THE INTEGRATION OF VIRTUAL REALITY INTO BASIC DESIGN EDUCATION AS A REPRESENTATION TOOL

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THE INTEGRATION OF VIRTUAL REALITY INTO BASIC DESIGN EDUCATION
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ABSTRACT

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Architectural education is going through a change with the developments of technology. Today, the increasing use of hardware and software has led to the emergence of new complex design possibilities. The equipment that is seen as a tool in the traditional designing process is now confronted with a digital design environment. Basic Design education as the first step of in architectural education is also first the first stage where technology in designing and representation is introduced. However, as representation tools, still, traditional methods are used. The technology in architectural representation into Basic Design education is not fully formulated.

Representation techniques by recent technologies provide an opportunity to increase the speed and quality of perception capabilities. In the study, Virtual Reality is analysed as an alternative approach to traditional architectural representation tools in Basic Design education. The integration of Virtual Reality into Basic Design education as a representation tool is investigated and the contributions of this technology as a means of representation explored. An experimental research is designed using Virtual Reality technology that aims to test and disclose students' perceptions of design through the representation methods. The experiment is concluded with a questionnaire in order to measure the level of Virtual Reality contribution to representation.

As an immersive technology, Virtual Reality as a representational tool offers more opportunities to represent both traditional and digital designs. The results show that VR significantly helps basic design students to understand architectural design, to discover the details and to explore the projects on a real scale and realistic representation.

Keywords: Architectural Education, Basic Design Education, Architectural Representation, Digital Architecture, Virtual Reality.

ÖZ

SANAL GERÇEKLİĞİN BİR TEMSİL ARACI OLARAK TEMEL TASARIM EĞİTİMİ İLE BÜTÜNLEŞTİRİLMESİ

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Mimarlık eğitimi, teknolojinin gelişimi ile bir değişim göstermektedir. Günümüzde, donanım ve yazılımın artan kullanımı, yeni karmaşık tasarım olanaklarının ortaya çıkmasına yol açmıştır. Geleneksel tasarım sürecinde bir araç olarak görülen ekipmanlar, dijital bir tasarım ortamıyla karşı karşıya gelmiştir. Mimarlık eğitiminin ilk adımı olarak Temel Tasarım eğitimi de tasarım ve temsil teknolojilerinin tanıtıldığı ilk aşamadır. Bununla birlikte, mimari temsil araçları olarak, yine de geleneksel yöntemler kullanılmaktadır. Mimari temsil bağlamında Temel Tasarım eğitimindeki teknoloji tam olarak formüle edilmemiştir.

Son teknolojik gelişmelerle uygulanan temsil teknikleri, algılama yeteneklerinin hız ve kalitesini artırmak için bir fırsat sağlamaktadır. Tez kapsamında, Sanal Gerçeklik, Temel Tasarım eğitiminde alışılagelmiş mimari temsil araçlarına alternatif bir yaklaşım olarak analiz edilmektedir. Sanal Gerçeklik teknolojisinin bir temsil aracı olarak Temel Tasarım eğitimi ile bütünleştirilmesi araştırılmış ve bu teknolojinin Temel Tasarım eğitimine katkıları incelenmiştir. Sanal Gerçeklik teknolojisi kullanılarak, öğrencilerin tasarımı algılama yetilerini temsil yöntemleriyle test etmeyi ve açıklamayı amaçlayan deneysel araştırma metodu uygulanmıştır. Deney, mimari temsilde Sanal Gerçeklik teknolojisinin katkısını ölçmek için bir anket ile sonuçlandırılmıştır.

Sürükleyici bir teknoloji olarak, Sanal Gerçeklik, temsil aracı olarak hem geleneksel hem de dijital tasarımların temsilinde konvansiyonel yöntemlere oranla daha fazla avantaj sağlamaktadır. Elde edilen sonuçlar, Sanal Gerçeklik teknolojisinin temel tasarım öğrencilerinin mimari tasarımı anlamalarına, detayları keşfetmelerine ve tasarımı gerçekçi bir biçimde deneyimlemelerine önemli ölçüde yardımcı olduğunu göstermektedir.

Anahtar Kelimeler: Mimarlık Eğitimi, Temel Tasarım Eğitimi, Mimari Temsil, Dijital Mimarlık, Sanal Gerçeklik.

To my parents:

Nurcan & Yaşar Özkan,

And to my brothers:

Burak Kaan & Mustafa Serdar

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ABBREVIATIONS

2D: Two-Dimensional

3D: Three-Dimensional

CAD: Computer Aided Design

VR: Virtual Reality

AR: Augmented Reality

MR: Mixed Reality

CAAD: Computer Aided Architectural Design

DAD: Digital Architectural Design

CIT: Computer and Information Technologies

IUA: The International Union of Architects

MSFAU: Mimar Sinan Fine Arts University

ITU: İstanbul Technical University

METU: Middle East Technic University

IUE: Izmir University of Economics

HMD: Head Mounted Display

VRDL: Virtual Reality Design Lab

CHAPTER 1

INTRODUCTION

1.1 Introduction

Architecture education has undergone a rapid change in the last twenty years in the direction of development in computer representation technologies. Representation in architecture has a great importance in explaining design. From the first line of sketches to technical drawings and concept explanations, design studios in architecture face troubles dealing with techniques of representing (Massera, 2010). Therefore, the type of representation tool, during design process meaningfully affects the result of the project, since the choice unavoidably develops one design explanation over alternative possibilities.

Today, architectural design and representation are presented as the most common interface; the architectural model both digitally and physically. There has been a movement in the representation of design from physical modelling methods to Computer-Aided Design (CAD), hereby; digital design methods have been founded. With the use of computers in the design process, the ability and the easiness of drafting, modelling and detailing architectural forms have been improved.

In the process of architectural design and practice, CAD process has begun to be used as part of designing since the 1970s (Weisberg, 2008). Thanks to this technology, CAD systems are now widely accepted and used commonly. It has also allowed designers to see alternative forms quickly by comparison with the traditional design process. Usage of hardware and software as a tool allows the designer to solve many design problems quickly, as well as to see the space with a new approach.

Thus, to understand how CAD provides a wide range of diversity and thinking modes, architectural education is also required to integrate digital techniques. Even if the students of architecture programs use both traditional and digital media in order to discover and represent design ideas today, it is important for them to understand conceptual frameworks and strategies to approach new technology (Oxman, 2008).

As one of the most important course through architectural education, Basic Design is the first design course by which students meet design education first. Since it is also to the first place where students learn design fundamentals and principles and design tools and representation, it has a particular importance in developing students' capacity for perception. Hence, three basic characteristics of design education are summarised as learning and practising a number of new skills, such as visualisation and representation, learning a new language - vocabulary of design and learning to think architecturally (Ledewitz, 1985). Therefore, the basic design course is the first step of design education where fundamentals of design education are required to build on a solid basis, and, the students are prepared to the next levels of design education.

In basic design education, students are encouraged to improve their understanding of architecture as a creative and innovative field of study. Basic design education aims to teach students to develop an understanding of issues, elements, and processes of design, introducing them shapes, colours, rhythm, and light. Basic Design means teaching and learning of design fundamentals that may also be generally referred to the principles of two- and three-dimensional design (Boucharenc, 2006).

With the emerging technologies, computers have been used in design starting from the design process to the final design and representation in basic design education. Lately, the technological developments have begun to effect design theory. Architectural design has become involved with complex geometries related to materialisation processes of fabrication and manufacturing technologies. These developments have influenced on the theoretical, conceptual and methodological contents of design (Oxman, 2008). Thus, traditional design methods have begun to change.

Initially, design education has been founded firstly with paper-based design and it became broadly accepted. By the early 1980s, Schon and his collaborators mentioned traditional paper-based sketches as a representation of design process (Schon and Wiggins, 1988). It is still a dominant model for explaining ideas in many design studios. The general characterization of design as reflection supported by representational processes has had an almost universal influence on architectural design education (Oxman, 2008).

> The traditional educational model in the design studio usually employs a simulation of practice as an instructive model. That is, the instructive stages are driven by a theoretical point of view of program, site and conditions carried through stages of conceptualization, schematic design and design development. Also, most studios still employ well-accepted knowledge-bases and typologies as well as traditional paper-based sketches as media of what was referred to as a conceptual and explorative medium (Oxman, 2006).

However, today the students learn a number of new skills, such as visualisation and representation, with the intersection of technology, and start to think architecturally as mentioned above. As one of the recent approaches, as Toni Kotnik mentions, computation as a design tool is defined as the representational level of computability. According to Kotnik, there are three levels of computational design: representational, parametric and algorithmic levels. He states that:

> A representational level there is no real sensitivity to the computational nature that rules the digital environment. Rather, the design process is still harmonised with the visual thought of a paper-based design approach. What occurs is simply a consciousness of a possible addition of the traditional geometric language of architecture that is current in the unseen mathematical explanation of digital design tools (Kotnik, 2010:8).

So, even the current digital design tools for representation includes the traditional methods at a level. Traditional representation methods are still not updated. Since the same methods are represented with a recent technology, computer, the only improvement in terms of representation is to transfer hand-drawings to computer drawings.

In the first year of architecture education, with the implementation of CAD into architectural design education, basic skills of design, graphic expression, various representation and rendering techniques are conveyed to the students. Therefore, students gain an understanding of two- and three-dimensional design principles and representation techniques to include this knowledge in the basic design education.

In addition, the traditional methods of representation in basic design education imply 2D drawings of design or 3D models and rarely animations. However, all techniques are restricted from the viewpoint of the experiencer. For this reason, both students and instructors are limited to see and understand the design represented. The current representation methods i.e. 3D representation techniques - 3D renders are still just a newer version of the traditional paper-based design approach in the 20th century. Therefore, as Oxman (2008) states: "As a result, traditional concepts of (paper-based) representation today lose their centrality as a conceptual basis for explicating the processes and knowledge associated with digital design."

Since the process of architectural education has always been directly affected by the technological developments in CAD and design tools, digital media, and information technology, the representation techniques are required to be up-to-date. As the usage of CAD for design development has been rapidly increasing over the last decade, the additional technologies offer more tools to the designer in terms of designing and representing.

The most known technologies are Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). VR is the use of computer technology to generate an imitated environment. Augmented reality is the integration of digital information with the user's environment in real time. Unlike VR, which creates an entirely artificial atmosphere, AR uses the present environment and overlays new information on top of it. MR provides people to evolve through real spaces, into AR models, where virtual objects are correctly superimposed onto real ones, into augmented virtuality environments, where real video displays are overlaid onto virtual computer generated objects (Figure 1).

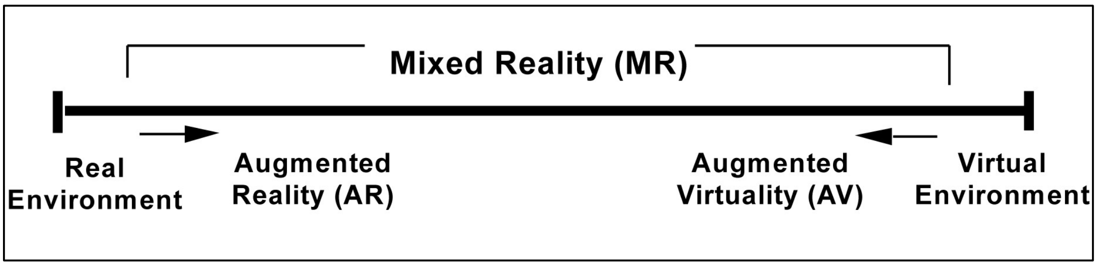


Figure 1: Simplified Reality-Virtuality (RV) Continuum (Milgram and Kishino, 1994)

As recently developed technologies, virtual, augmented and mixed reality systems have started to be used as assistive techniques in different learning and designing environments. VR, AR and MR tools have been used to support teaching and learning methods. In fact, three-dimensional (3D) visualisation limitations have been overcome, leading to a rich immersive 3D experience.

The use of VR, AR and MR accelerates the process of understanding, interpreting, evaluating and creating space. The visual models that contain the effects of the possibilities are designed to allow the designer to see the effects such as light, colour, texture, reflection; thus, it allows them to perceive the design better (Rouse, 2016). These features of real-like visual simulations and animations allow students to experience space.

In the light of these developments in computer technology, VR technology has been used by late 1980 that participates in the architectural design process. This technology which enhances the level of human-computer interaction brings the two-dimensional interface of the mouse, keyboard and monitor to the three-dimensional world. It is a particularly effective technology for learning, especially for students in artificially created environments. Moreover, getting familiar with the new digital technologies increasingly brings a changing point into recent approaches. The irreversibility and focus of this phenomenon have driven the practice and evaluation of new educational backgrounds and methods. Also, design education faces new challenges and opportunities, delivering new approaches (Gul, Gu and Williams, 2010).

The diversity of design alternatives in the digital environment depends on the hardware and software used. The increasing use of hardware and software has led to the emergence of new complex design possibilities. The equipment that is seen as a tool in the traditional designing process is now confronted with a design environment. A significant part of all of the design process takes place in the digital environment, communication during the process and changes in the conception of presentation at the end are also observed. In addition to computer programs used in architectural education, the usages of VR technologies which improve the representation have become important.

Further than the new potentials that these tools suggest for design, thanks to the developments in technology, VR is now an option to achieve maximum efficiency for representing the ideas of students and works in the early stages of architectural education. It deals with the opportunity to see CAD models entirely, in a physical environment as physical models. Thus, from the very beginning of Basic Design course to the end, students are able to use VR with a basic knowledge of computer applications and VR hardware.

VR is now not in a challenge with the programs already taught from the first year of architecture education. Many architecture schools have included the Computer and Information Technologies (CIT) in Design Education into their curriculum as design and representation tools. Then, after modelling in one of the CAD software, the model can be converted into a VR model via free and online services. Moreover, if the students have not known the CAD modelling or if just a review or research is given as a task, the existing models can be downloaded from the Internet, and then can be converted to VR via online services.

The development of various 3D techniques from models to perspective drawings and the fact that they are still being developed reveal to the importance of the third dimension in architecture (Massera, 2010). So, today's researchers use software and hardware technology to the end and develop technical and digital methods like VR and try to strengthen the 3D representation techniques in architecture.

In this research, VR will be proposed as a representation technique in basic design education that contributes to understanding of design for students in their design process which are both traditional design and digital design. As an immersive technology, VR as a representational tool offers more opportunities to represent both traditional and digital designs.

1.2 Scope and Structure

In this study, it is aimed to investigate the influence of VR as a representation tool used to increase perception capabilities in Basic Design Education. The research will analyse the contribution of VR as a representation technique in Basic Design education, by comparing it with the traditional representation methods in both traditional design and digital design.

The chapter two and tree examine a literature review on basic design in architecture education, current designing tools, representation, technology and recent hardware developments in the field of VR and its reflections in the field of architectural representation in basic design education and evaluate through examples. In addition, recent developments in design and representation techniques are explained to understand how basic design education works and why the basic design education must be applied in accordance with the emerging technologies of recent years.

In the fourth chapter, an experimental research is designed that aims to evaluate students' perceptions of design through the representation. The experiment is concluded with a questionnaire in order to measure the level of VR contribution to representation.

The following research questions will be responded through the study:

- What are the current design and representation methods used in Basic Design Education?
- How does virtual reality affect the representation of design in Basic Design education?
- How does 'virtual reality as a representation tool' contribute students' understanding and perception of the traditional design?
- How does 'virtual reality' contribute students' understanding and perception of the digital design?

1.3 Methodology

The study aims a systematic and scientific approach in which two variables are controlled and measured with any change in the variables. Thus, an experimental research method is applied. It has a control group, so the subjects have been randomly assigned between two groups, and it is tested the effects at a time. Two basic design elements; size/scale and colour are used to control the understanding of design in using VR as a representation tool. Before the method is applied, a literature review was made majorly based on Rivka Oxman and Toni Kotnik's studies by taking into consideration the traditional and digital design methods in basic design education.

The experimental research includes two methods of representation in Basic Design education to compare the traditional method (3D models and axonometric views) and proposed method (Virtual Reality). For this purpose, two designs of students at Izmir University of Economics (IEU) produced in Basic Design Course in IEU are modelled using CAD software. One is a traditional design method; the other is a recent design method, digital design. After the chosen designs are modelled, two methods of representation are prepared: 4 axonometric views for each 3D model as a traditional representation technique and VR representations for each model for proposed technique.

The research consists of 81 students in two groups. The first group experiences the traditional representation methods of traditional and digital designs. In the second group, VR is used as a representation tool besides the traditional methods. The aim of the first group, which uses the traditional techniques, is to evaluate the rationality of the proposed VR representation technique.

As the models are represented in both techniques used for two groups of students, the survey is handed out and a questionnaire is filled by each student to determine the perception level of the designs in the context of size/scale and colour with the purpose of understanding the result of the experiment and gather data comparing two techniques of the representation techniques.

Since the traditional design methods in architecture programs are still taught, in addition, the digital designs are also inserted into the architecture programs in many schools; a single model is unlikely to reveal enough aspects of attention to provide enough data. Thus, two designs are modelled in order to provide the chance to observe enough case of interest. So, use of multiple models will generate larger measures of data.

In conclusion, although the results do not differ greatly in points of total average, the motivation and success range of the second group demonstrate that VR experience makes a remarkable difference. VR develops the architectural representation techniques in architectural design. Unlike other mediums, the students using VR are active in a virtual setting and can interact in a virtual environment.

CHAPTER 2

BASIC DESIGN IN ARCHITECTURAL EDUCATION

2.1 Historical Overview of Architectural Education

Architecture is a synthesis of art and technique in general; and described as a process of a combination of theory, design and practice. Although architecture has existed since Neolithic times, the definition of architecture as a distinct discipline and legal recognition of the profession dates back to the 17th century (Palmer, 2016: 274).

The first school of architecture is the 'Royal Academy of Architecture' founded in France in the second half of the 17th century. 'Royal Academy of Architecture' and '*École des Beaux-Arts*', founded in the second half of 18th century, in France, emphasises the adaptation of important works of classical Greek, Roman, Renaissance and Baroque periods. This education system, which brings tradition into the forefront rather than originality, has been adopted in many architecture schools around the world.

The Bauhaus School was founded in 1919 under the leadership of Walter Gropius in Weimar, Germany as a reaction to the *Beaux-Arts* architecture education system based on copying and adapting the architectural styles of the past periods. With the establishment of a school which aims the awareness and responsibility of the social issues of the society where the artist lives, modernist design has become increasingly widespread in the world. It was based on learning at Bauhaus, a philosophical centre that aims to integrate art branches into architecture, such as sculpture, painting, hand-workmanship (Conrads, 1970). The change that started with Bauhaus still continues in the present architectural education.

According to Rittel, the first three of the qualities, that can be taught, in architectural design school are, the qualities that can be acquired through a kind of conditioning are:

- Skill: Free hand drawing, modelling;
- Judicial Ability: Harmony, comprehension, the values that only can be transferred by demonstration of examples;
- Factual Information: All of the information that can be obtained by reading books, listening course relating to the bricks, beams, building construction, costs etc.

All the mentioned skills clearly demonstrate how broad the background architect should have. It is important for an architect to have qualifications, from hand skills to construction costs. An architectural student who comprises these three general qualities together can look at the problems holistically. In a sense, what is important is that the student can think all these simultaneously, without experiencing one better than another. The fourth quality that Rittel proposes is a qualification that can cover all. It requires an understanding of problems, knowledge of the ways to cope with problems and development of a high level of consciousness and critical skills (Rittel, 1985). As it is pointed out by Ritter, qualifications and skills make great importance in an architect’s life.

Approaching the 2000s since 1985, in the UNESCO-UIA Validation System for Architectural Education which was accepted in principle by the General Assembly of the International Union of Architects in Berlin in 2002, it is expected that the architecture students acquire the following qualifications in the field of design for the appropriateness of the education programs: ability to combine imagination, creative thinking, innovation and the leadership of the design team; ability to formulate action strategies, collecting information, identifying problems, analysing and critically evaluating; ability to explore three-dimensional thinking and discovering searching methods of design; ability to use skills to create design solutions, bringing contradictory factors in harmony, integration of knowledge (Düzgün, 2004). Among these qualities, creative thinking, innovation, three-dimensional thinking and searching methods of design are at the forefront. Therefore, it is important to extend the use of today's technology and to take place in education, to take advantage at maximum level. In addition, the ability to think in three-dimensional computer programs and to evaluate them firstly in imagination and to position them in various forms, as a result, bringing together all the factors, come to the forefront.

The aim of architectural education is to train individuals who are constantly thinking, to make their thoughts come true and to provide individual and social development. In the first year of undergraduate education of architecture, the skills that have to become habit beforehand are being expedited because of the disconnection between the educations. During architectural education programs, students often have to acquire design skills and knowledge in order to be able to fulfil their duties that can coordinate interdisciplinary relationships. However, students cannot achieve the promised gains; even if they can be obtained, they are random, and therefore they are not possible to be obtained the desired yield. Architecture students must have the ability to think sophistically and be able to relate different areas in order to be able to make evaluations and transform their experiences.

2.1.1 The Beaux-Arts School

The original *École des Beaux-Arts* is a Fine Arts School emerged from *the French Académie Royale de Peinture et de Sculpture*, established in Paris in 1648. The *Académie Royale* School moved to a separate building and was renamed as *the École des Beaux-Arts* in 1863 (TATE, n.d.). The school offered education in Fine Arts such as drawing, painting, sculpture, and architecture until 1968. The *Beaux Arts* period in Paris had four principal components: *the École*, private ateliers, *the Salon*, and *the Café* life.

The École was the inflexible, old-style training of classical painting and architecture ending with a competition, the *Grand Prix de Rome*, which the student who received a scholarship. In the small independent ateliers, students learned directly under a 'master', with all the achievement of the students reflected directly back on the master. The annual *Paris Salon* was the show in which the best works chosen by a jury displayed to the public. Lastly, the Parisian life of cafes was the informal extension of *the ateliers* and *the École*, in which people came together to discuss design. Wozniak suggests that *the cafe life*, thus the informal setting of studying has remained incapable. She also states that the strict hierarchy and the division between professors as jury and students create a gap between the two (Wozniak, 2016).

The *Beaux-Arts* Education was developed in the framework of design critics, new drawing techniques and the subtleties of painting art, and with the participation of academicians in architectural competitions. It was a privilege to be educated in this school and the graduate architect profile was aimed to have the features of 'scientific, structural, artistic, analysing details, prone to painting and sculpting'.

In *Beaux-Arts*, drawings were artistic representations. Working drawings, design sketches, perspective renderings and full-scale details were made with advanced care and artistry as competition drawings. Drawing skill was necessary adjunct to design judgement, technical mastery and even knowledge of construction practices. By 1900, critics could suggest that École had created a new academic tradition. Artistic methods of representation were influential in academic circles in that time (Hewitt, 1996).

The tradition of the *Beaux-Arts* lasted until the change in students' movements and demands in 1968. Students 'criticism was aimed at the following characteristics of the school: 'away from interdisciplinary interactions; a non-realistic, non-objective and non-rational understanding of education, the domination of feudal institutions, the conditioning of professors (Jacoby, 2013).

Contemporary architecture departments preserve many of the core ideas of the *Beaux-Arts* method: the creation of competition and intensity between students, the strict hierarchy of students and teachers, and the jury or professor's power to decide upon the 'right' and finest student work. Yet schools today have lost informal *café* aspect and with it, the spirit of discussing design occurs in a more informal setting.

2.1.2 The Bauhaus School

In the first thirty years of the 20th century, the avant-garde trends emerged parallel to the events and cultural exchanges in the society. The developments in industry and technology in this period caused the need for aesthetic forms. Bauhaus, an institution that has fundamentally influenced art education after the First World War, was founded in Germany in 1919 at an important point within the re-creation of the artistic, technical and production divisions of industrialism.

Bauhaus aims to create an environment suitable for mutual interaction of the two fields of action by removing the concept from the obstacle between the applied arts and the fine arts (Erkmen, 2008). At Bauhaus, the aim was not to educate craftsmen but to build on the workshop system that will develop the personal skills of the applied education and training. The workshops were used as research laboratories and the modules needed by the industry were prepared in these workshops. For the first time in Bauhaus, designs were prepared to meet the needs of the industry, prototypes were made in textile, glass, metal, printing and ceramics workshops, and production was carried out in the factory. Also, for the first time, society has had the opportunity to use these designs, which have been passed on by artists, in everyday life.

Besides, the purpose of establishing the school was to raise awareness and responsibility for the social issues that the artist is faced with. At the same time, the school was also aimed at solving the problems of art, as well as expressing the problems of artists. The Bauhaus, based on constructive thinking, the education and training system is divided into three; architecture, painting and sculpture. Gropius sees the common side of fine arts and design arts, aiming re-establishing ties among craftsmen, artists, architects, and industry in this school, thus combining art and industry. Therefore, Bauhaus has become an educational centre of industry thought.

The major revolution in architectural design and modelling was recognised to a great extent by the Bauhaus education. The Bauhaus presented a revolutionary methodology to recombine conception, visuality and materiality (Caragonne, 1995: 155). Walter Gropius and Johannes Itten prepared the curriculum of Bauhaus education with the hope of "connecting the tragic gulf between reality and idealism." (Gropius, 1935: 48) In this perspective, the students were greatly encouraged to work with models and carry their designs closer to reality, differing to paper designs. Although the curriculum involved studies of drafting and plane geometry, students were fostered to test the mass and space relationships and lighting. Johannes Itten had also presented a form of the model which was a "vehicle of pure creativity." (Morris, 2006) Bauhaus professors were trying to release the architectural model from its representational character, and bring it into the design.

2.2 Basic Design Education

2.2.1 History and Purpose

The introductory course was established by Johannes Itten and continued by László Moholy-Nagy and Josef Albers. Those inspired in Bauhaus had the chance to investigate themselves in the introductory course to understand whether they had any talent as a designer. For the period of this course, imagination and creativeness were considered, in addition to understanding, carefulness, strengths and teamwork. Johannes Itten arranged three aims for his introductory course education:

1. To free the creative forces and thus the artistic talent of the students. Individual experience and insights were to lead to real work. The students were to free themselves

step by step from all dead conventions and pluck up the courage to do their own work.

2. To make the students' choice of profession easier. Materials and texture practise were a valuable aid in this. Every student found out after a short period of time which material attracted him, whether glass, wood, stone, clay, metal or spinning products, stimulating him to creative activity.

3. Students were to be taught the basic laws of artistic design for their later artistic professions. The laws of form and colour opened the world of the objective to the students. In the course of their work, objective and subjective form and colour problems could intermingle in various ways (Siebenbrodt and Schöbe, 2015).

In history, Basic Design had been united educational practice with the theory and methodology established on design. It was first applied as a design practice at Bauhaus School of Art and Architecture throughout the first half of the last century. The practice was founded principally on visual practice, and its exploration in terms of simple, abstract properties, such as forms, patterns, or colours.

The Bauhaus discovered formal abstraction in relation to human perception, with the ambition of discovering a worldwide visual language, independent from cultural restrictions. In these investigations, academics were not interested in individual choices, but in intuitive replies and in the most commonly occurring perceptual relations between abstract choices i.e. graphics, colour, texture etc. Also, new objects were considered through researching with features of shape, form, colour, and texture while exploring the manipulation of basic elements predominantly for creating new design concepts (Franinovic and Visel, 2008).

The idea of Basic Design education at this point requires a structure which will express the theoretical and practical stages of the education. The aim of the Basic Design education is not only to inform students but also explain how to get understanding and knowledge of design and how to develop themselves. Also, it is aimed to create an environment which students get an understanding in their first year of architecture education and to benefit from the educational course. What is looked for, at the end of basic design education is to have a useful design process.

In *École des Beaux-Arts*, tutor coordination is respected for design education program. Two-dimensional and symmetric design methods were leading. Besides, it is well-known that studio system is settled to improve communication between the mentor and the student. As a response to Beaux Arts, Bauhaus students were not forced into conditionings and creativity, imaginings and different communication chances are encouraged by instructors (Ketizmen, 2002).

In Bauhaus, basic design course was firstly discovered and accepted as a pre-course of the design education. Students were mostly taught to understand themselves, to have individual ideas which can be supported by others. The main purpose was to highlight students own talents and ideas which they are able to defend.

In addition, the basic design also targets to contribute perspectives to the students' perspectives culturally, socially as well as historically and ideologically. Basic design studios also aim to incorporate the knowledge and skills earned by students through working to form an analytic thinking in the problem-solving process to unite the student to the outside world more to cheer them to develop decision making ability, and more essentially to improve their designing talents within the context of designing philosophies and theories (Hacıhasanoğlu, O, Hacıhasanoğlu, I. and Emer, 2003). It is expected from students to be practical in the context of problem solving and creative thinking, to be qualified in visual memory and investigation, to know how to use several drawing methods and presentation methods, besides of two-dimensional thinking also to be capable of three-dimensional thinking and perception, to have an understanding of colour and material.

2.2.2 Basic Design Studios

Basic design course is a practical course given in a studio environment in line with other design courses. Basic design studios are places where students get initial knowledge on architectural education. In architectural education, the studio is the core experience of learning architectural design (Arıdağ and Uraz, 2006). The design studio is an ideal learning environment where students can develop their skills and explain their ideas about architecture (Ketizmen, 2002). The instructor gives to students keywords that will give an opportunity to discover the creativity of the student and teach them to learn the design.

In the first year, when the concept of the basic design is given, a pedagogical approach is adopted to teach how to think analytically and from two dimensions to three dimensions, help to solve problems. In this approach, it is aimed to increase the perception level of the student with criteria given in the first studio, to be able to think three-dimensionally, to introduce art and aesthetics and to transform the design related concepts into spaces in the context of the training process that will increase creativity. For this reason, in the communication and interaction of the student-teaching staff in the basic education studios, the knowledge accumulation, perception, problem determination and solving skills of the student, the tool used by the instructor and the method applied is important (Dikmen, 2011).

In studio education, the way to develop the ability for criticism and understanding through the completeness of experimental and theoretical knowledge is through an argumentative atmosphere and counter criticism. The basic structuring of studio education can be identified as follows:

- Student centred education,
- The possibilities of multiple solutions for the problem, and
- Programs that can change in accordance with studio dynamics.

The design studio, since *École des Beaux-Arts*, is one of the cornerstones of design education. Unlike classical classroom environment with the narrative base, in traditional studio education, students learn basic design principles as well as produce solutions on design problems and gain practical skills (Öztürk, 2016). The solutions they produce are shared by educators and students by exchanging ideas and using sketches or three-dimensional models while presenting their work. Evaluation is provided by interim and final jury, and therefore face-to-face communication is an important issue in the traditional design studio.

2.2.3 Design Elements in Basic Design Education

The most significant educational development at the Bauhaus was including of 'foundation' or 'basic course' in design. According to this education, all of the design-centred disciplines require a theoretical and practical understanding of 'basic design concepts'. Many basic design course syllabi are still depending on the education advanced in the Bauhaus school.

Visual form is considered by Bauhaus professors, Itten, Moholy-Nagy, Kandinsky and Klee, in line with certain elements which are the visual components of the design. Design elements create the composition. The elements are defined as (Stribley, n.d.):

1. Colour: Colour has three properties. The first is hue, which is the name of the colours. The primary hues are yellow, red, and blue. Secondary colours are made by mixing two primaries. Intermediate colours are mixtures of a primary and adjacent secondary colour. The second property of colour is value, which refers to the lightness or darkness of a hue. The third property of colour is intensity, which refers to the purity of the hue.

2. Line: A line is a form with width and length, without a depth. Lines are used to create edges and the frameworks of objects. Lines can be horizontal, vertical, dotted, zigzag, curved, straight, diagonal, bold, or fine. Lines can show direction, lead the eye, outline an object, divide a space, and communicate a feeling or emotion.

3. Shape: Shape is an area that is controlled by implied line, or is seen and recognised because of colour or value changes. Shapes have two dimensions, length and width, and can be geometric or free-form. Design in the painting is mainly the planned arrangement of shapes in a work of art. Visual composition of shapes in 2D or 3D, are supposed to be basic design education's main concerns. Therefore, 2D or 3D abstract organisations are universally used in this structure.

4. Form: Form defines volume and mass, or the 3D characteristics of objects that take up space. Forms can be and should be viewed from any angles.

5. Scale: Scale is the dimensional element defined by other elements of design size relative to art, its surroundings, or in relation to humans. The scale is the size of an element as it relates to its usual physical size. When the scale is used in a design, it can greatly influence the meaning of the work.

6. Space: Actual space is a 3D volume that can be unfilled or filled with objects. It has a width, height, and depth. Space that appears 3D in a 2D painting is an illusion that generates a feeling of actual depth. Several techniques can be used to show such visual depth or space.

7. Texture: Texture refers to the surface quality, both imitation and actual. Techniques used in painting serve to show texture, i.e. the dry brush technique produces a roughly simulated quality and heavy application of pigment with a brush or another implement produces a rough actual quality.

These elements can be the basic knowledge and analytical framework for a designer. The elements are components or parts which can be isolated and defined in any visual design or work of art. They are the structure of the work and can carry a wide variety of messages. They also provide an understanding of design and make possible perceive the design.

2.3 Architectural and Basic Design Education in Turkey

The rapid change observed in every area of life in the age of information and communication has also dramatically affected the architectural environment. Besides, there are also differences in the architectural departments of the universities in Turkey based on different models and traditions. To understand this difference better and to see the development of Basic Design education within the context of architectural education in Turkey, the undergraduate programs of four selected universities are examined.

2.3.1 Mimar Sinan Fine Arts University (MSFAU)

'Sanayi-I Nefise Mekteb-i Alisi', one of the oldest educational institutions providing architecture education in Turkey, was founded in 1883 by 'Osman Hamdi Bey'. The institution that took the name of Academy of Fine Arts in 1928 and named Mimar Sinan University in 1982 has now become Mimar Sinan Fine Arts University (MSFAU) (Nalçakan and Polatoğlu, 2008). The influence of *École des Beaux-Arts* in the university at the beginning of the century is strong. In the 1930s, the Central European School in the university gained activity, with the participation of some well-known architects of that time from Europe as faculty members. In MSFAU, the first two years are regarded as the preparation period and the students were taught in construction, planning knowledge, building material and drawing, mathematics and aesthetic knowledge which are necessary for project design (Nalçakan and Polatoğlu, 2008).

From the third year on, the students who completed this part started design work on a project theme which had been chosen by their professor. After these five semesters, one subject is given to the whole class on the diploma semester. Everybody had been working on their house for not getting the ideas by others and completing the diploma project away from the school. The projects are exhibited and evaluated and the students graduate with the title of ‘Master Architect’ ‘*Yüksek Mimar*’. Thus, MSFAU has achieved Turkish architecture to reach a contemporary level.

The basic design education in Mimar Sinan University was included in the curriculum in 1967. In the first year of all art departments, the course given under the title 'Basic Art Education' covered the basic principles of plastic arts (Müridoğlu, 1973: 26 cited Pasin, 2007). In 1980, a special basic education structure emerged in the Architecture Department. Within this structure, Basic Design Education is given under the title of 'Introduction to Architecture and History of Architecture I' in the following topics: Differences between Architecture and Visual Arts, Basic Concepts Related to Composition, Basic Design Elements and Mass, Multicolumn Compositions (Bayındır, 1994: 97 cited Pasin, 2007).

Basic Design education today in MSFAU are given to architecture students as a course called 'TEM 113 - Basic Art Education' during the first semester of the first year. The course content includes the use of basic elements and principles that create works of art and design for creativity. It covers the definition of basic elements and principles in design and composition. It involves the use of data in the life context to create visual effects within the observation analysis system (MSGSU, 2017).

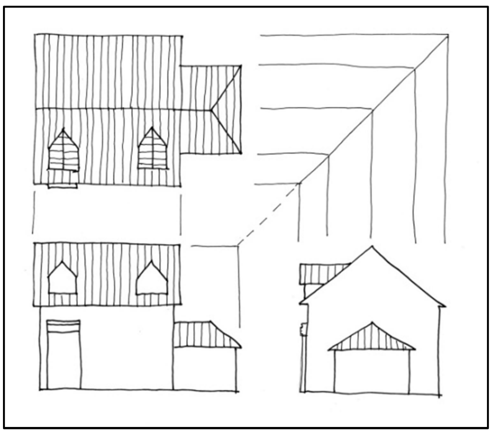


Figure 2: A drawing example based on 'Descriptive Geometry'
(Bilgiç and Konak, 2016)

Architectural representation techniques in MSFAU are given under 'MIM 105 - Descriptive Geometry' and 'MIM 208 - Technical Drawing' courses in the first year. While Technical Drawing course is aimed for three-dimensional thinking, design and the visualisation of this in two and three dimensions through the architectural communication language of descriptive geometry-technical drawing, perspective, 'Descriptive Geometry' (Figure 2) is defined as a method that gives the mind the flexibility (Bilgiç and Konak, 2016). However, it is the previous revolution of drawing not using ornaments and subjectivity of *École des Beaux-Arts* in the drawings before the drawing in the computer environment. Consequently, the education system in MSFAU can be advanced with an update both in basic design education and representation technique regarding current technological developments.

2.3.2 İstanbul Technical University (ITU)

'Mühendishane-i Bahri-I Hümayun' which was founded in 1773 to educate naval engineers is the basis of today's İstanbul Technical University (ITU). It is the first in Turkey and the third oldest in the world higher education institution. Until it turned to ITU in 1944, throughout three years, the students followed a curriculum consisting of positive sciences. At the end of this, after gaining expertise in specialisation in Civil Engineering, Mechanical Engineering, Electrical Engineering and Architecture, architects graduated with the title of Master Engineer (Nalçakan and Polatoğlu, 2008).

The artist-based academy training has continued for a while compared to this educational system of engineering origin. When the Higher Engineer School turned to ITU and engineering became a separate faculty, new faculty members set up a new curriculum program. The aim of the Department of Architecture is to train competent architects who are equipped with contemporary tools and up-to-date knowledge to shape the built environment (ITU, 2017).

In Istanbul Technical University, Department of Architecture, Basic Design education started to be given by Prof. Dr. Lütfi Zeren firstly under the name of Basic Course in 1960. The course was based on the Bauhaus School and aimed to improve the creative skills of students. Zeren's Basic Design Teaching program consisted of five phases. These steps are summarised by Bayındır as follows:

In the first stage, design elements are taught through colourless work. In the second stage, visual perception and organisation principles are taught through colourful studies. The design elements and principles discussed in the first two stages in the third phase are used to solve the problems given by different combinations. Work until the end of this phase is always two-dimensional. In the fourth stage, the concept of space is applied in three-dimensional studies through various design principles. In the fifth and last stage, space organisation is explained by variables such as function and measure (Bayındır, 1994: 84-85 cited in Pasin, 2007).

Basic Design education today in ITU is given to architecture students in a course called 'MIM 121 - Basic Design and Plastic Arts' during the first semester of the first year. Basic Design subjects in this course are specified as:

- Design Elements: Point line, plane, volume, texture, colour, light, shape,
- Design Principles: Repeat rhythm, rate, scale, balance, harmony, and contrast, the unity of contrasts, continuity, and sovereignty,
- Visual perception: Perceptual psychology, Gestalt principles: proximity, similarity, shape-ground.
- Visual illusion, Space Concept: Space fiction in two and three-dimensional works, space geometry in architecture,

- Plastic Arts: Presentation of different materials and techniques, Analysis of natural and artificial cycle: decomposition, distortion, abstraction and reinterpretation,
- Pattern information: Point, line, value, contour plot, motion plot. Colour information, psychological effects of colours.
- Artistic stages in historical flow: Interaction between art branches, similar and different developments (ITU, 2017).

Architectural Representation techniques in ITU are taught in 'MIM 111 - Architectural Design I and Rendering Techniques' course. In this course, simple design problems are given as tools to increase ability in several representation techniques; 2D - 3D drawings and modelling; introduction of computer techniques through uncomplicated design work; aptitude in explication of ideas through a personalized visual language; enhancement of intuition relevant to issues of design such as building construction and structural systems through simple design problems; discussion on the relationship of architectural materials with the environment through small scale design exercises; organization of field trips for understanding and evaluating natural, historical and cultural environments (ITU, 2017). While ITU provides the representation techniques as integrated to design course, it is an up-to-date approach introducing computer techniques.

2.3.3 Middle East Technic University (METU)

In 1956, in Ankara, Middle East High Technology Institute started training to contribute to the development of Turkey and the Middle East countries. Faculty of Architecture was opened first and Faculties of Architecture, Engineering and Administrative Sciences were established at the beginning of the 1957-1958 academic year (METU, 2017).

With the establishment of METU Faculty of Architecture, there stated some innovations in architectural education in Turkey. The first of these is the use of the deduction method instead of induction in design education. The deduction system started to be given to the students in the first year in the Basic Design Course. In other courses, topics that emphasise architectural culture were being studied. The second innovation coming with METU was that the 5-year education was divided into 4 + 2 years to distinguish between architects and master architects. Another innovation was the evaluation method in studies. The open jury system has evolved from an oral exam to a forum atmosphere.

Since 1956, in Middle East Technical University Faculty of Architecture, Basic Design education included in the curriculum. Bayındır summarises the content of this course which is given as a studio lesson including in the first year and drawing education as follows (Bayındır, 1994: 102 cited in Pasin, 2007):

> Explanation of materials used in drawing. Drawing, application areas of text and graphical elements. Composition studies by means of materials and elements. Introduction to space concept through proportion, scale, colour, rhythm, balance, harmony and organisation principles. Perspective education.

Today, Basic Design education in METU is given to architecture students in a course called 'ARCH 101 - Basic Design' in the first semester of the first year. The main objective of this course is to prepare architecture students to architectural design and introduce them to the studio setup by establishing the fundamental skills of design thinking and design exploration. The students are expected to explore organisation, form and space using a variety of design elements and materials. The formal and tectonic characteristics of design are focused on experimental techniques of design thinking and making (METU, 2017).

'ARCH 103 - Graphic Communication' is a foundation course that equips students with means and methods in graphic medium to be utilised in documenting and analysing existing 3D objects as well as designing new ones. Basic manual drawing techniques are conveyed to the students through exercises about basic geometrical shapes. Students are expected to develop and complement the basic knowledge and skills introduced in ARCH 103 in representing architectural works. This course aims to furnish the students with basic skills of graphic expression during the exercises in various presentation and rendering techniques, orthographic, praline, pictorial drawing and freehand sketching (METU, 2017). Similar to ITU's education system METU is also one of the leading universities in Turkey since it is possible to see technological approaches from the first year of architectural education.

2.3.4 Izmir University of Economics (IUE)

İzmir University of Economics (IUE), which is the first private university in İzmir and in Aegean region, was established in 2001 and supported by the İzmir Chamber of Commerce Education and Health Foundation. Architectural education in the Department of Architecture is based on the 21st-century architecture education in which studio education is at the core of the program and it is supported by technical, computer-based, theoretical and history courses (IUE, 2017).

Design teaching is realised in small groups, making use of the latest hardware and software in computers and information technologies. IUE aims to contribute to science by conducting interdisciplinary and practice-oriented researches and positions itself as a research-oriented university. IUE also believes that research activities nurture education and thus raise quality. Considering the needs and demands of the region and society, and its own capabilities, IUE has determined four main research themes as follows:

- Information, Computation and Communication,
- Energy, Social Development and Sustainability,
- Understanding Human and Social Behaviour,
- Innovative Design Studies.

Basic Design education today in IUE is given to architecture students as a course called ' FFD 101 Art and Design Studio I - FFD 102 Art and Design Studio II' during the first year. These courses aim to establish the foundation to comprehend the common design language for five different disciplines, providing the basis for multidimensional thinking, developing the manual and mental skills to complement the 'hands-on practice' (IUE, 2107).

Architectural Representation techniques in IEU are taught in 'FFD 111 - Drawing and Representation' in the first semester and 'FFD 104 - Computer Aided Technical Drawing' in the second semester. FFD 111 introduces basic drawing techniques to increase the students' observation and drawing skills. Emphasis is placed on the fundamentals of both perceptual and conceptual drawings using freehand technical drawing as a method. Nevertheless, IUE, as in the previous universities, is an institution which follows technological developments and FFD 104 is designed to introduce various modes of representation; to develop the ability to express ideas through both hand and

CAD and stressing the incorporation of those two media; to develop further the drawing vocabulary gained in the first semester; to develop effective studio work habits.

Today, the traditional representation techniques including plan, section, elevation, perspective and model are taught in many of the architecture programs of universities during Basic Design Education. These areas of representation are obtained with hand drawing tools such as pencil, ruler and mitre. With these tools, yet, only projective geometries can be formed. However, especially in ITU, METU and IEU, the computer techniques as representation tools are used in Basic Design education.

Basic Design education in these four selected architecture schools has similar or different processes adapted to the current architectural design approaches of Bauhaus interdisciplinary. In this context, it is seen that in four schools there is a special visual communication and design language predominant in architectural education. The schools in Turkey are generally using a progressive approach to design; however, the representation methods are still not updated.

Basic Design education at IUE follows similar content and teaching method with MSFAU, ITU and METU. The course content of the FFD 101 course is based on Bauhaus education methodology similar to METU, which is still a prominent architectural school in Turkey. As opposed to METU, which has a specific basic design course for each design discipline i.e. architecture, city planning, industrial design, etc., the FFD 101 course follows an interdisciplinary approach. First-year students of five departments i.e. architecture, fashion design, interior architecture, industrial Design and visual communication design share the same studio and follow the same curriculum. Similarly, the technical drawing course at IEU follows parallel methods as METU ARCH 103 and MSFAU MIM 105 and MIM 208, as it includes both technical and freehand drawings.

As this study examines alternative representation methods at the first year of architectural education, it is important to note that the CAD course, FFD 104 at IEU is highly influenced by the graduate program of ITU, Computational Design in Architecture. Starting from an emerging 3D free-form, the course concentrates on the alternative digital methods with an emphasis on interchangeability of the representation (Varinlioğlu et al. 2016). Starting from this flow, this thesis concentrates on the students learning outcomes of an alternative method of virtual reality in both traditional orthographic forms and digital free-forms.

CHAPTER 3

TECHNOLOGY AND REPRESENTATION IN BASIC DESIGN EDUCATION

3.1 Computer and Information Technology in Design Education

When architectural design education is thought as a whole, the effects and results of information and computer technologies are easily observed. In particular, information technology is used not only in the field of design but also in theoretical courses, creating archives and creating interactive environments in architecture based on visuality as well as cinema, theatre and other performing arts.

It is an important step to demonstrate understanding by using all the possibilities of information technology in educational institutions and architecture education. Information technology provides a versatile environment for effective knowledge access, design research and design representation. It also encourages students to improve their knowledge, throughout their education and professional lives and helps them to increase their perception capabilities.

The use of computers in architecture has been widespread since the 1960s, as it is in all other fields. Before the computer, visualising was made with ink and paper as the basic tools for architectural representation. The most important factor in this development is the rapid development of computer software and hardware technology. Emerging technology has also been reflected in architecture education, and the use of technological opportunities has given a different perspective to education. These technological developments have provided a more qualitative change in the structure of learning by providing more than improving teaching efficiency.

Today, technology allows the development of new learning environments that expand the possibilities of traditional and useful learning environments. Since most of the new technologies are interactive, it is easier to create an environment that allows learning, feedback, perception and adaptation of new information production. These methods identify digital platforms that prevent unnecessary information, instead, provide data analysis, interaction and inspiration with other people who produce information (Greenfield and Cocking, 1996).

In the light of these developments in the field of architectural education, design tools have also been strengthened and have begun to be used in schools. Today, CAD classes are called as Digital Architecture and Computational Design by distinct theories. These are started to be taught in the early design education parallel to the training of design element and principle used in Basic Design education. Since the hand-drawn images, computer images, computer animations are the main approaches to architectural representation today, it is important to know in terms of perceiving what to be represented.

3.1.1 Computer Aided Design / CAD

In the 1980s, with the intensive introduction of computer technology, new horizons were opened within the methods used in education and training today. The development of information technology has also led to significant changes in architectural education. The one-sided approaches seen in traditional design studios have been replaced with interactive and collaborative applications. Design education provides advantages through both visual and auditory teaching in terms of development, openness to innovation and durability. In today's architectural environment, computers are often used as a means of representation. Techniques such as computer-aided drawing, three-dimensional modelling, and animation are widely used to support visualisation tools in the traditional design process.

Computer-aided design (CAD) is the use of computer programs to create 2D or 3D graphical representations of physical objects. CAD is mainly used in all areas of design. Accordingly, they are referred to by different names and abbreviations. The name of CAD used in architectural design is named as Computer Aided Architectural Design (CAAD).

The earliest and the most widespread recognition of CAD has been through 2D drawing. This is followed by 3D modelling. Although CAD has been known since the 1960s, it had not influenced architectural design until 1990s. In the early 1980s and the early 1990s, architectural drawings were introduced into the computer environment. The research on architectural geometry and form management with CAD made it possible for future vehicles to be seen and used in practice a few years later (Penttilä, 2006).

Conceptually, through the evolution from CAD to CAAD as well as digital design, now, the computer should be considered as a design environment, not just as a visualisation tool. For this reason, when a modern design practice is introduced, it is likely that early learning by architects and designers in current CAD applications will lead students to take the advantage (Akipek and İnceoğlu, 2007).

CAD technology is a good way of managing design data in terms of designer and design data. CAD has improved its ability to control the design geometry of the design. Thanks to CAD systems, not only simple geometries but also complex geometries can be easily drawn and modelled. It is likely that the introduction of the computer into the early design life has facilitated and encouraged the students in their design (Pak and Arzu, 2010). CAD systems control both the design and the construction process. This application has motivated people to combine the creative power of the designer on a computer with analytical and numerical power to make the architectural design process more instructive and productive.

Various simulation techniques and tools have been used in the course of expressing design forms since the beginning of architectural education. Tools such as traditional drawing techniques and model making an abstract thought concrete and visuals are replaced by computer simulations which are contemporary technology tools. It appears that this technology brings speed, precision and realistic presentations to the building design.

The basic function of CAAD software is to enable the user to make drawings by controlling the lines, circles, rectangles and texts interactively on the computer screen. The architectural drawing and visualisation software, CAD, has shown great improvements in recent years and diversifying and taking part in architectural education. These technologies have to be used as a dominant feature; otherwise, they make it difficult to form when compared to traditional methods, negatively direct the designer and cause waste of time.

In the mid-20th century, Ivan Sutherland's Sketchpad program established that computers could be used for drafting and modelling (Kalay, 2004). Then, in the late 20th century, architectural practice without software had become inevitable, and today, digital design technologies are implemented almost universally as the principal means of production in architectural practice. Therefore, by the 1989s, Oxmans have mentioned "the considerations of implications of a well-defined body of architectural and design knowledge for design education and the potential mutual interaction in a knowledge-rich environment of design learning and CAAD learning. The computational factors connected with the representation of design knowledge and its integration in design systems are among the key problems of CAAD (Oxman and Oxman, 1989)." Furthermore, digital technologies have supported new methods of design, which has led to a re-examination of current design theories and educational concepts (Oxman, 2006).

3.1.2 Digital Architecture

Digital architecture is described as; architecture that strategically uses computing digital media in the development of architectural design, from the design idea; over early design phase, design progress, detail design, and structure design; until the definite building. This description absolutely sets free the traditional architecture as nearly all applies in the world let at least one form of computation or the other (Liu, 2002). Also, Kolaveric mentions that digital architecture is described by digitally created developments of form origination and revolutions such as topological geometries, isomorphic poly surfaces, motion kinematics and dynamics, animation, parametric design, algorithms, presentation, etc. (Kolaveric, 2003).

Digital architecture is defined by Oxman (Oxman, 2008) as ‘Digital Architectural Design (DAD)’ and makes a distinction between CAD and DAD: While principles, theories and methods of CAD have been basically based on imitating paper-based design, the novel concepts of digital design models are re-introducing a different medium of conceptualization, replacing paper-based media. Computation, conversely, does not need digitisation as the human intelligence thinking development can be considered, represented graphically and utilised without using computers (Terzidis, 2003). The task of computation in the pre-digital period was depended on mathematical charts on paper, differential geometry and associated systems of curved surfaces.

In the past, form-finding methods were more unplanned, as designers could not represent their thoughts. This traditional design development was led generally the designer’s instincts instead of an explicit systematic methodology which was frequently challenging to evaluate. Also, the developments do not have formalisation with the concept of creativity.

Digital media now offers practicality and materiality to an area that was once generally abstract and could be barely utilised. CAD developments now offer chances for creations of architectural forms and it opposes traditional procedures and developments in project conceptualization and the final result. Oxman stated that "the emphasis on the influence of new media upon design processes and design thinking is a research contribution to this rapidly growing field of design computation" (Oxman, 2006).

Kotnik mentioned (Kotnik, 2010) the levels of computational utilisation during the design process that can be defined as levels of design computability: the representational level, the parametric level, and the algorithmic level.

The representational level is specified by the practising computer mainly as an electronic drawing tool. The use of common CAD software accessible to students and architects supports this assertion. They are widely used to create drawings and make notes on drawings and media such as plans, sections, elevations and other traditional representation techniques. On this level, the form of thinking is not considered as computational, as it is still parallel to the paper-based method of designing. This means that on a representational level, there is no real understanding of the computational environment that serves the digital environment. What takes place is simply a realisation of a conceivable addition of the traditional language of architecture that is currently in the unseen mathematical explanation of digital design tools.

A parametric level is regarded by the use of a connection between input and output by means of constant distinction along the parameter space. On the parametric level, there is already a clear understanding of the existence of a digital connection between input and output and its mixture into the design progress as an outline of interdependency between diverse parts of the design.

The algorithmic description of the connection, conversely, is not actively used as a design tool. The connection is stable and the emphasis is rather on the possibility of quantification of the input that allows an organised distinction of the output. On the algorithmic level, therefore, the focus is on the development of digital design logic that is a system of algebraic, analytic, and geometric operations for the use of data and its conversion into architectural properties. It is the algorithmic description of the computable function itself and the chance of a personalised accomplishment of the restrictions of the usual functionality of the used software.

All these definitions suggest that the dissimilarity between the three levels of design computability is not founded on a valuation of the architectural value of the final project, but on the level of understanding and development in the search of the digital environment of digital tools. This shows that the levels are not about forms, but about methods of thinking that need to be realised as a digital ability that is a degree for the computational skilfulness in the practice of the tools.

Parallel approaches to the digital can be traced in the work of Oxman and her effort to formulate a theoretic base of design in the 'first digital age'. In an attempt to bring altogether current design concepts and approaches, she proposed five elements of digital design models according to several relations between the designers, the content, the design development and the design: CAD models, formation models, generative models, performance models and integrated compound models. For her, all these sub-classes are characterised by a comparable level of "interaction with an enabling digital technique rather than with an explicit representational structure as in the CAD model." The threshold between digital and representative processes of generation of architectural form is not something that separates. Rather, the digital way of designing and exploring architecture should be identified as an extensive form of representation that is engaged with the non-digital in several ways.

As Kotnik (Kotnik, 2010) mentioned, today, the use of computers in architectural design still is dominantly only an efficient tool of representation of form through drafting and modelling. Thereby, within the realm of the peculiarities of the deployed CAD-software, a digital model of the architecture gets build up inductively using primary forms and a set of different possibilities of modification of these forms.

Therefore, for Oxman, CAD models are descriptive by using different geometrical modelling and rendering software, however, have a little qualitative influence on design thinking and are basically isomorphic with paper-based design methods. Thus, CAD models depict methods of digital design on a level of representational computability. Additionally, on the representational level, the contribution with computation is very low and the form of design thinking is not determined by computation. If the digital design is described by design techniques that are driven by an occupation with computability, then representational design techniques have to be seen as non-digital. The variations of design computability, thus, consist of the evolution from non-digital towards digital design processes.

However, parametric and algorithmic design computability are digital design techniques and as part of the varieties, they mark an extension of traditional non-digital design approaches by computability. The designers have been troubled with the usage of digital tools for the consideration of formal systems for the last two decades (Terzidis, 2003). These applications have tried to redirect formal issues using new methods and approaches. Digital tools are in leading role in this survey.

3.2 Digital Architecture in Representation at the Early Stages of Architectural Education

In architecture programs, students generally perceive the digital tools and computer skills as discrete objects which create struggles to learn frequently complex digital media interfaces. Furthermore, the skill set led in the basic design studio is poorly applied to computerised design outcomes. In other words, students forget the skill sets learned in the basic design course which often leads to poor results in CAD problems. On the other hand, 'togetherness of the digital technologies' or integrated models, do not mean straight attaching of the CAD technologies to design studios. So, like Oxman's statement (Oxman, 2006), new pedagogical explorations are needed to intensify the togetherness of the digital technologies and their application into basic design. According to a study on technical drawing, when students are encouraged to integrate digital tools at an elementary design stage, they show more motivation to solve advanced design problems by employing more complex interfaces in their later years of education (Varinlioğlu, Alaçam and Halıcı, 2015).

Commonly, the main problem early architectural design courses challenge is how to support undergraduates in learning basic skills, concepts, and imaginative practices that are important in architectural design. Textbooks are the best to an emphasis on traditional design concepts and methods introductory architectural design. Yet, design thinking exploration recommends gaining of concepts and skills, problem-solving approaches and enlightens the generation of design thinking and design outcomes. Hence, if the aim is to make students be in countenance for design thinking and design practices that equate traditional and non-traditional understanding and abilities, both should be presented and early balanced in the program. Unluckily, instructional materials are rare on harmonising traditional concepts and abilities with non-traditional like digital design thinking and associated algorithmic and parametric concepts.

Differences in traditional and non-traditional design thinking are not difficult to define, even if only provisionally. What is less well understood is how traditional and non-traditional problem-solving skills can be balanced in the introductory architectural design studio to best prepare students for architectural practice. One difficulty is that the literature on introductory design focuses on traditional design knowledge. On the other hand, examples of non-traditional design focus on digital design results rather than computational design thinking. According to Oxman (Oxman, 2006):

> In digital design, the centrality of traditional concepts of paper-based representation is no longer valid conceptions for explicating the thinking and methodological processes associated with digital design. Digital design has moved away from the static abstractions that are implied in the concept of representation. Digital design is moving towards dynamic concepts that are creating a new definition of the role of representation itself. Advanced digital techniques are not simply changing our modes of design representation; they are forging new bases for design thinking as the liberation from the traditional logic of representation has occurred.

As it is discussed above, graphical evolution in design representation has been well-formulated by various design theoreticians. Any approach to digital design thinking must necessarily move beyond the formal syndrome of representation, formal language and compositional collage aesthetics.

3.3 Immersive Technologies in Basic Design Education for Representation: Virtual Reality Technology

The concept of benefiting from technology in education taking advantage of the large storage capabilities of computers with communication possibilities and increasing processing capacity facilitates every stage of education. Today, computers are used by students; in the preparation of homework, in solving various problems, in researching, in reaching new information, also by trainers and teachers; preparation of lecture notes, documents to be distributed to students, and visual materials to be presented. In architectural education, this advantage also can include representation techniques.

The methods to express space, forms and design in architecture are defined as architectural representation. Visualisation technology as how it is today did not come out suddenly. It is a consequence of constant work by humans to discover the best method to represent the real world with the techniques invented. In architecture, representation of the real world is important because it helps to understand spaces before they are built, or if built, to understand it even without being there at the real place. The curiosity in visualisation has begun with 2D drawings, drafting and perspectives on traditional mediums.

Today, sketches, perspectives, physical models, digital models, photographs or drawings are some of the methods of architectural representation. During/after the design process or after the construction of the space; these representation methods are used to perceive architectural space. In today's education system, when the methods of representation which aim to convey the idea of architectural space are considered, it is seen that most of them address only the sense of sight. So, it would be incomplete to represent the architectural space in such a way as to address only one sensory perception.

Representation techniques provided by current technologies increase the speed and quality of perception capabilities. Introducing especially computer architectural design theories, methods and models to students in rapidly developing software environment and digital evolving process and educating students on these topics gain importance in terms of perceiving how to solve a design problem in a computer environment (Çağdaş and Tong, 2004). Basic Design education as the first step of in architectural education is also first the first stage where technology in designing and representation is introduced.

The main character of basic design education is the transfer of design elements and principles to students in two or three-dimensional works. Students try to represent a lot of work, considering design elements and principles. However, since intellectual processes do not come into play at the same time, students may get bored, have difficulties, and unable to defend their endeavours as they cannot understand themselves. When emerging technology and contemporary changes in the world are taken into consideration, the basic design applications need to be updated as well.

The 21st century is a period of intensive interdisciplinary work, in which design and technology come into play and original and different applications take place. The developments in our time, in which many disciplines complement one another, bring about different quests in Basic Design education. What is expected from the students in Basic Design courses is to study the objects they see on a two-dimensional surface, as well as three-dimensional studies considering the design elements and principles. The student who grasps the language of design can represent any design in mind afterwards. Therefore, representation is the next issue to be updated.

The method of architectural representation, the only way of expression that can perceive the architectural space by addressing all senses is the space itself as constructed. However, with technological developments, the perception of space can be improved. As in the current techniques of designing have been integrated to Basic Design education, it is important to integrate recent techniques of representation.

The recognition of innovation in basic design education in terms of representation will enable the field to gain new dimensions. In Basic Design education, it is necessary to create original programs in the direction of innovations and to introduce the students to contemporary and different applications.

VR technologies in this manner have drawn noteworthy attention because of creating realistic environments, in which the users can interact with virtual designs in a 3D world. As a result, VR technologies may solve many problems since it creates an ideal perception of space, as the nearest perception of constructed version creates. To study these potentials, the next section provides a review on VR.

3.3.1 Virtual Reality/VR

Virtual Reality is defined as the act of creating and interacting with computer generated virtual environments (Vince, 1999). VR is also explained as an approach to generate and provide a perception of reality using simulated means, generally the computer. VR is mentioned alternatively as virtual worlds and virtual environment. The idea of VR assumes the presence of material reality. Users perceive and interact with material reality through human sensation.

VR has an experimental frame that grows from three bases: immersion, interactivity and multi-sensory response. In Immersion, a user is enclosed by an atmosphere that confirms a sense of existence or the sensation seen really in the represented world (Schuemie, Straaten and Krijn, 2001). Interactivity can be seen as the capability to control actions in the virtual reality environment with body movements which in turn initiate responses in the virtual reality environment in consequence of these movements.

VR generates an imitation of reality through five senses i.e. vision, touching, hearing and smelling. The level to which a VR performance allows the usage of many or all of the senses specifies the reality or level of immersion of the performance. Technologies of VR are differentiated based on the degree to which they are able to simulate reality, particularly in their display. The VR technology differs from completely immersive technology where the user is integrated into a simulated 3D world with the senses enabled, to non-immersive technology, which offers a partial sense of reality.

There are several kinds of VR tools ubiquitous. The most common ones include Head Mounted Display (HMD), the Binocular Omni-Orientation Monitor (BOOM), and the Cave Automatic Virtual Environment (CAVE) (Vince, 1999). The mentioned VR systems are screen-based projection systems that provide a display through projections on screens. The level of immersion differs from the projection of animation to multimedia presentations on large screens or systems using 3D glasses.

HMDs are the premier immersive VR technology (Vince, 1999). The user experiences the visuals with a head-mounted tool. This is occasionally used with a tactile system to experience immersion fully. BOOM is another system of VR with a head-coupled stereoscopic display device. Additionally, The CAVE is composed of a room with visuals projected. The images on the wall are projected from behind the walls with a sound system to provide depth. Users are encircled by the visuals to provide full immersion. The CAVE can also be experienced by a number of people in the room at the same time living the same moment.

To create a VR system, the general technology necessities are separated into four groups:

1. Hardware: 'capable of rendering real-time 3D visuals and high-quality stereo sound'
2. Input devices: 'to sense user interaction and motion'
3. Output devices: 'to replace the user's sensory input from the physical world with computer-generated input'
4. Software: 'that handles real-time input/output processing, rendering, simulation and access to the world database in which the environment is defined.' (Louka, 1998)

For a fully immersive VR, all of the visual, auditory and tactile material may be required, while for others that are principally visual experiences, hardware and software relating to auditory and tactile sensation can be derived out of it.

VR application has reached to nearly an unlimited level with the development of the technology. VR has improved the manner of individuals' interaction with technology, providing unexplored ways for the sharing the knowledge, visualisation of developments and representation of creative ideas. Using a VR system, either as real design such as buildings, landscape, reconstructions or abstract design in three dimensions with interactivity can be experienced by users. This technology releases limitless potentials for the VR applications in a variety of fields.

Architecture, by the importance of visualisation and experimentation, is one of the major fields where VR has a significant influence on. VR allows the simulation of design, training of concerns as function, construction, performance and more. VR ensures designers to develop design over an earlier version of the design. Therefore, the use of VR in architectural education as representation tool can increase the communication of design ideas with professors and other students.

For architecture students, VR offers a chance to advance design skills through representations with the reality of the perception of the design. Furthermore, the design education process is enhanced through the usage of VR, as criticism and comments which might be hard to understand from traditional representations turn out to be more effortlessly valued when a simulation of the design is experienced.

VR requires more equipment than standard desktop systems do. Additional input and output hardware devices and special drivers for them are needed for enhanced user interaction. VR involves multisensory interactions with computer-simulated worlds through visual, auditory, and haptic feedback. Some of the input and output devices that provide these sensations are trackers, gloves, 3D audio cards, stereo displays and haptic clothes. However, since this research focuses on Basic Design students who are mostly new to these developments and cannot afford all the hardware system, head-mounted display (HMD) systems are reviewed.

The Oculus Rift is one of the most common HDM for experiencing VR. The Oculus Rift uses stereoscopic vision technology, rendering a slightly different perspective of the 3D image for each eye. "For a complete wide field of view, the Oculus Rift uses optical lenses. To track head movements the headset is integrated with a high-speed gyroscope, accelerometer, and magnetometer. This enables the natural interaction of looking around while exploring a virtual 3D world (Ruyg, Teunisse and Verhage, 2014)."

Another HDM is HTC Vive. The headset is designed to utilize 'room scale' technology which turns a room into 3D space via sensors, with the virtual world allowing the user to navigate naturally, with the ability to walk around and use motion tracked handheld controllers to vividly manipulate objects, interact with precision, communicate and experience immersive environments (D'Orazio, 2015).

Figure 3: Google Cardboard (Google, 2016)

Both of the devices mentioned are still costly for students. However, one HDM device is very popular. Google Cardboard (Figure 3) is a VR glass for use with a head mount for a smartphone. The platform is intended as a low-cost system to encourage interest and development in VR applications. Users can either build their own viewer from simple, low-cost components using specifications published by Google or purchase a pre-manufactured one. To use the platform, users run cardboard-compatible applications on their phone, place the phone into the back of the viewer, and view content through the lenses (Branstetter, 2015).

In addition to hardware, designs which is modelled in digital environment is also required to an engine to turn it into something that can be experienced in virtual environment. These are the tools to create digital environments, but also physical items to interface with digital experiences. For students, an online VR service, Sketchfab is one of the free and easy-to-use tools. Sketchfab is a website used to publish, share and discover 3D and VR content online. It provides a viewer that allows displaying 3D models on the web, to be viewed on any mobile browser with Google Cardboard, desktop browser or Virtual Reality headset.

3.3.2 Virtual Reality in Basic Design Education

Formerly, time, technology, technological knowledge and cost factors had limited an ability of VR to create a representation of geometry, material and light compared to a hand-drawn image, a computer image, or a computer animation. Fortunately, this situation is improving quickly with the technological improvements, the development of computer hardware, VR software, and VR projection systems. Since the Basic Design students are new to designing and representing, now, VR can make the execution process of design representation easier and improve the rendering quality, as easier to traditional methods which are taught through more than a year. VR projection systems work to help achieve a more realistic visual experience in an easy path.

In an experiment by Gul, 2009, which is directed by designers revealed that in digital design environments perceptual activities seem to be more regular than in traditional (freehand sketching) environments. The virtual environment provided a platform for designers in which they could easily focus on the visual analyse of the design solution. It is possibly by reason of an easy system of control navigation and views, in addition to the comparatively realistic look of the design (Gul, 2009). Consequently, it is possible that VR technology can give opportunities to involve beginner level Basic Design students in the perceptual activities.

3.3.3 VR in Architectural Education

The potential of VR application in design education has made the technology the focus of implementation in many architectural schools. One of the leading universities in the context of VR integration to architectural education in the US, the University of Minnesota invested in design grounded in critical representation (materials and media literacy, or drawing and making as a way of thinking) and social engagement (ethically motivated work that strives to make the world a better place). As distinct from the many other schools which use VR externally from the curriculum, Minnesota School of Architecture is an institution that uses VR effectively within the curriculum.

In the Bachelor of Design in Architecture program, students discover a broad range of methods to design in relation to architecture. Students learn to think through architecture, frequently in ways and with projects not essentially tied to the traditional building scale or to building systems. Students use the lens of architectural design to discourse a wide range of issues within architecture and in connection to other disciplines. Students improve verbal and visual abilities in architecture and practice the design development as a dialogue between divergent and convergent making and thinking. They undertake projects that link architecture with explorations in visual media including film, photography, and VR.

The Virtual Reality Design Lab (VRDL) is located at the University of Minnesota and concentrated on the engagement with the architectural, construction and design disciplines to discover methods to advance or improve the design and teamwork process. VRDL is an exceptionally effective means for non-designers to understand and interact with designed environments. The user experience is highly accessible and completely immersive (Mortenson, 2013).

The group at the VRDL are working with digital design models. Their ability to quickly immerse students in a digital version of the designs is well for designers of the future who want to share a collective experience on multiple levels, in multiple dimensions, and in a fraction of the time that it would take to otherwise achieve a similar experience.

The VRDL worked with a construction company which capitalised on the connection by exploring the use of the VRDL using one dorm room and one restroom as the study model. In 6 weeks the model was prepared and represented (Figure 4). In this project, issues regarding lighting and stall partitions are solved with the VR experience. Besides, the benefits are reported. The advantages which VR provides in terms of representation and perception among the all can be listed as:

- Understand spatial relationships of equipment and systems,
- Validate size and scale of rooms to be used for all programming,
- Confirmation of visual assumptions,
- Understand how space feels and looks,
- Understand function critical spaces (Mortenson, 2013).

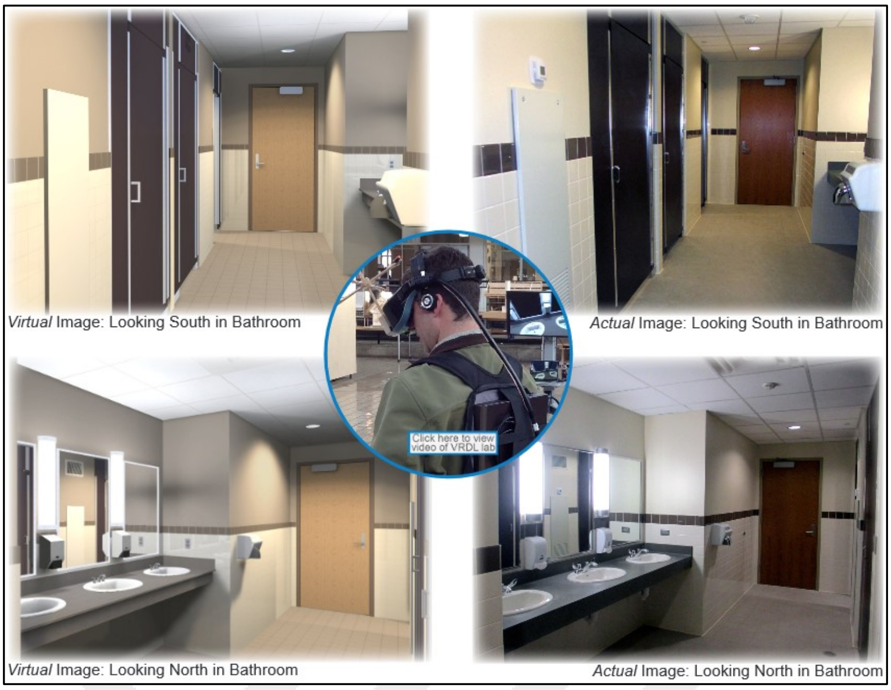


Figure 4: Virtual vs. Actual Images (Mortenson, 2013)

Also, in the curriculum of architecture program, there is a discrete VR course, 'Design and Perception in Virtual Reality' which focuses on issues of design and perception in the context of various types of virtual environments. Several design drawings offer students with a chance to make use of the HMD and immersive wide-screen VR Window in the Digital Design Consortium VR design lab to study the effects of VR on their approach to design and the way they perceive what they have designed.

Although the course is elective and not given as a parallel to Basic Design education, students have a chance to visit VRDL and introduce VR system. The students who have the opportunity to experience VR can be motivated. Also, the program which includes VR into the curriculum can be also integrated into Basic Design education in time.

This chapter indicates that the technological developments in design and representation in Basic Design education are not evenly updated. Design theories and design tools which are included in the curriculum in recent years have been reviewed and the difficulties in representing with traditional methods of the designs created with these design tools are explained. Since VR has resurged thanks to recent technological developments in software and hardware, the contribution of this technology to basic design education, especially in the perceptual context is clarified and the next chapter will analyse the VR integration in Basic Design education

CHAPTER 4

EXPERIMENTAL RESEARCH AND EVALUATION

4.1 Introduction

Basic Design is a course that addresses Schön's 'design studio environment', defined by Schön. The course comprehensively includes basics design concepts in common, in addition to the development of creativity in particular. As well as the extensive range of theoretic and practical concerns of design, architectural representation is covered.

Architectural representation techniques that involve the visuals of a final design within the design process have always been of interest for designers. Physical models, drawings including both hand sketches and digital media, 3D CAD modelling, graphs, illustrations, papers, animations are used in design representations.

The process of representation for a designed product is also a way for students to learn how to create and design. Despite the fact that it is a rare tool for representation in architectural education, VR has great potential as a practical tool for representation. VR might impact positively the teaching and learning experiences of the Basic Design course.

The properties of VR offer great opportunities for experiencing the design in real scale with low costs. By inserting VR to Basic Design education, more expressive potentials for increasing students' understanding of design and creativity could be added. In addition to design elements, different points of view, movement, distance and scale could improve perception skills, visualisation and imagery imagination, prompting creativity. The forms in 3D are understood easily with the real scale representation in virtual space in which all the dimensions required for the realisation of the mass, depth and area, in addition to the materials which are used. Moreover, "using simple 3D modelling software can be experienced in infinite ways, at different scales, benefiting from all areas of design. Feeling their own creations as real life objects could work as an upgrade to the traditional verbal "citations" that never seem to result for all (Duarte and Neves, 2015)." Then, connections with students' own designs could trigger potentials for a makeover of objects.

In focus of determining VR contribution, an experimental research method is applied. To find out how VR can be used in Basic Design Education and what benefits can be gained two models of two IUE students are used in this research. One of the models is designed as hand-made (traditionally) in Art and Design Studio. The other is a digital design. The designs are uploaded online converting VR application in order to be experienced in a VR environment. Then, with a planned experiment VR is applied to IUE Basic Design students in FFD 104 - Computer Aided Technical Drawing course.

1. Year Fall Semester						
Code	Pre.	Course Name	Theory	App/Lab	Credits	ECTS
ARCH 101		Introduction to Architecture I	1	4	3	4
ENG 101		Academic Skills in English I	2	2	3	3
FFD 101		Art and Design Studio 1	1	8	5	8
FFD 111		Drawing and Representation	0	4	2	4
FFD 121		History of Art and Design 1	2	0	2	2
IUE 100		Academic and Social Orientation	0	2	1	1
POOL 004		GEC- Social Sciences B: Humanities and Social Sciences	3	0	3	4
SFL 1013		Second Foreign Languages I	2	2	3	4
Total :						30

Table 1: IEU Architecture Program First Year Curriculum (IEU, 2017)

1. Year Spring Semester						
Code	Pre.	Course Name	Theory	App/Lab	Credits	ECTS
ARCH 102		Introduction to Architecture II	1	4	3	3
ENG 102		Academic Skills in English II	2	2	3	4
FFD 102		Art and Design Studio 2	1	8	5	8
FFD 104		Computer Aided Technical Drawing	2	2	3	3
POOL 001		GEC- Mathematics and Computer Sciences	3	0	3	4
POOL 004		GEC- Social Sciences B: Humanities and Social Sciences	3	0	3	4
SFL 1024		Second Foreign Languages II	2	2	3	4
Total :						30

Table 1 (Continue): IEU Architecture Program First Year Curriculum (IEU, 2017)

4.2 Research Group

Izmir University of Economics is an institution that provides a four-year undergraduate degree in architecture. In IUE, Basic Design education is given in the first year (Table 1)) in the meanwhile architectural representation techniques in the first year curriculum in separate courses are included. FFD 111 Drawing and Representation and FFD 104 Computer Aided Technical Drawing courses are given in order to cover representation techniques in architecture simultaneously with Art and Design Studio 1 & Art and Design Studio 2 as the two Basic Design courses. FFD 111 course introduces basic drawing techniques and is designed to increase students' observation skills and develop basic drawing skills. Emphasis is placed on the fundamentals of both perceptual and conceptual drawings using freehand technical drawing as a method (IEU, 2017). Additionally, FFD 104 introduces various modes of representation; to develop the ability to express ideas through both hand and computer aided drawing and stressing the incorporation of those two media (IEU, 2017).

4.3 Sampling Method

In order to test VR as representation tool, the experimental research was carried out among 81 first year students studying in two classrooms in two sections of FFD 104 course. The experiment was applied once in one hour in the middle of the second semester. The first group includes 46 students for the experiment; while, the second group includes 35 students. The students joined the test on a voluntary basis.

The students studying in the two classes in the study group were randomly selected. In order to determine whether the study groups are equivalent, Basic Design I grades were asked to the volunteer students at the beginning of the experimental process and analysed afterwards. Since no significant difference was found between the success rates of two groups, the test results are reliable in terms of measuring the capability levels.

4.4 Experimental Method

4.4.1 Models and VR Set-up

Since both traditional and digital designing is taught in IUE, two models (see Figure 5 and Figure 6) were required for the experiment. Also, Basic Design elements were specified in the models. To avoid complexity for the students who would use VR for the first time, two Basic Design elements were selected: colour and scale. The models are selected to determine awareness of the two units of measure.

The first design which was produced traditionally as hand-made during the Art and Design I course is a cubic frame surrounded by thin-thick and long-short tapes that are used in determination from the point of scale (Figure 5). 5 colours are used: black, white, and primary colours.

Second design (Figure 6) which was produced digitally in Rhinoceros, 3D CAD application software, and Grasshopper plug-in, a visual programming language and environment that runs within the Rhinoceros, by instructors during the course FFD 104 Computer Aided Technical Drawing: A cubic frame filled with a complex combination of triangles. The triangles are in different sizes to perceive the Size/Scale relation and again 5 colours are used: black, white, red, yellow and blue.

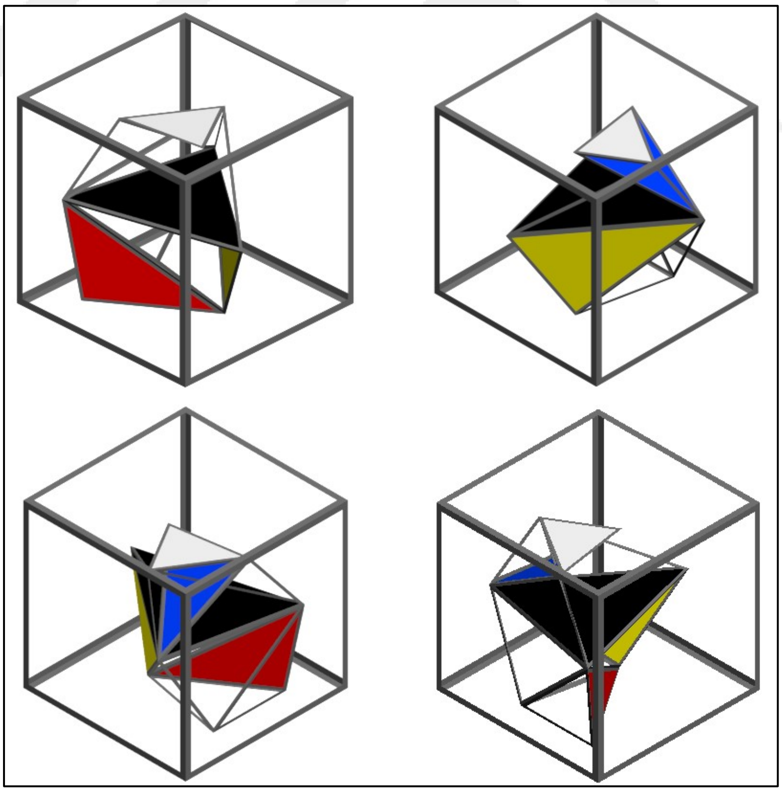


Figure 5: Traditional Design

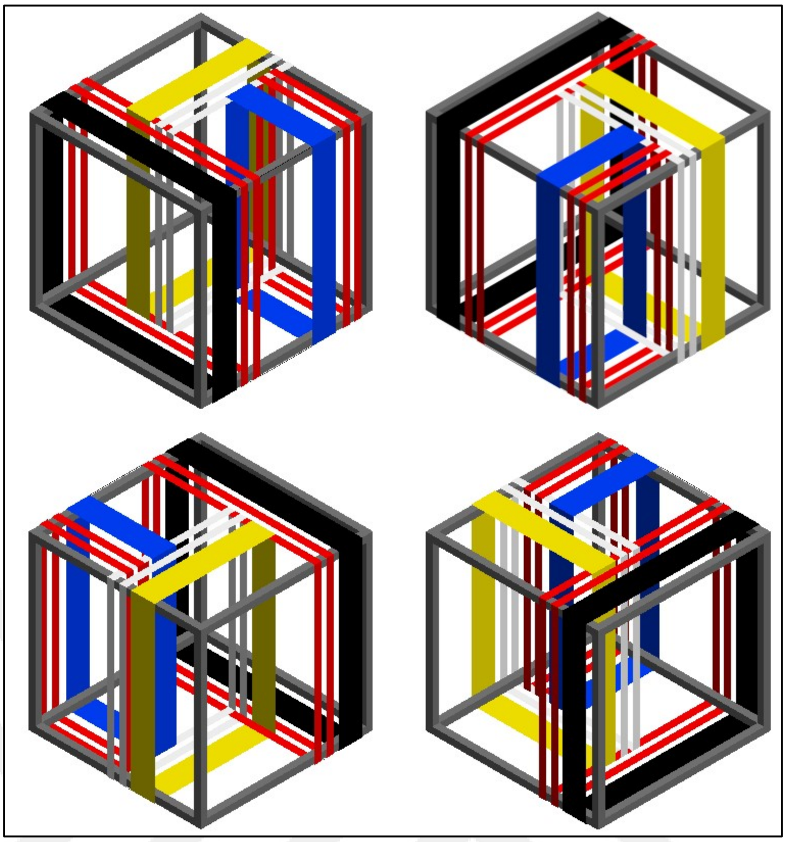


Figure 6: Digital Design

For the second design, formal analysis is made by sketches after the production of the dynamic bubble that changes the form and the process of the change was recorded in digital environment. They are used to convey the form, and hence the change in design. In the 'Processing' a scripting program, it was explained how coding works for drawing. With the aid of Rhinoceros and Grasshopper environments (Figure 7), a digital design is created (Varinlioğlu et al. 2016). Then, the two models are uploaded into an online VR service.

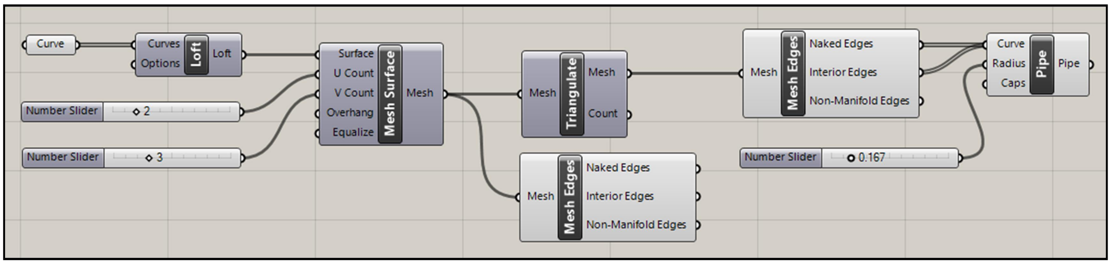


Figure 7: Grasshopper Definition (FFD 104 Instructors, 2017)

4.4.2 Experiment

In the beginning of FFD 104 course, the research process was introduced in two sections. While both groups were given 4 axonometric views of each design, VR was added only to the second group. In the first group, axonometric views were shown for 15 minutes. Then, they were asked to fill the questionnaire in 30 minutes. In the second group, while axonometric views were shown, each student had a VR representation via Google Cardboard. After 5 minutes of VR experience, each student was asked to complete the questionnaire (see Appendix A) in 30 minutes.

4.5 Results

At the end of the experiment session, students submitted the questionnaire. The questionnaire includes two parts (see Appendix A). In the first part, students answered general questions regarding user acceptance, user behaviour, knowledge and organisational aspects. Afterwards, in the second part contains 9 questions related colour and size of the designs.

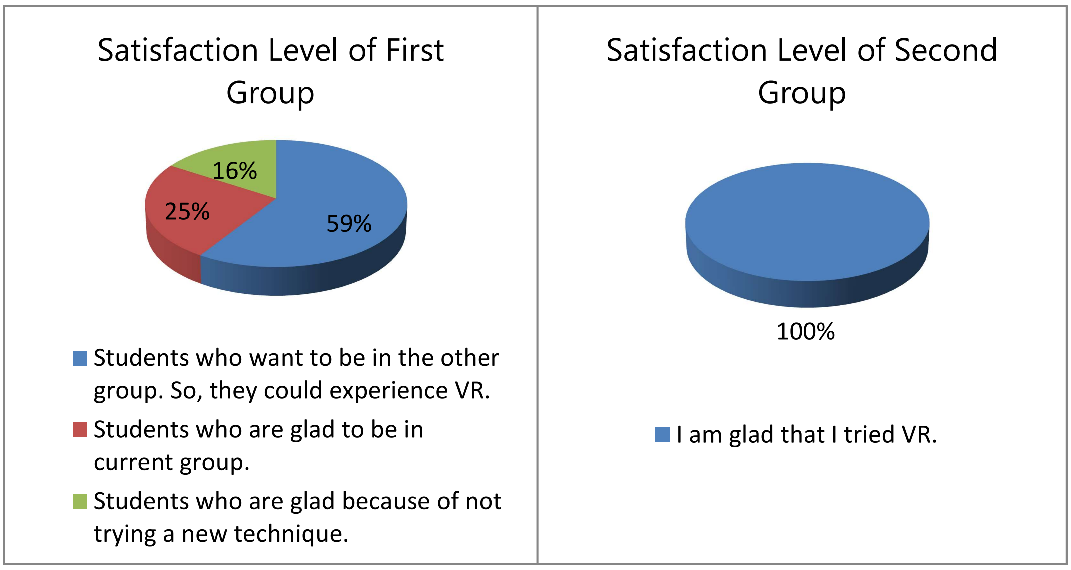


Figure 8: Group 1 Satisfaction Chart and Group 2 Satisfaction Chart

At the beginning of the questionnaire, students were asked if they were glad in which group they were assigned. In the first group which did not use VR, the majority of the students expressed that they prefer to be in the other group in order to try a new technique. 25 percent of the group was satisfied with the group they belonged. Lastly, 16 percent of the students did not want to try a new technique. More than half of the class, 26 out of 44 students stated that they wished to try a new representation tool (see Appendix B).

In the second group, students experienced both traditional representation and VR. All of these students expressed that they were glad to try VR as a representation tool (see Appendix C). The curiosity level of the group was also recorded during the explanation of the experiment in comparison to the first group.

The other information which gathered in the first part of the survey is computer software knowledge of the students and representation method they use. In IUE Architecture program, CAD classes start to be given the first year. Therefore, %100 of the class notified that they know at least one modelling software. Additionally, in the first group, while %15.6 of students expressed that they have already used VR for representation, the rest stated that they had been using the traditional methods of representation as perspective projections, oblique projections, axonometric projections, and multi-view projections; top view, front view, left view etc. (see Appendix B).

All of the students also notified in the second group that they knew at least one modelling program. While %18.2 of students expressed that they had already used VR for representation, the rest stated that they had been using the traditional methods of representation as perspective projections, oblique projections, axonometric projections, and multi-view projections; top view, front view, left view etc. (see Appendix C).

Afterwards, students were asked whether they follow technological developments in architecture. The majority of the students in the first group (%42.2) follow latest technological developments in architecture normally, while %24.4 follow closely and %13.3 follow mainly. On the other hand, while %15.6 of students follow technological developments barely, %4.4 stated they did not follow at all (see Appendix B). Moreover, after the experiment, %68 of the students stated that they ambitiously preferred to see VR tool in Basic Design education although they had never tried VR.

In the second group, the majority of the students (%47.1) follow latest technological developments in architecture normally, %26.5 follow closely and %8.8 follow mainly. On the other hand, while %14.7 of students follow technological developments barely, %2.9 stated that they did not follow at all (see Appendix C). Moreover, after the experiment, %75 of the students stated that they ambitiously preferred to see VR tool in Basic Design education.

For the first group, the test evaluation was concluded with an average understanding of designs. The majority of the students had chosen the wrong answer in half of the questions. There were only 2 out of 46 students who got full marks, contrarily; there were 4 out of 46 students who failed in the answers. Figure 9 shows the current condition on the understanding level. Additionally, the frequently missed questions are the questions of the digital designs.

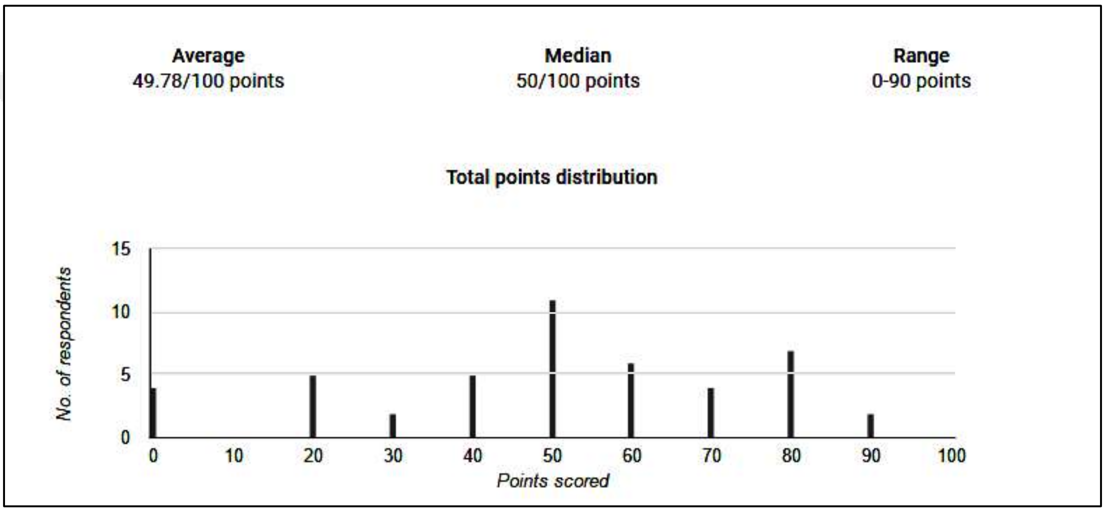


Figure 9: Group 1 Total Point Chart

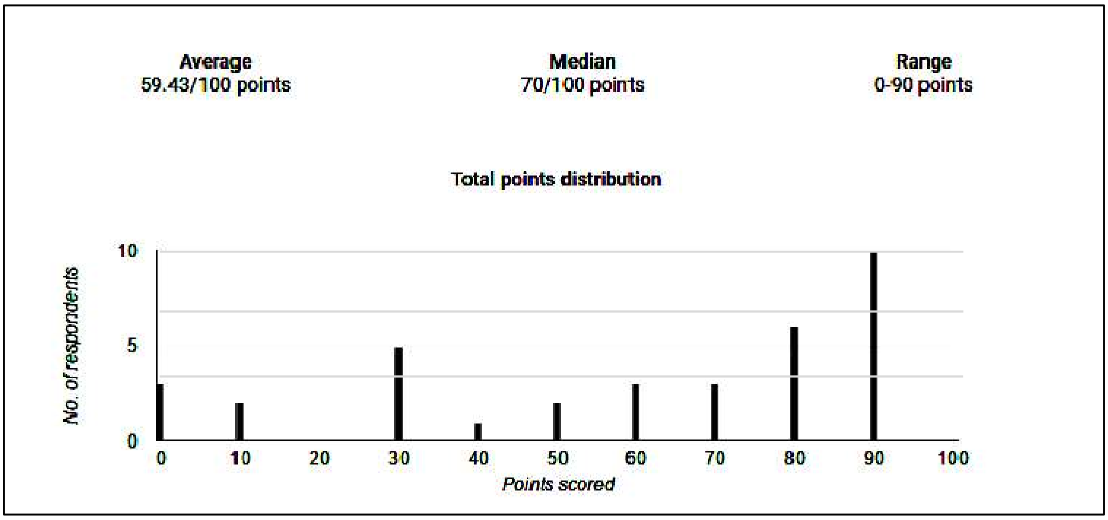


Figure 10: Group 2 Total Point Chart

The test evaluation was concluded with a promising understanding of designs for the second group. The majority of the students got full marks as it is seen in Figure 10 in the second group. While 10 of 35 students who gave the correct answer to all the questions, there were only 3 students who failed in the answers. The diagram shows the current condition of the understanding level. In comparison to the first group's results, the second group was 5 times more successful when a number of students who got full marks was considered.

As seen in the charts and ratios in the first group's results, even the axonometric views are provided by 3D modelling software; the understanding level of the students is not adequate. With the development of technology, a development in representation techniques is needed in order to increase the first-grade students' perceptions of design in Basic Design education.

The charts and ratios in second group's results show that adding VR technology to the traditional representational methods, the understanding level of the students is encouraging. With the recent technological tools, the development of representation techniques is possible in order to increase the first-grade students' perception capabilities of design in Basic Design education.

CHAPTER 5

CONCLUSION

With the emergence of Computer Aided Design (CAD), digital media has started to be applied universally to architectural design. CAD not only works as a representation technology but also as a design method. It transforms architectural design drastically. Through CAD's progress, computer images, computer animations are introduced as the main media of architectural representation. However, today although design tools and theories develop rapidly, the same significance is not given to representation techniques.

As the first step of architectural education, Basic Design course is the key stage to show how students raise a perspective of design and representation. Basic Design Studio is the venue where the students perceive fundamentals of design, technological approaches and recognise various disciplines. Since the recent design tools have been already integrated into Basic Design education, it is important to improve representation methods in advance. In this thesis, VR is proposed as a representation tool that improves the perception capabilities of the students.

VR improves the architectural representation techniques in architectural design. Unlike other mediums, the students using VR are not inactive but active in a virtual setting. Since the students can interact in a virtual environment like in the physical world, VR is likely to become the final product of architectural design besides being a representation tool. As an eventual technique of representation, today VR is gaining attention as the most effective representation tool.

As VR increases the realistic side of architectural visualisation compared to hand-drawn images, computer image, and computer animation, the widespread use of VR in architectural representation may be more common in architectural education in the future especially with the low-budged solutions. Still, VR is not the last but the first step in chasing high perception skills in architectural representation. VR is still a rapidly developing technology itself and becoming preferable through architectural representation techniques in basic design education.

The study shows that VR can be applied to architecture education starting with the Basic Design education and it helps to students increase the speed and insight of understanding. VR is a highly suitable tool that can significantly develop 3D perception of architectural models. Students understand the design easily with VR and can focus. As a result, perception capabilities of the students are increased.

Further research can be designed to include more variables. Computer Graphics algorithms, such as global illumination, or advanced shading, can be implemented with their full potential. Adding variables would take a lot more time and effort for the experiment but it definitely provides students more options in experiencing VR during basic design education. Besides being a representation tool, VR can also be used for designing. The exploration of using VR as a representation tool for Basic Design education and not only for the final visualisation is another field for further research. The integration can be completed with adding VR as a design tool. The influence of the VR-based tools will be measured certainly in the future based on the popularity of the universities which use the VR technology.

BIBLIOGRAPHY

Augmented Reality, 2016. *Simplified Reality-Virtuality (RV) Continuum*. Available at: https://plus.google.com/113902800292911820853/posts/gJ1N2iTgHcY [Accessed 14.04.2017]

Achten, H.H. Roelen, W.A.H. Boekholt, J.T. Turksma, A.A.E. Jessurun, A.J. 1999. *Virtual Reality in the Design Studio: The Eindhoven Perspective.* Architectural Computing: The Education Process. 169-177.

Akipek, F. Ö. and İnceoğlu, N. 2007. *Bilgisayar Destekli Tasarım Ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları*, Megaron. Vol. 2:4

Arıdağ L. and Uraz, T.U. 2006. *Tasarım Diyalogunda İmgeler ve Sözcükler*. İTÜ Dergisi Mimarlık, Planlama, Tasarım. 5-1: 57-68.

Bilgiç, D. E. and Konak, N. 2016. *"Tasarı Geometri - Teknik Resim" ve "Perspektif" Derslerinin, Mimarlık Eğitimi Düşünsel Altyapısına Etkisi ve Prof. Dr. Yılmaz Morçöl.* Journal of Architectural and Life. Vol. 1-1:1-12

Boucharenc, C, G. 2006. *Research on Basic Design Education: An International Survey*. International Journal of Technology and Design Education Vol 16:1-30.

Branstetter, G. 2015. *Cardboard is Everything Google Glass Never was.* Available at: http://kernelmag.dailydot.com/issue-sections/staff-editorials/13490/google-cardboard-review-plus/ [Accessed 03.05.2017]

Caragonne, A. 1995. *The Texas Rangers, Notes from an Architectural Underground.* Cambridge. The MIT Press.

Çağdaş, G. and Tong, H. 2004. *Global Bir Tasarım Stüdyosuna Dogru*. Stüdyo Tasarım Kuram Elestiri Dergisi. Vol: 3.

Çetinkaya, Ç. 2014. *Basic Design Education Parameters in Turkey*. Humanitas. Vol. 4

Conrads, U. 1970. *Programs and Manifestoes on 20Th-Century Architecture*. 1st Ed. Cambridge, Mass. MIT Press.

Dikmen, Ç. 2011. *Mimarlık Eğitiminde Stüdyo Çalışmalarının Önemi: Temel Eğitim Stüdyoları*. E-Journal of New World Sciences Academy. Vol. 6- 4

Dizdar, Safiye, İ. 2014. *Some Options about Design Studios Of Architectural Education.* European Scientific Journal. Vol:10-36

D'Orazio, D. 2015. *Valve's VR Headset Is Called the Vive and It's Made By HTC.* Available at: https://www.theverge.com/2015/3/1/8127445/htc-vive-valve-vr-headset [Accessed 24.04.2017]

Duarte, E. Neves, A.G.2015. *Using Virtual Environments in Basic Design Education.* Proceedings of the 8th International Conference Senses and Sensibility. Lisbon.

Düzgün, E. 2004. *Mimari Tasarım Eğitiminde Başarı Yöneliminin Ölçülmesi*. PhD Thesis. Yıldız Technical University,

Erkmen, N. 2008. *Bauhaus Ekolü Işığında Devlet Tatbiki Güzel Sanatlar Yüksekokulu Ve Marmara Üniversitesi Güzel Sanatlar Fakültesinin Dünü Bugünü*. 1st Ed. Marmara Üniversitesi Güzel Sanatlar Fakültesi.

Franinovic K.Visel Y. 2008. *Strategies for Sonic Interaction Design: From Context to Basic Design*. Proceedings of the 14th International Conference on Auditory Display. France.

Freeman, J. Avons, S., Pearson, D. and Ijsselsteijn, W. 1999. *Effects of Sensory Information and Prior Experience on Direct Subjective Presence Ratings. Presence Teleoperators and Virtual Environments*. Vol: 8-1:1-13.

Greenfield, P.M. ve Cocking, R.R., 1996. *Interacting with Video*. Ablex, Norwood, NJ. 164.

Gropius, W. 1935. *The New Architecture and the Bauhaus*. Trans. Shand, P. M. London. Faber&Faber,

Gul , L. F. 2009. *Studying the Impact of Immersion on Design Cognition*. Virtual Architecture. eCAADe 27:615-622.

Gul, L. F. GU, N. Williams, A. 2010. *Methods forE 3D Virtual Worlds in Design Education*. International Design Conference - Design 2010. 1259-1266.

Hacıhasanoğlu, O., Hacıhasanoğlu, I. ve Emer, Ö. 2003. *Tasarım Stüdyosundaki Amaçlar.* Ege Mimarlık, 3-47:29-31.

Hewitt, M. A. 1996. Beaux Arts Representation and the Golden Age of American Draftsmanship. Classicist Vol. 3:27-37.

IEU. 2017. *About.* Available at: http://www.ieu.edu.tr/international/en [Accessed 11.05.2017]

IEU. 2017. *FFD 111 - Course Introduction and Application Information.* Available at: http://mmr.fadf.ieu.edu.tr/en/syllabus/type/read/id/FFD+111 [Accessed 11.05.2017]

IEU. 2017. *FFD 104 - Course Introduction and Application Information.* Available at: http://mmr.fadf.ieu.edu.tr/en/syllabus/type/read/id/FFD+104 [Accessed 11.05.2017]

ITU. 2017. *Information: About the Department.* Available at: http://www.mimarlik.itu.edu.tr/Icerik.aspx?sid=6736 [Accessed 02.04.2017]

Jacoby, S. 2013. *The Reasoning of Architecture: Type and the Problem of Historicity.* Phd Dissertation. Technischen Universität Berlin.

Jason and Robyn Sand, 2016. *Design Elements & Principles*. Available at: http://mrjasonsand.blogspot.com.tr/2016/03/ga-2030-elements-and-principles-of.html [Accessed 20.04.2017]

Kalay, Y. E. 2004. *Architecture's New Media: Principles, Theories, and Methods of Computer Aided Design*, MIT Press. Cambridge.

Ketizmen, G. 2002. *Mimari Tasarım Stüdyosunun Biçimlenmesinde Yöntemsel ve Mekânsal Etkilerin İncelenmesi: Anadolu Üniversitesi Mimarlık Bölümü Mimarlık Stüdyosu Örneği.* Master Thesis. Anadolu University.

Kimbell, Lucy. 2011. *Rethinking Design Thinking: Part 1*. Design and Culture. Vol: 3-3

Kolaveric ,B. 2003. *Architecture In The Digital Age: Design And Manufacturing*. Spon Press. New York.

Kotnik, T. 2010. *Digital Architectural Design as Exploration of Computable Functions.* International Journal of Architectural Computing. 8-1:1-16.

Ledewitz, S. 1985. *Models of Design in Studio Teaching. Journal of Architectural Education*, 38-2:2-8.

Liu, Y.T. 2002. *Developing Digital Architecture*. 2002 FEIDAD Award. Basel. Birkhauser.

Louka, M. 1998. *An Introduction to Virtual Reality*. Ostfold University College. Norway. Available at: http://www.ia.hiof.no/~michaell/home/vr/vrhiof98/index.html. [Accessed 02.05.2017]

Makaklı, E. S. and Özker S. 2015. *Basic design in architectural education in Turkey.* SHS Web of Conferences. 26-2016.

Massera, C, A. 2010. *Architectural Representation and Experiencing Space in Film.* Universidad ORT Uruguay. Available at: http://www.ort.edu.uy/farq/pdf/documentodeinvestigacion1.pdf [Accessed 14.04.2017]

MSFAU. 2017. Architecture Program Curriculum. Available at: http://www.msgsu.edu.tr/Assets/UserFiles/akademik_xmimfak_xmimbolm/form3_ders_programi.pdf [Accessed 04.03.2017]

METU. 2017. *ARCH101 Basic Design*. Available at: https://catalog.metu.edu.tr/course.php?prog=120&course_code=1200101 [Accessed 04.03.2017]

Milgram, P. and Kishino, F. 1994. *A Taxonomy of Mixed Reality Visual Displays*. IEICE (Institute of Electronics, Information and Communication Engineers) Transactions on Information and Systems, Special Issue on Networked Reality.

Morris, M. 2006. *Models: Architecture and the Miniature.* Chichester. West Sussex. Wiley Academy.

Nalçakan, H. Polatoğlu , Ç. 2008. *Türkiye'deki ve Dünyadaki Mimarlık Eğitiminin Karşılaştırmalı Analizi ile Küreselleşmenin Mimarlık Eğitimine Etkisinin İrdelenmesi*. Megaron. Vol. 3-1:79-103

Oxman, R. and Oxman, R. 1989. *The Computability of Architectural Knowledge*. CAAD futures Digital Proceedings. 171-185.

Oxman, R. 2006. *Re-thinking Digital Design*. Paper presented at Digital Architecture and Construction. WIT Transactions on the Built Environment. 239-243. WIT Press.

Oxman, R. 2006. *Digital Design Thinking: in the New Design is the New Pedagogy*. CAADRIA 2006.

Oxman, R. 2006. *Theory and Design in the First Digital Age*. Design Studies. 27-3: 229-265.

Oxman, R. 2008. *Digital Architecture as a Challenge for Design Pedagogy: Theory, Knowledge, Models and Medium*. Design Studies, Vol 29-2:99-120.

Oxman, R. 2008. *Digital Architecture as a Challenge for Design Pedagogy: Theory, Knowledge, Models and Medium.* Journal of Design Studies. Vol 29:99-120.

Öztürk, Ahsen. 2016. *Tasarım Stüdyosuna Teknolojinin Entegrasyonu: Sanal Tasarım Stüdyosu.* Journal of Research in Education and Teaching. Vol:5-1:28

Pak, B. and Arzu, E. 2010. *Bilgisayar Destekli ve Geleneksel Mimari Tasarım Süreçlerinde Tasarım Kararları*, İTÜ Dergisi Mimarlık, Planlama, Tasarım. 9-2:63-70

Palmer, A. L. 2016. *Historical Dictionary of Architecture.* Rowman & Littlefield. London. 2:274

Pasin, B. 2007. *Mimarlık Okullarındaki Temel Tasarım Eğitiminde Müzikal Kompozisyonun Kullanımı Üzerine Bir Alan Çalışması.* Master Thesis. Dokuz Eylül University

Pazarlıoğlu B. M. 2016. *Temel Tasarim Eğitiminde Kavramdan Üç Boyuta Geçişe Yönelik Bir Uygulama Örneği*, İdil. Vol: 5- 21.

Pentilla, H. 2006. *Describing the Changes in Architectural Information Technology to Understand Design Complexity and Free-Form Architectural Expression*. ITcon Vol. 11:398

Rittel H. 1985. *Tasarım Eğitiminin Tasarımına İlişkin Bazı İlkeler*. Trans. Balamir, A. Mimarlık. 85-8: 20-22.

Rouse, M. *Augmented Reality (AR).* Available at: http://whatis.techtarget.com/definition/augmented-reality-AR [Accessed 19.03.2017]

Ruyg, M., Teunisse C. and Verhage, S. 2014. *Virtual Reality for the Web: Oculus Rift.* Available at: http://mediatechnology.leiden.edu/images/uploads/docs/wt2014_oculus_rift.pdf [Accessed 06.05.2017]

Schon, D, A. and Wiggins, G. 1988. *Kinds of Seeing and Their Functions in Designing.* Design Studies. Vol 13- 2:135-156.

Schuemie, MJ., Straaten, P. and Krijn M. 2002. *Research on Presence in Virtual Reality: A Survey.* Cyberpsychology and Behaviour. 4-2:183-202.

Siebenbrodt, M. and Schöbe, L. 2015. *Bauhaus.* 1st Ed. U.S. Confidential Concepts.

Smith, K, S. 2004. *Architects' Drawings: A Selection of Sketches by World Famous Architects through History.* Architectural Press. United States. 156.

Stribley, M. n.d. *Design Elements & Principles.* Available at: https://designschool.canva.com/design-elements-principles [Accessed 17.05.2017]

Sun, M. and Howard, R. 2004. *Understanding IT in Construction*. London: Spoon Press

TATE. *École des Beaux-Arts.* Available at: http://www.tate.org.uk/art/art-terms/e/École-des-beaux-arts [Accessed 16.05.2017]

Terzidis, K. 2003. *Expressive Form: A Conceptual Approach to Computational Design*. Spoon Press. New York.

Varinlioğlu, G., Halıcı, S. Alaçam, S. 2015. *Computational Approaches for Basic Design Education, Pedagogical Notes Based on an Intense Student Workshop.* Sigradi 2015

Varinlioğlu, G. et al. 2016. *New Approaches to Computer-Aided Technical Drawing: Inter-representational Transfer.* Yapı. Vol. 419:137-141

Vince, J. 1999. Virtual Reality. Springer. London.

Weisberg, D. 2008. *The Engineering Design Revolution CAD History*. 2:1-22.

Wozniak, M. 2016. *How to Improve Architectural Education: Learning (and Unlearning) from the Beaux Arts Method*. Available at: http://www.archdaily.com/785820/how-to-improve-architectural-education-learning-and-unlearning-from-the-beaux-arts-method. [Accessed 22.03.2017]

APPENDICES

Appendix A:

Questionnarie for IUE Basic Design Students

Virtual Reality in Basic Design Education

This survey is designed to know contributions of the emerging trend of virtual reality (VR) in basic design education.

1. **Basic Design Grade**

   ____

2. **In which group were you?**

   Mark only one oval.

   - ( ) I was in the first group. I have seen the designs as axonometric projections.
   - ( ) I was in the second group. I have seen the designs which represented with VR.

3. **I wish I was in the other test group.**

   Mark only one oval.

   - ( ) So, I could experience VR.
   - ( ) So, I do not have to try something new.
   - ( ) I am glad in which group I was.

General Evalution

4. **Which modelling software(s) can you use? (Check multiple if you use more than one.)**

   Tick all that apply.

   - [ ] Rhinoceros
   - [ ] SketchUP
   - [ ] 3DS MAX
   - [ ] AutoCAD 3D
   - [ ] Other: ______________________________

5. **Which methods do you use for representation of your designs? (check multiple if you use more than one)**

   Tick all that apply.

   - [ ] Perspective Projections
   - [ ] Oblique Projections
   - [ ] Axonometric Projections
   - [ ] Multiview Projections: (Top view, front view, left view etc.)
   - [ ] Virtual Reality (VR)

6. **I follow latest technological developments in architecture.**

Mark only one oval.

	1	2	3	4	5	
not at all true	◯	◯	◯	◯	◯	very true

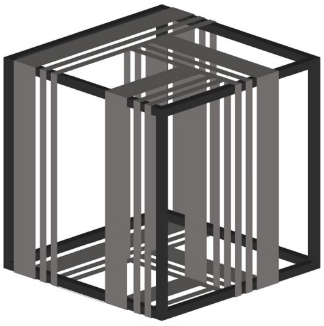
7. **I would like to use VR in my design education.**

Mark only one oval.

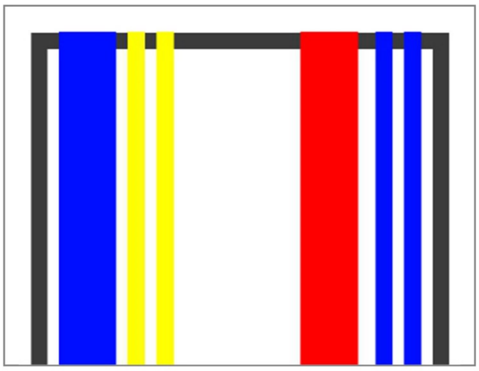
	1	2	3	4	5	
not at all true	◯	◯	◯	◯	◯	very true

Please, answer the questions according to the experience you had in the classroom.

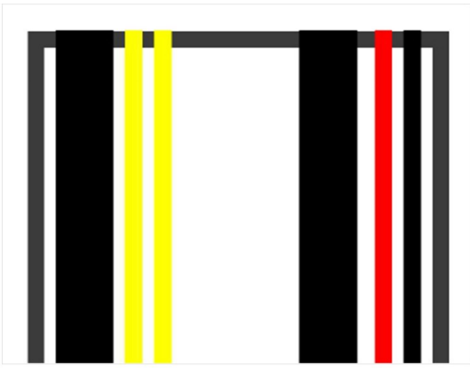
8. **Which colour combination is true for a view of the Design A?**



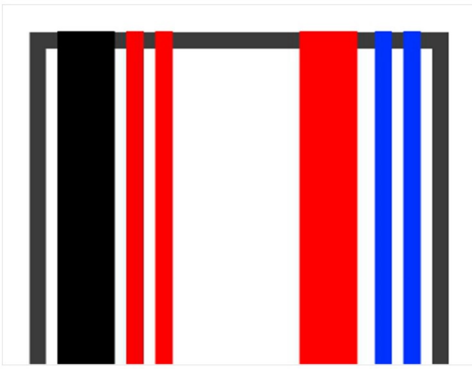
Mark only one oval.



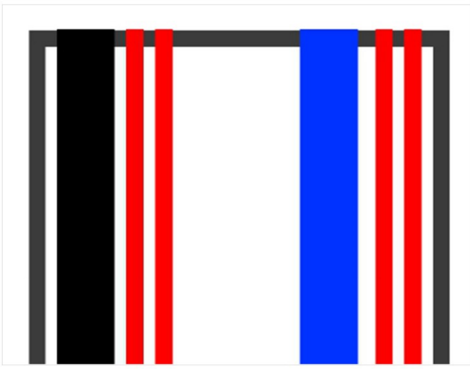
◯ Blue-Yellow-Red-Blue



◯ Black-Yellow-Black-Red-Black

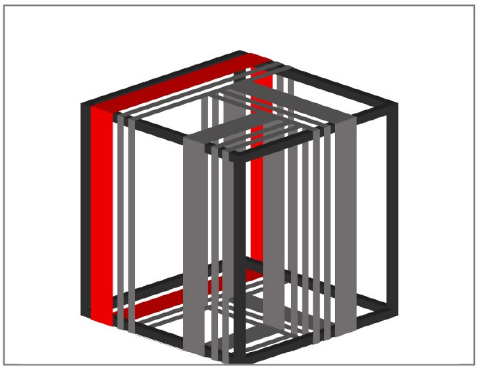


◯ Black-Red-Red-Blue

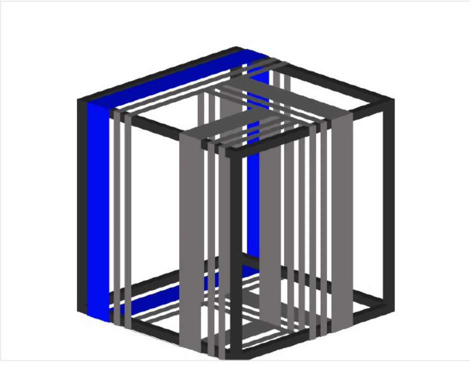


◯ Black-Red-Blue-Red

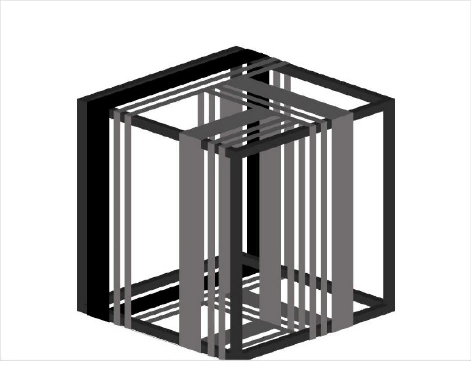
9. **Which colour is the longest-thick tape?**
Mark only one oval.



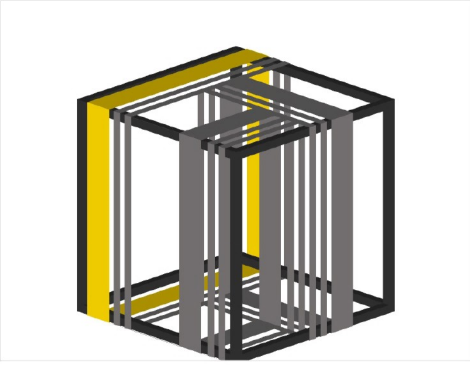
Red



Blue

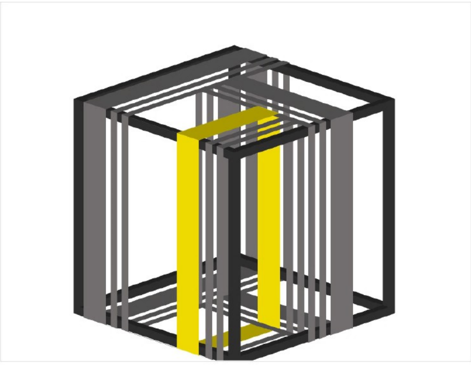


Black

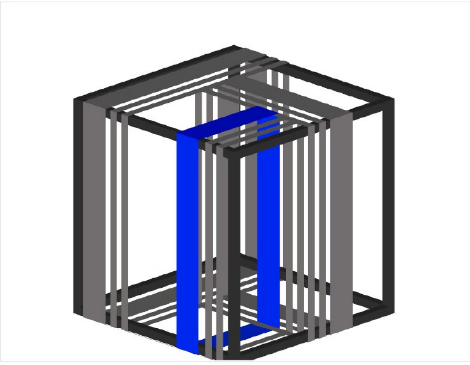


Yellow

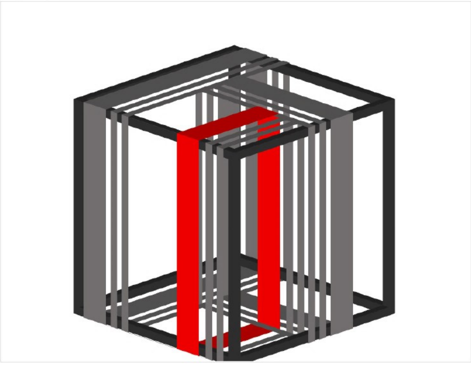
10. **Which colour is the shortest-thick tape?**
Mark only one oval.



Yellow



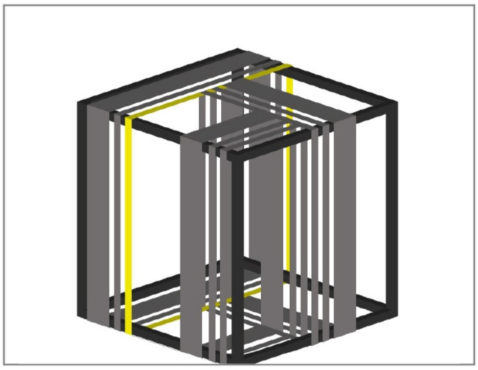
Blue



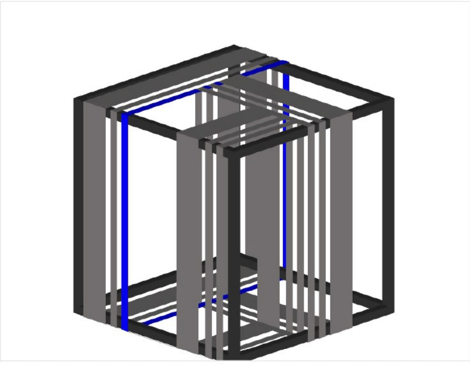
Red

White

11. **Which colour is the longest-thin tape?**
Mark only one oval.

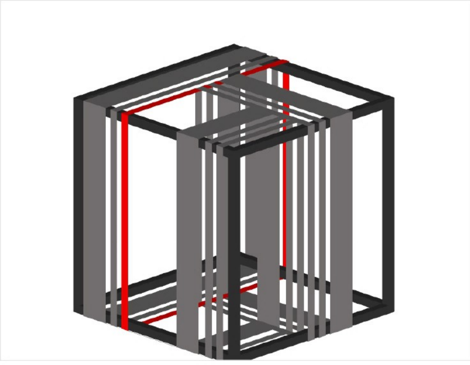


Yellow



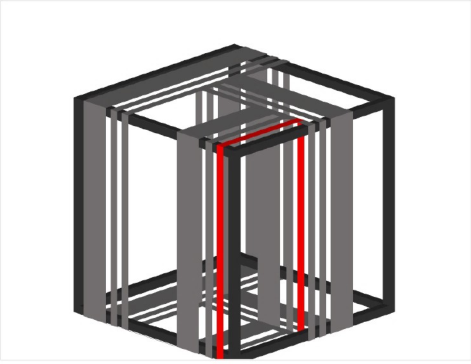
Blue

Black

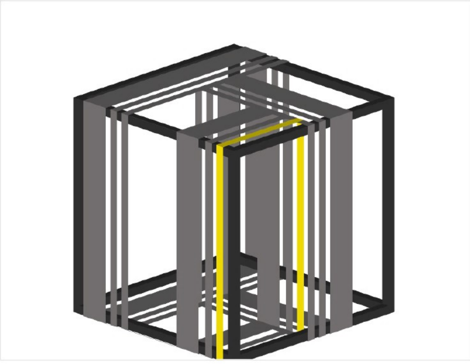


Red

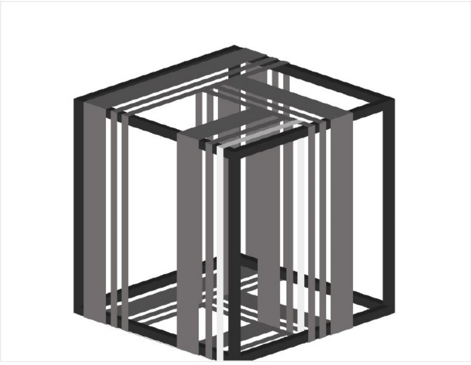
12. **Which colour is the shortest-thin tape?**
Mark only one oval.



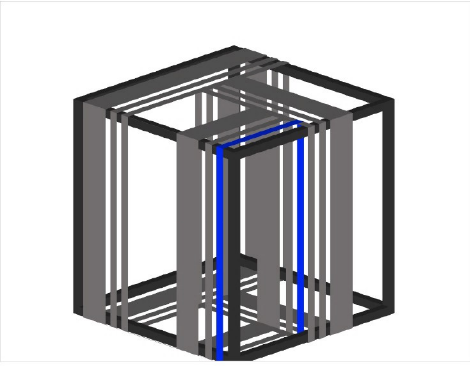
Red



Yellow

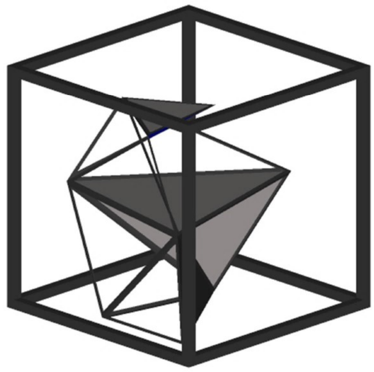


White

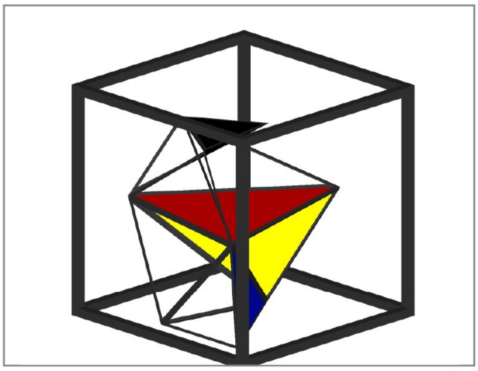


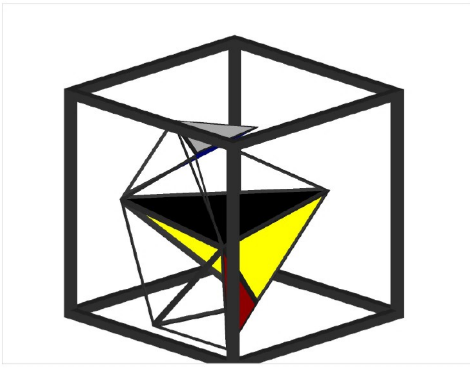
Blue

13. **Which colour combination is true for perspective of the Design B?**

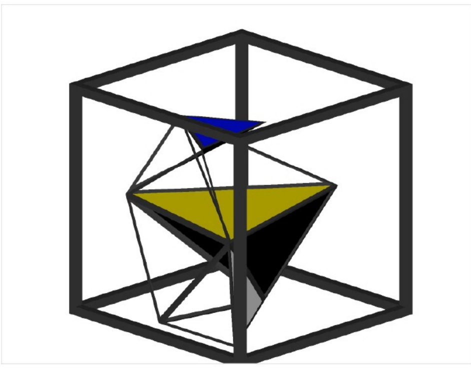


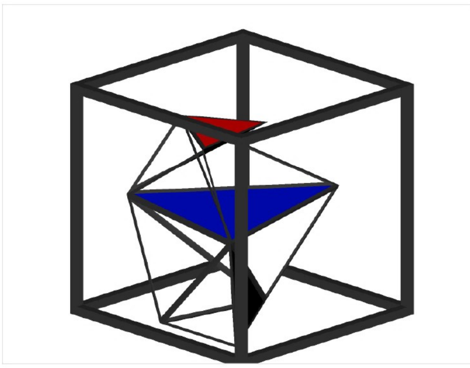
Mark only one oval.





- ⬭ 1. Seçenek
- ⬭ 2. seçenek





- ⬭ 3. seçenek
- ⬭ 4. seçenek

14. **In which colour a triangle is intersected by another?**

Mark only one oval.

- ⬭ White
- ⬭ Black
- ⬭ Blue
- ⬭ Red

15. **Which colour is the smallest triangle?**

Mark only one oval.

- ⬭ White
- ⬭ Black
- ⬭ Blue
- ⬭ Red

16. **Which colour is the biggest triangle?**

Mark only one oval.

- White
- Black
- Blue
- Red

Thank you in advance for your interest!

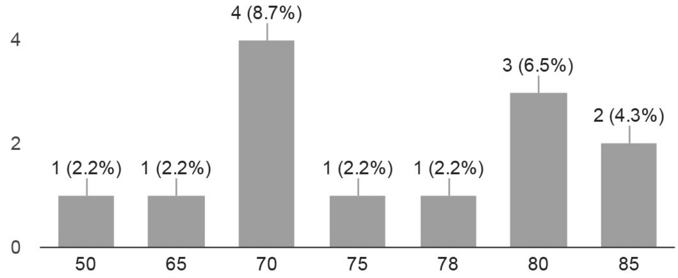
Appendix B:

Results of First Group:

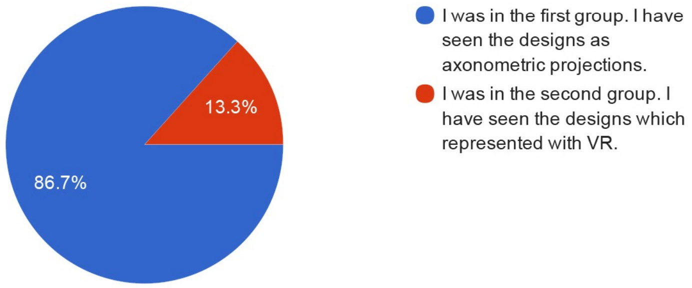
Virtual Reality in Basic Design Education

46 responses

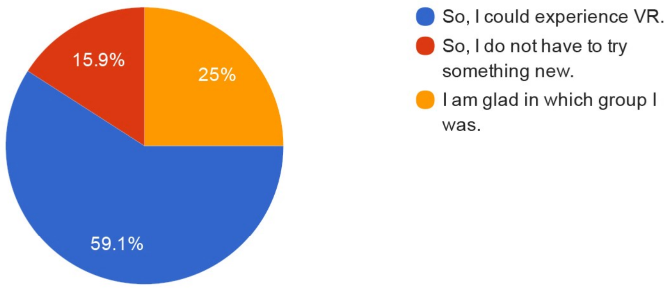
Basic Design Grade (13 responses)



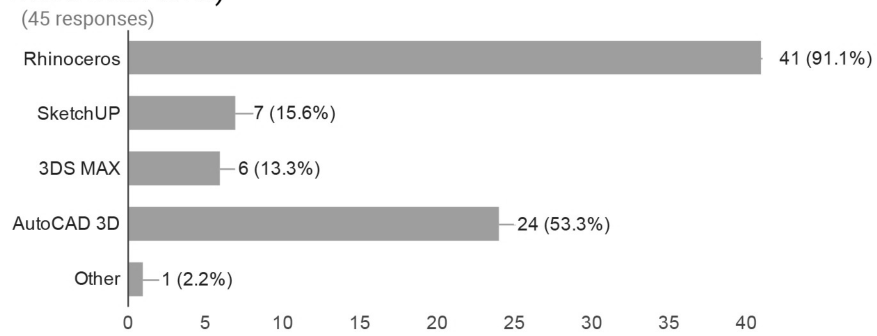
In which group were you? (45 responses)



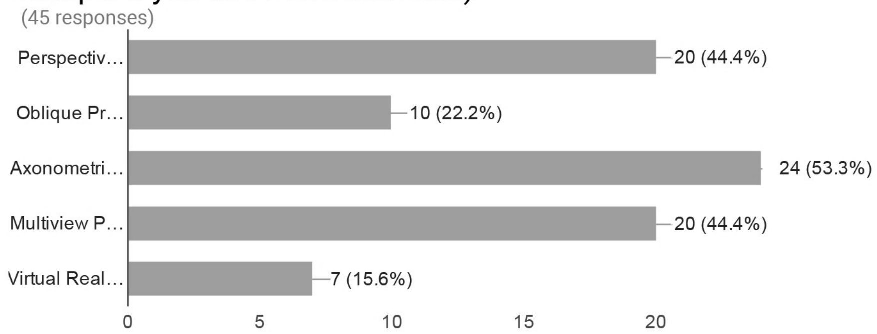
I wish I was in the other test group. (44 responses)



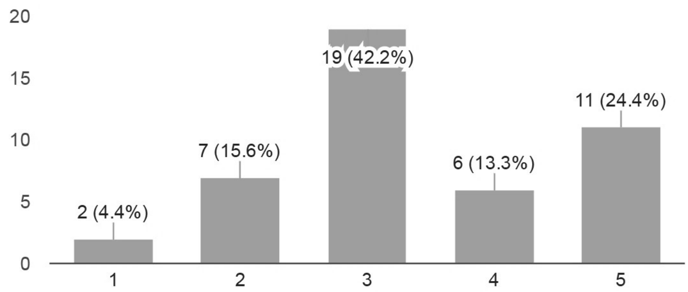
Which modelling software(s) can you use? (Check multiple if you use more than one.)



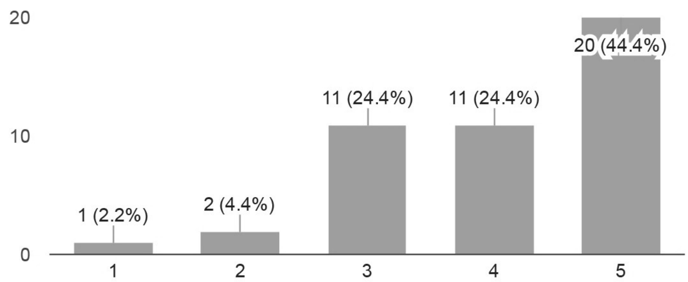
Which methods do you use for representation of your designs? (check multiple if you use more than one)



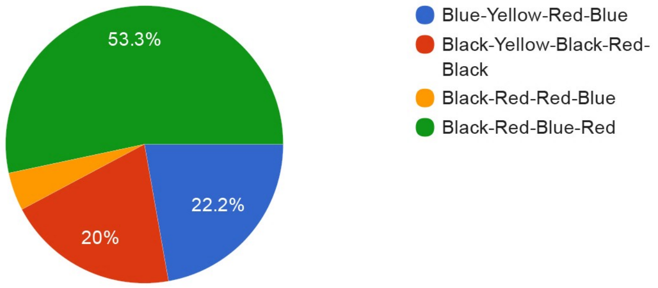
I follow latest technological developments in architecture. (45 responses)



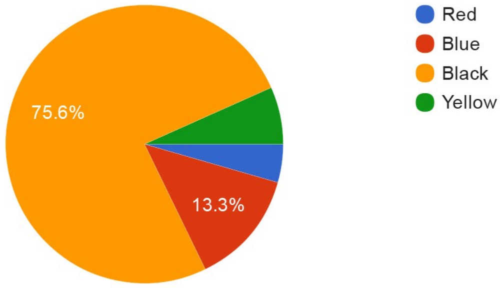
I would like to use VR in my design education. (45 responses)



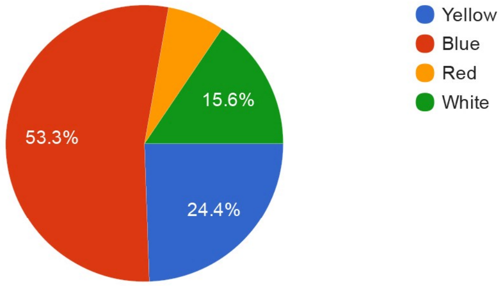
Which colour combination is true for a view of the Design A? (45 responses)



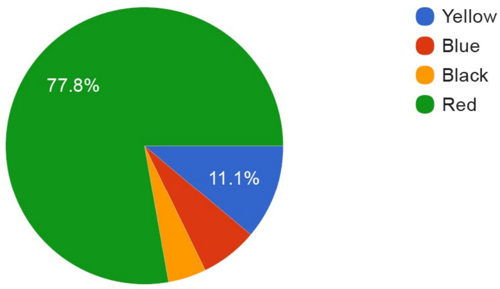
Which colour is the longest-thick tape? (45 responses)



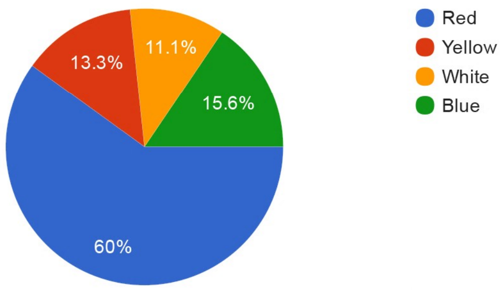
Which colour is the shortest-thick tape? (45 responses)



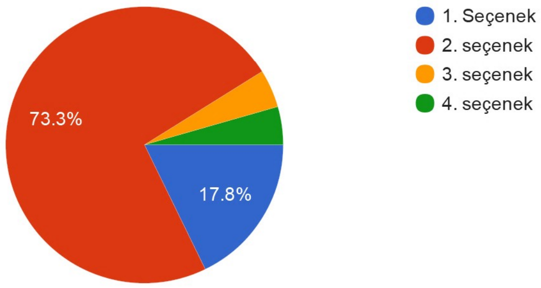
Which colour is the longest-thin tape? (45 responses)



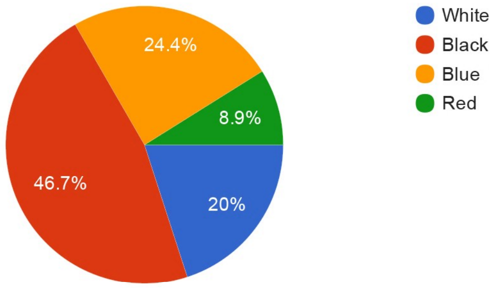
Which colour is the shortest-thin tape? (45 responses)



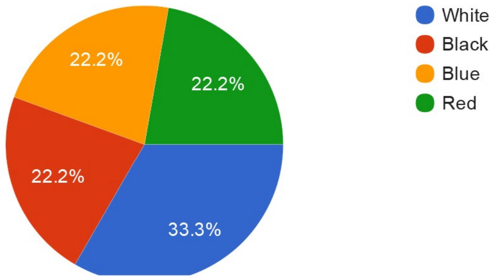
Which colour combination is true for perspective of the Design B?
(45 responses)



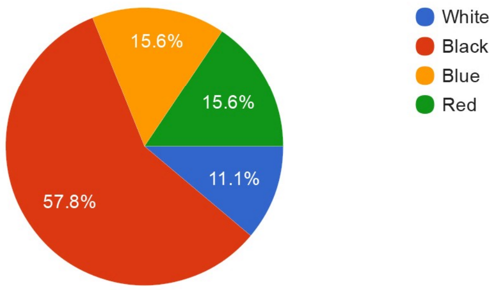
In which colour a triangle is intersected by another? (45 responses)



Which colour is the smallest triangle? (45 responses)



Which colour is the biggest triangle? (45 responses)



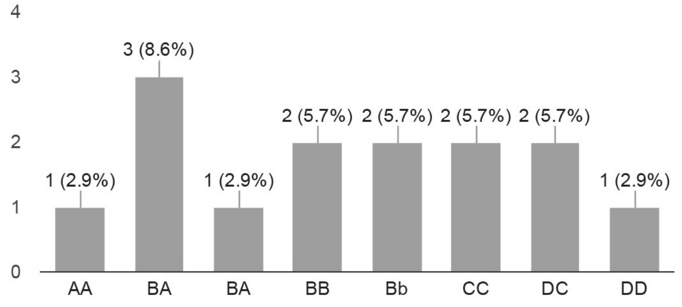
Appendix C:

Results of Second Group:

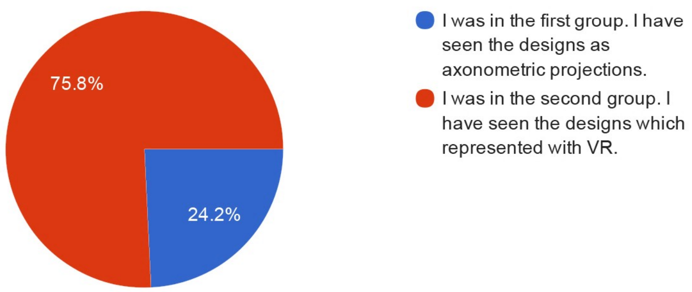
Virtual Reality in Basic Design Education

35 responses

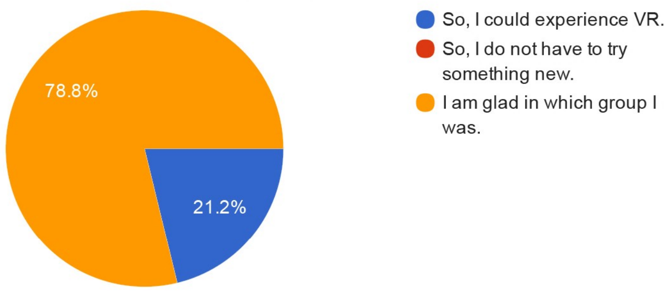
Basic Design Grade (14 responses)



In which group were you? (33 responses)

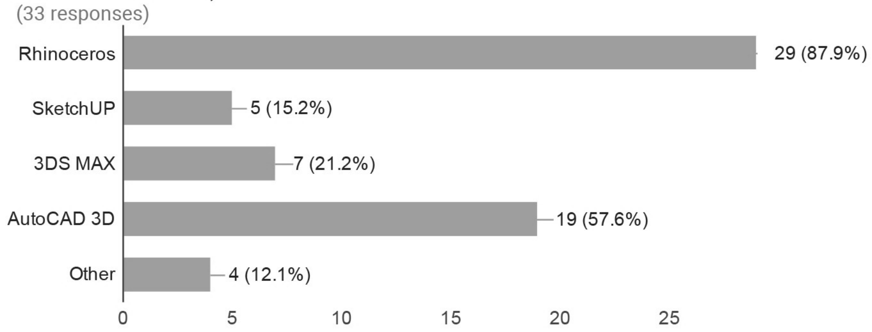


I wish I was in the other test group. (33 responses)



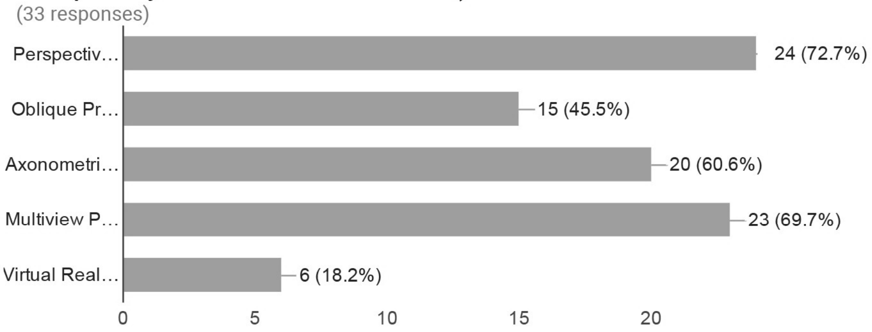
Which modelling software(s) can you use? (Check multiple if you use more than one.)

(33 responses)

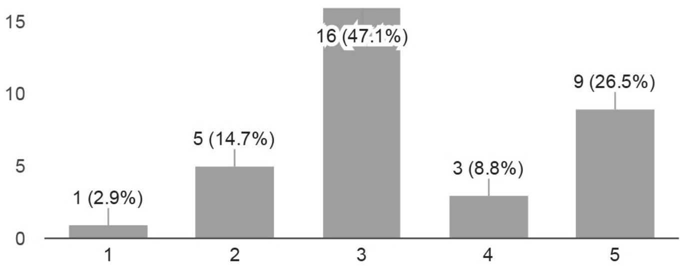


Which methods do you use for representation of your designs? (check multiple if you use more than one)

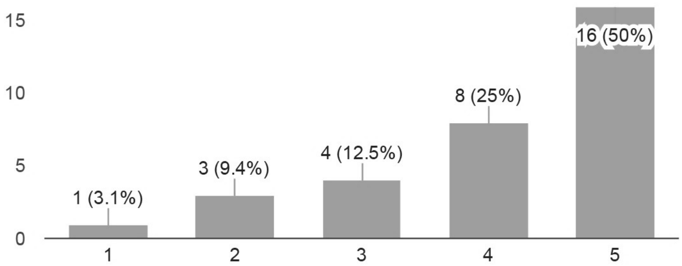
(33 responses)



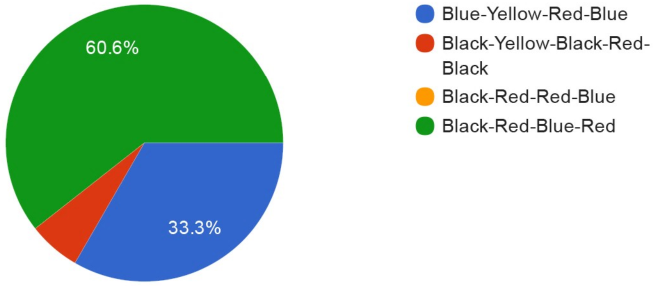
I follow latest technological developments in architecture. (34 responses)



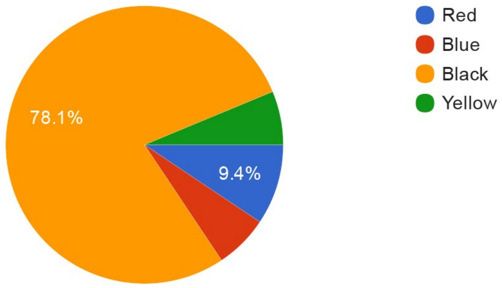
I would like to use VR in my design education. (32 responses)



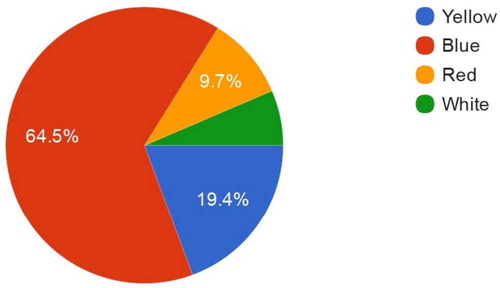
Which colour combination is true for a view of the Design A? (33 responses)



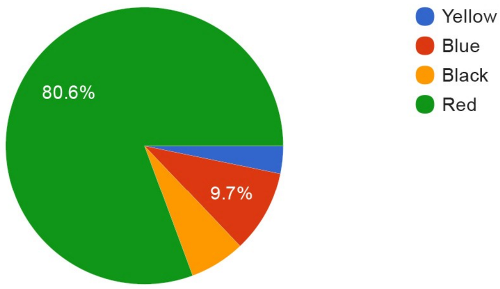
Which colour is the longest-thick tape? (32 responses)



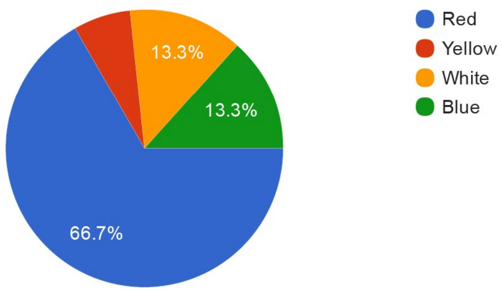
Which colour is the shortest-thick tape? (31 responses)



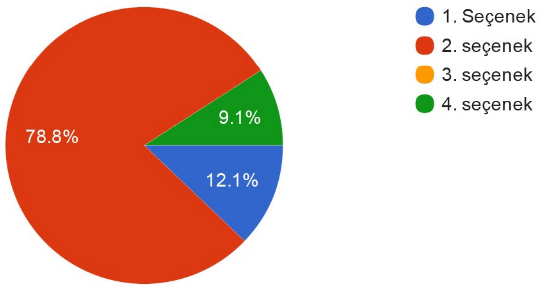
Which colour is the longest-thin tape? (31 responses)



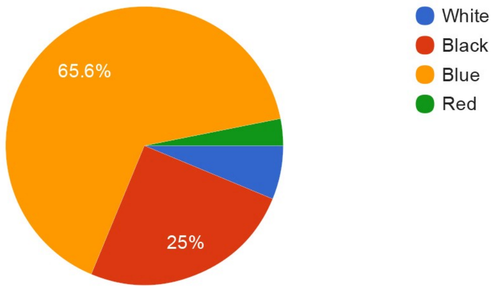
Which colour is the shortest-thin tape? (30 responses)



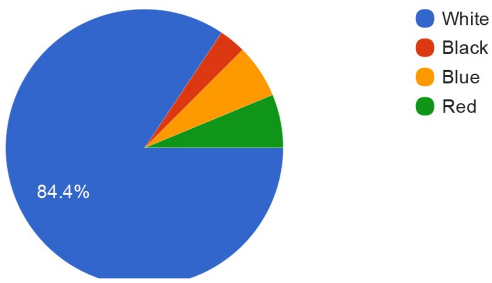
Which colour combination is true for perspective of the Design B?
(33 responses)



In which colour a triangle is intersected by another? (32 responses)



Which colour is the smallest triangle? (32 responses)



Which colour is the biggest triangle? (32 responses)