure 3.2 General workflow of the interactive visual learning tool

3.4 Interaction Method of the Virtual Learning Tool

In this study, interaction with VR environment is based on "interaction without touching" method. This method enables the user to control the programme only with the reflected live image via projector without using any input device like a mouse or keyboard. In this way, user can interact with the VE without physically touching any computer hardware. This system was made usable for people of all ages who does not/cannot use computer.

Webcam images were taken as basis to establish interaction in the virtual system. As a working principle, OpenCV handles continuous images taken from a video

camera as frames when processing them. Every mobile image is used successively as in the case of film frames shown one after another on the filmspool in a cinema. From this point forth, when the VR education tool is started, webcam is turned on firstly and then real images start to flow continuously. To initialize the interaction, this system necessitates “colour detection” process for determination of reference colour. For this reason, the user should show the reference colour that will be used during interaction to the square after 10 seconds from the beginning of the VE. When the colour detection process is completed, the VE is ready to be controlled by the user. Just after this process, the course menus are opened and the interactive visual learning tool application can be freely used.

When the programme’s course menu parts are opened, interaction is accomplished by the virtually created buttons. Utilizing video-capture VR technique, the user’s image is reflected to the screen and by moving the worn gloves or objects having the reference colour, the user can make his/her image touch the virtual buttons. According to the opened menus, specific buttons are continuously controlled depending on the reference colour. The user can start the virtual application of the desired course by clicking on the buttons in the menus “without touching” and navigate through the menus via these buttons. Besides, the user can change the course menu contents or can open the answers of the questions with the help of the “New” and “Show Info” buttons. Therefore, the user has the control of the programme.

To provide the interaction of the VR application generated by using OpenCV and OpenGL libraries and Blender 3D modelling programme, the relations between the libraries and the modelling programme are displayed according to the utilization steps and intended purposes in the workflow as given in Figure 3.3.

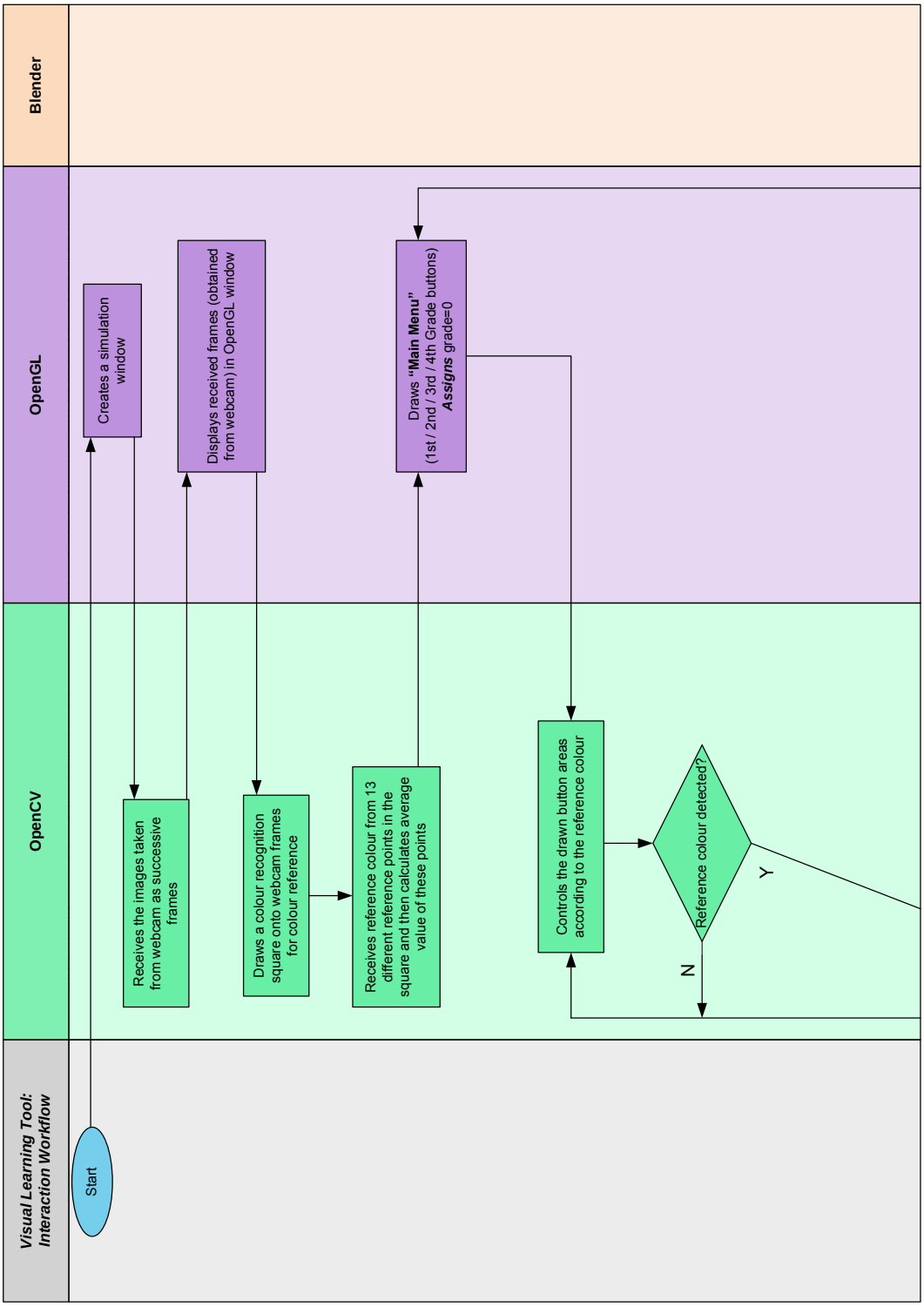


Figure 3.3 (a) Interaction workflow of the visual learning tool

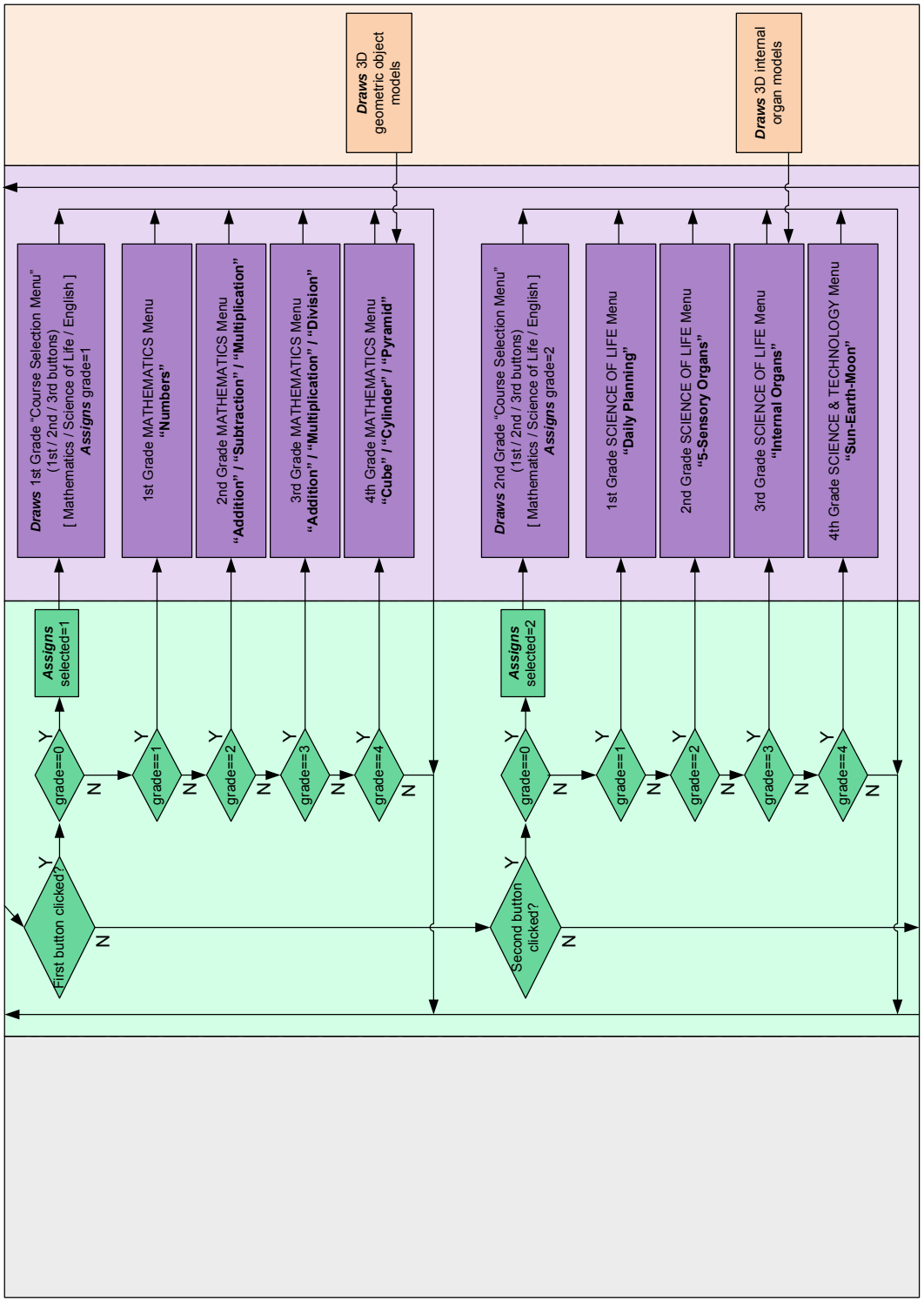


Figure 3.3 (b) Interaction workflow of the visual learning tool

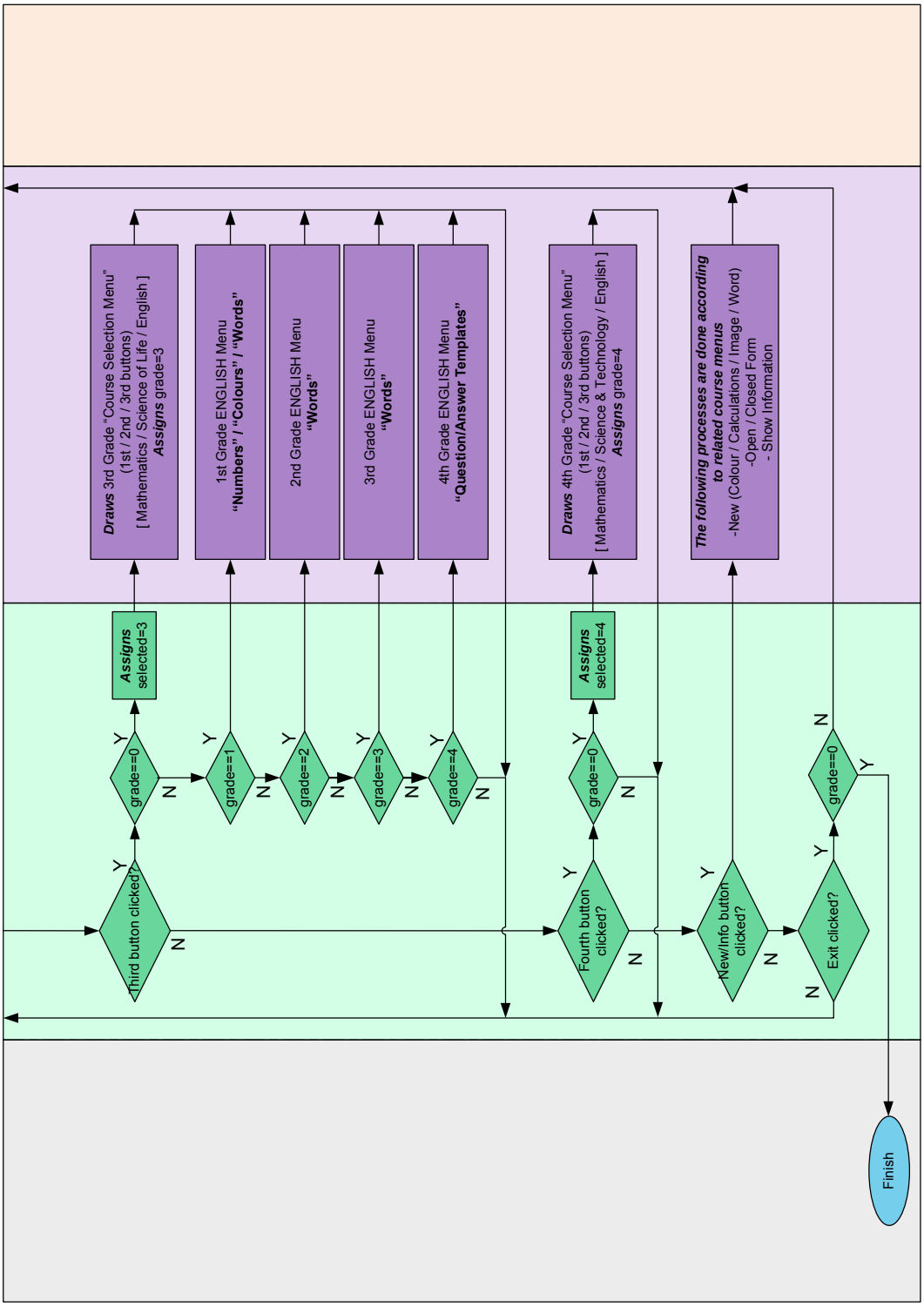


Figure 3.3 (c) Interaction workflow of the visual learning tool

CHAPTER FOUR
IMPLEMENTATION

This study presents a VR environment for primary school education system. The programme generally depends on the primary school curriculum of the Republic of Turkey Ministry of National Education (TMNE). Since national education system was changed as primary-middle-high school as 3 staged 4 year (4+4+4), this study was designed to be used only for the first four years of primary school. In this chapter, every course menu and their contents designed virtually were examined in detail. While creating the course menus in the learning tool, the contents which support third dimension concept and visualisation were taken into consideration.

4.1 First Grade Menu

In this grade menu shown in Figure 4.1, three courses can be chosen as "Mathematics", "Science of Life" and "English". The English menu contains three submenus as "Numbers", "Colours" and "Words".

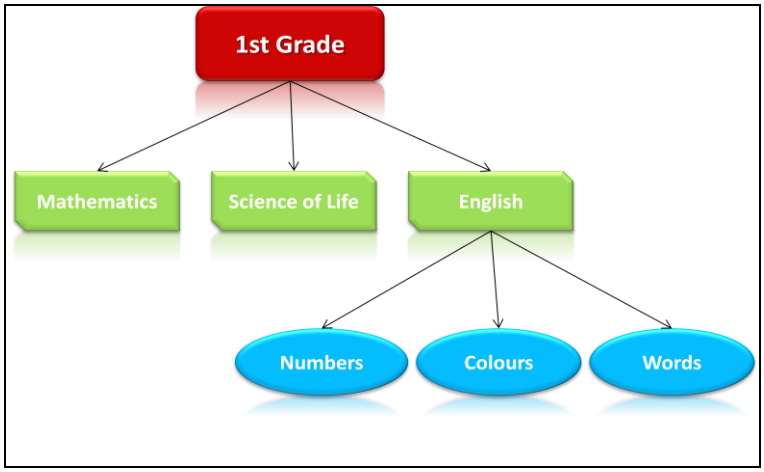


Figure 4.1 First grade course menus and english submenus

4.1.1 Mathematics Menu

The first grade Mathematics menu aims introducing numbers. To accomplish this, numbers from 1 to 10 are shown in 5 second time intervals on the left side and

numbers written in words are shown in the bottom right corner of the VE window as shown in Figure 4.2. Every number is shown with the same amount of moving box(es) that increase starting from 1 to 10 and when number 10 is reached the system counts down to 1. The Mathematics menu is designed to teach the number counting from 1 to 10 and from 10 to 1 to students.

Figure 4.2 Screenshot of first grade mathematics menu

4.1.2 Science of Life Menu

The Science of Life menu is based on daily planning. Student's one day is represented as six activities following each other. TMNE books frequently utilize this kind of exercise in order for the students to divide one day into hourly specific activities and to learn these activities. This menu includes digital and analogue watch presentations next to the activity images. The goal here is to aid students' hour reading.

4.1.3 English Menu

The last menu of the first grade is the English menu. Figure 4.1 shows three submenus of the English menu as "Numbers", "Colours" and "Words", respectively.

4.1.3.1 Numbers Submenu

This submenu introduces numbers in English. Similar to the Mathematics menu, numbers from 1 to 10 are shown in 5 second time intervals on the left side and numbers written in English words are shown in the bottom right corner of the VE window. Every number is shown with the same amount of moving box(es) that increase starting from 1 to 10 and when number 10 is reached the system counts down to 1. The Numbers submenu aims to teach students the number concept from 1 to 10 in English.

4.1.3.2 Colours Submenu

The Colours submenu includes a coloured cube as shown in Figure 4.3. Students are expected to define the colour of the cube in English. Afterwards, the student defines the colour and clicks on the "Show Colour" button to see the answer written at the bottom of the VE. After having written the name of the colour in English, students can change the colour by "change colour" option within the submenu.

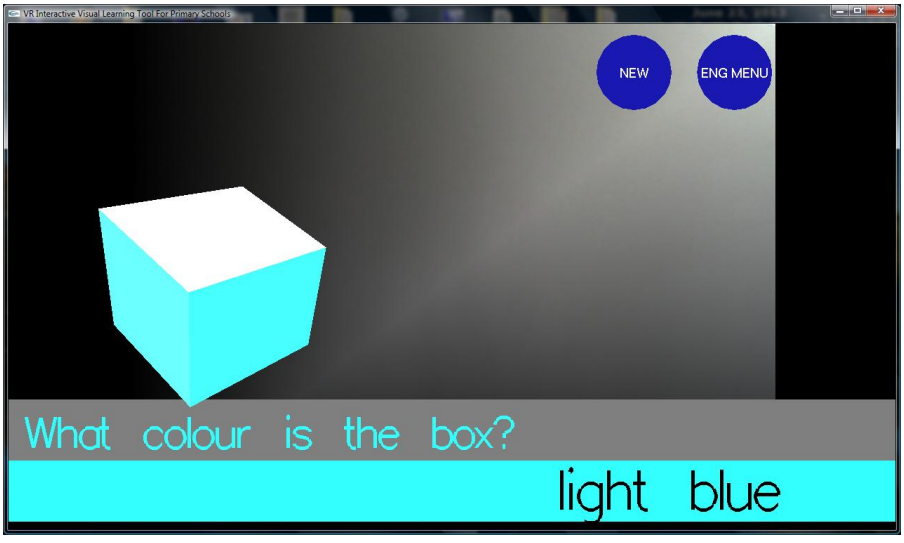


Figure 4.3 Screenshot of first grade english menu's colours submenu

4.1.3.3 Words Submenu

Basic words in English with their corresponding images are shown one by one in the Words submenu. Using the "Show Word" button, the English word related with the image can be seen in the VE. The "New" button clears the image and its word by displaying a new image with its corresponding word.

4.2 Second Grade Menu

In the second grade menu, the students can select a course among three course menus as "Mathematics", "Science of Life" and "English", respectively. The Mathematics menu also includes three submenus as "Addition", "Subtraction" and "Multiplication" shown in Figure 4.4.

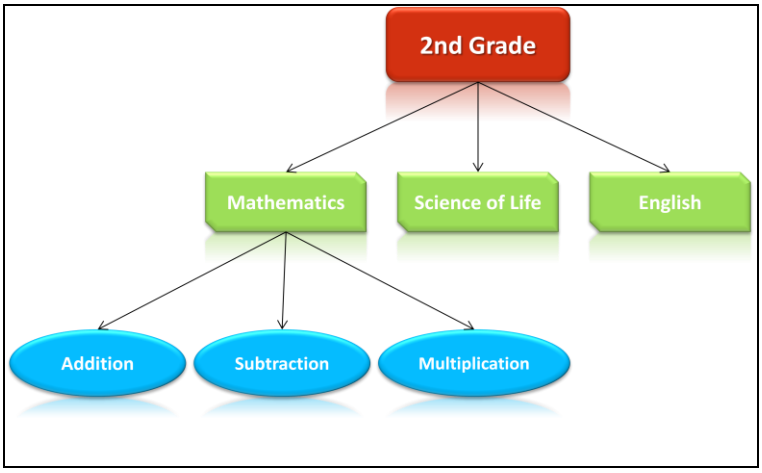


Figure 4.4 Second grade course menus and mathematics submenus

4.2.1 Mathematics Menu

2-digit mathematical calculation examples are given in the three submenus of the Mathematics menu. The first submenu is "Addition", the latter is "Subtraction" and the last is "Multiplication". In the Mathematics menu, numbers are generated by random number generator. This menu enables students to reinforce addition, subtraction and multiplication calculations including two 2-digit numbers. Within

this menu, mathematical calculations are done only with natural numbers to comply with the curriculum.

4.2.1.1 Addition Submenu

This submenu includes examples of addition of two 2-digit numbers. After this submenu is selected, two numbers are seen at the bottom of the VE with a plus sign between them. At first, there is a question mark instead of the result. When the result is calculated, student can open the result via the "Show Result" button. The "New" button clears the numbers and the result before generating two new 2-digit numbers.

4.2.1.2 Subtraction Submenu

The Subtraction submenu includes examples of subtraction of two 2-digit numbers. Figure 4.5 shows the same "Show Result" and "New" buttons which can be utilized in this submenu, too. Achieving the compatibility for the primary school curriculum, negative number result is hindered.

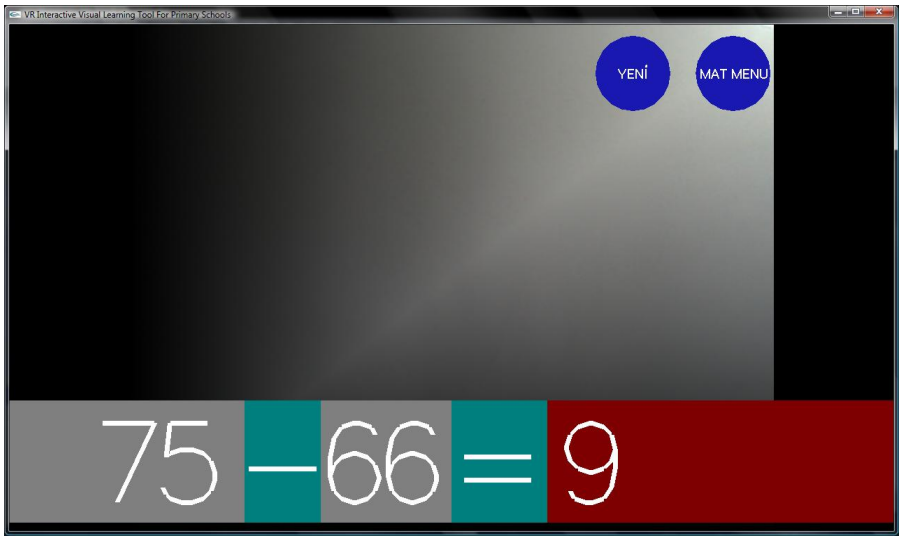


Figure 4.5 Screenshot of second grade mathematics menu's subtraction submenu

4.2.1.3 Multiplication Submenu

The last submenu of the second grade Mathematics menu includes multiplication calculations. Students can have the chance of meeting maximum 4-digit numbers as a result of multiplying two 2-digit numbers. Similar to the addition and subtraction submenus, this submenu supports the “Show Result” and “New” buttons.

4.2.2 Science of Life Menu

The Science of Life menu introduces five senses and five sensory organs that perceive stimuli through the senses in compatible with the TMNE. When the menu is started, an image representing a sense is shown. Name of the sensory organ which perceives stimulus is expected from student. The “Show Answer” button shows both the names of the sense and the sensory organ and short written information about them. This menu aims students to learn sensory organs and their locations in the body.

4.2.3 English Menu

The second grade’s last menu is the English menu. The VE shows “school” themed English words and the images representing them. The “Show Word” button is used to see the English word related with the image. The “New” button shows new image of another word.

4.3 Third Grade Menu

In the third grade menu shown in Figure 4.6, three courses can be chosen as “Mathematics”, “Science of Life” and “English”. The third grade Mathematics menu includes three submenus which can be classified as the “Addition”, “Multiplication” and “Division” submenus.

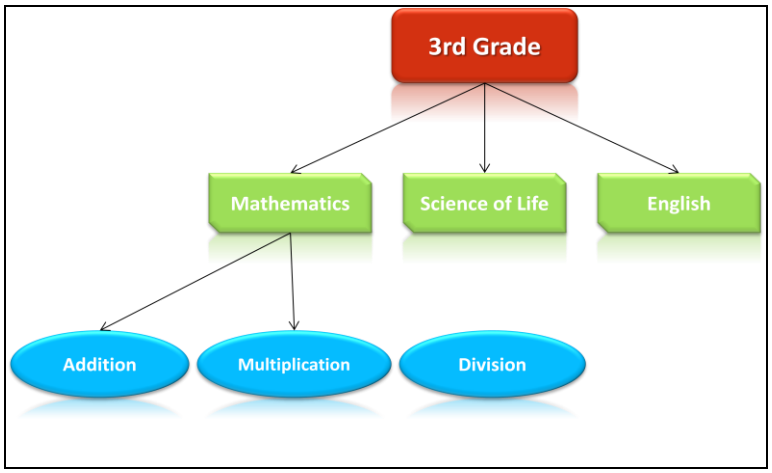


Figure 4.6 Third grade course menus and mathematics submenus

4.3.1 Mathematics Menu

Third grade Mathematics menu includes 2 and 3-digit number calculations. The Mathematics menu has three submenus. The first submenu is "Addition", the latter is "Multiplication" and the last is "Division". This menu uses numbers which are generated randomly similar to the second grade Mathematics menu. The aim of this menu is to reinforce the students' 2 and 3-digit number calculations by using two numbers. Only natural numbers are used in this menu to comply with the curriculum.

4.3.1.1 Addition Submenu

Examples of two 2-digit number addition calculation are included in this submenu. In the beginning, two numbers are seen at the bottom of the VE with a mathematical calculation symbol (plus sign) between them. One of these numbers can be 3-digit according to the numbers created by random number generator. The student who calculates the result sees the answer using the "Show Result" button. New addition example can be created with the "New" button.

4.3.1.2 Multiplication Submenu

Multiplication of two numbers is given in this submenu. Result can have 5-digits. In this way, students have the chance to meet 5-digit numbers as second grade

students' chance to see 4-digit numbers. The buttons which show results and which initialize new calculation examples used in the addition submenu are valid for this submenu, too.

4.3.1.3 Division Submenu

The Division submenu is the last one among the third grade Mathematics submenus. By choosing the first number with 3-digits and the second number with 2-digits, the possibility of the result being smaller than zero is prevented so that it is compatible with the curriculum. Additionally, it was avoided that divisor is equal to zero. Like the other submenus the "New" and "Show Answer" buttons can also be used in this submenu.

4.3.2 Science of Life Menu

Third grade Science of Life menu introduces six internal organs and their locations in the human body as shown in Figure 4.7. When this menu is selected, an image showing the location and 3D animation model of this organ created with Blender modelling program are shown. By moving the 3D model continuously in 360 degrees on the vertical axis, the front, back and side views of the internal organ are tried to be introduced to students. After seeing the 3D models of the internal organs and their locations in the body, students are expected to know the name and location of the organs correctly. The "Show Answer" button shows the name of the internal organ and gives short written information about this organ. This menu endeavours to teach students the internal organs, their sizes compared to each other and their locations within the human body.

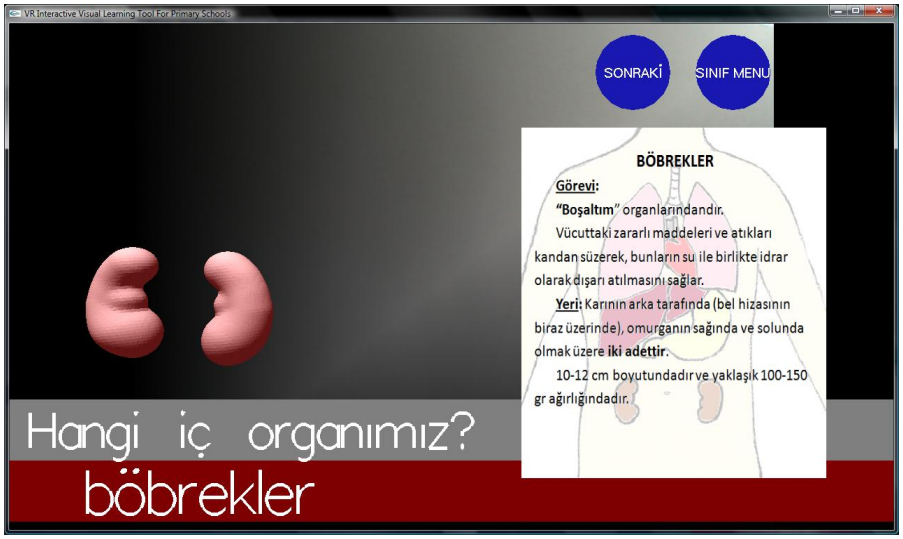


Figure 4.7 Screenshot of third grade science of life menu

4.3.3 English Menu

The English menu is the last menu of the third grade. A screenshot of this menu is depicted in Figure 4.8. "Transport vehicles and occupations" themed English words and images representing these words are shown in the VE. The "Show Word" button shows the English word related to the image seen in the VE and the "New" button changes the image with a new one.

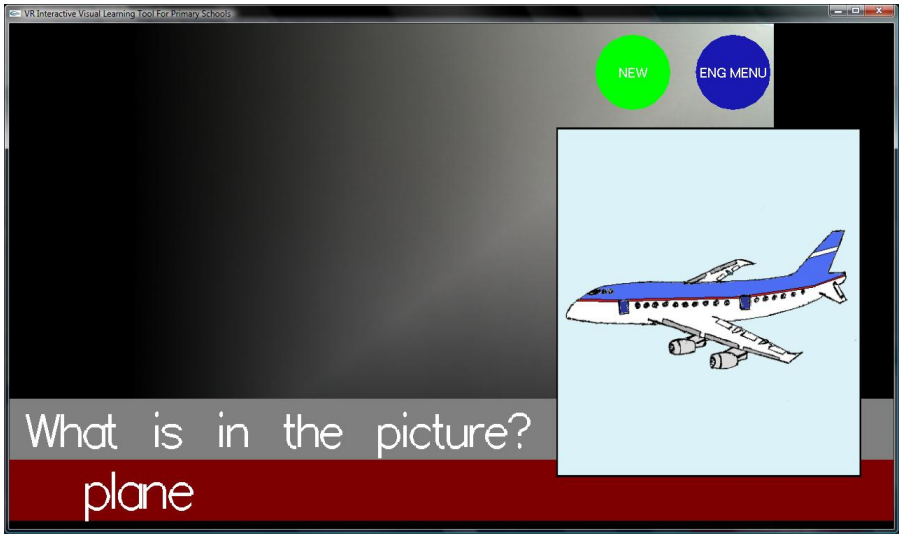


Figure 4.8 Screenshot of third grade english menu

4.4 Fourth Grade Menu

Interactive visual learning tool's last grade menu is the fourth grade menu. This menu includes "Mathematics", "Science & Technology" and "English" as shown in Figure 4.9. Three submenus "Cube", "Cylinder" and "Pyramid" are included in the Mathematics menu.

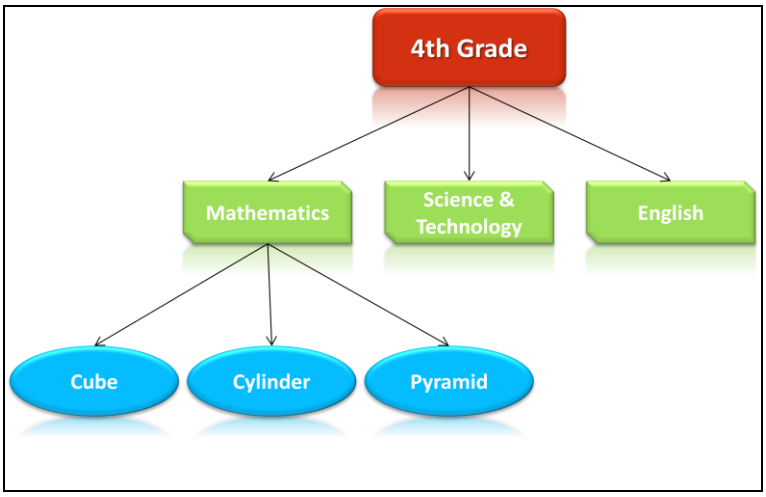


Figure 4.9 Fourth grade course menus and mathematics submenus

4.4.1 Mathematics Menu

The Mathematics menu was designed for geometric concepts. This menu has three submenus. The first submenu is "Cube", the latter is "Cylinder" and the last is "Pyramid". Geometric objects in this menu contribute to students' perception of third dimension concept. The 3D cube, cylinder and pyramid models were created via Blender 3D Modelling programme. When these submenus of the VE are opened, the closed forms of these models rotating 360 degrees around a vertical axis can be seen. The "Open Form" / "Closed Form" button helps transforming the model from open form to closed form.

4.4.1.1 Cube Submenu

Cube shape among the geometric objects is introduced in this submenu as shown in Figure 4.10. A short definition of the cube and some formulas like the area and volume of the cube are given in the VE. The "Open Form" button shows the open form of the cube as six squares depicted on the left side of the VE.

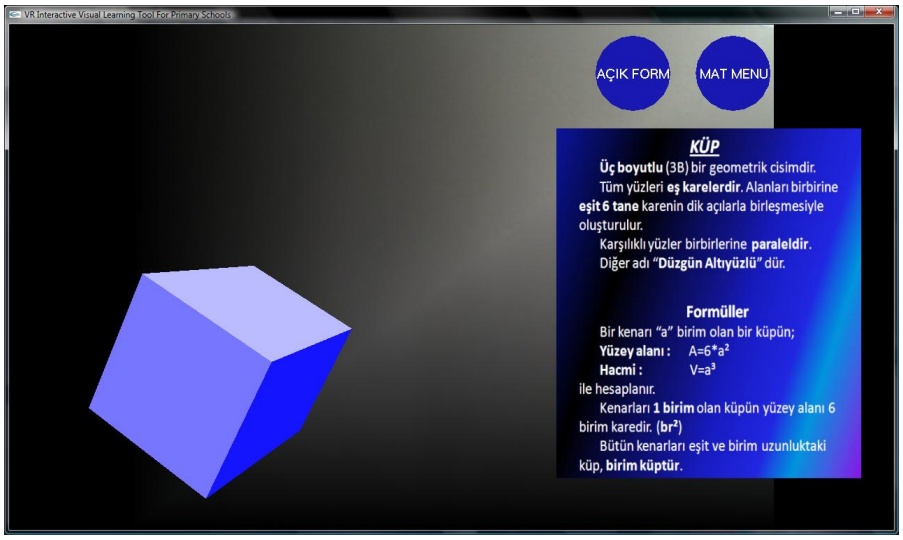


Figure 4.10 Screenshot of fourth grade mathematics menu's cube submenu

4.4.1.2 Cylinder Submenu

This submenu represents cylinder shape using 3D modelling. Brief information about the cylinder is given in this submenu. A short definition of the cylinder and some formulas like the area and volume of the cylinder are given in the VE. The cylinder's open form composing of two circles and one rectangle can be seen by "clicking" on the corresponding button.

4.4.1.3 Pyramid Submenu

The last submenu of the fourth grade Mathematics menu is the Pyramid submenu. It includes the 3D pyramid model and information including the pyramid definition and its surface area and volume. "Open Form" button shows the open form of the pyramid consisting of one square and four triangles around it.

4.4.2 Science & Technology Menu

Fourth grade Science & Technology menu represents the Sun, the Earth and the Moon. Rotation of the Moon around the Earth and the Earth's rotation around the Sun are animated in the VE as shown in Figure 4.11. The time elapsed during the rotations of the Earth and Moon is shown in the units of month and year on the left side of this environment at the same time with the animations. The "Show Info" button shows the written information about the definitions of these heavenly bodies, time elapsed during one rotation, explanations of the Earth's axial tilt and the solar/lunar eclipse definitions. This button also shows the rotation axes of the Earth around the Sun and the Moon around the Earth for a better visualisation. In this menu, since the Sun is positioned as an illumination source with the help of OpenGL, the day-and-night formation can be seen as animation. Aims of this menu are to give students information about the Sun, the Earth and the Moon and to enable them to have a comment on natural events like the day and night formation or the solar and lunar eclipses.

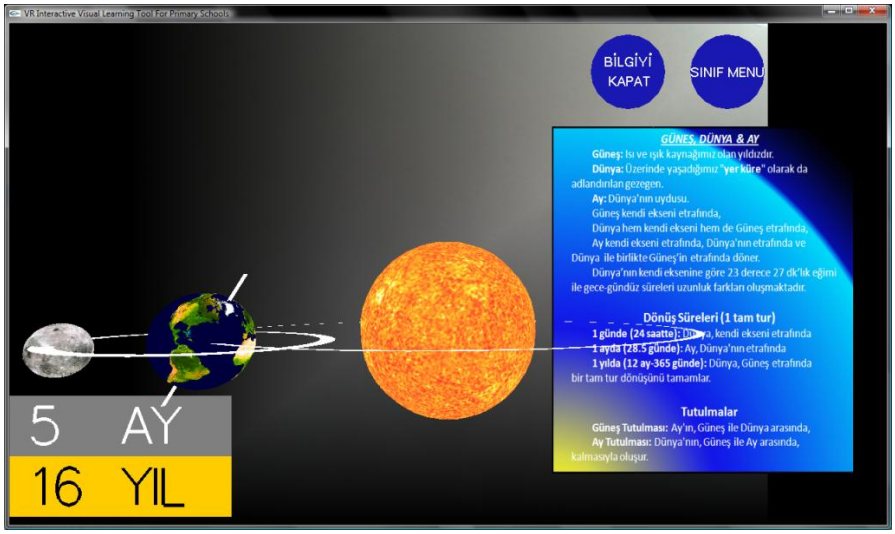


Figure 4.11 Screenshot of fourth grade science and technology menu

4.4.3 English Menu

The last menu of both the fourth grade and the interactive visual learning tool is the English menu. This menu includes English questions and answers as depicted in Figure 4.12. Students are expected to correctly answer the questions which are shown at the bottom of the VE. The purpose of this menu is to present the basic English question/answer templates in comply with the curriculum. The "Show Answer" button displays the answer of the question in the general template and the "New" button shows new question template.

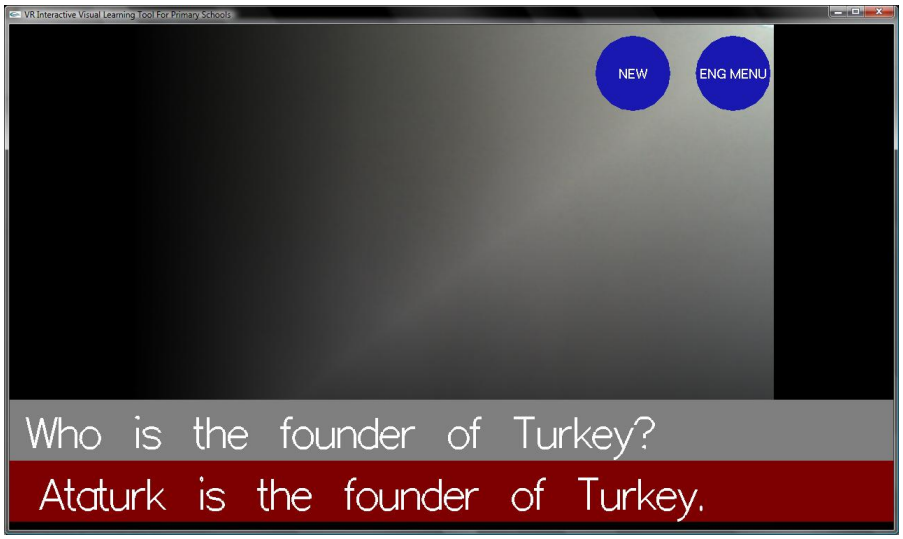


Figure 4.12 Screenshot of fourth grade english menu

CHAPTER FIVE
ANALYSIS RESULTS

In order to evaluate the VE designed as a visual learning tool for primary schools, the application was tested at T.R. İzmir Dokuz Eylül University, Özel 75.Yıl Primary School. In this chapter, statistical analysis of the results obtained by the evaluation forms (see also Appendices) which were used in the tests for the 1st, 2nd, 3rd and 4th grades and the comments on the surveys were investigated. Each evaluation form including the questions parallel to the topics of the course menus of the related grade in the VE was applied to the students as pre-test and post-test on papers. The students were required to answer the questions of the tests (pre-tests) in a given period just before the start of the VE. The measurements were made in seconds.

After the pre-tests had been completed, the virtual application was started and the students were able to use the environment one by one. While the students were using the virtual application, the time was taken into account. Upon completion of the VE application, the evaluation forms including the similar questions to the pre-test ones were applied to the students as post-test considering the time.

Unlike the pre-test, a survey including the seven questions (which have "Yes / No / Have no idea" options) by which the students could evaluate the VR application was added to the end of the evaluation forms that were handed out as post-test. The first three questions in the survey which were prepared separately for all grades evaluate the contents and measure whether the contents of Mathematics, Science of Life (Science and Technology) and English were comprehensible or not. The fourth question investigates ease of use of the buttons and the fifth one examines if using the VR programme is funny or not. The sixth question asks the students whether they would use such a programme when studying at home and the last one investigates if they wanted their teacher to use such a system during the lesson.

The evaluation results obtained from the pre/post tests before and after the students utilized the VE were analysed by the "Statistical Package for the Social

Sciences (SPSS®)" (IBM SPSS software, 2013) statistical programme. 15 scores were distributed equally to each of the three courses included in the evaluation forms. By this way, determination of the VE's effectiveness based on the different courses was aimed in addition to its general success.

"Wilcoxon Signed Ranks Test (WSRT)" was used to see whether the course contents in the virtual programme create interactive education environment. By using this test, the aim was to specify if there is a difference in the success before and after the VR environment utilization.

WSRT is conducted to determine if the two related/paired result groups taken from the same participant have the same distribution. This test is a non-parametric test used as an alternative to Paired Sample T-tests which compares the averages of two parameters of a group. When groups do not show a normal distribution or when the number of participants is small, the Paired Sample Sign Test or WSRT is used instead of T-tests. In WSRT, it's considered that the sample population is symmetric and observations are independent. This test is employed to measure the differences between specific time intervals (Paired-sample sign test and Wilcoxon signed rank test, 2013; Statistical Package for the Social Sciences help page, 2013; Wilcoxon signed-rank test, 2013; Wilcoxon signed-rank test using SPSS, 2013).

In order for the VE to be evaluated, H_0 null and H_1 claim hypotheses were developed for the pre-test and post-test.

H_0: VE does not create an interactive learning environment.
H_1: VE creates an interactive learning environment.

The significance level (α) was chosen as 0.05. Statistical analysis results for each grade were investigated taking into account the specified H_0 and H_1 hypotheses and the significance level (α). The obtained results were explained as pre/post-tests according to the courses and their contents by the tables and graphics under the following titles. Since the used data were analysed non-parametrically, median was

used as the y axis value on the graphics that show the courses separately and their general success. The results obtained from the survey questions attached to the post-tests were investigated separately by evaluating the answers according to number of students through graphics for each grade under the following titles.

5.1 First Grade Statistical Analysis Results

In the 1st grade, statistical analysis was implemented for 20 students who used the VR programme. From the student results obtained by WSRT, the evaluation form questions (see also Appendix A) and the total score only in the situation where the score of the post-test is higher than or equal to (positive ranks > negative ranks and/or positive mean rank > negative mean rank and analysis result $p<0.05$) that of the pre-test are given in Table 5.1 as the WSRT result table. The p values calculated according to the pre/post-test results are given with the question numbers of the courses in Table 5.2.

Table 5.1 First grade Wilcoxon signed ranks test results

1st Grade Wilcoxon Signed Ranks Test		**N**	**Mean Rank**	**Sum of Ranks**
PostT.ENG.Q10 - PreT.ENG.Q10	Negative Ranks	0	0	0
	Positive Ranks	16	8.5	136
	Ties	4	-	-
	Total	20	-	-
PostT.TOTAL - PreT.TOTAL	Negative Ranks	6	9.75	58.5
	Positive Ranks	12	9.38	112.5
	Ties	2	-	-
	Total	20	-	-

According to the WSRT results given in Table 5.1, positive ranks were higher for the 10th question (ENG.Q10) of the English course. In this question, the students' numerical knowledge was tried to be measured. Different numbers of cubes were given in the question and the students were expected to know the number of the cubes and the English word for that numeral. From Table 5.1, it is clear that 20 students answered the ENG.Q10 question, 16 of them had higher post-test results than the pre-test ones (PreT.ENG.Q10 < PostT.ENG.Q10), 4 had the same results (PreT.ENG.Q10 = PostT.ENG.Q10) for the pre-test and post-test. That's why the

calculated p value ($p<0.001$) for the ENG.Q10 question shown in Table 5.2 was significant ($p<0.05$).

When Table 5.1 is examined as the total score, 6 of 20 students had lower post-test results than the pre-test ones (PreT.TOTAL > PostT.TOTAL), 12 had higher post-test results (PreT.TOTAL < PostT.TOTAL) and 2 had the same results (PreT.TOTAL = PostT.TOTAL) for the pre-test and post-test. However, since the mean rank value of the negative ranks (9.75) is higher than that of the positive ranks (9.38), the p value obtained for the total score was not significant.

Table 5.2 First grade pre/post test analysis results regarding the course contents

1st Grade						
Course	**Contents**	**Questions**	**Pre-Test (Mean ± S.D.)**	**Post-Test (Mean ± S.D.)**	**Number of Students**	**p**
Mathematics	*Numbers*	*M.Q01*	3.00 ± 0.000	2.95 ± 0.218	20	0.317
		M.Q02	3.00 ± 0.000	2.81 ± 0.512	20	0.157
		M.Q03	8.80 ± 0.696	8.76 ± 0.768	20	0.317
Science of Life	*Daily Planning*	*SL.Q04*	4.80 ± 1.765	4.76 ± 1.480	20	0.931
		SL.Q05	8.70 ± 0.923	8.29 ± 1.309	20	0.180
English	*Colours*	*ENG.Q06*	2.00 ± 0.000	2.00 ± 0.000	20	1.000
		ENG.Q07	2.70 ± 0.657	2.62 ± 0.740	20	0.480
	Words	*ENG.Q08*	3.75 ± 1.020	4.00 ± 1.000	20	0.236
	Numbers	*ENG.Q09*	2.75 ± 0.444	2.76 ± 0.436	20	1.000
		ENG.Q10	0.10 ± 0.447	1.52 ± 0.750	20	0.000
		TOTAL	**39.60 ± 2.501**	**40.48 ± 3.140**	**20**	**0.237**

P<0.05

Although the students whose total post-test scores are higher than the pre-test ones are greater in number, the differences in the Mathematics and Science of Life menus of the 1st grade were not found to be significant as shown in Table 5.2. However, since the p value of the ENG.Q10 question of the Numbers submenu under the English menu was smaller than 0.001 as shown in Table 5.2, it was found to be significant ($p<0.05$). Therefore, it was seen that the VE can be effectively used in learning English in the 1st grade.

Figure 5.1 shows the distribution of the scores taken from the evaluation forms according to the courses and total scores by using median values.

As can be seen from Figure 5.1, there was no difference between the pre and post test scores for the Mathematics course. However, the students' scores decreased in the Science of Life course and increased in the English course. When considering the total score, it was observed that the post test scores increased compared to that of the pre-test.

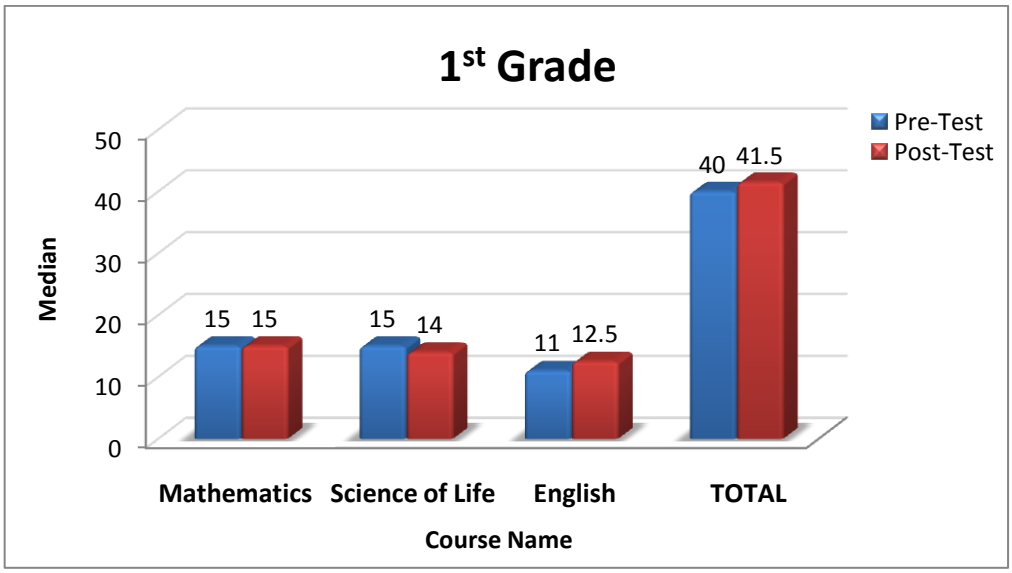


Figure 5.1 First grade pre/post test results as median values for each course

5.1.1 First Grade Post-Test Survey Results

The 1st grade's survey prepared for the designed VR application contains the following. The students were asked to evaluate the following statements written on the survey as "Yes / No / Have no idea".

A.1 I could easily understand the **numbers** in the Mathematics menu.
A.2 Drawings in the Science of Life menu were comprehensible.
A.3 I learnt **new English words** by the English menu.
A.4 I could make my choices **easily** by the buttons.
A.5 Using the education programme was **entertaining**.

A.6 If I had a programme like this, I would use it **at home** when studying.
A.7 I would like **my teacher** to use such a programme in lesson.

The 1st grade students' answers to the survey questions are given in Figure 5.2 according to the number of the students.

As can be seen from Figure 5.2, 20 students of the 1st grade who answered the surveys stated that they could easily understand the numbers of the Mathematics menu, 19 stated the drawings in the Science of Life menu were comprehensible and 17 stated they learnt new English words. The survey result of the 4th question that includes ease of use of the buttons was lower (12 students) than other survey question results. The reason for this is considered that the students used the programme for the first time. 19 students said that they found the programme entertaining. 20 stated that they would use a programme like this at home when studying and 19 wanted their teacher to use such a programme in lesson.

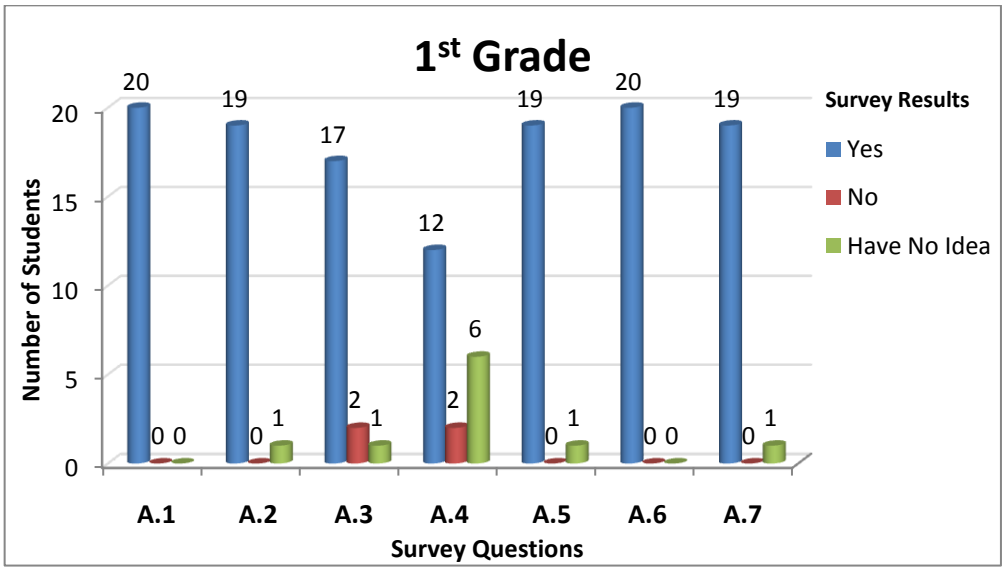


Figure 5.2 First grade survey results question by question

5.2 Second Grade Statistical Analysis Results

In the 2nd grade, statistical analysis was implemented for 19 students who used the VR programme. From the student results obtained by WSRT, the evaluation form

questions (see also Appendix B) and the total score only in the situation where the score of the post-test is higher than or equal to (positive ranks > negative ranks and/or positive mean rank > negative mean rank and analysis result $p<0.05$) that of the pre-test are given in Table 5.3 as the WSRT result table. The p values calculated according to the pre/post-test results are given with the question numbers of the courses in Table 5.4.

Table 5.3 Second grade Wilcoxon signed ranks test results

2nd Grade Wilcoxon Signed Ranks Test		**N**	**Mean Rank**	**Sum of Ranks**
PostT.ENG.Q09 - PreT.ENG.Q09	Negative Ranks	2	2.5	5
	Positive Ranks	10	7.3	73
	Ties	7	-	-
	Total	19	-	-
PostT.TOTAL - PreT.TOTAL	Negative Ranks	3	4.33	13
	Positive Ranks	13	9.46	123
	Ties	3	-	-
	Total	19	-	-

According to the WSRT results given in Table 5.3, positive ranks were higher for the 9th question (ENG.Q09) of the English course. In this question, the students' English vocabulary was tried to be measured. The students were asked to fill in the blanks with five school themed Turkish/English words given with their figures in this question. From Table 5.3, it is clear that 19 students answered the ENG.Q09 question, 2 of them had lower post-test results than the pre-test ones (PreT.ENG.Q09 > PostT.ENG.Q09), 10 had higher post-test results (PreT.ENG.Q09 < PostT.ENG.Q09), 7 had the same results (PreT.ENG.Q09 = PostT.ENG.Q09) for the pre-test and post-test. That's why the calculated p value ($p=0.007$) for the question ENG.Q09 shown in Table 5.4 was significant ($p<0.05$).

When Table 5.3 is examined as the total score, 3 of 19 students had lower post-test results than the pre-test ones (PreT.TOTAL > PostT.TOTAL), 13 had higher post-test results (PreT.TOTAL < PostT.TOTAL) and 3 had the same results (PreT.TOTAL = PostT.TOTAL) for the pre-test and post-test. As a result of the total score, the p value given in Table 5.4 is ($p=0.004$), which means it is significant ($p<0.05$).

Table 5.4 Second grade pre/post test analysis results regarding the course contents

2nd Grade						
Course	**Contents**	**Questions**	**Pre-Test (Mean ± S.D.)**	**Post-Test (Mean ± S.D.)**	**Number of Students**	**P**
Mathematics	*Addition*	*M.Q01*	4.65 ± 0.671	4.74 ± 0.562	19	0.608
	Subtraction	*M.Q02*	4.80 ± 0.410	4.68 ± 0.478	19	0.317
	Multiplication	*M.Q03*	1.95 ± 0.945	2.32 ± 0.946	19	0.083
Science of Life	*5-Sensory Organs*	*SL.Q04*	4.25 ± 1.118	4.58 ± 0.607	19	0.066
		SL.Q05	3.70 ± 2.080	3.79 ± 2.097	19	0.414
		SL.Q06	3.60 ± 0.821	3.47 ± 0.905	19	0.564
English	*Words*	*ENG.Q07*	5.00 ± 0.000	4.95 ± 0.229	19	0.317
		ENG.Q08	3.10 ± 1.334	3.53 ± 0.964	19	0.131
		ENG.Q09	3.05 ± 1.432	4.21 ± 0.787	19	0.007
		TOTAL	**34.10 ± 4.541**	**36.26 ± 3.619**	**19**	**0.004**

P<0.05

Although the students whose total post-test scores are higher than the pre-test ones are greater in number, the differences in the Mathematics and Science of Life menus of the 2nd grade were not found to be significant as shown in Table 5.4. However, since the p value of the ENG.Q09 question of the Words submenu under the English menu is p=0.007 as shown in Table 5.4, it was found to be significant (p<0.05). Therefore, it was seen that the VE can be effectively used in learning English in the 2nd grade.

Figure 5.3 shows the distribution of the scores taken from the evaluation forms according to the courses and total courses by using median values.

As can be seen from Figure 5.3, there was no difference between the pre and post test scores similar to that of the 1st grade for the Mathematics course. However, the students' scores decreased in the Science of Life course and increased in the English course. When considering the total score, it was observed that the post-test scores increased compared to that of pre-test.

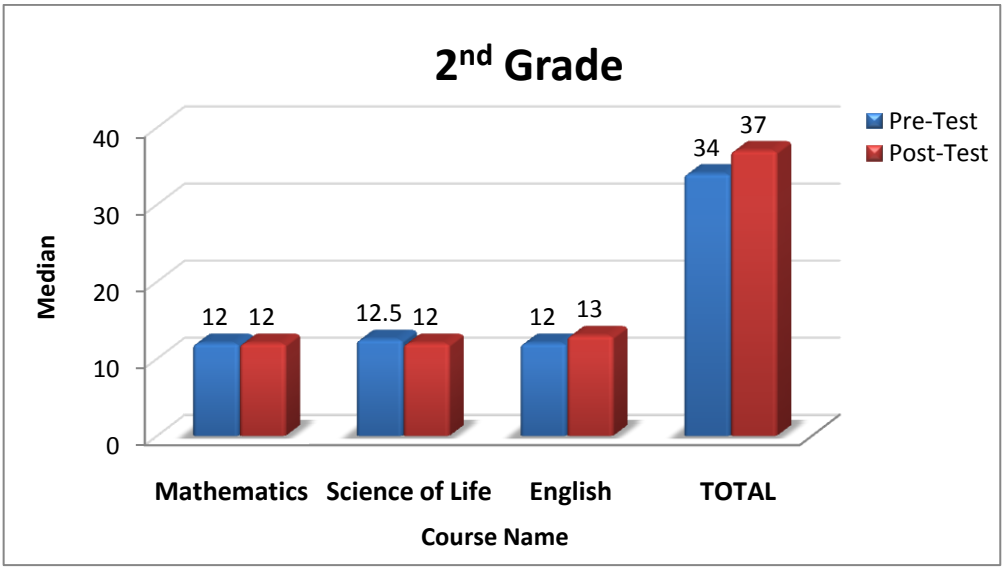


Figure 5.3 Second grade pre/post test results as median values for each course

5.2.1 Second Grade Post-Test Survey Results

The 2nd grade's survey prepared for the designed VR application contains the following. The students were asked to evaluate the following statements written on the survey as "Yes / No / Have no idea".

A.1 I could easily find the **results of the calculations** in the Mathematics menu.
A.2 The **models of the sensory organs** in the Science of Life menu were comprehensible.
A.3 I learnt **new English words** by the English menu.
A.4 I could make my choices **easily** by the buttons.
A.5 Using the education programme was **entertaining**.
A.6 If I had a programme like this, I would use it **at home** when studying.
A.7 I would like **my teacher** to use such a programme in lesson.

The 2nd grade students' answers to the survey questions are given in Figure 5.4 according to the number of the students.

As can be seen from Figure 5.4, 16 of 19 students of the 2nd grade who answered the surveys stated that they could easily find the results of the calculations in the

Mathematics menu, 16 stated the Science of Life course contents were comprehensible and 17 stated they learnt new English words. 17 students said they could make their choices easily by the buttons and 18 said they found the programme entertaining. 14 stated that they would use a programme like this at home when studying and 17 wanted their teacher to use such a programme in lesson.

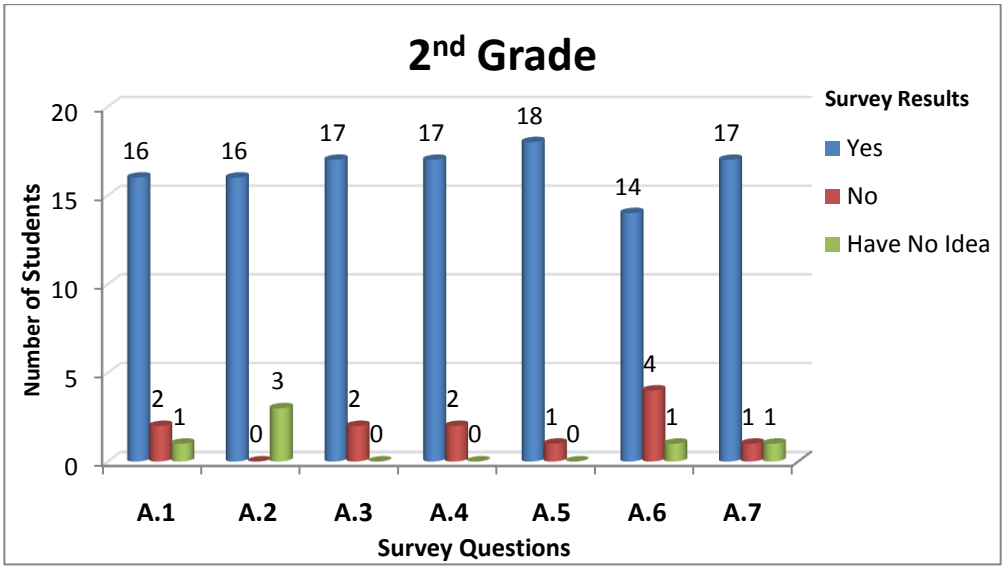


Figure 5.4 Second grade survey results question by question

5.3 Third Grade Statistical Analysis Results

In the 3rd grade, statistical analysis was implemented for 21 students who used the VR programme. From the student results obtained by WSRT, the evaluation form questions (see also Appendix C) and the total score only in the situation where the score of the post-test is higher than or equal to (positive ranks > negative ranks and/or positive mean rank > negative mean rank and analysis result $p<0.05$) that of the pre-test are given in Table 5.5 as the WSRT result table. The p values calculated according to the pre/post-test results are given with the question numbers of the courses in Table 5.6.

WSRT results given in Table 5.5 were significant for the 4th and 5th questions (SL.Q04 and SL.Q05) of the Science of Life course and for the 8th and 9th questions (ENG.Q08 and ENG.Q09) of the English course.

Table 5.5 Third grade Wilcoxon signed ranks test results

3rd Grade Wilcoxon Signed Ranks Test		N	Mean Rank	Sum of Ranks
PostT.SL.Q04 - PreT.SL.Q04	Negative Ranks	2	5.5	11
	Positive Ranks	11	7.27	80
	Ties	8	-	-
	Total	21	-	-
PostT.SL.Q05 - PreT.SL.Q05	Negative Ranks	0	0	0
	Positive Ranks	5	3	15
	Ties	16	-	-
	Total	21	-	-
PostT.ENG.Q08 - PreT.ENG.Q08	Negative Ranks	2	2	4
	Positive Ranks	6	5.33	32
	Ties	13	-	-
	Total	21	-	-
PostT.ENG.Q09 - PreT.ENG.Q09	Negative Ranks	1	6	6
	Positive Ranks	18	10.22	184
	Ties	2	-	-
	Total	21	-	-
PostT.TOTAL - PreT.TOTAL	Negative Ranks	1	9	9
	Positive Ranks	19	10.58	201
	Ties	1	-	-
	Total	21	-	-

In the 4th question (SL.Q04), the students are expected to classify the six internal organs from top to bottom according to where they locate in the human body and in the 5th question (SL.Q05), they are asked to answer the closed-ended question in which the definition of the lung is given.

The 8th question (ENG.Q08) requires four Turkish/English word translations and the 9th question (ENG.Q09) (which is similar to the second grade's 9th English question) expects students to draw a figure related to the word and to fill in the blanks with the English/Turkish word translations. In these two questions, five words related with transportation vehicles and occupations were selected parallel to the English menu of the VE used for the 3rd grade.

From Table 5.5, it is clear that 21 students answered the SL.Q04 question, 2 of them had lower post-test results than the pre-test ones (PreT.SL.Q04 > PostT.SL.Q04), 11 had higher post-test results (PreT.SL.Q04 < PostT.SL.Q04) and 8

had the same results (PreT.SL.Q04 = PostT.SL.Q04) for the pre-test and post-test. That's why the calculated p value (p=0.015) for the SL.Q04 question shown in Table 5.6 was significant (p<0.05).

When Table 5.5 is examined for the SL.Q05 question, 5 of 21 students had higher post-test results than the pre-test ones (PreT.SL.Q05 < PostT.SL.Q05), 16 had the same results (PreT.SL.Q05 = PostT.SL.Q05) for the pre-test and post-test. However, since the mean rank value of the positive ranks (3) is higher than that of the negative ranks (0), the p value (p=0.025) calculated for the SL.Q05 question is significant as shown in Table 5.6 (p<0.05).

From Table 5.5, it is clear that 21 students answered the ENG.Q08 question, 2 of them had higher pre-test results than the post-test ones (PreT.ENG.Q08 > PostT.ENG.Q08), 6 had higher post-test results (PreT.ENG.Q08 < PostT.ENG.Q08) and 13 had the same results (PreT. ENG.Q08 = PostT.ENG.Q08) for the pre-test and post-test. Since the mean rank value of the positive ranks (5.33) is higher than that of the negative ranks (2), the p value (p=0.048) calculated for the ENG.Q08 question is significant as shown in Table 5.6 (p<0.05).

From Table 5.5, it is clear that 21 students answered the ENG.Q09 question, 1 of 21 students had lower post-test results than the pre-test ones (PreT.ENG.Q09 > PostT.ENG.Q09), 18 had higher post-test results (PreT.ENG.Q09 < PostT.ENG.Q09) and 2 had the same results (PreT.ENG.Q09 = PostT.ENG.Q09) for the pre-test and post-test. That's why the calculated p value (p<0.001) for the ENG.Q09 question shown in Table 5.6 was significant (p<0.05).

When Table 5.5 is examined as the total score, 1 of 21 students had lower post-test results than the pre-test ones (PreT.TOTAL > PostT.TOTAL), 19 had higher post-test results (PreT.TOTAL < PostT.TOTAL) and 1 had the same results (PreT.TOTAL = PostT.TOTAL) for the pre-test and post-test. As a result of the total score, the p value given in Table 5.6 is (p<0.001), which means it is significant (p<0.05).

Table 5.6 Third grade pre/post test analysis results regarding the course contents

3rd Grade						
Course	**Contents**	**Questions**	**Pre-Test (Mean ± S.D.)**	**Post-Test (Mean ± S.D.)**	**Numbers of Students**	**P**
Mathematics	*Addition*	*M.Q01*	4.43 ± 0.746	4.33 ± 0.856	21	0.726
	Multiplication	*M.Q02*	2.90 ± 1.179	2.67 ± 1.653	21	0.531
	Division	*M.Q03*	2.19 ± 1.167	2.48 ± 0.928	21	0.167
Science of Life	*Internal Organs*	*SL.Q04*	5.43 ± 5.182	8.19 ± 4.285	21	0.015
		SL.Q05	0.62 ± 0.498	0.86 ± 0.359	21	0.025
		SL.Q06	0.81 ± 0.402	0.86 ± 0.359	21	0.317
		SL.Q07	0.95 ± 0.218	0.90 ± 0.301	21	0.317
English	*Words*	*ENG.Q08*	4.14 ± 1.621	4.81 ± 0.512	21	0.048
		ENG.Q09	4.86 ± 1.931	7.76 ± 2.119	21	0.000
		TOTAL	**26.33 ± 7.479**	**32.86 ± 6.747**	**21**	**0.000**

P<0.05

Although the students whose total post-test scores are higher than the pre-test ones are greater in number, the difference in the Mathematics menu of the 3rd grade was not found to be significant as shown in Table 5.6. However, in the Table 5.6 the p values for the questions SL.Q04 and SL.Q05 related with the internal organ concept of the Science of Life menu is 0.015 and 0.025, respectively. The p values for the question ENG.Q08 is p=0.048 and for the question ENG.Q09 is p<0.001 which are related with the words concept of the English menu shown in Table 5.6, too. Since these results are significant (p<0.05), it was seen that the created VE can be effective in learning the Science of Life and English courses in the 3rd grade.

Figure 5.5 shows the distribution of the scores taken from evaluation forms according to the courses and total scores by using median values.

As can be seen from Figure 5.5, the 3rd grade students' post-test scores were higher than the pre-test ones for all course menus. When the increase in the total scores of all grades was considered, the highest increase was observed in the scores of the 3rd grade. The reasons for this increase were the internal organs topic in the Science of Life menu that individually contributed most to the increase of the scores and the new words topic including transportation vehicles and occupations within the

English menu. By visually learning the internal organs and their locations in the human body, the students were able to correctly answer the questions in the post test which they could not answer in the pre-test. Besides, it can be obviously understood from the answers of the post-test and from Figure 5.6 that most students learnt the new English words after interacting with the programme.

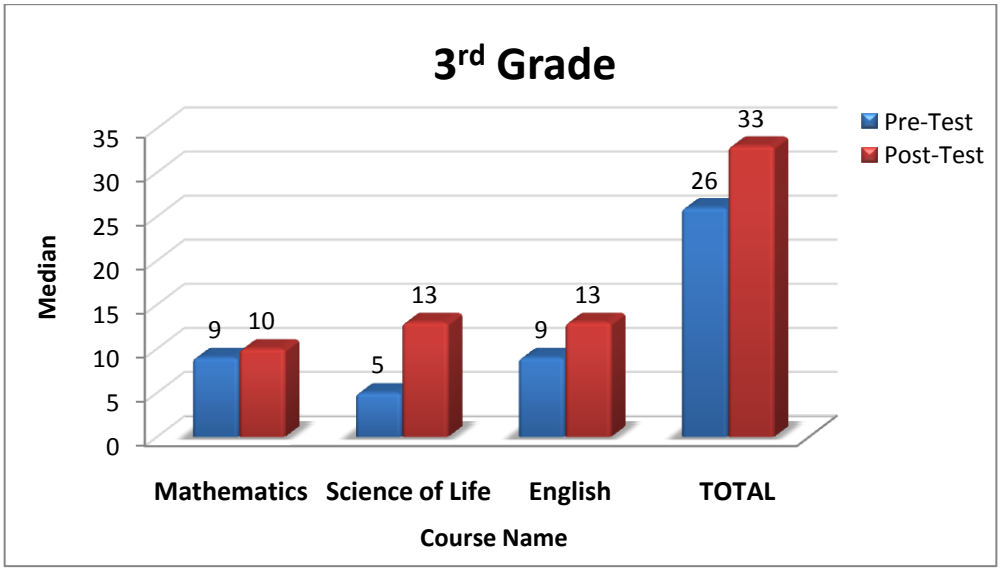


Figure 5.5 Third grade pre/post test results as median values for each course

5.3.1 Third Grade Post-Test Survey Results

The 3rd grade's survey prepared for the designed VR application contains the following. The students were asked to evaluate the following statements written on the survey as "Yes / No / Have no idea".

A.1 I could easily find the **results of the calculations** in the Mathematics menu.
A.2 The models of the **internal organs** in the Science of Life menu were comprehensible.
A.3 I learnt **new English words** by the English menu.
A.4 I could make my choices **easily** by the buttons.
A.5 Using the education programme was **entertaining**.
A.6 If I had a programme like this, I would use it **at home** when studying.
A.7 I would like **my teacher** to use such a programme in lesson.

The 3rd grade students' answers to the survey questions are given in Figure 5.6 according to the number of the students.

As can be seen from Figure 5.6, 14 of 21 students of the 3rd grade who answered the surveys stated that they could easily find the results of the calculations in the Mathematics menu, 16 stated that the Science of Life course contents were comprehensible and 18 stated they learnt new English words. For the 4th survey question, the students who said that they could make their choices easily by the buttons were little lower than that of the first grade. 18 students stated they found the programme entertaining, 19 stated they would use a programme like this at home and 20 wanted their teacher to use such a programme in lesson.

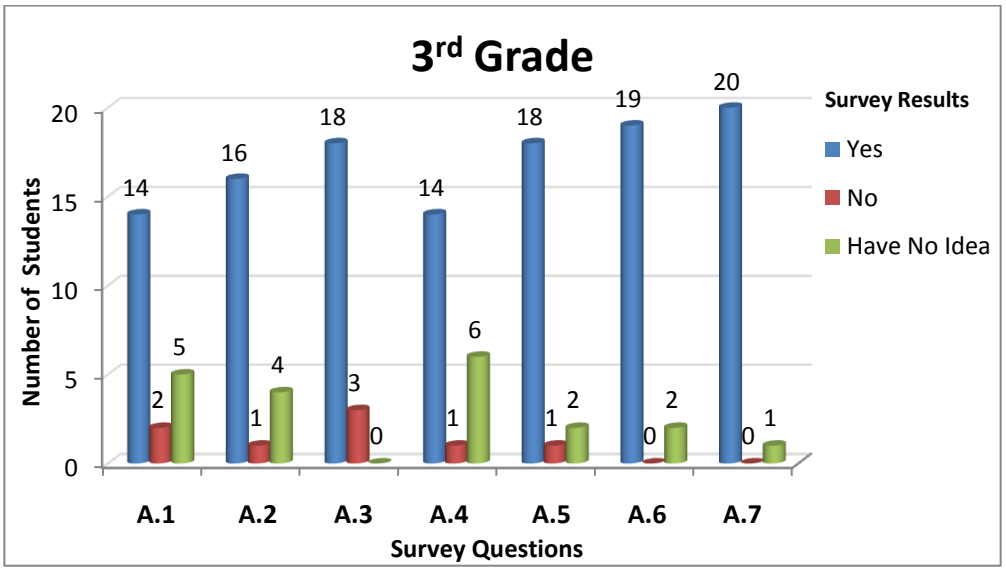


Figure 5.6 Third grade survey results question by question

5.4 Fourth Grade Statistical Analysis Results

In the 4th grade, statistical analysis was implemented for 17 students who used the VR programme. From the student results obtained by WSRT, the evaluation form questions (see also Appendix D) and the total score only in the situation where the score of the post-test is higher than or equal to (positive ranks > negative ranks and/or positive mean rank > negative mean rank and analysis result $p<0.05$) that of the pre-test are given in Table 5.7 as the WSRT result table. The p values calculated

according to the pre/post-test results are given with the question numbers of the courses in Table 5.8.

Table 5.7 Fourth grade Wilcoxon signed ranks test results

4th Grade Wilcoxon Signed Ranks Test		**N**	**Mean Rank**	**Sum of Ranks**
PostT.M.Q03 - PreT.M.Q03	Negative Ranks	0	0	0
	Positive Ranks	8	4.5	36
	Ties	9		
	Total	17		
PostT.TOTAL - PreT.TOTAL	Negative Ranks	3	3.17	9.5
	Positive Ranks	8	7.06	56.5
	Ties	6		
	Total	17		

WSRT results were significant for the 3rd question (M.Q03) of the Mathematics menu given in Table 5.7. In this closed-ended question, the students were asked to know the name of the cylinder via its given definition. From Table 5.7, it is clear that 17 students answered the M.Q03 question, 8 of them had higher post-test results than the pre-test ones (PreT.M.Q03 < PostT.M.Q03), 9 of them had the same results (PreT.M.Q03 = PostT.M.Q03) for the pre-test and post-test. However, since the mean rank value of the positive ranks (4.5) is higher than that of the negative ranks (0), the p value ($p=0.005$) calculated for the question M.Q03 is significant as shown in Table 5.8 ($p<0.05$).

When Table 5.7 is examined as the total score, 3 of 17 students had lower post-test results than the pre-test ones (PreT.TOTAL > PostT.TOTAL), 8 had higher post-test results than the pre-test ones (PreT.TOTAL < PostT.TOTAL) and 6 had the same results (PreT.TOTAL = PostT.TOTAL) for the pre-test and post-test. As a result of the total score, the p value given in Table 5.8 is ($p=0.036$), which means it is significant ($p<0.05$).

Although the students whose total post-test scores are higher than the pre-test ones are greater in number, the differences in the Science & Technology and English menus of the 4th grade were not found to be significant as shown in Table 5.8. However, since the p value of the M.Q03 question of the geometric objects content

under the Mathematics menu is p=0.005 as shown in Table 5.8, it was found to be significant (p<0.05). Therefore, it was seen that the VE can be effectively used in learning geometric objects in the 3rd grade.

Table 5.8 Fourth grade pre/post test analysis results regarding the course contents

4th Grade						
Course	**Contents**	**Questions**	**Pre-Test (Mean ± S.D.)**	**Post-Test (Mean ± S.D.)**	**Number of Students**	**P**
Mathematics	*Geometric Objects*	*M.Q01*	3.00 ± 0.000	2.65 ± 0.996	17	0.157
		M.Q02	2.65 ± 0.996	2.82 ± 0.728	17	0.317
		M.Q03	0.53 ± 1.179	1.94 ± 1.478	17	0.005
		M.Q04	2.65 ± 0.996	2.29 ± 1.312	17	0.317
		M.Q05	3.00 ± 0.000	2.82 ± 0.728	17	0.317
Science & Technology	*Sun Earth Moon*	*ST.Q06*	1.00 ± 0.000	0.94 ± 0.243	17	0.317
		ST.Q07	1.00 ± 0.000	1.00 ± 0.000	17	1.000
		ST.Q08	1.00 ± 0.000	1.00 ± 0.000	17	1.000
		ST.Q09	1.41 ± 0.939	1.76 ± 0.664	17	0.180
		ST.Q10	2.71 ± 0.849	2.88 ± 0.485	17	0.317
		ST.Q11	4.06 ± 2.045	5.06 ± 1.749	17	0.078
English	*Quest/Answer Templates*	*ENG.Q12*	11.29 ± 3.754	12.00 ± 4.500	17	0.395
		TOTAL	**34.29 ± 6.401**	**37.18 ± 6.957**	**17**	**0.036**

P<0.05

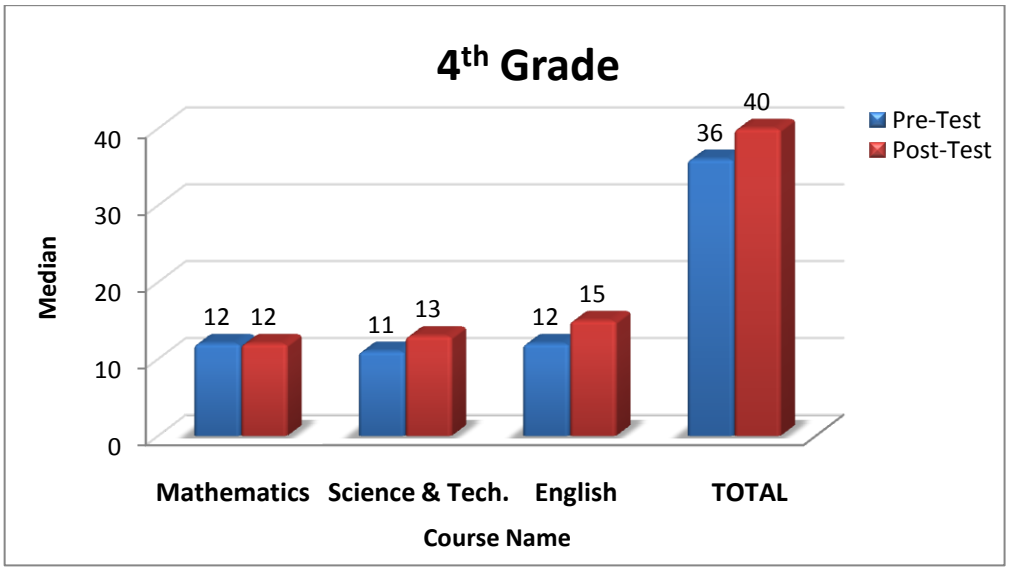


Figure 5.7 Fourth grade pre/post test results as median values for each course

Figure 5.7 shows the distribution of the scores taken from the evaluation forms according to the courses and total scores by using median values.

As can be seen from Figure 5.7, there was no difference between the pre and post test scores for the Mathematics course. However, the scores of the students increased both in the Science & Technology and English courses. When considering the total score, it was observed that the post-test scores increased compared to that of the pre-test.

5.4.1 Fourth Grade Post-Test Survey Results

The 4th grade's survey prepared for the designed VR application contains the following. The students were asked to evaluate the following statements written on the survey as "Yes / No / Have no idea".

A.1 I could easily understand the **geometric objects (open/closed forms)** in the mathematics menu.
A.2 Axes of rotation in the Science & Technology menu were comprehensible.
A.3 I learnt **new English question templates** by the English menu.
A.4 I could make my choices **easily** by the buttons.
A.5 Using the education programme was **entertaining**.
A.6 If I had a programme like this, I would use it **at home** when studying.
A.7 I would like **my teacher** to use such a programme in lesson.

The 4th grade students' answers to the survey questions are given in Figure 5.8 according to the number of the students.

As can be seen from Figure 5.8, 16 of 17 students of the 4th grade who answered the surveys stated that the geometric objects were understandable and 12 stated the rotation axes were comprehensible. 11 students said they learnt new English question templates by the VE, 11 could make choices easily by the buttons and 12 found the education programme funny. When compared to the first three grades, the

willingness to use a virtual programme when studying at home was low for the fourth grade. 14 students stated that they wanted their teacher to use a programme like this in lesson.

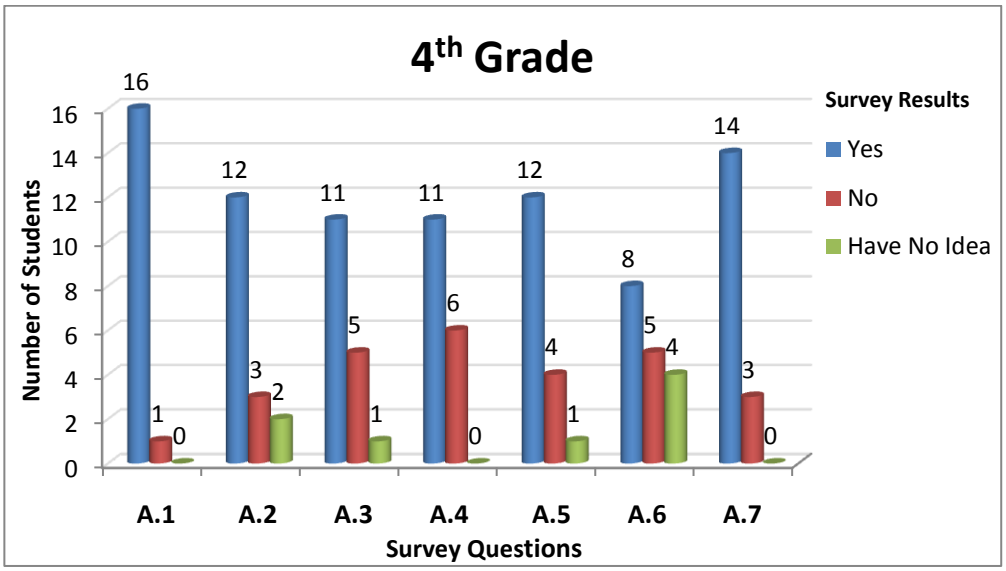


Figure 5.8 Fourth grade survey results question by question

CHAPTER SIX
CONCLUSIONS

In this study, a VR application which utilizes user images received from webcam was designed. The main purpose of the application is to create an interactive visual learning environment for primary schools. Beside this, facilitating primary school students' perception of third dimension concept by mobile 3D animation models was also aimed. After the programme started, student interacts with the VE only with the help of his/her projected image via a projector without touching any computer devices. For this reason, the designed virtual system eliminates the need to use input devices like mouse and keyboard. By this way, it also provides convenience for primary school students who have no information to use computer. The application captures student's attention by creating a visual entertaining environment and it helps student better understand the course contents in the menus. Other advantages brought about by the programme are that it enables primary students to easily understand the topics that are difficult to visualise like the day and night formation by modelling the topics in 3D and that it eliminates the need for additional equipment during teaching.

The environment provides virtuality using devices as low cost as possible. Both utilization of open source software and easy obtaining of webcam and projector in educational institutions pave the way for application to become widespread as an education tool. Because of the used devices, the programme cannot conceptually provide the feature of "immersion" which a good system enabling VR offers. Although the user's field of view is covered by a large screen, the user can still see the real (outer) world at every stage of the application and can feel himself/herself only in the VE when using buttons during interaction. Because, at that time the user controls the application by his/her own guidance. Projecting the user's own image onto screen and his/her contact with the virtual objects also make great contribution to enhance the control level.

In the fifth (analysis results) chapter, the analyses done by the SPSS® statistic programme were explained in detail with the help of the tables and graphics.

Evaluation forms applied separately in every grade were statistically analysed using WSRTs and the p values were obtained. In analyses, for the evaluation form questions in which p values were smaller than 0.05, H_0 hyphotesis is rejected and H_1 is accepted ($p<0.05$). The analyses done to specify if the used VR creates interactive learning environment gave meaningful results for these questions and consequently for the related courses. According to the results, this programme can be utilized in learning English in the 1st, 2nd and 3rd grades. Besides, it was seen that the programme can be effectively used when presenting 3D internal organs and learning their locations in the body in the 3rd grade Science of Life lessons. It was also seen that the VE can be effective in learning 3D geometric concepts of the 4th grade Mathematics lessons. The evaluation forms were handed out to the students as "pre-test" and "post-test" before and after the testing of the programme. The results obtained from these pre/post tests for Mathematics (1st, 2nd and 3rd grades), Science of Life (1st, 2nd and 4th grades) and English (4th grade) menus were not significant. The testing of the programme was able to be conducted in the last week just before the end of school year. Since the menus in the VE were prepared parallel to the TMNE primary school curriculum, the students had already learnt these topics in lessons during the school terms. For this reason, the success of the pre-test results was high. Therefore, the advantages that will be gained by the VE application in learning could not be identified clearly for some course menus.

Effectiveness of the application for building interactive environment and for providing ease of use for students can be seen from the results of the survey questions applied with the post-tests. When the survey questions of all grades were evaluated generally, it was seen that the majority of the students could understand the menu contents easily, that they learnt new English words and found the virtual application funny. Some students had difficulty in employing the buttons. Using the application for the first time was thought to cause this problem. In general, the students stated that they would use the application at home and a considerable majority of the students stated they wanted their teacher to use such a virtual application when teaching.

In the scope of future work, in order for the application to be used more effectively in primary education, enhancing the lesson contents or addition of new courses to the existing menus will be effective to extend the study. Besides, by investigating the elementary and high school curriculum, new menus including 3D concepts and lessons that are convenient for visualisation can be created so that the application complies with the 3 stages of (4+4+4) TMNE.

REFERENCES

4D virtual reality theme park (2013). Retrieved July 5, 2013, from http://www.designboom.com/technology/4d-virtual-reality-theme-park/

Andrews, W. (2010, February 4). *Augmented reality cosmetic mirror in Tokyo*. Retrieved July 5, 2013, from http://www.shifteast.com/augmented-reality-cosmetic-mirror-in-tokyo/

Blender (2013). Retrieved July 5, 2013, from http://www.blender.org

Bradski, G., & Kaehler, A. (2008). *Learning OpenCV-computer vision with the OpenCV library.* The United States of America: O'Reilly Media, Inc.

Cambridge Dictionaries online (2013). Retrieved July 5, 2013, from http://dictionary.cambiridge.org/dictionary/british/

Cameron, J. (2009). *Avatar* [Motion Picture].

Craig, A. B., Sherman, W. R., & Will, J. D. (2009). *Developing virtual reality applications: Foundations of effective design.* China: Morgan Kaufmann Publishers.

d'strict (2013). Retrieved July 5, 2013, from http://global.dstrict.com/

d'strict: The live park (2013). Retrieved July 5, 2013, from http://www.thelivepark.com/blog/en/

Federick, B. (2010). *Myron Krueger biography*. Retrieved July 5, 2013, from http://thedigitalage.pbworks.com/w/page/22039083/Myron%20Krueger

Flavell, L. (2010). *Beginning Blender: Open source 3D modelling, animation, and game design.* The United States of America: Apress.

Gutiérrez, M. A., Vexo, F., & Thalmann, D. (2008). *Stepping into virtual reality.* England: Springer-Verlag London.

Hatem, A. K. (2011). E-learning systems in virtual environment. *The International Arab Journal of Information Technology, 8* (1), 23-29.

Hawkins, K., & Astle, D. (2001). *OpenGL game programming.* The United States of America: Prima Publishing.

Hsieh, M. C., & Lee, J. S. (2008). AR marker capacity increasing for kindergarten English learning. *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 663-666.

IBM SPSS software (2013). Retrieved July 5, 2013, from http://www-01.ibm.com/software/analytics/spss/

Indrusiak, L. S., & Reis, R. A. (2001). 3D integrated circuit layout visualization using VRML. *Future Generation Computer Systems, 17* (5), 503–511.

Kantarcı, A., & Çakır, Ş. (1998). Sanal gerçeklik ve turizm. *3rd International & 9th National Tourism Congress*, 17-21.

Kayabaşı, Y. (2005). Sanal gerçeklik ve eğitim amaçlı kullanılması. *The Turkish Online Journal of Educational Technology, 4* (3), 151-158.

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). Making it real: Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality, 10* (3-4), 163–174.

Ko, C. C., & Cheng, C. D. (2009). *Interactive web-based virtual reality with Java 3D.* The United States of America: Information Science Reference.

Krueger, M. W., Gionfriddo, T., & Hinrichsen K. (1985). Videoplace: An artificial reality. *Proceedings of the Special Interest Group on Computer–Human Interaction Conference on Human Factors in Computing Systems*, 34-40.

Kurbanoğlu, S. S. (1996). Sanal gerçeklik: Gerçek mi, değil mi? *Türk Kütüphaneciliği, 10* (1), 21-31.

Lányi, C. S., Lányi, Z., & Tilinger, Á. (2003). Using virtual reality to improve space and depth perception. *Journal of Information Technology Education, 2*, 291-303.

Light the Ocean photo gallery (2013). Retrieved July 5, 2013, from http://natgeotv.com.au/tv/light-the-ocean/gallery.aspx

MakeHuman (2013). Retrieved July 5, 2013, from http://www.makehuman.org

Mazuryk, T., & Gervautz, M. (1996). *Virtual reality history, applications, technology and future.* Vienna: Vienna University of Technology.

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education, 56* (3), 769–780.

Minogue, J., Jones, M. G., Broadwell, B., & Oppewall, T. (2006). The impact of haptic augmentation on middle school students' conceptions of the animal cell. *Virtual Reality, 10* (3), 293–305.

Monahan, T., McArdle, G., & Bertolotto, M. (2008). Virtual reality for collaborative e-learning. *Computers & Education, 50* (4), 1339–1353.

Murtagh, I. (2011). Developing a linguistically motivated avatar for Irish sign language visualisation. *Institute of Technology Blanchardstown Journal,* 72-102.

Nar, S. (2008). *A virtual human animation tool using motion capture data*. M.Sc Thesis, The Middle East Technical University the Department of Medical Informatics, Ankara.

Nicholls, S. (2011). *Light the Ocean* [Motion Picture].

Nokia live view (2013). Retrieved July 5, 2013, from http://n9-apps.com/nokia-live-view

OpenCV (2013). Retrieved July 5, 2013, from http://opencv.org/

OpenGL (2013). Retrieved July 5, 2013, from http://www.opengl.org/

Oxford Dictionaries (2013). Retrieved July 5, 2013, from http://oxforddictionaries.com/definition/english/real?q=real

Paired-sample sign test and Wilcoxon signed rank test (2013). Retrieved July 5, 2013, from http://www.originlab.com/index.aspx?go=Products/Origin/Statistics/NonparametricTests&pid=1084

Phantom Premium (2013). Retrieved July 5, 2013, from http://www.geomagic.com/en/products/phantom-premium/overview

Primal Pictures 3D human anatomy software (2013). Retrieved July 5, 2013, from https://www.primalpictures.com/Home.aspx

Rand, D., Kizony, R., Feintuch, U., Katz, N., Josman, N., Rizzo, A., et. al. (2005). Comparison of two VR platforms for rehabilitation: Video capture versus HMD. *Presence, 14* (2), 147-160.

Real Dictionary (2013). Retrieved July 5, 2013, from http://www.realdictionary.com/?q=virtual

Sezer, L. (2009). *Development of a virtual reality based physically interactive game system for virtual rehabilitation with a case study*. M.Sc Thesis, Atılım University Computer Engineering, Ankara.

Sherman, W. R., & Craig, A. B. (2003). *Understanding virtual reality-interface, application and design.* The United States of America: Morgan Kaufmann Publishers.

Shiseido: Skincare, makeup & fragrance (2013). Retrieved July 5, 2013, from http://www.shiseido.com/

Shreiner, D. (2010). *OpenGL programming guide* (7th ed.). The United States of America: Pearson Education, Inc.

Smithsonian National Museum of Natural History panaromic virtual tour (2013). Retrieved July 5, 2013, from http://www.mnh.si.edu/vtp/1-desktop/

Smithsonian virtual tour (2013). Retrieved July 5, 2013, from http://www.mnh.si.edu/panoramas/

Statistical Package for the Social Sciences help page (2013). Retrieved July 5, 2013, from http://hp-pc:50068/help/index.jsp?topic=/com.ibm.spss.statistics.tut/introtut2.htm

Sun, H. M., & Cheng, W. L. (2009). The input-interface of webcam applied in 3D virtual reality systems. *Computers & Education, 53* (4), 1231–1240.

Tüzün, H., Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2009). The effects of computer games on primary school students' achievement and motivation in geography learning. *Computers & Education, 52* (1), 68–77.

University of Washington spider world (2013). Retrieved July 5, 2013, from http://www.nvisinc.com/case_study.php?id=5

Vandergrift, K. E. (Ed.). (1996). *Mosaics of meaning: Enhancing the intellectual life of young adults through story* (425-455). London: The Scarecrow Press, Inc.

Weiss, P. L., Rand, D., Katz, N., & Kizony, R. (2004). Video capture virtual reality as a flexible and effective rehabilitation tool. *Journal of Neuro-Engineering and Rehabilitation, 1* (1), 1-12.

Whyte, J. (2002). *Virtual reality and the built environment.* Great Britain: Architectural Press.

Wilcoxon signed-rank test (2013). Retrieved July 5, 2013, from Wikipedia: http://en.wikipedia.org/wiki/Wilcoxon_signed-rank_test

Wilcoxon signed-rank test using SPSS (2013). Retrieved July 5, 2013, from https://statistics.laerd.com/spss-tutorials/wilcoxon-signed-rank-test-using-spss-statistics.php

Yang, J. C., Chen, C. H., & Jeng, M. C. (2010). Integrating video-capture virtual reality technology into a physically interactive learning environment for English learning. *Computers & Education, 55* (3), 1346–1356.

APPENDICES

Appendix A - First grade evaluation form

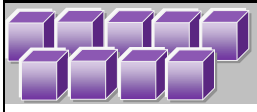
1. Aşağıda verilen boşlukları uygun ***sayı / yazı*** ile doldurunuz.

Sayı	Yazı
…	Üç
1	…
7	…

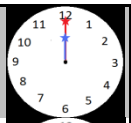
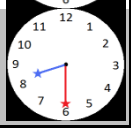
2. Aşağıda verilen boşlukları uygun ***şekil / yazı*** ile doldurunuz.

Şekil	Yazı
	…
…	Beş
	…

3. Aşağıda verilen boşlukları uygun ***şekil / sayı / yazı*** ile doldurunuz.

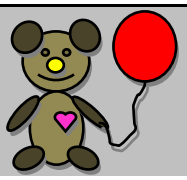
Şekil	Sayı	Yazı
	…	…
	…	…
	…	…
…	8	…

4. Aşağıda verilen eşleştirmeleri tamamlayınız.

	Saat	Planımız
12.00 (Öğle vakti)		…
21.00 (Akşam vakti)		…
08.30 (Sabah vakti)		…

Kahvaltı
İlk Ders
Öğle Yemeği
Ödevler
Oyun
Uyku Vakti

5. Aşağıda verilen eşleştirmeleri tamamlayınız.

Şekil	Planımız
	…
	…
	…

?

Kahvaltı
İlk Ders
Öğle Yemeği
Ödevler
Oyun
Uyku Vakti

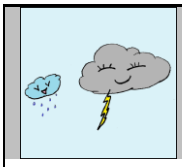
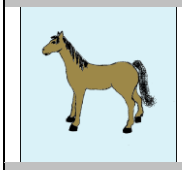
6. Aşağıdaki renklerin ***İngilizcelerini*** yazınız.

Renk	İngilizce
	…
	…
	…
	…
	…

7. Aşağıdaki **Türkçe/*İngilizce*** yazılışları verilen renklerin **İngilizce/*Türkçe*** karşılıklarını yazınız.

Türkçe	İngilizce
…	White
Kahverengi	…
…	Dark green
Açık mavi	…
…	Orange

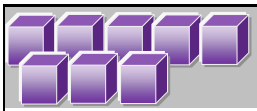
8. Aşağıda verilen boşlukları uygun ***şekil / Türkçe kelime / İngilizce kelime*** ile doldurunuz.

Şekil	Türkçe	İngilizce
	…	…
…	Kitap	…
…	…	Apple
	…	…
…	Ağaç	…

9. Aşağıda verilen boşlukları uygun ***sayı / yazı (İngilizce)*** ile doldurunuz.

Sayı	İngilizce
…	Three
4	…
2	…
…	Seven
8	…

10. Aşağıda verilen boşlukları uygun ***şekil / sayı / yazı (İngilizce)*** ile doldurunuz.

Şekil	Sayı	Yazı
	…	…
…	…	Four
	…	…
	…	…
…	1	…

Appendix B - Second grade evaluation form

1. Aşağıda verilen ***toplama işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
10	+	10	=	…
41	+	53	=	…
23	+	19	=	…
54	+	17	=	…
22	+	4	=	…

2. Aşağıda verilen ***çıkarma işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
74	-	52	=	…
81	-	81	=	…
9	-	8	=	…
26	-	21	=	…
47	-	28	=	…

3. Aşağıda verilen ***çarpma işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
83	x	13	=	…
12	x	4	=	…
3	x	23	=	…
34	x	20	=	…
54	x	8	=	…

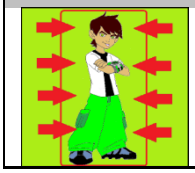
4. Aşağıda verilen boşlukları uygun ***duyu / duyu organı*** ile tamamlayınız.

Duyu	Duyu Organları
Duyma (İşitme)	…
…	Göz
Tatma	…
…	Burun
Dokunma (Hissetme)	…

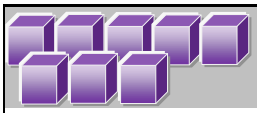
5. Aşağıda verilen boşlukları uygun ***şekil / duyu*** ile doldurunuz.

Şekil	Duyu
	…
…	Duyma (İşitme)
	…

6. Aşağıda verilen boşlukları uygun ***şekil / duyu organı*** ile doldurunuz.

Şekil	Duyu Organı
…	Göz
	…

7. Aşağıda verilen boşlukları uygun ***şekil / sayı / yazı (İngilizce)*** ile doldurunuz.

Şekil	Sayı	Yazı
	…	…
…	…	Four
	…	…
	…	…
…	1	…

8. Aşağıdaki **Türkçe/*İngilizce*** yazılışları verilen kelimelerin **İngilizce/*Türkçe*** karşılıklarını yazınız.

Türkçe	**İngilizce**
…	Chair
Kitap	…
…	Desk
Öğrenci	…

9. Aşağıda verilen boşlukları uygun ***şekil / Türkçe kelime / İngilizce kelime*** ile doldurunuz.

Şekil	**Türkçe**	**İngilizce**
	…	…
…	Sandalye	…
…	…	Cupboard
	…	…
…	Kitap	…

Appendix C - Third grade evaluation form

1. Aşağıda verilen ***toplama işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
45	+	10	=	…
54	+	553	=	…
34	+	4	=	…
355	+	71	=	…
223	+	19	=	…

2. Aşağıda verilen ***çarpma işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
343	x	52	=	…
41	x	81	=	…
56	x	8	=	…
65	x	21	=	…
476	x	27	=	…

3. Aşağıda verilen ***bölme işlemlerinin*** sonuçlarını bulunuz.

1.Sayı	İşlem	2.Sayı	Sonuç	
833	/	13	=	…
12	/	4	=	…
300	/	23	=	…
344	/	2	=	…
56	/	7	=	…

4. Aşağıda verilen boşluklara ***iç organlarımızı***, **vücutta bulundukları yere göre** yukarıdan aşağıya doğru sıralayarak yazınız.

Sıralama	İç Organlar
1	…
2	…
3	…
4	…
5	…
6	…

5. Aşağıdakilerden hangisi soluk borusu ile birbirine bağlı iki parçadan oluşan **iç organımızdır**?

a.) Böbrek b.) Akciğer c.)Bağırsak d.) Mide

6. Aşağıdakilerden hangisi karnın arka tarafında (bel hizasının biraz üzerinde) omurganın sağında ve solunda olmak üzere iki tane olan **iç organımızdır**?

a.) Mide b.) Akciğer c.) Böbrek d.) Kalp

7. Aşağıdakilerden hangisi görevi vücuda kan pompalamak olan **iç organımızdır**?

a) Böbrek b.) Kalp c.) Mide d.) Akciğer

8. Aşağıdaki **Türkçe/*İngilizce*** yazılışları verilen kelimelerin **İngilizce/*Türkçe*** karşılıklarını yazınız.

Türkçe	**İngilizce**
…	Bus
Doktor	…
…	Train
Öğretmen	…

9. Aşağıda verilen boşlukları uygun ***şekil / Türkçe kelime / İngilizce kelime*** ile doldurunuz.

Şekil	**Türkçe**	**İngilizce**
	…	…
…	Araba	…
…	…	Soldier
	…	…
…	Helikopter	…

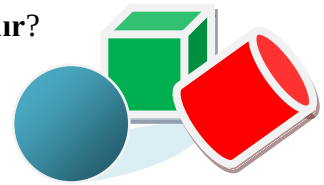
Appendix D - Fourth grade evaluation form

1. Aşağıdakilerden hangisi tüm yüzleri eş kareler olan ve **6 adet kareden** oluşan 3 boyutlu geometrik cisimdir?

a.) Piramit b.) Küp c.) Silindir d.) Küre

2. Yandaki şekilde aşağıdakilerde hangisi **bulunmamaktadır**?

a.) Silindir b.) Küre c.) Piramit d.) Küp



3. Aşağıdakilerden hangisi bir **dikdörtgenin** bir kenarının etrafında döndürülmesiyle oluşturulmuş 3 boyutlu geometrik cisimdir?

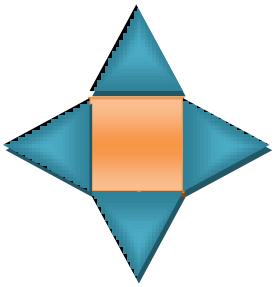
a.) Küp b.) Küre c.) Silindir d.) Koni

4. Aşağıdakilerden hangisi **tabanı çokgen olan** ve yan yüzleri eş üçgenlerden oluşan çok yüzlü 3 boyutlu geometrik cisimdir?

a.) Silindir b.) Piramit c.) Küp d.) Küre

5. Yanda açık şekli verilen geometrik cismin **kapalı şekli** hangi seçenekte doğru olarak verilmiştir?

a.) Küre b.) Küp c.) Piramit d.) Silindir



6. Aşağıdakilerden hangisi diğer adı "**yerküre**" olan gezegendir?

a.) Güneş b.) Mars c.) Ay d.) Dünya

7. Aşağıdakilerden hangisi ısı ve ışık kaynağımız olan **yıldızdır**?

a.) Dünya b.) Güneş c.) Ay d.) Mars

8. Aşağıdakilerden hangisi Dünya'nın **uydusudur**?

a.) Mars b.) Ay c.) Plüton d.) Güneş

9. Aşağıdakilerden hangisi Dünya'nın **eksen eğikliğinin derece ve dakika olarak** ifadesidir?

a.) $25^0\ 32'$ b.) $14^0\ 52'$ c.) $23^0\ 27'$ d.) $45^0\ 37'$

10. Aşağıda verilen boşluklara ***Dünya, Ay ve Güneş*** sıralamasını **büyüklük olarak** en büyükten en küçüğe doğru sıralayarak yazınız.

Sıralama	**Gök Cismi**
1	…
2	…
3	…

11. Aşağıda verilen boşlukları uygun ***bir tam tur dönüş süresi / dönen gök cismi / döndüğü eksen*** ile doldurunuz.

Bir Tam Tur Dönüş Süreleri	**Dönen Gök Cismi**	**Döndüğü Eksen**
1 gün (24 Saat)	…	…
…	Ay	Dünya etrafında
1 yıl (12 Ay)	…	Güneş etrafında

12. Aşağıda verilen diyalogdaki boşlukları uygun ***soru / cevap*** ile İngilizce olarak doldurunuz.

Sue: Hello, what is your name?
Vince: …
Sue: …
Vince: I'm 9 years old.
Sue: …
Vince: It's 2 o'clock.
Sue: The teacher is coming. Maths lesson is starting. What is your favourite lesson?
Vince: …
Sue: Oh, Really! Science is very interesting.
Ellen: History is also interesting, too. What is the name of the founder of the Turkish Republic?
Sue / Vince (together): …

ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AR	Augmented Reality
AV	Augmented Virtuality
CAVE	The CAVE Automatic Virtual Environment
GLUT	OpenGL Utility Toolkit
HMD	Head-Mounted Display
HTML	Hyper Text Markup Language
ISL	Irish Sign Language
TMNE	Turkish Ministry of National Education
MR	Mixed Reality
OpenCV	Open Source Computer Vision Library
OpenGL	Open Graphics Library
PC	Personal Computer
SPSS	Statistical Package for the Social Sciences
VE	Virtual Environment
VR	Virtual Reality
VRML	Virtual Reality Modeling Language
Webcam	Web Camera
WSRT	Wilcoxon Signed Rank Test
X3D	Extensible Three Dimensional