SAMAH OBEID

THE INFLUENCE OF VIRTUAL REALITY
ON DESIGN PROCESS CREATIVITY IN BASIC DESIGN EDUCATION

Bilkent University 2019

THE INFLUENCE OF VIRTUAL REALITY ON DESIGN PROCESS CREATIVITY IN BASIC DESIGN EDUCATION

A Master's Thesis

by

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Ankara

September 2019

To my parents,

Nouha & Ahmad

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The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

A Master's Thesis

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SAMAH OBEID

In Partial Fulfillment of the Requirements for the Degree of
MASTER OF FINE ARTS

THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
İHSAN DOĞRAMACI BILKENT UNIVERSITY
ANKARA

September 2019

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

Prof. Dr. Halime Demirkan

Supervisor

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

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ABSTRACT

THE INFLUENCE OF VIRTUAL REALITY
ON DESIGN PROCESS CREATIVITY IN BASIC DESIGN EDUCATION

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Supervisor: Prof. Dr. Halime Demirkan

September 2019

Creativity is an integral part of a design process. Recently, creativity supporting tools become very common in research. This study examines the influence of immersive and non-immersive virtual design environments on design process creativity in the first year basic design studio, through observing factors related to creativity as the flow state and motivation. Consequently, an experiment was conducted to investigate the relationships between spatial ability, flow state and motivation in immersive and non-immersive virtual design environments. Forty-two first year undergraduate basic design students joined the experiment. The data analysis demonstrated that the immersive virtual design environment facilitates participants' design process creativity. Also, the findings indicated a positive weak correlation between spatial ability and flow state, and a positive strong correlation between motivation and flow state. Study results contributed to a greater understanding of implementing immersive virtual reality as a creativity supporting tool.

Keywords: Creativity, Flow State, Motivation, Spatial Ability, Virtual Reality

ÖZET

TEMEL TASARIM EĞİTİMİNDE
YARATICI TASARIM SÜRECİNE SANAL GERÇEKLİĞİN ETKİSİ

Obeid, Samah
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Yaratıcılık, tasarım sürecinin ayrılmaz parçasıdır. Son zamanlarda yaratıcılığı destekleyen araçlar üzerine yapılan araştırmalar çok yaygın olarak görülmektedir. Bu çalışma birinci sınıf temel tasarım dersinde, kapsayan ve kapsamayan sanal tasarım ortamlarının tasarım süreci yaratıcılığına etkisini, düşünce akışı ve motivasyon faktörlerini gözlemleyerek incelemektedir. Bu nedenle, kapsayan ve kapsamayan sanal tasarım ortamlarında mekânsal beceri, düşünce akışı ve motivasyon arasındaki ilişkileri incelemek için bir deney tasarlandı. Birinci sınıf kırk iki temel tasarım öğrencisile deney gerçekleştirildi. Sonuç olarak, kapsayan sanal tasarım ortamının katılımcıların yaratıcı tasarım sürecini arttırdığı saptandı. Ayrıca analiz sonuçları, mekânsal beceri ve düşünce akışı durumu arasında pozitif zayıf ilişki; motivasyon ve düşünce akışı arasında pozitif kuvvetli ilişki olduğunu ortaya çıkardı. Araştırma sonuçları, kapsayan sanal tasarımın yaratıcılığı destekleyen bir araç olarak kullanımının, derinlemesine anlaşılmasını sağladı.

Anahtar Kelimeler: Düşünce Akışı, Mekânsal Beceri, Motivasyon, Sanal Gerçeklik Yaratıcılık

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LIST OF ABBREVIATIONS

ARCS	Attention Relevance Confidence Satisfaction
FSS	Flow State Scale
IMMS	Instructional Materials Motivation Survey
MRT	Mental Rotation Test
SPSS	Statistical Package for Social Sciences
VDE	Virtual Design Environment
2D	Two-dimensional
3D	Three-dimensional
PQ	Presence Questionnaire
SD	Standard Deviation
VE	Virtual Environment
VR	Virtual Reality
$\mathbf{M_d}$	Median
$\mathbf{M_o}$	Mode
df	Degree of Freedom
p	Significance Level
$\mathbf{r_s}$	Spearman's rho correlation tests
t	t-Test Statistic
x^2	Chi-square test for independence

CHAPTER I

INTRODUCTION

In today's design world, the implementation of immersive virtual reality (VR) technologies is becoming very common especially in basic design education. Studies about creativity support environments and creativity factors are also, recent topics in the design research field. However, educational institutions are not yet, able to adapt to this rapid development of creativity support tools. Today's design instructors aim at developing students design skills without paying much attention to their creativity skills or even more importantly the factors affecting the students' design creativity. Design process creativity is a critical phase that significantly influences the design product creativity (Jansson & Smith, 1991; Le Masson, Hatchuel, & Weil, 2011; Liu, Li, Pan, & Li, 2011; Shai, Reich, & Rubin, 2009). Therefore, in order to increase the product creativity it is necessary to understand the design process creativity and identify ways to facilitate it.

Basic design is a fundamental unit in design curriculums (Boucharenc, 2006; Cetinkaya, 2014; Findeli, 2001). Basic design studio courses are, in general, the basis for learning the visual language of design. This course prepares students for design programs by introducing them to the fundamental design skills and knowledge. Therefore, it is the base for advanced design studios. Immersive virtual design environments (VDEs) allow the users to experience 3D environments in a higher sense (Pausch, Shackelford, &

Proffitt, 1993). Immersive VDE is a simulated environment that enables the users to interact with the virtual space, in a somewhat real way, with the aid of devices such as a headset and controllers (Riva, 2006). Non-immersive VDE is a computer generated environment that enables the users to interact with the virtual space through a display screen (Vergara, Rubio, & Lorenzo, 2015). Previous studies demonstrated that VR tools, such as games, simulations and environments, could improve learning and education (Lau & Lee, 2015; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014).

Design students and designers should have high spatial ability, so they can easily understand and translate 2D and 3D spatial relations (Ho, 2006; McKim, 1972; Oxman, 2002). To improve spatial and creative abilities, Bonnardel and Zenasni (2010) suggested the development of simple computer software that allow users to easily design 3D virtual environments and objects.

Another important component that influences creativity is the flow state of the individual. In the process of an activity, Veale, Feyaerts, and Forceville (2013) found that the state of mind of an individual is a crucial factor that affects one's creative performance. Bhatt (2004) found that immersion is significantly correlated with the flow state. Lastly, motivation was recently identified as one of the crucial factors of creativity. Jeamu, Kim, and Lee (2008) claimed that the lack of motivation could restrict learners' success. Therefore, motivation is a crucial factor that could influence the learning process and performance (Sha, Looi, Chen, Seow, & Wong, 2012).

1.1 Problem Statement

The application of VR tools is observed in various fields. VR tools have a great potential for visualizing and understanding the complex design concepts, provoking new product design and motivating designers and design instructors for teaching and learning in immersive VDEs (Abulrub, Alex, & Mark, 2011; Arbeláez-Estrada & Osorio-Gómez, 2013). However, the use of immersive VDEs is rarely observed in the design process in profession and design education (Antonieta, 2015). In addition, creativity and spatial ability are found as crucial factors in design process and product, however, limited research exists on their relationship and role in design process (Cho, 2017). Moreover, previous studies claimed that motivation could be among the most significant components of creativity (Collins & Amabile, 1999; Runco, 2004; 2005). They also stated that even with the presence of other creativity components, the lack of motivation demonstrates in a less creative product (Collins & Amabile, 1999; Runco, 2004; 2005). In spite of the significance of motivation in design creativity, not much research is carried out in this domain.

1.2 Aim of the Study

In this respect, this study aims to present design instructors with means to facilitate students' design creativity. This study examines the influence of immersive and non-immersive VDEs on design process through observing factors of creativity as flow state and motivation. Also, this study aimed at investigating the relationships between the students' spatial ability, flow state and motivation. Previous studies examined the relations of spatial ability, flow and motivation to creativity separately, but did not examine them together (Pandey, Luthra, Yammiyavar, & Anita, 2015; Wei, Weng, Liu, & Wang, 2015; Yang et al., 2018). These studies generally observed creativity factors between traditional and VDEs. By examining these factors together between two VDEs, immersive and non-immersive, this study aims to offer different perspectives on the understanding of design process creativity and ways to facilitate it.

1.3 Structure of the Thesis

The chapters of the thesis are organized as follows. The second chapter aims at describing design process creativity by briefly presenting a literature review on creativity in the design field. Also, it includes a section on the factors that influence design process creativity, as spatial ability, flow state and motivation. In addition, the related studies are investigated and discussed in regard of their purposes and results.

In the third chapter, a literature review on the creativity supporting design environments is presented, focusing on immersive VR as the main creativity supporting environment. Recent creativity support studies are emphasized. Furthermore, the related studies on the applications of immersive VR in education and design are shortly covered in order to shape/develop the design framework of the study.

The fourth chapter covers the methodology of the study. Based on the previous chapters, the aim, research questions and hypotheses of the study are introduced. In addition, the research design and framework of the study are introduced in this chapter. The participants, the procedure and the design instruments are also explained in this chapter. Moreover, evaluation methods of factors related to creativity are discussed.

The fifth chapter presents the results of the study. In addition, the findings regarding the influence of immersive and non-immersive VDEs on design process creativity are demonstrated and the relationships between spatial ability, flow state and motivation of students are discussed.

The sixth chapter discusses the findings of the study and relates them to the existing literature. It develops on the influence of immersive and non-immersive VDEs on design process creativity and on the relationships between spatial ability, flow state and motivation and their implications. This chapter also compares findings with relevant previous studies.

The final chapter draws an overall conclusion on the research study. This chapter discusses the limitations of the study and possible future research areas. It also states the thesis’s contribution to the literature. This chapter is followed by the references and appendices covering the design brief, the questionnaires and sample projects of the experimental study.

CHAPTER II

UNDERSTANDING DESIGN PROCESS CREATIVITY

This chapter briefly presents a literature review on design process creativity while emphasizing the role of creativity as a crucial factor in design process that greatly influences the design outcome. Also, it includes a section on the observed factors that influence creativity in design process, which are spatial ability, flow state and motivation. Furthermore, it introduces the basic design studio as the ideal environment to develop and explore design creativity.

2.1 Basic Design Education

Basic design is a fundamental course in all fine art institutions. According to Denel (1998), among design courses, basic design is considered essential since it introduces the students to the fundamental design principles. In basic design studios students are exposed to theory and practice that help them in developing required skills for later stages of design education. This course deals with the design elements, principles, geometric forms in 2D and 3D compositions and their relations and systems of organization. Design students must be first introduced to these basic principles and concepts in order to provide them with the ability to visually read and express design. This visual language is the core of design. Wong (1993) claims that designers should learn the basic design principles and relationships in order to enhance their abilities in visual organization.

In basic design studios, students deal with abstract design problems with the main focus on aesthetic rather than functionality in design solutions (Yoon & D'souza, 2009). This course is the basis of design development. It prepares students for further design studios and provides them with the fundamental skills and knowledge needed for design education. Therefore, it is a foundation must course for all design departments. In this respect, the sample of this study was targeted at basic design students and the experiment required participants to solve a basic design problem.

Design studio environment influences students' understanding of basic design thinking, action and theory (Schön, 1985). Varínlíoğlu, Akçam, and Halıcı (2015) demonstrated that the implementation of digital tools in early design process significantly influences the design outcomes. Varínlíoğlu et al. (2015) claimed that when digital environments are experienced in early design stages, students tend to participate more enthusiastically in the process and to be more motivated to solve advanced design problems.

Hasirci and Demirkan (2007) examined the three components of creativity by addressing the intuitive phases of the creative decision making process in a design studio. The findings of this study confirm that the most signification interaction was between process and overall creativity. Demirkan and Afacan (2012) conducted a study with the aim to examine creativity in design education and determine the factors of creativity assessment in basic design studios.

2.2 Creativity in Design Process

Design is characterized as a repetitive process aimed at testing design ideas (Zeisel, 2006). Design process consists of a series of determined problem solving activities (Karakaya & Demirkan, 2015). It includes tasks such as questioning, imagining, planning, creating and improving design ideas (Yu-Shan, Hung-Chang, Yu-Hung, & Wan-Hsuan, 2018). The outcome of a design process consists of an abstract or concrete design solution to a specified design problem (Milgram, 1989). The outcome of a design process is usually expected to be original, functional and new that adds value to the world of design (Christiaans, 2002). Design outcomes, products and ideas are often examined to assess the design product creativity in terms of novelty and functionality (Sternberg & Lubart, 1999). The elements of design process are reflected on the design outcome (Weisberg, 1988).

One of the essential components of a design process is creativity. Due to the complex nature of this concept, there is no concise definition that comprises all the characteristics of creativity (Demirkan & Afacan, 2012; Horn & Salvendy, 2006). In this research, creativity is defined as the creative transition that arises between the problem and solution phases of a design (Demirkan, 2010), and is investigated by examining related factors.

Creativity is a main factor in the assessment of products, such as ideas, solutions and inventions (Horn & Salvendy, 2006). Besides, creativity is as a major component in assessing the quality of design performance (Christiaans, 2002). Furthermore, design creativity is considered as the process that occurs repetitively in design problem and solution phases (Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004; Wiltschnig, Christensen, & Ball, 2013). Therefore, in order to improve the product creativity, it is necessary to understand the design process creativity and identify the means to facilitate it.

Creativity is studied in many disciplines as cognitive science and neurology (Dietrich, 2004), management (Sawyer, 2011), sociology and psychology (Simonton, 2000). Creativity is a current common issue in educational environments (Castillo-Vergara, Galleguillos, Cuello, Alvarez-Marin, & Acuña-Opazo, 2018). Hansenne and Legrand (2012) reported, in a previous study, a positive significant association between creativity and academic performance.

Generating creativity is the main objective in design education (Casakin, Davidovitch, & Milgram, 2009; Sim & Duffy, 2004) and design problem solving process (Christiaans, 2002; Cross, 1997; Gero, 2000). In a previous study, researchers investigated methods to stimulate and support creativity, especially in education (Shneiderman, Fischer, Czerwinski, Resnick, Myers, Candy et al., 2006). In this research, creativity is investigated by the assessment of three main factors that are found to be influential components of design process creativity that are spatial ability, flow state and motivation.

In the previous years, a few studies have examined the creative process in order to better understand the development of creative design and to define the relation between creative process development and creative product development (Roy & Design Innovation Group, 1993). Hasirci and Demirkan (2003) investigated the relationship between the three components of creativity, person, process and product, inside two sixth grade art rooms that were considered as the creative environment. The findings of this study showed a significant difference between the three components of creativity.

Demirkan (2010) examined that it is necessary to consider the relationship between the components of creativity, person, process and product, inside a creative environment in architectural design processes, and in the assessment of creativity. Even though these four components of creativity were claimed to act together, some studies focused on one component or the relation between the components (Demirkan & Afacan, 2012).

2.3 Factors Influencing Creativity in Design Process

Design process creativity could be improved by facilitating the factors related to it. In this study, three main factors are observed, which are spatial ability, flow state and motivation. This part briefly introduces these factors and their relation to creativity.

2.3.1 Spatial Ability

The term spatial ability covers a range of abilities mainly related to 2D and 3D mental representations. Spatial ability is referred to as the ability to represent, transform, induce and generate physical and abstract information (Linn & Petersen, 1985). In the literature, spatial ability was referred by various terms that differ according to the studied field, such as spatial cognition (Ho, 2006), spatial reasoning (Hegarty & Waller, 2005) and spatial skills (Linn & Petersen, 1985; Miller & Bertoline, 1991). Spatial ability involves different abilities (Hegarty & Waller, 2005) and encloses three different subcategories, defined by Linn and Petersen (1985) as spatial visualization, mental rotation and spatial perception.

In a longitudinal study, Wai, Lubinski, and Benbow (2005) demonstrated that early spatial ability of students affects their creativity and academic performance at later stages of their life. Therefore, according to Pandey et al (2015), a student with a higher spatial ability is able to provide more creative solutions. Furthermore, previous studies in the literature pointed out that both spatial ability and creativity are considered as important abilities in interior design (Allen, 2010; Ho, 2006). The main objective of interior design is to generate 3D designs with the consideration of different design elements (Gabrielli & Gardner, 2014). Spatial ability is essential for designers, so they can easily communicate and transform 2D and 3D spatial information to design outcomes.

The generation of architectural forms is by definition a creative act (Pandey et al., 2015). The creative solutions proposed by students are mainly a product of their spatial ability (Pandey et al., 2015). When students are creating a 3D composition from abstract mental representations, they are basically employing their spatial ability (Pandey et al., 2015). In the design process, students deal with 2D and 3D spaces in all stages where they need to interpret and transform 2D information to 3D information and vice versa. Therefore, the ability to visualize, infer and present 2D and 3D spatial information is crucial for communicating and generating design solutions (McKim, 1972; Oxman, 2002). The designers' ability to imagine 3D spaces highly affects the design outcome and the reflected design quality (Cho, 2017). As Ho (2006) stated, Frank Lloyd Wright emphasized spatial ability as a necessary ability for designers, since it assists them in completing design solutions mentally before finalizing the physical drawings.

Cho (2017) investigated the relationships between design studio performance and cognitive abilities in design such as individual creativity, spatial ability and visual cognitive style. The findings illustrated that design studio performance could not be directly evaluated by the cognitive abilities of students. Therefore, results highlight the need for understanding students' abilities and supporting design process in education.

2.3.2 Flow State

The flow state is defined by Jackson and Marsh (1996) as a positive observational state that occurs when the performer is completely linked to the performance, with the condition that personal skills of the performer match with the imposed challenges of the task. When people enter the flow state, they become completely involved in the activity and they experience different positive sentiments such as freedom, self-consciousness and great satisfaction of the process (Jackson & Marsh, 1996). The flow state is accompanied by different sentiments whereby the person involved in the activity experiences clarity of goals and knowledge of performance, complete concentration, feelings of control and feelings of being totally connected to the performance (Jackson & Marsh, 1996).

Bhatt (2004) stated that immersion is significantly correlated with the state of flow. Immersion is a mental state users of VR tools experience when they feel totally separated from the real world (Yang et al., 2018). Being highly immersed in a situation facilitates the generation of creative ideas (Csikszentmihalyi, 1996; Witmer & Singer, 1998). Csikszentmihalyi (1996) defined flow, as the psychological state individuals experience when they are fully immersed and focused on a certain activity. A previous study by

Seligman and Csikszentmihalyi (2014) observed that people demonstrate a higher level of performance creativity when they are in the flow state.

Veale et al. (2013) found that the flow state is a crucial factor in creative design process that influences the designer’s creative performance. Therefore, the flow theory provides a conceptual framework for the relationship between designers’ state of mind and performance creativity (Yang et al., 2018). The flow state scale (FSS) developed by Jackson and Marsh (1996) covers nine dimensions defined by Csikszentmihalyi (1996), namely as, challenge-skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness, transformation of time and autotelic experience.

The nine dimensions were defined by Csikszentmihalyi (1996) as follows. Challenge-skill balance refers to how the flow state allows individuals to feel that their skills match the challenges of the situation they are involved in. Action-awareness merging is when the involvement of the individual with the situation is so deep that it becomes spontaneous. Thus, the individuals only become aware of the actions that they are performing. Clear goals refers to a state where the individuals’ goals in a certain situation are clearly defined so the individual knows exactly what they are going to do. Unambiguous feedback occurs when the individuals are able to evaluate their performance. Concentration on task at hand is a dimension where the flow state allows individuals to experience total concentration on the matter at hand. Sense of control is experienced when the individual feels in operated control of the situation without having to try to take control. Loss of self-consciousness is when the individuals are not worried about their performance or others’ opinion as they feel connected with the activity. Transformation of time is when the individuals experience the time alters distinctly, either slowing down or speeding up. Alternatively, time may simply become irrelevant or out of one’s awareness. Autotelic experience is the intrinsically rewarding experience that individuals feel when in the flow state. An activity is autotelic when it’s done for its own sake, with no expectation of reward or benefit.

2.3.3 Motivation

In the previous literature, it was frequently demonstrated that creativity depends on various different factors, while recently, motivation is identified as a major factor influencing creativity (Collins & Amabile, 1999; Runco, 2004; 2005). Casakin and Kreitler (2009) investigated the role of motivation as a crucial component of creativity. Previous studies suggested that the lack of motivation reflects on the expected product creativity (Collins & Amabile, 1999; Runco, 2004; 2005). Based on design studio courses, Casakin and Kreitler (2009) observed that teachers assess creativity based on the design outcome rather than the motivational aspects that led to it. They claimed that most of the time, the focus is on stimulating creativity without being aware of the designers' motivation. Therefore, teachers mainly focus on the structure of creativity without noticing the driving factors that influence it. Despite the importance of motivation as an influential component in design creativity, not much research is carried out in this domain. In this study, the aim is to demonstrate that creativity can be improved by facilitating the factors influencing it.

In education, motivation is defined by Keller and Litchfield (2002) as the students' desire to participate in a learning environment. A study conducted by Jeamu et al. (2008) demonstrated that the lack of motivation could prevent learners' success. Motivation is a major component that stimulates and improves learning performance (Gagné, 1985; Keller, 1987). Taking into consideration the influential effect of motivation on learning process, many studies were conducted to investigate the relationship between motivation and learning performance (ChanLin, 2009; Huang, Huang, Diefes-Dux, & Imbrie, 2006; Johnson, 2012; Sha et al., 2012). In a study conducted by Sha et al. (2012), the researchers demonstrated that motivation is a crucial factor that could influence the learning process and performance.

According to Keller and Suzuki (2004) there are four components in learning process that affect motivation, which are attention, relevance, confidence and satisfaction (ARCS). A variety of strategies should be integrated to gain learners' attention (Attention), clear goals should be defined and the instructions should be relevant to the learners past experience (Relevance), the learning environment should help learners develop a feeling of success (Confidence), and attain a satisfactory feeling from the activity (Satisfaction) (Keller & Suzuki, 2004).

Liu et al. (2011) claimed that it is difficult for many people to develop creative ideas using typical tools such as papers and pens. Many individuals require the assistance of tools that facilitate creativity in order to develop creative designs and products (Gabriel, Monticolo, Camargo, & Bourgault, 2016). Thus, creativity support tools could offer great assistance in the development of creative designs and products (Wang & Nickerson, 2017). In the following chapter, creativity support environments are examined within the scope of virtual design environments.

CHAPTER III

DESIGN PROCESS CREATIVITY SUPPORT ENVIRONMENTS

This chapter briefly presents a literature review on VR. It shortly covers some of the applications of VR in education and design. Furthermore, it introduces immersive and non-immersive VDEs as creativity supporting environments in design process.

3.1 Virtual Environments Supporting Creativity

Previous studies argued that creativity support tools are crucial for development of ideas and creative designs (Gabriel et al., 2016; Klein & Dologite, 2000; Shneiderman, 2007; Wang & Nickerson, 2017). Creativity support tools could be defined as the tools that help create appropriate environments for facilitating the generation of creativity. Several studies reported the limitation of existing creativity support tools (Gabriel et al., 2016; Olszak, Bartuś, & Lorek, 2018; Wang & Nickerson, 2017).

Creativity support tools were developed to facilitate computer based design (Chaudhuri & Koltun, 2010) and decision making (Voigt, Niehaves, & Becker, 2012). Forgionne and Newman (2007) found that creativity support tools could assist in solving complex design problems. Moreover, Shneiderman (2002) claimed that creativity support tools eliminate the expertise barrier and cost limitation of developing different design solutions in real environments, thus, making designers more motivated towards accomplishing tasks in a creativity support environment.VR was defined by Sherman and Craig (2002) as a technology that uses computer software to generate interactive simulations that are capable of sensing the user's movements with the capacity to expend the responses, allowing the user to experience the feeling of being mentally immersed or present in the simulation, which is the VE. Therefore, the user is able to interact with the simulated VE by lifting, moving and selecting virtual objects. This VE might occur in an empty room by the means of a headset or any other VR tool (Billinghurst, 2002). Computer generated environments, VEs, could be described as a continuous process between a completely real environment and a completely virtual environment (Milgram et al., 1995) (see Figure 1).

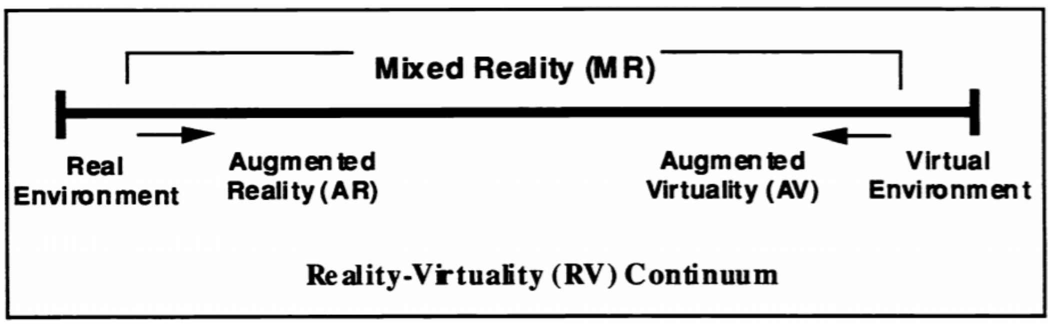

Figure 1. Reality-Virtuality Continuum (Milgram et al., 1995, p. 283)

3.2 Virtual Environments in Design Education

VR tools are basically designed to create a digital environment with one or more sensory input and to power interactivity, real-time rendering and self-navigation. Other related terminologies to VR include the terms immersive environments, mixed reality, hyper reality and augmented reality (Erdoğan Ford, 2017). Erdoğan Ford (2017) claimed that VR is rapidly becoming a remarkable component for educational institutions. Its capacity to enclose multiple formats and types of documentation within the virtual space gave it the advantage and strength as a tool for instruction (Erdoğan Ford, 2017). VR is found by Teklemaria, Kakati, and Das (2014) as the appropriate tool for speeding up the decision making process in early design stages. However, there is not enough research dedicated to the implementation of VR within the design education (Milovanovic, Moreau, Siret, & Miguet, 2017).

It is obvious that the application of VR tools positively contributed to several scientific fields (Teklemariam et al., 2014). However, the application of VR tools in architectural design remains rare (Donath & Regenbrecht, 1999; Hemmerling, 2008; Knight, Brown, Hannibal, Noyelle, & Steer, 2003). Antonieta (2015) argued that it is the researchers and instructors responsibility to develop approaches for the implementation of the appropriate VR tools in design education. VR tools could improve the physical settings, and facilitate real experience and individual creativity (Jou & Wang, 2013; Wei et al., 2015). Fox, Arena, and Bailenson (2009) claimed that VR is an important tool that could be implemented for social science research.

VR presents as an essential and interactive tool to express ideas and overcome the technical gap in the design process (Ran & Zhenbiao, 2011). VDEs are found as the appropriate environment for design juries as it reduces the creation time and costs, and improves the quality and usability of new designs (Teklemariam et al., 2014). Thus, Teklemariam et al. (2014) claimed that it is necessary to integrate VR in design education, thus, requires research on design applications in this domain.

Previous studies demonstrated the potential of VR in stimulating motivation in learning (Huang, Liaw, & Lai, 2016; Roussou, 2004). Several studies demonstrated the positive effect of VR applications on the students in education and training as they could receive significant and interactive feedback in VEs (Atilola, Tomko, & Linsey, 2016; Carrozzino & Bergamasco, 2010; Hussein & Nätterdal, 2015; Jou & Wang, 2013; Kilmon, Brown, Ghosh, & Mikitiuk, 2010; Merchant et al., 2014; Thorsteinsson, 2013). In educations, VDEs can be classified mainly into two categories as being, immersive or non-immersive (Vergara, Lorenzo, & Rubio, 2015).

3.2.1 Immersive Virtual Design Environments

Immersion is described by Bhatt (2004) as the mental condition users of VR tools enter in which they feel isolated from the real world. The psychological state achieved by physical immersion is found to be positively related to the development of the sense of presence. The presence is defined as the persuasive sense of being totally immersive in the virtual world, allowing the evaluation of more advanced aspects of the VE (Rebelo, Duarte, Noriega, & Soares, 2011). Thus, the effectiveness of a VE is linked to the level of presence that a person experiences during the experience (Antonieta, 2015). The characteristics of immersive VR tools made them so popular in education and training (Burdea & Coiffet, 2003; Gavish et al., 2015). Previous studies found that creative ideas are more likely to develop when people are immersive in a certain activity (Csikszentmihalyi, 1996; Witmer & Singer, 1998). However, the use of immersive VDE is mainly limited to the presentation of the final artifact due to its cost and technical complexity (Antonieta, 2015).

VR is characterized by enhancing the interaction, immersion and imagination in a VE, resulting in different levels of presence (Burdea & Coiffet, 2003). These factors, along with the degree of intrusion and discomfort caused by the devices, result in different degrees of presence. Currently, immersive VR tools are used mostly in the gaming industry, however, little research has been done in the education and research fields (Freina & Ott, 2015). Immersive VR tools are advantageous, since they allow people to experience environments that are difficult to experience in reality in terms of time and safety. A previous study conducted by Yang et al. (2018) examined the effect of immersive VR on individual’s creativity between traditional, paper and pencil, and VR tools. The findings of the study showed that the immersive VDEs could stimulate performance creativity.

3.2.2 Non-Immersive Virtual Design Environments

In education, a non-immersive VDE, allows the users to perceive the world through the glasses of a digital tool, thus the users are able to experience the virtual space through the means of a flat digital screen (Vergara et al., 2015).

Tano et al. (2003) investigated creativity between traditional 2D and digital 3D environments. The findings of this study demonstrated that 3D perspectives and digital tools could stimulate creativity. One of the main advantages of VR is that it provides the user with a somehow real 3D environment perspective and facilitates 3D designs. Yang et al. (2018) claimed that VR environments could improve one's creative thinking and behavior due to its additional perspectives, tools and full-body involvements. In addition, full-body movements and interactions were previously discussed in research as advantageous in education and training. Digital tools promote individual and group creativities in different areas (Wang & Nickerson, 2017). Digital tools can assist creative people in generating and communicating knowledge in the development of creative ideas (Greene, 2002; Harley, Poitras, Jarrell, Duffy, & Lajoie, 2016).

The following chapter introduces the methodology design of this study. It states the aim, the proposed research questions, hypotheses and framework of the study. It also provides information about the participants, settings, procedure and instruments of this study.

CHAPTER IV

METHODOLOGY

Based on the previous literature review, this chapter introduces the objectives and the research design of this study. Also, it describes the experiment conducted within this research. Thus, it briefly presents the research questions, hypotheses and framework of the study. It also provides information about the participants, settings, procedure and instruments of the experiment.

This study investigated the influence of immersive and non-immersive VDEs on design process creativity in basic design studio through observing factors related to creativity as flow state and motivation. This study also aimed at investigating the relationships between the students' spatial ability, flow state and motivation. To do so, an experiment was conducted to understand the relationships between spatial ability, flow state and motivation in immersive and non-immersive VDEs. In the non-immersive VDE, participants used iPad mini A1432 in the design phase. Whereas, in the immersive VDE, participants used Oculus Rift DK2 to complete the design task.

4.1 Research Questions and Hypotheses

The objective of this study was to investigate the influence of immersive and non-immersive VDEs on factors related to individuals' creativity and therefore, provide to design instructors the means to facilitate and support design creativity. In this respect, the following research questions were formulated and the correspondent hypotheses were tested:

Q_1: Does the immersive VDE stimulate design process creativity?

- **Q_{1a}:** Does the immersive VDE influence the flow state in design process?
- **Q_{1b}:** Does the immersive VDE influence motivation in design process?

Q_2: Is there a relationship between spatial ability and design process creativity?

- **Q_{2a}:** Is there a relationship between spatial ability and the flow state?
- **Q_{2b}:** Is there a relationship between spatial ability and motivation?

H_1: There is a significant difference in design process creativity between immersive and non-immersive VDEs.

- **H_{1a}:** The immersive VDE has a positive significant influence on the flow state.
- **H_{1b}:** The immersive VDE has a positive significant influence on motivation.

H_2: There is a positive correlation between spatial ability and design process creativity.

- **H_{2a}:** There is a positive correlation between spatial ability and flow state.
- **H_{2b}:** There is a positive correlation between motivation and the flow state.

4.2 Framework of the Study

The proposed framework aimed at constructing a more complete picture of how to facilitate design process creativity. Thus, it covers crucial factors that demonstrated impact on design creativity in the previous literature. These factors are spatial ability, flow state and motivation in the VDE (see Figure 2).

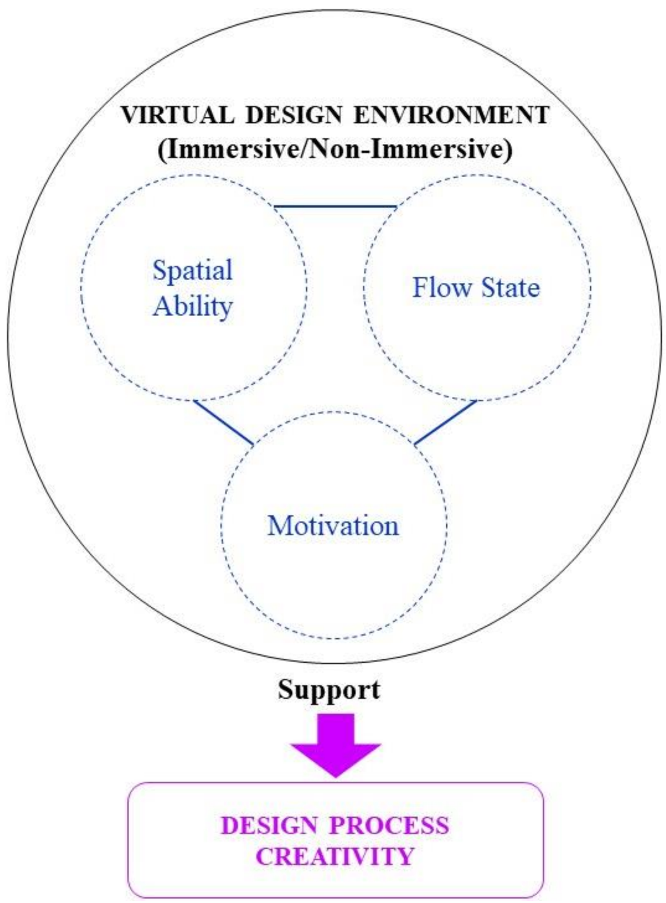

Figure 2. Conceptual Framework of the Study

4.3 Participants of the Study

Before starting the experiment, the approval of the ethics committee at Bilkent University was sought in order to work with Bilkent students (N_O: 2019_03_27_02). A document covering the study aims, methodology including participants, procedure and instruments was submitted to the committee. A students' consent form was also submitted and revised by the ethics committee. The consent form includes information about the purpose, procedure, benefits and confidentiality issues associated with the study. After having read, understood and accepted the procedure of the experiment a copy of the consent form was distributed and signed by each participant. Participants were selected by random sampling method. The participation in the study was entirely on voluntary basis and participants had the right to withdraw from the procedure at any stage of the experiment. Participants were not compensated for their participation in this experiment. No money was paid for participating in this research study nor were extra credits given within the course of Basic Design Studio II (for the students' consent form, see Appendix A).

The study was conducted in the Basic Design Studio II course offered as part of the interior architecture and environmental design program. The students attended the course during the 2018-2019 spring semester. The experiment took place in a regular empty office room at the department of Interior Architecture and Environmental Design with a desk and a chair placed inside the room. This office room is known as the experiment room and is mostly used for research purposes. The students were informed about the experiment by the researcher and they voluntarily signed up for participation. A total of 42 undergraduate design students at Bilkent University were recruited for the study. The participants were between 19 and 23 years old. Twenty-one participants (12 female and 9 male) solved the design task in an immersive VDE using Oculus Rift DK2, while the other 21 participants (17 female and 4 male) solved the design task in a non-immersive VDE using iPad mini A1432. Given the available tools, participants joined the experiment one by one, and they were divided randomly into the two groups, immersive and the non-immersive VDE.

4.4 Instruments of the Study

In this study, two virtual environment tools were used to complete the design task on the software Gravity Sketch; Oculus Rift DK2 and iPad mini A1432. While five survey instruments were used to assess the participants' responses; the demographic questionnaire (Appendix B), the mental rotation test (MRT) (Appendix C) (Peters, Laeng, Latham, Jackson, Zaiyouna, & Richardson et al., 1995), the presence questionnaire (PQ) (Appendix E) (Witmer & Singer, 2005), the flow state scale (FSS) (Appendix F) (Jackson & Marsh, 1996) and the instructional materials motivation survey (IMMS) (Appendix G) (Keller, 2010).

4.4.1 Virtual Environment Tools

This section covers the VE tools used in the design task, which are Oculus Rift DK2 and iPad mini A1432.

Oculus Rift DK2

The Oculus Rift DK2 is a high tech visual tool consisting of a headset, two wireless controllers and two sensors (see Figure 3). The Oculus Rift tool is an immersive VE tool that enabled the participants to feel present in the VR space, where they could create virtual objects and move freely around them. The participants were able to create, edit and interact with the virtual objects by using the wireless controllers held in both hands. The participants were able to walk around their design, and draw on any part of it.

Figure 3. Oculus Rift DK2 tool, retrieved from https://www.oculus.com

iPad mini A1432

The iPad allowed the user's to perceive the VE through its flat screen. Thus, the iPad is defined as a non-immersive VE tool (Vergara et al., 2017). In contrast with the immersive VDE, the participants in the non-immersive VDE were not able to interact with the VE, nor were they able to walk around their design.

4.4.2 Gravity Sketch

Gravity Sketch is an intuitive and immersive 3D design software that is compatible with the tools Oculus Rift DK2 and iPad mini A1432. The purpose of this study was to provide both groups with equally equipped digital design tools in different VDEs; immersive and non-immersive. Thus, Gravity Sketch software was chosen to design in the VR environment. The software offers a variety of options and tools allowing participants to conceptualize, visualize and communicate their ideas in no time. Some of the mainly used commands allowed participants to create regular geometric shapes that could be moved, rotated, scaled, copied and overlap in all directions. These characteristics made the software appropriate for the basic design problem (see Figures 4 & 5).

Figure 4. Gravity Sketch software in Immersive VDE, retrieved from https://gravitysketch.com

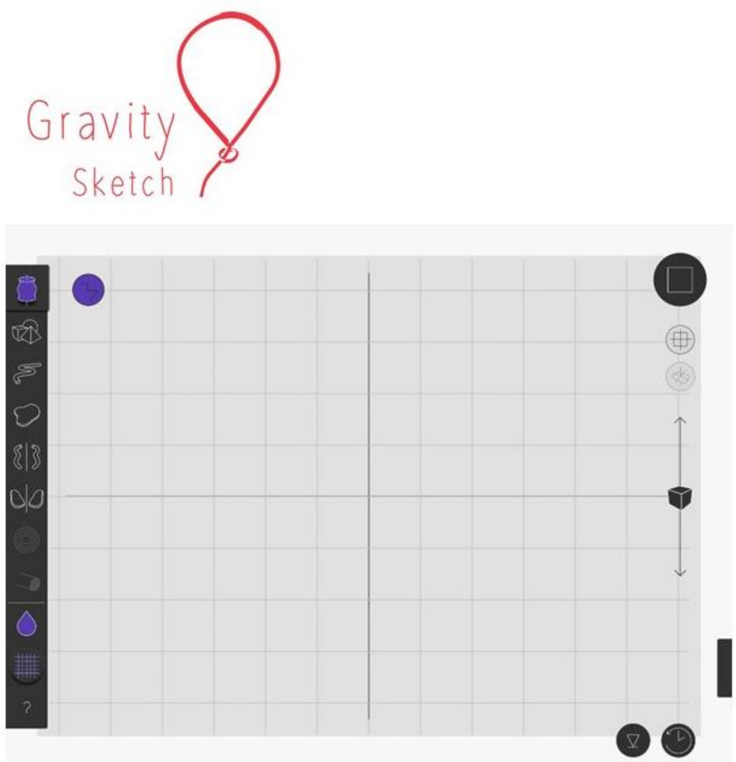

Figure 5. Gravity Sketch software in Non-immersive VDE, retrieved from https://gravitysketch.com

4.4.3 Survey Instruments

This section covers the instruments used in the assessment of the participants' experience, which are the demographic questionnaire, the MRT, the PQ, the FSS and the IMMS.

Demographic Questionnaire

The demographic questionnaire covered information about the participants' demographic variables including age and gender. It also covered information regarding the participants experience with VR (see Appendix B).

Mental Rotation Test for Spatial Ability

The participants' spatial ability was assessed by the MRT. The MRT is a major instrument in assessing spatial ability (Caissie, Vigneau, & Bors, 2009). Previous studies demonstrated the use of MRT in many design programs (Gorska & Sorby, 2008; Sorby, 2007). Vandenberg and Kuse (1978) claimed that the MRT assesses spatial visualization and mental rotation components.

The MRT consists of 24 items. Every item consists of five geometrical drawings with one target drawing on the left followed by four drawings including two correct rotated versions of the target drawing and two distractions. The test takers were required to indicate the two correct rotated reproductions (Caissie et al., 2009; Gorska & Sorby, 2008). The test takers were restricted in time as mentioned in the instruction section of the redrawn MRT. The maximum score that can be received on the MRT is 24. A score from 0 to 7 indicates a low spatial ability, while a score from 8 to 12 indicates a moderate spatial ability and a score from 13 to 24 indicates a high spatial ability.

Reliability of this instrument was found satisfactory; retest correlation was reported at 0.83 (Vandenberg & Kuse, 1978). However, available versions of the Vandenberg and Kuse (1978) are unclear since these are copies of copies. Thus, in a later study by Peters et al. (1995), the researchers redrew the Vandenberg and Kuse (1978) MRT and tested its reliability and validity. A copy of the redrawn MRT was provided to us by Prof. Dr. Micheal Peters under certain regulations. Due to these regulations the full MRT version was not included in this thesis (for sample items of the MRT see Appendix C).

Presence Questionnaire

When applied to a VE, Witmer and Singer (1998) define presence as the intuitive experience of feeling totally present in a virtual space while actually being physically situated in another one. The effectiveness of VEs is often measured by the sense of presence that is reported by the users (Witmer & Singer, 1998). Thus, the effectiveness of a VR experience is measured by the level of presence experienced by the participants in that VR space (Antonieta, 2015). To create effective immersive VR experiences and to study those environments it is, therefore, necessary to assess presence. The degree of presence is usually assessed by a questionnaire given to the users after experiencing a VR scene (Schwind, Knierim, Haas, & Henze, 2019). The PQ originally included 32 items, then, in a later study by Witmer and Singer (2005) the items were reduced to 19 (for sample items of the PQ see Table 1). The PQ was used to assess the degree of presence experienced by the participants in the immersive VDE on a 7-point Likert scale (for the full items of the PQ see Appendix E). A low score from 1 to 3 indicates that the participants experienced a low sense of presence during the design process, a medium score of 4 indicates that the participants experienced a moderate sense of presence during the design process and a high score from 5 to 7 indicates that the participants experienced a high sense of presence during the design process.

Table 2. Sample items of the PQ (Witmer & Singer, 1998, pp. 302)

Items	
Q1	How much were you able to control events?
Q2	How responsive was the environment to actions that you initiated?
Q3	How natural did your interactions with the environment seem?
Q4	How much did the visual aspects of the environment involve you?
Q5	How natural was the mechanism which controlled movement through the environment?

Flow State Scale

In this study, the design process was evaluated by the evaluation of the participants' flow state level during the task. The FSS is defined by Jackson and Marsh (1996) as a self-assessment survey that indicates the flow state level of an individual in a certain situation. The FSS includes 36 items on a 5-point Likert scale, where 1 refers to strongly disagree and 5 to strongly agree (Jackson & Marsh, 1996). A low score from 1 to 2 indicates that the participants experienced a low level of flow state during the design process, a medium score of 3 indicates that the participants experienced a moderate level of flow state during the design process and a high score from 4 to 5 indicates that the participants experienced a high level of flow state during the design process.

Jackson and Marsh (1996) verified the reliability of the scale with a sample of 394 where Cronbach's alpha of FSS full items is at any rate 0.8. The FSS developed by Jackson and Marsh (1996) is based on nine dimensions that the individual experience in the flow. These dimensions are defined by Csikszentmihalyi (1996) as challenge-skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness, transformation of time and autotelic experience. The FSS was used to assess the flow state of participants in the immersive and non-immersive VDEs (for sample items of FSS see Table 2 and for the full items of the FSS see Appendix F).

Table 3. Sample items of the FSS (Jackson & Marsh, 1996, pp. 34-35)

Items	
Q1	I was challenged, but I believed my skills would allow me to meet the challenge.
Q2	I made the correct design decisions without thinking about trying to do so.
Q3	I knew clearly what I wanted to do.
Q4	My attention was focused entirely on what I was doing.
Q5	I felt in total control of what I was doing.

Instructional Materials Motivation Survey

Motivation is a crucial factor in learning and creativity (Wei et al., 2015). In this study, the participants' motivation towards design was assessed by the IMMS which measures individuals' self-perception of motivation (Keller, 2010). According to Keller and Suzuki (2004), in the learning process, motivation is based upon four components, which are attention, relevance, confidence and satisfaction referred by ARCS model (ARCS). The IMMS is designed using the ARCS model (Keller, 2010). As applied by Wei et al. (2015), the questionnaire includes 19 items on a 5-point Likert scale. A low score from 1 to 2 indicates that the participants were not motivated during the design process, while a medium score of 3 indicates that the participants were moderately motivated during the design process and a high score from 4 to 5 indicates that the participants were highly motivated during the design process. The IMMS instrument was used to measure participants' motivation levels towards design process (for sample items of IMMS see Table 3 and for the full items of the IMMS see Appendix G).

Table 4. Sample items of the IMMS (Keller, 2010; Wei et al., 2015, pp.229)

Items	
Q1	Something interesting at the beginning of this experiment captured my attention.
Q2	After learning the introductory information, I felt confident that I knew what I was supposed to do in this experiment.
Q3	Completing the task in this experiment gave me a satisfying feeling of accomplishment.
Q4	Completing this experiment successfully was important to me.
Q5	I enjoyed this experiment so much that I would like to know more about this topic.

In total, eight instruments were used in the study, either to complete the design task (virtual environment tools and Gravity Sketch software) or to assess the participants' performance during the task (survey instruments). The survey instruments assessed the variables of the study. In order to test the research questions and hypotheses, five survey instruments were applied in the experiment (see Table 4).

Table 5. Summary of the survey instruments used to assess participants' responses

Order	Measured Variables	Instrument	Reference
1	Demographic variables and VR familiarity	The Students' Questionnaire	Developed by the researcher
2	Spatial ability	The Mental Rotation Test (MRT)	Peters et al. (1995)
3	Degree of presence	The Presence Questionnaire	Witmer and Singer (2005)
4	Flow state of mind	The Flow State Scale (FSS)	Jackson and Marsh (1996)
5	Design motivation	The Instructional Materials Motivation Survey (IMMS)	Keller (2010)

4.5 Setting and Procedure of the Study

To answer the research questions and test the hypotheses of this study, the following experiment procedure was proposed as seen in Figure 6:

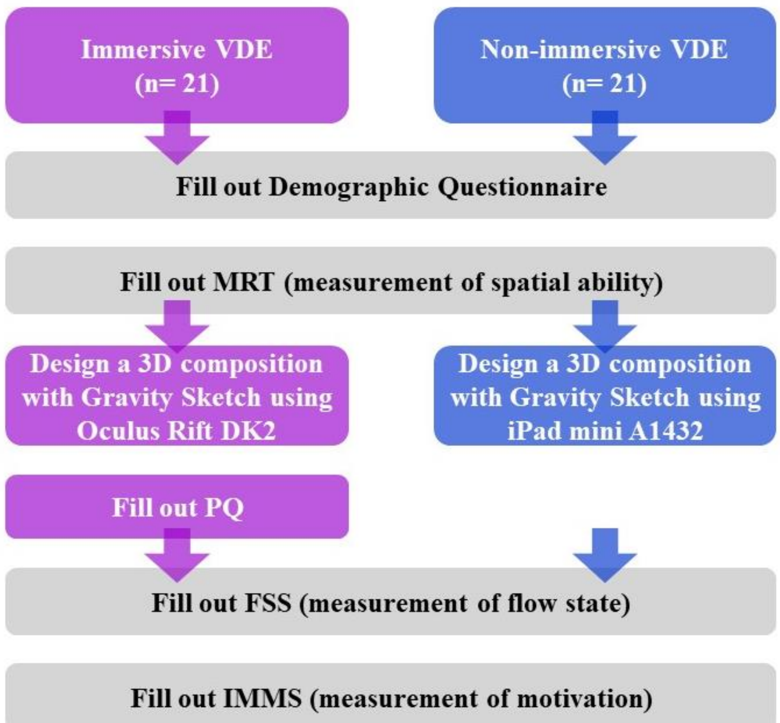

Figure 6. Procedure of the study

The first phase of the experiment consisted of a short training period that aimed to provide all participants with equal proficiency in using the 3D design software, Gravity Sketch, and the virtual environment tools, Oculus Rift or iPad. Prior to the experiment, all participants completed the demographic questionnaire covering information about their demographic variables, as age and gender, and familiarity with VR where participants had to indicate whether they have used a VR tool before and for what purpose (see Appendix B).

In order to identify the level of participants' spatial ability, participants were then asked to complete the MRT (see Appendix C). The MRT consists of 24 items where each item consists of five drawings. The first drawing on the left is the target geometrical drawing followed by four drawings where only two of them are correct rotated reproductions of the target figure, while the other two are distractions. The participants had to indicate the two correct rotated reproductions of the target figure on the left. The test takers had a time constraint of 10 to 15 minutes as mentioned in the instruction section of the MRT.

Later, both groups were presented with one identical design brief (see Appendix D). The design task was to create a 3D geometrical composition that expresses order, 8 to 16 geometric shapes, as cylinder, prism, pyramid and sphere. The participants had the freedom to choose any 8 to 16 shapes from the list above. The participants had a limited number of shapes. Participants in the immersive VDE were asked to use the Oculus Rift DK2 for the design task (see Figures 7 & 8). While the participants in the non-immersive VDE were asked to create their designs using iPad mini A1432 (see Figures 9 & 10).

Upon the completion of the design task, the participants of the immersive VDE completed the PQ in order to evaluate their experience with immersive VR (see Appendix E). The PQ assessed the degree of presence experienced by the participants in the immersive VDE.

In order to evaluate the design process creativity, the participants' experienced flow state and motivation levels were assessed. To do so, after submitting the designs all participants completed the FSS (Jackson & Marsh, 1996) so that their state of mind would be assessed (see Appendix F). To assess the participants' motivation level, the IMMS was distributed at the end of the design task. The IMMS based on the ARCS model which measures individuals' self-perception of motivation (see Appendix G).

Figure 7. Participants in the immersive VDE

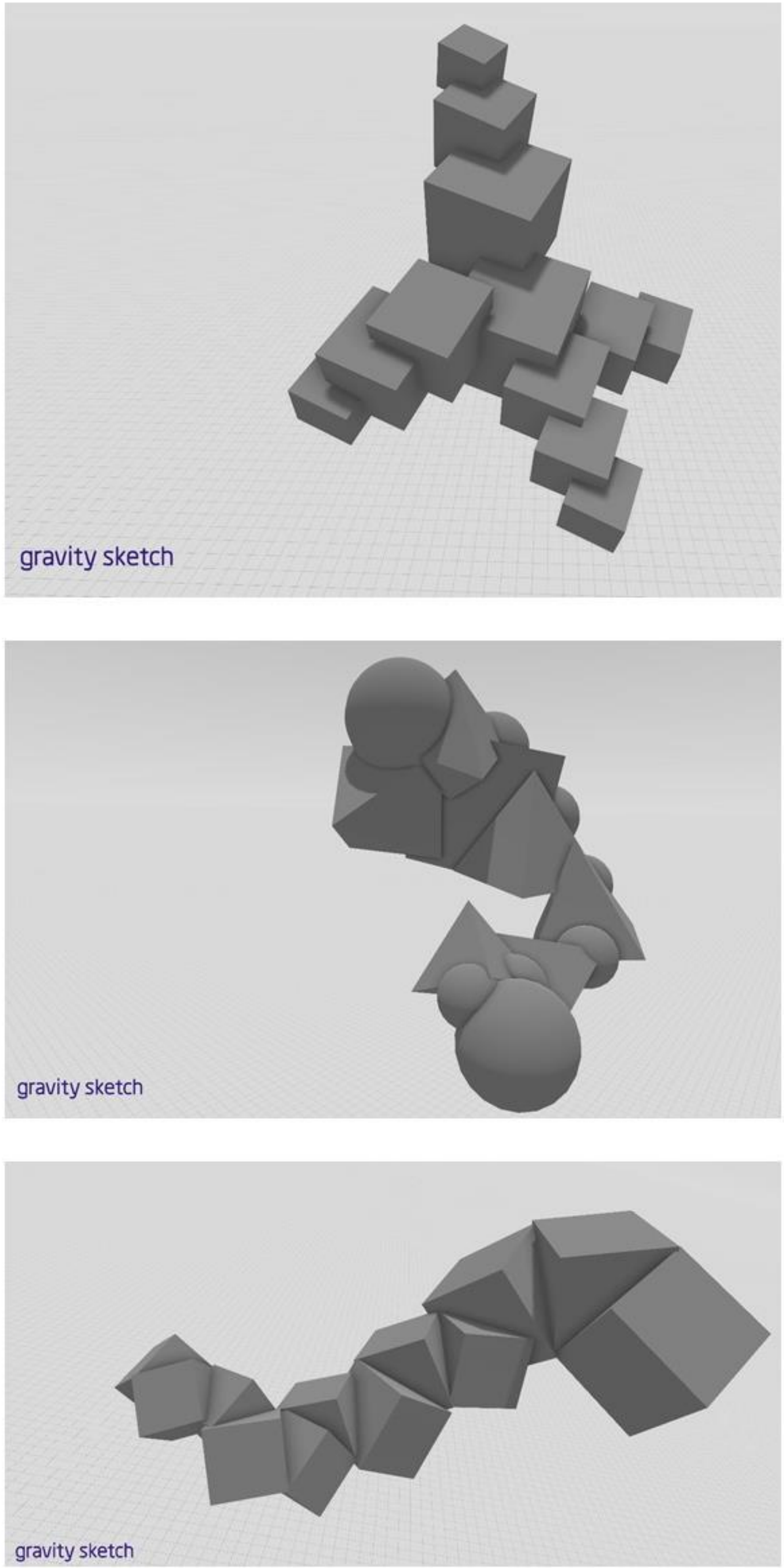

Figure 8. Sample of the participants' designs in the immersive VDE

Figure 9. Participants in the non-immersive VDE

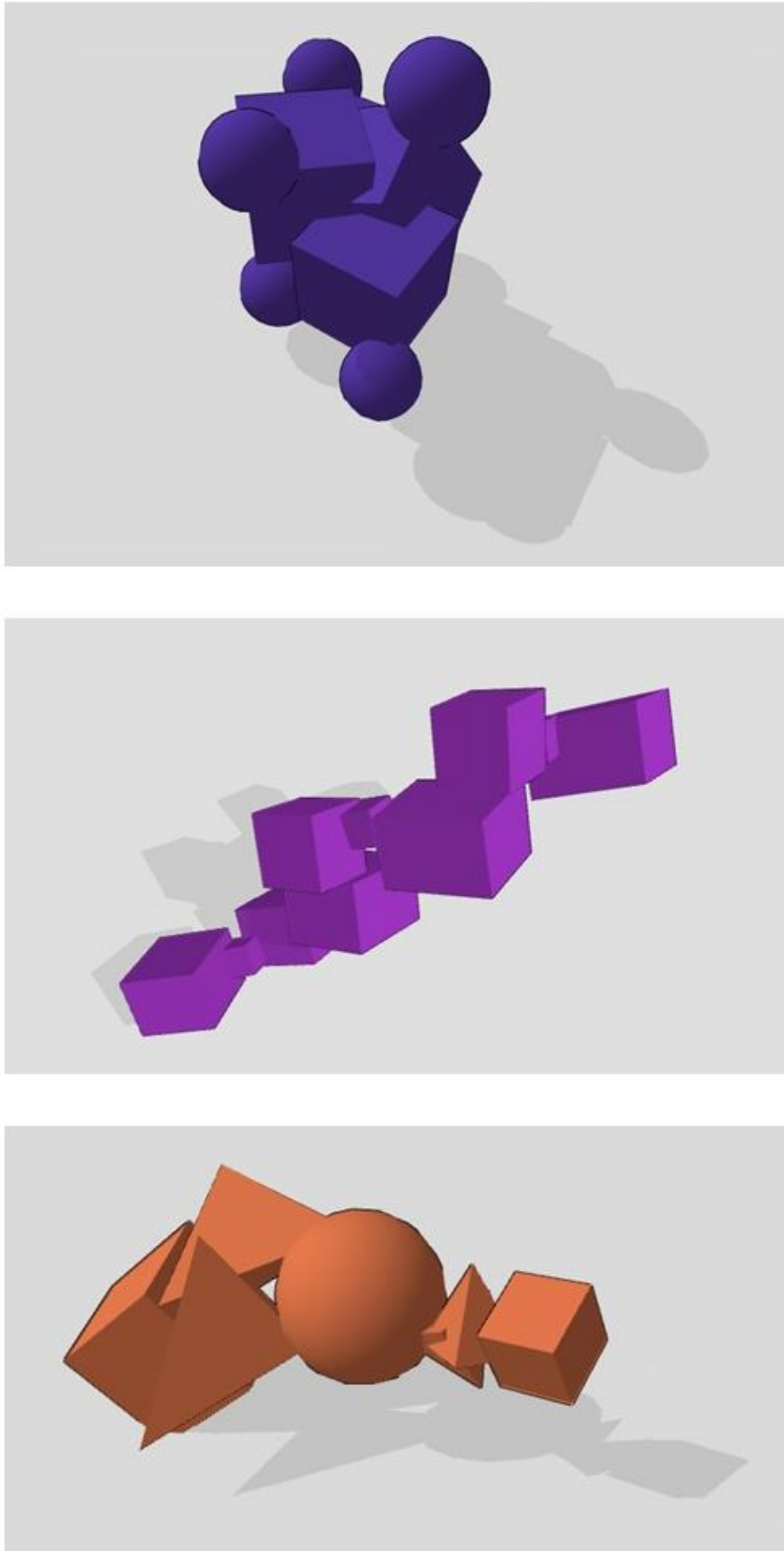

Figure 10. Sample of the participants' designs in the non-immersive VDE

The data gathered in the study was later analyzed and evaluated. The next chapter covers the results of the statistical analysis and the findings of the experimental study. Also, it tests the hypotheses and answers the research questions of the study.

CHAPTER V

RESULTS

This chapter presents the research findings related to the influence of immersive and non-immersive VDEs on design process creativity. Also, it presents the findings on the relationships between spatial ability, flow state and motivation of students. Statistical Package for Social Sciences (SPSS) software version 21 (IBM Corp, 2012) was used to process and analyze the collected data.

All quantitative data were listed using the SPSS software for statistical analysis. First, descriptive analysis was done in order to observe the demographic characteristics of the participants. In addition, reliability analysis tests were conducted in order to test for the items of the questionnaires' consistency. Second, mean scores were calculated and Independent Samples t-tests were conducted in order to examine the influence of immersive and non-immersive VDEs on design process creativity. Lastly, correlation analysis tests were done in order to investigate the relationship between spatial ability, flow state and motivation.

5.1 Descriptive Analysis

The demographic questionnaire distributed to the participants covered information about their gender and age. It, also, included a part on the participants' experience with VR (see Appendix B). Using this questionnaire, the demographic characteristics of the participants and their familiarity with VR were obtained.

The experiment was conducted with 42 participants among the students who are taking the course Basic Design Studio II in 2018-2019 spring semester. Twenty-one participants designed the product in an immersive VDE where 12 of them were females and 9 of them were males with a mean age of 20.24 (SD= 1.136). While the other half of the sample designed the product in a non-immersive VDE where 17 of them were females and 4 were males with a mean age of 20.14 (SD= 1.062). Overall, among the participants 29 were females and 13 were males. For the gender distribution of the participants see Table 5. The age range of the participants was between 19 and 23 years. The average age of the participants was 20.19 years (SD= 1.087).

Table 6. Distribution of gender by the design environment

Characteristic	**Category**	**Tool**		Total
		Immersive	**Non-immersive**	
Gender	Female	12	17	29
	Male	9	4	13
Total		21	21	42

Results regarding the familiarity of the participants with VR showed that, overall, within the immersive and non-immersive environments, 14 of the participants were familiar with VR while 28 of them were unfamiliar with VR. In particular, among the immersive group of the participants were unfamiliar with VR (see Table 6). Therefore, the majority of participants who used VR were unfamiliar with the tool.

Table 6. Distribution of familiarity with VR by the design environment

Characteristic	Category	Environment		Total
		Immersive	**Non-immersive**	
Familiarity with VR	Familiar	10	4	14
	Unfamiliar	11	17	28
Total		21	21	42

5.2 Analysis of Creativity Factors

This part covers the analysis results on the factors related to creativity studied in this research.

5.2.1 Analysis of the MRT for Spatial Ability

The first step towards assessing the participants' spatial ability involved calculating the scores of the MRT instrument. The MRT instrument was graded as described in the guidelines offered by Peters et al. (1995). The maximum score that could be received on the MRT was 24. The participants of the immersive VDE had a mean score of 10.48 (SD= 5.93) while the other group reported a mean score of 9.00 (SD= 4.572). These results indicated that the participants in the immersive VDE had a higher spatial ability level than those in the non-immersive VDE.

5.2.2 Analysis of the FSS for the Flow State Level

In order to examine the participants' experienced level of flow state, firstly, the mode (M_o) and median (M_d) of the questionnaire results were calculated. The FSS was answered on a 5-point Likert scale. The M_o and M_d for the FSS were found as 3 (nor disagree or agree) at a scale of 1 to 5. Thus, the participants experienced a medium state of flow in the design process.

Reliability of the instruments was explored in terms of Cronbach's alpha coefficients for the FSS in order to determine the internal consistency of the total items and its subscales; challenge-skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness, transformation of time and autotelic experience. According to Bowling (1997), an alpha value of 0.5 and above indicated a good internal consistency. The Cronbach's alpha for the overall scale was 0.957 which showed a very strong reliability of the FSS. The scores of the cronbach's alpha for the FSS nine subscales were 0.913, 0.772, 0.882, 0.861, 0.864, 0.906, 0.877, 0.668 and 0.867, respectively, which showed that all subscales had a high reliability and internal consistency.

5.2.3 Analysis of the PQ for the Degree of Presence

According to Witmer and Singer (1998), the effectiveness of immersive VEs is often evaluated by the degree of presence experienced by the users of those environments. Therefore, it was essential to evaluate the participants' experienced sense of presence. However, in the literature, the available PQ is developed for immersive virtual experiences, which makes it inappropriate for non-immersive virtual experiences. Therefore, only the degree of presence experienced by the participants in the immersive VDE was assessed.

The mean results for the reported scores of the PQ were calculated for each participant individually using SPSS. The mean score range for each student was from 3.79 to 7 where 1 indicated a low sense of presence, 4 a medium sense of presence and 7 a high sense of presence. The calculated mean score of the sample for the PQ was 5.35 (SD= 0.667). Thus, the results of the PQ demonstrated a positive high sense of presence for all participants indicating that all participants had a successful experience with VR. Therefore, there was no need to eliminate any of the data.

5.2.4 Analysis of the IMMS for motivation

First, in order to observe the participants' experienced level of motivation the M_o and M_d of the questionnaire results were calculated. The M_o and M_{ds} for the IMMS were found as 3 (nor disagree or agree) at a 1 to 5 Likert scale. Thus, the participants experienced a medium level of motivation in the design process.

Reliability of the instruments was explored in terms of Cronbach's alpha coefficients for the IMMS in order to determine the internal consistency of the total items and its subscales; attention, relevance, confidence and satisfaction. Cronbach's alpha indicated that all subscales had a high reliability and internal consistency. The Cronbach's alpha for the overall scale was 0.933 which showed a very strong reliability of the IMMS. The scores of the cronbach's alpha for the IMMS four subscales were 0.74, 0.85, 0.657 and 0.875, respectively.

5.3 Analysis of the Design Process Creativity

This study considered flow state and motivation as crucial factors that influence design process creativity. Therefore, in order to answer the question whether the immersive VDE facilitated design process creativity independent samples t-tests were conducted for the participants' flow state and motivation levels. The influence of the immersive VDE on design process creativity was examined by comparing the assessed results of flow state and motivation between the immersive and non-immersive environments.

5.3.1 Analysis of the Influence of Immersive VDE on the Flow State Level

In order to compare the participants' experienced level of flow state, firstly, the M_o and M_d values of the questionnaire results were calculated. The calculated M_o values indicated that the majority of the participants in the immersive VDE experienced a high state of flow, while the participants in the non-immersive VDE experienced a medium state of flow (M_o Immersive= 4 (agree), M_d Immersive= 3 (nor disagree or agree); M_o Non-immersive= 3, M_d Non-immersive= 3 (nor disagree or agree)) (see Table 7). The independent samples t-test was also conducted to detect if there was any difference between immersive and non-immersive VDEs in terms of the flow state level. The independent t-test results for equal variances assumed showed that there was no significant difference in the flow state level of participants in the immersive and non-immersive VDE (t= 1.609; df= 40; p= 0.115). However, we could still observe a difference in the M_o between the immersive and non-immersive environments, demonstrating that the participants in the immersive VDE entered a higher level of flow state than those in the non-immersive VDE.

Table 7. Distribution of flow state in immersive and non-immersive VDEs

	Category	**Environment**		Total
		Immersive	**Non-immersive**	
Flow State	Disagree	3	5	8
	Nor disagree or agree	8	10	18
	Agree	10	6	16
	Total	21	21	42

Secondly, in order to be able to examine and interpret the results in a more precise way, the mean scores for the subscales of the FSS were calculated. According to the FSS, items 1, 10, 19 and assess challenge-skill balance dimension; items 2, 11, 20 and 29 assess action-awareness merging dimension; items 3, 12, 21 and 30 assess clear-goals dimension; items 4, 13, 22 and 31 assess unambiguous feedback; items 5, 14, 23 and 32 assess concentration on task at hand; items 6, 15, 24 and 33 assess paradox of control; items 7, 16, 25 and 34 assess loss of self-consciousness; items 8, 17, 26 and 35 assess transformation of time; items 9, 18, 27 and 36 assess autotelic experience (see Table 8).

Table 8. Results of the mean scores for the FSS by subscales

Scales	Items	Environment	M	SD
Challenge-Skill Balance	1, 10, 19 & 28.	Immersive	3.74	0.937
		Non-immersive	3.43	0.898
Action-Awareness Merging	2, 11, 20 & 29.	Immersive	3.40	0.804
		Non-immersive	3.24	0.903
Clear-Goals	3, 12, 21 & 30.	Immersive	3.46	0.936
		Non-immersive	3.12	0.941
Unambiguous Feedback	4, 13, 22 & 31.	Immersive	3.37	0.846
		Non-immersive	3.01	0.781
Concentration on Task at Hand	5, 14, 23 & 32.	Immersive	3.89	1.045
		Non-immersive	3.76	0.838
Paradox of Control	6, 15, 24 & 33.	Immersive	4.00	1.135
		Non-immersive	3.49	0.963
Loss of Self-Consciousness	7, 16, 25 & 34.	Immersive	3.92	1.013
		Non-immersive	3.76	1.071
Transformation of Time	8, 17, 26 & 35.	Immersive	3.68	0.729
		Non-immersive	3.54	0.713
Autotelic Experience	9, 18, 27 & 36.	Immersive	4.57	0.565
		Non-immersive	3.68	0.811

In general, a slight difference in mean scores can be observed between both environments, immersive and non-immersive, throughout all subscales. The non-immersive VDE group gave a total mean score of 3.45 (SD= 0.634) for all questions, indicating that the experience did not provide the participants with a high state of flow. The independent samples t-test results showed that there were no differences between groups in terms of the subscales Challenge-Skill Balance, Action-Awareness Merging, Clear-Goals, Unambiguous Feedback, Concentration on Task at Hand, Paradox of Control, Loss of Self-Consciousness and Transformation of Time (see Table 9). However, in terms of Autotelic Experience the t-test results indicated a significant difference between participants in the immersive and the non-immersive VDE (t= 4.14; df= 40; p=0.0001).

Table 9. Results of the independent samples t-test for the FSS by subscales

Scales	Items	t	df	sig. (2-tailed)
Challenge-Skill Balance	1, 10, 19 & 28.	1.093	40	0.281
Action-Awareness Merging	2, 11, 20 & 29.	0.632	40	0.531
Clear-Goals	3, 12, 21 & 30.	1.192	40	0.24
Unambiguous Feedback	4, 13, 22 & 31.	1.421	40	0.163
Concentration on Task at Hand	5, 14, 23 & 32.	0.448	40	0.657
Paradox of Control	6, 15, 24 & 33.	1.576	40	0.123
Loss of Self-Consciousness	7, 16, 25 & 34.	0.481	40	0.633
Transformation of Time	8, 17, 26 & 35.	0.642	40	0.525
Autotelic Experience	9, 18, 27 & 36.	4.14	40	0.0001

5.3.2 Analysis of the Influence of Immersive VDE on the Motivation Level

In order to compare the participants' experienced level of motivation the M_o and M_d values of the questionnaire results were calculated. The calculated M_o values indicated that the majority of the participants in the immersive VDE were highly motivated, while the participants in the non-immersive VDE were moderately motivated, ($M_{o\ Immersive}$= 4, $M_{d\ Immersive}$= 4 (agree); $M_{o\ Non\text{-}immersive}$= 3, $M_{d\ Non\text{-}immersive}$= 3 (nor disagree or agree)) (see Table 10). The independent samples t-test was also conducted to detect if there was any difference between groups in terms of Motivation. The independent t-test results for equal variances assumed showed that there was no significant difference in the motivation of participants in the immersive and non-immersive VDE (t= 2.971; df= 40; p= 0.005). However, we could still observe a difference in the M_o between groups, demonstrating that the participants in the immersive VDE were more motivated for the design task than those in the non-immersive VDE.

Table 10. Distribution of motivation in immersive and non-immersive VDEs

	Category	Environment		Total
		Immersive	**Non-immersive**	
Motivation	Disagree	1	4	5
	Nor disagree or agree	9	12	21
	Agree	11	5	16
	Total	21	21	42

Second, in order to interpret the results in a more explicit way the mean scores for the subscales of the IMMS were calculated. The items of the IMMS assess four different factors, where items 1, 6, 8, 10, 12 and 15 are related to the attention factor; items 4, 7, 11, and 17 determine the relevance factor; items 2, 13 and 18 determine the confidence factor; and items 3, 5, 9, 14, 16 and 19 determine the satisfaction factor (see Table 11).

Table 8. Results of the mean scores for the IMMS by subscales

Scales	Items	Environment	M	SD
Attention	1, 6, 8, 10, 12 & 15.	Immersive	4.19	0.592
		Non-immersive	3.39	0.635
Relevance	4, 7, 11 & 17.	Immersive	4.10	0.864
		Non-immersive	3.51	0.768
Confidence	2, 13 & 18.	Immersive	4.02	0.792
		Non-immersive	3.46	0.94
Satisfaction	3, 5, 9, 14, 16 & 19.	Immersive	4.39	0.661
		Non-immersive	3.84	0.766

In general, a significant difference in mean scores was observed between immersive and non-immersive environments throughout all the subscales. The results reported by the participants of the VR group has a mean score of higher than 4 in all subscales, indicating that the experiment captured participants' attention, was relevant to their studies, left them confident and provided them with a satisfactory designing experience.

The independent samples t-test results showed that there was a significant difference between groups in terms of all subscales (see Table 12). On the attention factor, the t-test results indicated that the immersive VDE captured the attention of the participants greater than the non-immersive VDE throughout the experiment (t= 4.229; df= 40; p= 0.0001). On the relevance factor, the t-test results revealed that the content of the immersive VDE was more relevant to the participants than the content of the non-immersive VDE (t= 2.312; df= 40; p= 0.026). Thus, the participants in the immersive VDE were more willing to participate in the designing process. For the impact on the confidence scale the t-test results suggested a significant difference between the two environments (t= 2.071; df= 40; p= 0.045). These results indicated that the options provided by the immersive VDE helped the participants in enhancing their self-confidence in designing. Lastly, on the satisfaction factor, the t-test results demonstrated that the design process was more satisfying for the participants in the immersive VDE (t= 2.479; df= 40; p= 0.017).

Table 9. Results of the independent samples t-test for the IMMS by subscales

Scales	Items	t	df	sig. (2-tailed)
Attention	1, 6, 8, 10, 12 & 15.	4.229	40	0.0001
Relevance	4, 7, 11 & 17.	2.312	40	0.026
Confidence	2, 13 & 18.	2.071	40	0.045
Satisfaction	3, 5, 9, 14, 16 & 19.	2.479	40	0.017

5.4 Correlation Analysis of Creativity Factors

The relationships between spatial ability, flow state and motivation were analyzed using bivariate correlation analysis. To understand the nature of the relationships between the factors considered in this study, Spearman's rho correlation test (r_s) and Chi-square test for independence (x^2) were conducted. The results of the tests are shown in Table 13, 14 & 15.

Table 10. Results of the bivariate relationships among variables

Factors	Spearman's rho	Spatial Ability	Flow State
Spatial Ability	Correlation Coefficient	1.000	0.32*
	Sig. (2-tailed)	.	0.039
Flow State	Correlation Coefficient		1.000
	Sig. (2-tailed)		.
Motivation	Correlation Coefficient	0.189	0.713**
	Sig. (2-tailed)	0.229	0.0001

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 14. Relationship of spatial ability and flow state

		Spatial Ability			Total
		Low	Medium	High	
Flow State	Low	4	2	2	8
	Medium	9	7	2	18
	High	6	1	9	16
Total		19	10	13	42

Table 111. Relationship of motivation and flow state

		Flow State			Total
		Low	Medium	High	
Motivation	Low	3	1	1	5
	Medium	5	12	4	21
	High	0	5	11	16
Total		8	18	16	42

The results of the correlation tests indicated a positive strong relationship between the flow state and motivation factors (r_s= 0.713; p= 0.0001) and a positive weak relationship between the spatial ability and flow state factors (r_s= 0.32; p= 0.039). There was no detected relationship between the spatial ability and motivation factors. Furthermore, the results of the chi-square tests showed that spatial ability and flow state are not independent of each other (x^2= 9.827; df= 4; p= 0.043). Also, it showed that motivation and flow state are not independent of each other (x^2= 16.189; df= 4; p= 0.003). However, in consistency with the correlation test, the chi-square independency test showed that spatial ability and motivation are independent of each other (x^2= 4.572; df= 4; p= 0.334).

The findings of the study demonstrated that immersive VDE had a significant influence on flow and motivation and therefore, on design process creativity. Results, also, demonstrated a significant correlation between spatial ability and flow state, and between motivation and flow state.

The next chapter develops further on the statistical results of the study. It discusses the findings by relating to the previous literature. Also, it answers the research questions and hypotheses formulated at the beginning of the study.

CHAPTER VI

DISCUSSION

This chapter discusses the findings of this study and relates them to the existing literature review. The purpose of this study was to investigate the influence of immersive and non-immersive VDEs on design process creativity by examining the crucial factors influencing creativity such as flow state and motivation. A previous study demonstrated the importance of spatial ability in design and assumed a significant correlation between spatial ability and creativity (Pandey et al., 2015). As far as one can tell from the literature, no study has tested the effect of spatial ability on creativity factors. Thus, this study claimed that spatial ability has an impact on flow state and motivation and therefore, on design creativity. The findings demonstrated that immersive VDE had a significant influence on flow and motivation and, therefore, on design process creativity. Results also demonstrated a significant correlation between spatial ability and flow state, and between motivation and flow state.

Various data analysis was conducted in order to compare design process creativity in the immersive with the non-immersive VDEs through the examination of flow state and motivation levels experienced by the participants during the design process. Through data analysis, the impact of immersive VDE on design creativity was understood and interpreted. The findings demonstrated that the immersive VDE offered the participants with a higher sense of involvement with the design compared with the non-immersive

VDE. The immersive VDE allowed the participants to feel more motivated and experience a higher state of flow resulting in a greater design process creativity. The participants in the immersive VDE were more motivated in the design task than those in the non-immersive VDE. These findings provide new insights to design instructors for means to facilitate and support design creativity. In fact, this study introduces design instructors to the important impact of creativity factors on design process creativity and therefore, their performance creativity. It also presents the necessary tools to design instructors that facilitate the creativity factors and, therefore, supports creativity.

6.1 Discussion on the Design Process Creativity

The study investigated the influence of immersive and non-immersive VDEs on creativity by observing the participants' flow state and motivation during the design process. Through the comparison of the flow state and motivation levels of participants between the immersive and non-immersive VDEs, the results were interpreted and the research questions were answered.

6.1.1 Discussion on the Influence of Immersive VDE on Flow State

The first research question investigated the influence of immersive VDE on flow state in design process creativity (**Q_{1a}:** Does the immersive VDE influence the flow state in design process?). The results showed no significant difference in the flow state of participants between the immersive and non-immersive VDEs ($t= 1.609$; $df= 40$; $p= 0.115$). However, the difference in the M_o values between groups, indicated that the participants in the immersive environment experienced a higher state of flow than those in the non-immersive environment ($M_{o\ Immersive}= 4$ (agree); $M_{o\ Non\text{-}immersive}= 3$ (nor disagree or agree)). Thus, the immersive environment helped the participants experience a higher state of flow.

The hypothesis suggested that the immersive VDE has a positive influence on students' flow state in design process (**H_{1a}:** The immersive VDE has a positive significant influence on the flow state). The findings indicated that there was no significant difference in the flow state level of participants in the immersive and non-immersive VDEs. Therefore, the findings of this study are not in line with the previous findings by Yang et al. (2018), where immersive VDE was found to be effective on the flow state. Thus, **H_{1a}** was rejected.

This inconsistency with the Yang et al.'s (2018) study could be due to the nature of the compared settings. The researchers in Yang et al.'s (2018) study compared immersive VR with a traditional setting (paper and pencil). However, this study compared immersive with non-immersive VDE where the participants used the same software, Gravity Sketch, as a base for design. Therefore, both participants experienced a VE that offered them with technological tools allowing them to enter somehow a similar state of flow. However, in the Yang et al.'s (2018) study, a significant difference was found in the flow states between the two settings, as there is a huge gap between the tools and options a virtual and a traditional real environment could offer to the users.

Earlier studies indicated that creative designers could use traditional tools (paper and pencil) better than digital ones (technologies) (Bueno & Turkienicz, 2014; Lim, Qin, Prieto, Wright, & Shackleton, 2004). In this study, the participants experienced a VDE in both settings, in order to eliminate this bias. Many studies examined the effects of immersive VDE on design creativity through the comparison with traditional environments where the gap between the two environments leaves a great difference between the tools, options and sources provided to the participants. However, as far as one can tell from the literature, no study considered comparing immersive with non-immersive VDEs in terms of factors related to design creativity. Therefore, this study is the first to compare the immersive VDE with the non-immersive VDE in design process creativity.

Compared with designing in a non-immersive VDE, the additional features of an immersive VDE such as 3D perspective and full-body involvement could influence one's creative thinking and behavior (Yang et al., 2018). In a previous study, Tano et al. (2003) examined that 3D perspectives and digital tools could stimulate creativity. Moreover, research on immersive VR observed that full-body involvements has as an advantage in training and education.

6.1.2 Discussion on the Influence of Immersive VDE on Motivation

The second research question investigated the influence of immersive VDE on motivation in design process creativity (**Q_{1b}:** Does the immersive VDE influence motivation in design process?). The results showed a significant difference in the motivation of participants between the immersive and the non-immersive VDEs ($t= 2.971$; $df= 40$; $p= 0.005$). Therefore, the immersive VR made the participants feel more motivated ($M_{d\ immersive}= 4$ (agree)) in the design task when compared to participants in the non-immersive VDE ($M_{d\ Non\text{-}immersive}= 3$ (nor disagree or agree)). According to the IMMS analysis, the immersive VDE enabled the students to feel more motivated towards the design task as it allowed them to experience, somehow, in a realistic way the overall design process. The hypothesis suggested that the immersive VDE has a positive influence on the students' motivation in design process (**H_{1b}:** The immersive VDE has a positive significant influence on motivation). Therefore, **H_{1b}** was not rejected.

In the literature, no study was found that investigates the influence of immersive VR on the motivation of students' as a factor related to design creativity. Yang et al. (2018) investigated the effect of immersive VR on attention, flow state and meditation as factors related to creativity. However, little research exists on the role of immersive VDEs in learning motivation. Huang et al. (2016) showed that VR could stimulate motivation and interaction in learning. VR can intensify the physical settings, facilitate real experiences, reduce constraints, and therefore, facilitate individual creativity (Jou & Wang, 2013; Wei et al., 2015). These advantages increased the creative design learning motivation for participants in the immersive VDE.

The IMMS questionnaire is based on the ARCS models that includes 4 different subscales that are attention, relevance, confidence and satisfaction. The results showed a significant difference in the factor attention between groups ($t= 4.229$; $df= 40$; $p= 0.0001$). The findings are in line with the study of Yang et al.'s (2018) study that demonstrated that immersive VDE influenced attention.

A previous study demonstrated that individual creativity is affected by different factors, one of which is motivation (Sternberg, 1999). Fink and Benedek (2014) demonstrated a high correlation between creative ideas, attention and meditation. Another study by Nusbaum and Silvia (2011) reported that creativity depends on attention. The immersive VR led to greater attention levels.

6.2 Discussion on the Correlation of Creativity Factors

This study also aimed at examining the relationships between spatial ability, flow state and motivation in immersive and non-immersive VDEs. This study introduced spatial ability, flow state and motivation as crucial factors related to creativity that could affect the design process creativity and, therefore, the design outcome creativity.

The third research question investigated the relationship between the spatial ability and the flow state (**Q_{2a}:** Is there a relationship between spatial ability and the flow state?). The findings showed a positive weak correlation between spatial ability and flow state ($r_s= 0.32$; $p= 0.039$). The hypothesis supposed that spatial ability has a positive effect on flow state of students (**H_{2a}:** There is a positive correlation between spatial ability and flow state). Therefore, **H_{2a}** was not rejected.

A previous study demonstrated that one's flow state during a creative process is a crucial component that influences the performance creativity (Veale et al., 2013). Another study indicated spatial ability as an essential component that influences creativity (Pandey et al., 2015). Based on the previous literature, the study aimed to explore the effect of spatial ability on flow as a factor related to creativity. A study conducted by Pandey et al. (2015) demonstrated that the immersive VR can be used for enhancing spatial ability of students, and therefore, enables them to generate more creative solutions. However, there was no previous study in the literature that investigated the relationship between spatial ability and flow state in design process in a VDE.

The fourth research question investigated the relationship between motivation and the flow state (**$Q_{2b:}$** Is there a relationship between spatial ability and motivation?). The findings demonstrated a positive strong correlation between motivation and the flow state in design process (r_s= 0.713; p= 0.0001). The hypothesis supposed that the flow state has a positive effect on the motivation of students (**$H_{2b:}$** There is a positive correlation between motivation and the flow state). Therefore, **H_{2b}** was not rejected.

Recent studies focused on motivation as a crucial component of creativity (Casakin & Kreitler, 2009). Another study by Seligman and Csikszentmihalyi (2014) observed that individuals demonstrate a higher creative performance when they enter the flow state. With this respect, this study is the first to investigate the nature of the relationship between these two factors. The hypotheses and findings of the study are summarized in Table 16. The findings indicated that the immersive VDE influences significantly design process creativity (**$H_{1:}$** There is a significant difference in design process creativity between immersive and non-immersive VDEs). Also, the results show a significant relationship between spatial ability and design process creativity (**$H_{2:}$** There is a positive correlation between spatial ability and design process creativity). The study findings led us to a deeper understanding of the impact and relationship between immersive VR, spatial ability, motivation, flow state and process creativity.

Table 16. Summary of the hypotheses and findings of the study

Hypotheses	Findings	Decision	Consistent with	Inconsistent with
H_{1a}: The immersive VDE has a positive significant influence on the flow state.	($t= 1.609$; $df= 40$; $p= 0.115$)	No significant difference in the flow state between the immersive and non-immersive VDE.	.	Yang et al., 2018
H_{1b}: The immersive VDE has a positive significant influence on motivation.	($t= 2.971$; $df= 40$; $p= 0.005$)	A significant difference in the motivation between the immersive and non-immersive VDE.	Huang et al., 2016; Yang et al., 2018; Nusbaum & Silvia, 2011	.
H_{2a}: There is a positive correlation between spatial ability and flow state.	($r_s= 0.32$; $p= 0.039$)	A positive weak relationship between the spatial ability and flow state.	.	.
H_{2b}: There is a positive correlation between motivation and the flow state.	($r_s= 0.713$; $p= 0.0001$)	A positive strong relationship between the Motivation and Flow State.	.	.

CHAPTER VII

CONCLUSION

This study examined the influence of immersive and non-immersive VDEs on design process creativity in the basic design studio, through observing factors related to creativity as the flow state and motivation. This study also investigated the relationships between the students' spatial ability, flow state and motivation.

A previous study demonstrated the importance of spatial ability in design and assumed a significant correlation between spatial ability and creativity (Pandey et al., 2015). As far as one can tell from the literature, no study have tested the effect of spatial ability on creativity factors. Thus, this study claimed that spatial ability has an impact on flow state and motivation and therefore, on design creativity. The findings demonstrated that immersive VDE had a significant influence on flow and motivation and therefore, on design process creativity. Results also demonstrated a significant correlation between spatial ability and flow state, and between motivation and flow state. Through data analysis, the impact of immersive VDE on design creativity was explored and interpreted. The findings indicated that the immersive VDE offered the participants with a higher sense of involvement in design process compared with the non-immersive VDE. The immersive VDE allowed the participants to feel more motivated and experience a higher state of flow provoking a higher design process creativity. The participants in the immersive VDE were more motivated in the design task than those in the non-immersive VDE. Therefore, the findings of the study demonstrated that the immersive VDE, where participants experienced body involvement in the design process, allowed participants to experience a higher state of flow and made them feel more motivated. Moreover, the findings of the study indicated a positive weak relationship between spatial ability and the flow state, and a positive strong relationship between motivation and the flow state. However, no relationship was identified between spatial ability and motivation.

These findings provided new insights to design instructors for means to facilitate and support design creativity. In fact, this study introduced design instructors to the important impact of creativity factors on design process creativity and therefore, their performance creativity. It also presented the necessary tools to design instructors that facilitate these factors and therefore, support creativity. The results emphasized the importance of a holistic understanding of design students' abilities and factors influencing design process in education.

7.1 Limitations of the Study

There are a few limitations of the study. First, after examining the existing literature and studying the factors related to creativity, three main factors were considered in this study, namely as, spatial ability, flow and motivation. However, there are many other factors that could be considered in future research. For example, the individuals' creativity and motivation for the task could be assessed before the experiment as it could affect the flow and motivation during the design process.

The immersive VR equipment used in this study, the Oculus Rift DK2, was a new technology for the participants. The demographic questionnaire showed that only few of the participants were familiar with the tools. Also, the used 3D design software, Gravity Sketch, was new to the participants. Therefore, this experiment was an original experience for the participants that provided an impact on their flow and motivation. This study could be conducted with design students from senior classes where they are already familiar with digital tools and 3D design software.

Moreover, it should be noted that technologies and new tools can add tension on the user, which could affect their performance in a positive or negative way. Therefore, the individuals' levels of stress and relaxation need to be assessed as well. Lastly, due to the limited available tools and time restrictions this study involved 42 design students. A study with a larger sample should be considered. Still, much research is needed to understand the individual and environmental factors influencing creativity.

7.2 Suggestions for Further Studies

The fast development of low cost immersive VR tools will provide designers and design instructors with greater means to implement VR in education and investigate their impact on design process. Creativity support environments and immersive VR will probably attract more attention of the future researchers. Based on the analysis and findings of this study, there are some important suggestions for future studies.

In this study, students' initial spatial ability was measured before the experiment. In another studies, the impact of VR on spatial abilities was demonstrated in engineering and architecture (Katsioloudis, Jones, & Jovanovic, 2017; Pandey et al., 2015). However, the influence of VR on spatial ability is not examined yet in basic design. Therefore, the impact of VR on spatial ability can be further studied.

The relationships found in the study between spatial ability and flow state, and motivation and flow state play a major role on the individuals' performance. Therefore, they need to be further studied.

Previous studies examined creativity factors between traditional and VDEs (Pandey et al., 2015; Wei et al., 2015; Yang et al., 2018). This study examined design process creativity between two VDEs (immersive and non-immersive). The findings of the study demonstrated that the immersive VDE, where participants experienced body involvement, facilitated participants design process creativity. Therefore, it could be concluded that the body involvement is the factor influencing individuals' creative performance. Further studies should be conducted on the role of body involvement in design creativity.

In this study, the designs created by the participants were not assessed in terms of creativity. Therefore, the relationship between immersive VDE and design process creativity remains theoretical. A continuing part of this study could be added on the assessment of the product creativity and the relation with the factors considered in the study. This study emphasized the necessity to have a holistic understanding about the students' abilities and the individual and environmental factors influencing creativity as they are crucial factors affecting process and product creativity. Students' individual creativity and motivation towards the task must be taken into consideration in further studies.

Previous research questioned the level to which individuals' abilities can impact the design performance (Cho, 2017). The current study reveals the existence of a correlation between spatial ability, flow and motivation. This requires the design instructors to pay attention to these factors and take them into consideration in the judging process. Also, the age, gender and department variables differences could be studied in further studies. This study aimed to answer some of the main questions and fill some of the gaps in the literature. However, there is still so many questions, individual and environmental factors that need to be studied, thus, more research is needed.

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APPENDICES

APPENDIX A. Student Consent Form

Purpose

The aim of this research is to test the influence of virtual reality on the students' creativity in basic design courses. As a participant, I am responsible for only one of the two experiment settings of this research, which are the real experiment setting (setting 1) and the virtual experiment setting (setting 2). As a participant, I have the freedom to choose one of the two settings of the experiment.

Participation

I am one of the approximately 60 participants who will participate in this research study. My participation is entirely voluntary. I feel comfortable in taking part in this research. As a participant, I can decide to withdraw from participation while informing the researcher at any stage of the experiment or I can be excluded from the research if deemed necessary by the researcher. I am aware that my relation with Bilkent University and my academic evaluation will not be affected if I don't participate or if I withdraw from participation. Also, if I have any questions regarding this research, I can contact the investigator, advisor of the investigator or Bilkent University Local Ethics Committee.

Procedure

As a participant in this research, I will fill questionnaires covering information about my gender, age, familiarity with technology, spatial ability and flow state of mind. I will also have to solve a design problem either by using Oculus Rift VR tool or using an iPad. I will be shown how to use the design tool, Oculus Rift or iPad, by the experimenter. Also, I will have to fill in a questionnaire about my experience to rate my creativity and motivation.

Benefits and Risks

There will be no direct benefit to me from this study. However, the findings have the potential to make a contribution to the field of design. Participating in this research will help the research collect the necessary data to test the theories and therefore, add to the existing limited knowledge and research on VR applications in the field of design. I understand that this research will not cause me any harm, there are no known or expected risks caused by the participation in this study.

Compensation

I will not be compensated for my participation in this research. No money will be paid for participating in this research study nor will extra credits be given within the course of Basic Design II.

Confidentiality

Any information obtained in relation to this research study will be reported and published for scientific purposes. As a participant, any information about my identity will remain confidential and placed in investigator's locked secure storage for two years after the completion of the research.

By signing below, I am accepting that I have read and understood this form. I have asked all the questions I have and I understand what I am being asked to do. By signing below, I accept that I am willing and would like to participate in this study.

Name of the Participant: ______________________
(First) (Last)

☐ I am above 18 years old.

______________________ ______________________
Signature of the Participant Date

______________________ ______________________
Signature of the Investigator Date

______________________ ______________________
Signature of the Advisor Date

APPENDIX B. Demographic Questionnaire

Please answer the following questions about your socio-demographic variables including age, gender and experience with technology.

Participant Code ______

Demographic variables

Age ____________

Gender ☐ Female ☐ Male

Technology familiarity questionnaire

1. How many hours do you spend on the computer per week?
   - 2-5 hours a week
   - More than 5 but less than 10 hours a week
   - More than 10 hours a week

2. Have you ever used a Virtual Reality (VR) tool?
   - Yes
   - No

If yes,

3. Which VR tool have you experienced?
   - Oculus Rift
   - HTC Vive
   - Samsung Gear VR
   - Google VR
   - Other

4. For which purpose have you used the VR tool?

- Games
- Design
- Research
- Other

5. How many times did you use the VR tool?

- 1-2 Times
- 3-5 Times
- More than 5 Times

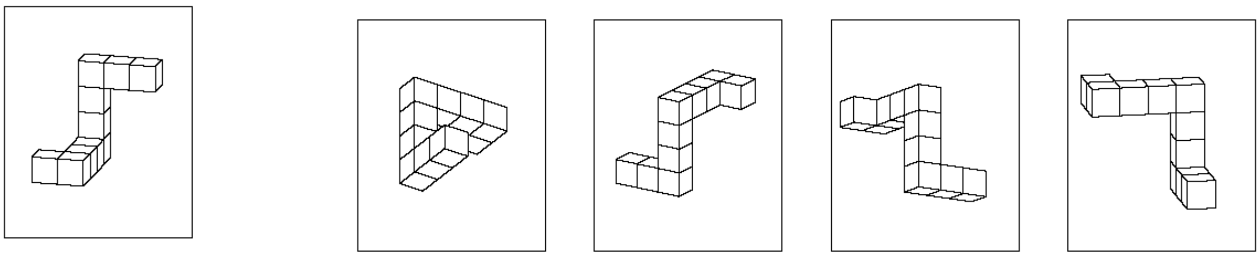
6. When did you last use VR tools?

- 1 Month ago
- 2 Months ago
- More than 2 months ago

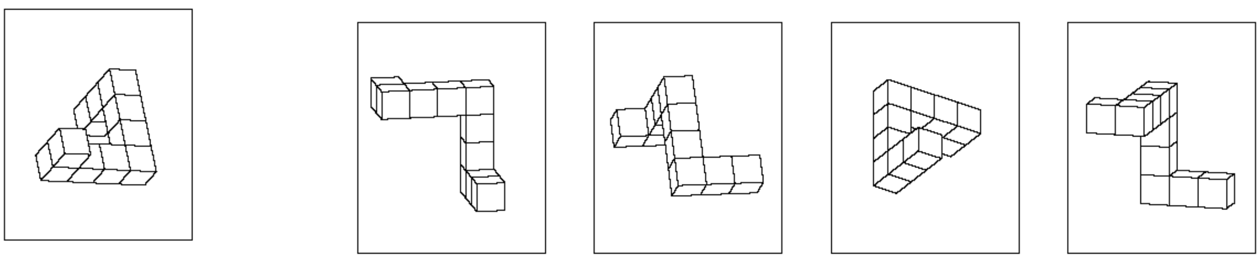
APPENDIX C. Mental Rotation Test (sample items)

This test is a redrawn version of the original Shepard and Metzler figures (Peters et al., 1995). Adapted with the permission of Dr. Michael Peters.

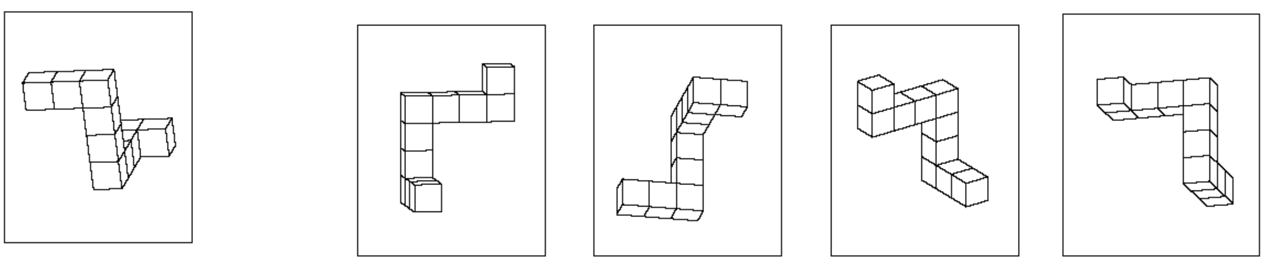
1.c



2.c



3.c

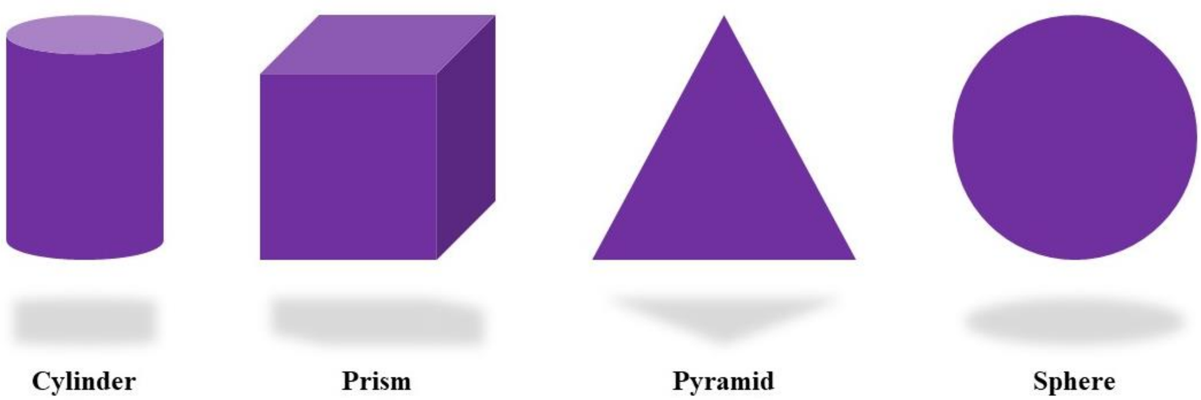


APPENDIX D. Design Brief

A 3D Composition in a Virtual Design Environment

Order is one of the basic components in design compositions. It is referred to as the arrangement of things in relation to one another following a certain sequence, pattern or method. Choosing a system of organization you are asked to design a creative 3D composition that considers meaningful interactions between the geometric forms. The aim is to achieve order in your design. Order should be expressed and understood from every side of your 3D composition.

Your 3D composition could include any of the following geometric forms: cylinder, prism, pyramid and sphere.



Put a selected number of geometric forms together to create your 3D organization. You should use at minimum 8 geometric forms to create your composition. The maximum number of geometric forms that you can use is 16. After having completed your 3D composition please mark below the system of organization that you have chosen.

System of Organization

Central	*Axial*	*Radial*	*Linear*	*Gridal*	*Nodal*	*Clustered*

APPENDIX E. Presence Questionnaire

Presence Questionnaire adapted from Witmer and Singer (2005).

Referring to the experiment you have just taken, please answer the following questions using the rating scale below.

Q1. How much were you able to control events?

Not at all			Somewhat			Completely
1	2	3	4	5	6	7

Q2. How responsive was the environment to actions that you initiated?

Not responsive			Moderately responsive			Completely responsive
1	2	3	4	5	6	7

Q3. How natural did your interactions with the environment seem?

Extremely artificial			Borderline			Completely natural
1	2	3	4	5	6	7

Q4. How much did the visual aspects of the environment involve you?

Not at all			Somewhat			Completely
1	2	3	4	5	6	7

Q5. How natural was the mechanism which controlled movement through the environment?

Extremely artificial			Borderline			Completely natural
1	2	3	4	5	6	7

Q6. How compelling was your sense of objects moving through space?

Not at all			Moderately compelling			Very compelling
1	2	3	4	5	6	7

Q7. How much did your experiences in the virtual environment seem consistent with your real-world experiences?

Not consistent			Moderately consistent			Very consistent
1	2	3	4	5	6	7

Q8. Were you able to anticipate what would happen next in response to the actions that you performed?

Not at all			Somewhat			Completely
1	2	3	4	5	6	7

Q9. How completely were you able to actively survey or search the environment using vision?

Not at all			Somewhat			Completely
1	2	3	4	5	6	7

Q10. How compelling was your sense of moving around inside the virtual environment?

Not compelling			Moderately compelling			Very compelling
1	2	3	4	5	6	7

Q11. How closely were you able to examine objects?

Not at all			Pretty closely			Very closely
1	2	3	4	5	6	7

Q12. How well could you examine objects from multiple viewpoints?

Not at all			Somewhat			Extensively
1	2	3	4	5	6	7

Q13. How involved were you in the virtual environment experience?

Not involved			Mildly involved			Completely involved
1	2	3	4	5	6	7

Q14. How much delay did you experience between your actions and expected outcomes?

No delays			Moderate delays			Long delays
1	2	3	4	5	6	7

Q15. How quickly did you adjust to the virtual environment experience?

Not at all			Slowly			Less than one minute
1	2	3	4	5	6	7

Q16. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

Not proficient			Reasonably proficient			Very proficient
1	2	3	4	5	6	7

Q17. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

Not at all			Interfered somewhat			Prevented task performance
1	2	3	4	5	6	7

Q18. How much did the control devices interfere with the performance of assigned tasks or with other activities?

Not at all			Interfered somewhat			Interfered greatly
1	2	3	4	5	6	7

Q19. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

Not at all			Somewhat			Completely
1	2	3	4	5	6	7

APPENDIX F. Flow State Scale

FSS Survey adapted from Jackson and Marsh (1996).

Referring to the experiment you have just taken, please answer the following questions using the rating scale below.

Q1. I was challenged, but I believed my skills would allow me to meet the challenge.

Strongly disagree				Strongly agree
1	2	3	4	5

Q2. I made the correct movements without thinking about trying to do so.

Strongly disagree				Strongly agree
1	2	3	4	5

Q3. I knew clearly what I wanted to do.

Strongly disagree				Strongly agree
1	2	3	4	5

Q4. It was really clear to me that I was doing well.

Strongly disagree				Strongly agree
1	2	3	4	5

Q5. My attention was focused entirely on what I was doing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q6. I felt in total control of what I was doing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q7. I was not concerned with what others may have been thinking of me.

Strongly disagree				Strongly agree
1	2	3	4	5

Q8. Time seemed to alter (either slowed down or speeded up).

Strongly disagree				Strongly agree
1	2	3	4	5

Q9. I really enjoyed the experience.

Strongly disagree				Strongly agree
1	2	3	4	5

Q10. My abilities matched the high challenge of the situation.

Strongly disagree				Strongly agree
1	2	3	4	5

Q11. Things just seemed to be happening automatically.

Strongly disagree				Strongly agree
1	2	3	4	5

Q12. I had a strong sense of what I wanted to do.

Strongly disagree				Strongly agree
1	2	3	4	5

Q13. I was aware of how well I was performing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q14. It was no effort to keep my mind on what was happening.

Strongly disagree				Strongly agree
1	2	3	4	5

Q15. I felt like I could control what I was doing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q16. I was not worried about my performance during the event.

Strongly disagree				Strongly agree
1	2	3	4	5

Q17. The way time passed seemed to be different from normal.

Strongly disagree				Strongly agree
1	2	3	4	5

Q18. I loved the feeling of that performance and want to capture it again.

Strongly disagree				Strongly agree
1	2	3	4	5

Q19. I felt I was competent enough to meet the high demands of the situation.

Strongly disagree				Strongly agree
1	2	3	4	5

Q20. I performed automatically.

Strongly disagree				Strongly agree
1	2	3	4	5

Q21. I knew what I wanted to achieve.

Strongly disagree				Strongly agree
1	2	3	4	5

Q22. I had a good idea while I was performing about how well I was doing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q23. I had total concentration.

Strongly disagree				Strongly agree
1	2	3	4	5

Q24. I had a feeling of total control.

Strongly disagree				Strongly agree
1	2	3	4	5

Q25. I was not concerned with how I was presenting myself.

Strongly disagree				Strongly agree
1	2	3	4	5

Q26. It felt like time stopped while I was performing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q27. The experience left me feeling great.

Strongly disagree				Strongly agree
1	2	3	4	5

Q28. The challenge and my skills were at an equally high level.

Strongly disagree				Strongly agree
1	2	3	4	5

Q29. I did things spontaneously and automatically without having to think.

Strongly disagree				Strongly agree
1	2	3	4	5

Q30. My goals were clearly defined.

Strongly disagree				Strongly agree
1	2	3	4	5

Q31. I could tell by the way I was performing how well I was doing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q32. I was completely focused on the task at hand.

Strongly disagree				Strongly agree
1	2	3	4	5

Q33. I felt in total control of my body.

Strongly disagree				Strongly agree
1	2	3	4	5

Q34. I was not worried about what others may have been thinking of me.

Strongly disagree				Strongly agree
1	2	3	4	5

Q35. At times, it almost seemed like things were happening in slow motion.

Strongly disagree				Strongly agree
1	2	3	4	5

Q36. I found the experience extremely rewarding.

Strongly disagree				Strongly agree
1	2	3	4	5

APPENDIX G. Instructional Materials Motivation Survey

Instructional Materials Motivation Survey based on the ARCS model (Keller, 2010) as applied by Wei et al. (2015).

Referring to the experiment you have just taken, please answer the following questions using the rating scale below.

Q1. Something interesting at the beginning of this experiment captured my attention.

Strongly disagree				Strongly agree
1	2	3	4	5

Q2. After learning the introductory information, I felt confident that I knew what I was supposed to do in this experiment.

Strongly disagree				Strongly agree
1	2	3	4	5

Q3. Completing the task in this experiment gave me a satisfying feeling of accomplishment.

Strongly disagree				Strongly agree
1	2	3	4	5

Q4. Completing this experiment successfully was important to me.

Strongly disagree				Strongly agree
1	2	3	4	5

Q5. I enjoyed this experiment so much that I would like to know more about this topic.

Strongly disagree				Strongly agree
1	2	3	4	5

Q6. The content of this experiment appeared to be dry and unappealing.

Strongly disagree				Strongly agree
1	2	3	4	5

Q7. The content of this experiment was relevant to my interests.

Strongly disagree				Strongly agree
1	2	3	4	5

Q8. This experiment contained things that stimulated my curiosity.

Strongly disagree				Strongly agree
1	2	3	4	5

Q9. I really enjoyed joining this experiment.

Strongly disagree				Strongly agree
1	2	3	4	5

Q10. The amount of repetition in this experiment caused me to become bored at times.

Strongly disagree				Strongly agree
1	2	3	4	5

Q11. The content of this experiment gave the impression that its content was worthwhile.

Strongly disagree				Strongly agree
1	2	3	4	5

Q12. I learnt some things that were surprising or unexpected.

Strongly disagree				Strongly agree
1	2	3	4	5

Q13. After the training phase, I was confident that I would be able to create novel work.

Strongly disagree				Strongly agree
1	2	3	4	5

Q14. The evaluation after the exercises in this experiment helped me feel rewarded for my effort.

Strongly disagree				Strongly agree
1	2	3	4	5

Q15. The variety of tasks and questionnaires helped maintain my attention during the experiment.

Strongly disagree				Strongly agree
1	2	3	4	5

Q16. It felt good to complete this experiment successfully.

Strongly disagree				Strongly agree
1	2	3	4	5

Q17. The content of this experiment will be useful to me.

Strongly disagree				Strongly agree
1	2	3	4	5

Q18. The good organization of the experiment helped me be confident that I would accomplish the task.

Strongly disagree				Strongly agree
1	2	3	4	5

Q19. It was a pleasure to work on such a well-designed experiment.

Strongly disagree				Strongly agree
1	2	3	4	5