DİLAY SEDA ÖZGEN TURAN
ENHANCING SUSTAINABLE BEHAVIOR VIA A SERIOUS GAME: THE ROLE OF BIOPHILIC DESIGN IN REAL AND VIRTUAL SETTINGS
Bilkent University 2024

ENHANCING SUSTAINABLE BEHAVIOR VIA A SERIOUS GAME: THE ROLE OF BIOPHILIC DESIGN IN REAL AND VIRTUAL SETTINGS

A Ph.D. Dissertation

by

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Ankara
September 2024

To my family…

ENHANCING SUSTAINABLE BEHAVIOR VIA A SERIOUS GAME: THE ROLE OF BIOPHILIC DESIGN IN REAL AND VIRTUAL SETTINGS

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

by

DİLAY SEDA ÖZGEN TURAN

In Partial Fulfillment of the Requirements for the Degree of
DOCTOR OF PHILOSOPHY IN INTERIOR ARCHITECTURE
AND
ENVIRONMENTAL DESIGN

THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
İHSAN DOĞRAMACI BİLKENT UNIVERSITY
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By Dilay Seda Özgen Turan

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 Doctor of Philosophy in Interior Architecture and Environmental Design.

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ABSTRACT

ENHANCING SUSTAINABLE BEHAVIOR VIA A SERIOUS GAME: THE ROLE OF BIOPHILIC DESIGN IN REAL AND VIRTUAL SETTINGS

Özgen Turan, Dilay Seda

Ph. D., Department of Interior Architecture and Environmental Design

Advisor: Prof. Dr. Yasemin Afacan

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September 2024

Traditional sustainable design efforts often fail to significantly influence human behavior towards sustainability. This gap highlights the need for innovative approaches to encourage environmentally responsible actions in built environments.

The aim of this thesis is to explore the potential of biophilic design—an architectural approach that integrates natural elements into built environments—to foster sustainable behaviors. Additionally, the study introduces the use of serious games as a novel tool to simulate real-world scenarios and influence behavior towards sustainability. Serious games can bridge the gap between awareness and action, offering a unique opportunity to reshape attitudes toward sustainability.

The research involved 162 participants and was conducted in four distinct environments: two real-world settings, a non-immersive computer environment, and an immersive

virtual reality (VR) setting. The study compared behaviors in biophilic and non-biophilic environments, and examined the role of serious games in enhancing sustainable behaviors in these different contexts.

Findings reveal that biophilic design in real environments positively influences sustainable behaviors more than non-biophilic environments. Moreover, integrating biophilic design into serious games further enhances these behaviors, especially when experienced in an immersive virtual reality (VR) setting. The study underscores the potential of combining biophilic design with serious games as a powerful strategy to promote sustainable behaviors, offering insights into how digital tools can reconnect individuals with nature and encourage environmentally responsible actions.

Keywords: Sustainable Behavior, Biophilic Design, Serious Games, Virtual Reality

ÖZET

CİDDİ BİR OYUN YOLUYLA SÜRDÜRÜLEBİLİR DAVRANIŞLARIN GELİŞTİRİLMESİ: GERÇEK VE SANAL ORTAMLARDA BİYOFİLİK TASARIMIN ROLÜ

Özgen Turan, Dilay Seda

Doktora, İç Mimarlık ve Çevre Tasarımı Bölümü

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Eylül 2024

Geleneksel sürdürülebilir tasarım çabaları, genellikle insan davranışlarını sürdürülebilirliğe yönlendirme konusunda önemli bir etki yaratamamaktadır. Bu boşluk, yapılılı çevrelerde, doğal çevreye duyarlı eylemleri teşvik etmek için yenilikçi yaklaşımlara olan ihtiyacı ortaya koymaktadır.

Bu tezin amacı, doğal unsurları yapılı çevrelere entegre eden bir mimari yaklaşım olan biyofilik tasarımın sürdürülebilir davranışları teşvik etme potansiyelini araştırmaktır. Ayrıca, çalışma, gerçek dünya senaryolarını simüle ederek sürdürülebilir davranışları etkilemek için ciddi oyunların kullanımını yenilikçi bir araç olarak tanıtmaktadır. Ciddi

oyunlar, farkındalık ve eylem arasındaki boşluğu doldurarak sürdürülebilirliğe yönelik tutumları yeniden şekillendirmek için benzersiz bir fırsat sunabilir. Araştırma, 162 katılımcıyı içermekte olup, iki gerçek dünya ortamı, bir bilgisayar ortamı ve bir sanal gerçeklik (VR) ortamı olmak üzere dört farklı ortamda gerçekleştirilmiştir. Çalışma, biyofilik ve biyofilik olmayan ortamlardaki davranışları karşılaştırmış ve farklı bağlamlarda ciddi oyunların sürdürülebilir davranışları artırmadaki rolünü incelemiştir. Bulgular, biyofilik tasarımın gerçek ortamlar içinde, biyofilik olmayan ortamlara kıyasla sürdürülebilir davranışları daha olumlu yönde etkilediğini ortaya koymaktadır. Ayrıca, biyofilik tasarımın ciddi oyunlara entegre edilmesi, özellikle daldıran bir VR ortamında deneyimlendiğinde, bu davranışları daha da güçlendirmektedir. Çalışma, biyofilik tasarımın ciddi oyunlarla birleştirilmesinin sürdürülebilir davranışları teşvik etmek için güçlü bir strateji olduğunu vurgulamakta, dijital araçların bireyleri doğa ile yeniden bağlayabileceği ve çevreye duyarlı eylemleri teşvik edebileceği yönünde önemli içgörüler sunmaktadır.

Anahtar Kelimeler: Sürdürülebilir Davranış, Biyofilik Tasarım, Ciddi Oyunlar, Sanal Gerçeklik

ACKNOWLEDGMENTS

First and foremost, I would like to express my deepest gratitude to my supervisor, Prof. Dr. Yasemin Afacan for their unwavering support, insightful guidance, and invaluable advice throughout my doctoral journey. Besides I would thank my co-supervisor Assoc. Prof. Elif Sürer, committee members Assist. Prof. Dr. Çağrı İmamoğlu, Prof. Dr. Hüseyin Boyacı and Assist. Prof. of Practice, Dr. Burçak Altay. Your expertise were instrumental in shaping the direction of my research and bringing this thesis to fruition.

My heartfelt appreciation goes to my family and friends for their unwavering support, patience, and understanding during this challenging time. To my parents, Hediye Özgen and Erdal Özgen, my sister, Hilal Söyler and nephews Yusuf Söyler and Zeynep Naz Söyler thank you for your endless encouragement and for always believing in me. To my partner, Ali Turan your love and support have been my greatest source of strength. Without your generosity, this work would not have been possible. Special thanks to my father-in-law Prof. Dr. Bahri Turan for his assistance.

Lastly, I would like to express my deepest gratitude to my colleague Dilara Beder and my precious Bal, who has been by my side and supported me throughout this challenging

period. Your support, patience, and presence have made this journey much more meaningful and bearable for me. I am truly grateful.

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LIST OF ABBREVIATIONS

AR: Augmented Reality

BIDI: Biophilic Interior Design Index

CareEnvWellbeing: Care Environmental Wellbeing

EAS: Environmental Action Scale

EIS: Environmental Identity Scale

EnvIdentity: Environmental Identity

IVR: Immersive Virtual Reality

NA: Natural Analogues

NIS: Nature in the Space

NOF: Nature of the Space

PEB: Pro-Environmental Behavior

PEBS: Pro-Environmental Behavior Scale

ProEnvBehs: Pro-Environmental Behaviors

QualityofLife: Quality of Life

SBS: Sustainable Behavior Scale

SCB: Sustainable Consumption Behavior

TPB: Theory of Planned Behavior

VE: Virtual Environment

VR: Virtual Reality

CHAPTER I:

INTRODUCTION

The rapid growth of industrial production, coupled with increased consumption and a disregard for natural resources, has led to significant climate change and ecological crises. The United Nations (2019) report clearly warns that if these issues are not urgently addressed, the global temperature is projected to rise by 1.5°C, exceeding previous expectations. In response, various organizations have begun raising awareness among governments, societies, and individuals about the impending environmental catastrophe. However, certain governments, particularly those contributing most to environmental degradation, remain indifferent to these warnings. Greta Thunberg, a young environmental activist, has highlighted the severity of the situation, stating, “Nature is dying, and almost nothing is being done.” (BBC Thunberg, 2019, 0:45). This raises critical questions about the role of built environment design in mitigating environmental harm and how these spaces can contribute to protecting nature.

While sustainable design practices have made strides in reducing environmental impacts by minimizing pollution, waste, and energy consumption, they often fall short in achieving long-term sustainability. Kellert (2008) criticizes the sustainable design movement for focusing too narrowly on reducing environmental impacts, without fostering a deeper, mutually beneficial relationship between humans and nature. This approach, while necessary, does not fully address the need to reconstruct human-nature relationships within the built environment. Therefore, the question arises: how can the design of spaces influence people's attitudes toward nature?

Biophilic design, which includes natural elements into the built environment, is supported by literature as a means to encourage environmentally responsible behavior. However, implementing biophilic design in existing buildings can be challenging due to complex renovation processes, stakeholder priorities, and regulatory constraints (Clarke et al., 2018; Thuvander et al., 2012; Kamari, Corrao, & Kirkegaard, 2017). Furthermore, some environments, such as intensive care units or military zones, may face restrictions on incorporating biophilic elements due to government regulations ("T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi", 2020).

To address these challenges and promote environmental responsibility, digital tools like immersive virtual reality (VR), augmented reality (AR), and serious games have been utilized to simulate biophilic environments. Studies have shown

that exposure to natural elements in VR can reduce negative moods similarly to physical environments (Emamjomeh et al., 2020; Yin et al., 2018; Zou & Ergan, 2019). These technologies offer a promising avenue for understanding the effects of biophilic design on human behavior without the need for costly and time-consuming physical construction.

The concept of serious games, which are designed to influence behavior through education, training, and engagement, has been identified as a key tool for promoting pro-environmental behaviors (Schuller et al., 2013; Aldrich, 2009; Tobler-Ammann et al., 2017). Research indicates that serious games can effectively enhance users' cognitive outcomes, experiences, and environmental awareness (de Vries & Knol, 2011; Connolly et al., 2012; Johnson et al., 2017; Senbel et al., 2014). By incorporating biophilic design into serious games, it is possible to create virtual environments that foster sustainable behaviors.

1.1.Problem Statement

The rapid rise in industrial production, excessive consumption, and neglect of natural resources have caused major environmental issues like climate change and ecological degradation. These problems stem from people’s disconnection from nature, as most now live in built environments without natural elements (Nisbet et al., 2009). While sustainable design aims to address these issues through eco-friendly architecture, it often focuses only on reducing environmental impacts,

without fostering a deeper connection with nature (Kellert, 2008). This has highlighted the need for more effective strategies that not only reduce environmental footprints but also encourage pro-environmental behaviors by transforming individuals' relationships with their environment.

A promising way to address this challenge is by using biophilic design, which involves adding natural elements to built environments. This approach can improve human well-being and encourage care for the environment. (Browning & Ryan, 2020). However, the potential of biophilic design to influence sustainable behaviors is underexplored, particularly in digital environments such as serious games. Serious games, which blend educational content with interactive gameplay, present an opportunity to simulate real-world scenarios and influence player behavior in a controlled, engaging manner (Connolly et al., 2012). Research has shown that exposure to natural elements in immersive VR can positively impact mood and behavior, similar to physical biophilic environments (Yin et al., 2018).

The significance of this research stems from its potential to offer valuable insights into how biophilic design can be effectively utilized in both real and virtual environments to foster a deeper connection to nature and encourage sustainable behaviors. By understanding the impact of biophilic elements within serious games, this study could inform the development of new strategies for environmental education and behavior change, thereby contributing to broader

sustainability goals.

To address this problem, the research will focus on the following objectives:

To assess the impact of exposure to biophilic and non-biophilic environments on sustainable behaviors in real-world settings

To evaluate how incorporating biophilic design elements into a serious game influences sustainable behaviors compared to biophilic built environment.

To compare sustainable behaviors between participants exposed to real-world environments and those exposed to virtual reality environments, particularly with a focus on biophilic design.

1.2. Aim and Scope

This thesis seeks to encourage sustainable behaviors through the use of a biophilic environment within a serious game. It introduces the concept of a serious game as an innovative tool to assess the influence of exposure to a biophilic environment on sustainable behaviors. The study is guided by three research questions:

RQ1: Is there any difference between exposure to biophilic and non-biophilic environments in real-world settings regarding sustainable behaviors?

RQ2: Does playing a serious game with biophilic design elements in a biophilic environment change sustainable behaviors compared to a biophilic built environment?

RQ3: What are the contrasting sustainable behaviors observed in real-world

settings versus virtual reality environments?

The research involves three studies and three hypotheses:

H1: There is a statistically significant difference between the control group (experiencing the non-biophilic built environment) and the treatment group (experiencing the built environment with biophilic design) regarding sustainable behaviors.

H2: Participants who engage in a serious game incorporating biophilic design elements exhibit more substantial improvements in sustainable behaviors than those who only interact with the actual built environment.

H3: Participants demonstrate different sustainable behaviors in a virtual reality environment compared to real-world settings.

1.3. Structure of the Thesis

This thesis is organized into eight chapters. The first chapter provides an introduction to the study, outlining the research problem, objectives, research questions, hypotheses, and the significance of the work. Following the introductory chapter, two chapters are dedicated to reviewing the relevant literature.

The second chapter delves into sustainable behaviors. It explores the definitions, importance, and implications of sustainable behaviors, providing a comprehensive

overview. Additionally, this chapter examines related concepts such as pro-environmental behavior, environmental identity, and sustainable consumption behavior.

The third chapter focuses on the concept of biophilic design. It covers various definitions and approaches to biophilic design, as well as its connection to sustainable behaviors. This chapter also discusses how biophilic environments influence sustainability efforts.

The fourth chapter addresses the topic of serious games. It defines serious games and explores their various applications. The chapter further explains how serious games are used to promote sustainable behavior and how they function within virtual environments.

Chapter five presents the methodology employed in the thesis. This includes the research aims, questions, hypotheses, and the proposed game design framework. Moreover, this chapter details the study's settings, participants, and the instruments used, such as surveys, questionnaires, and game development tools. The procedures for the pre-game, game, immersive game, and controlled experiments are also outlined.

The sixth chapter presents the qualitative and quantitative findings derived from the surveys and questionnaires. It distinguishes the findings from each

experimental stage under separate headings. Additionally, this chapter provides a statistical analysis of all the collected data sets. Moreover,

In chapter seven, the discussion section is presented. This chapter discusses the results from all study phases, comparing them with existing literature. The findings are critically analyzed in the context of the literature.

Finally, the chapter eight concludes the thesis by summarizing the key findings and discussing the limitations of the study. It also offers suggestions for future research. Additionally, this chapter introduces the serious game as a tool for evaluating sustainable behaviors. All relevant written and visual materials, evaluation tools, and statistical analyses are included in the appendices.

CHAPTER II:

SUSTAINABLE BEHAVIOR

Sustainability is typically understood as the ability to fulfill current needs without hindering future generations from fulfilling theirs. It involves maintaining a balance between economic development, environmental conservation, and social fairness (World Commission on Environment and Development, 1987). Achieving sustainability requires the responsible use of resources to guarantee their long-term availability, supported by a holistic approach that considers the interconnectedness of environmental, economic, and social factors (Gladwin et al., 1995). Environmental sustainability, in particular, focuses on reducing harmful environmental effects and encouraging practices that safeguard natural resources (Gibson, 2006). Examples of such practices include cutting down on carbon emissions (IPCC, 2018), ensuring water conservation (Gleick, 2003), protecting biodiversity (Chapin et al., 2000), and improving waste management (Kaza et al., 2018). These actions help maintain the health of ecosystems, which

is crucial for sustaining essential services such as clean air, water, and food supplies (Daily, 1997).

Environmental sustainability is one of the most pressing challenges facing contemporary societies. As the detrimental impacts of human activities on the planet become increasingly apparent, the need for sustainable behaviors that protect and preserve the environment has never been more critical. Understanding the factors that drive such behaviors is essential for developing strategies that can effectively promote sustainability across different contexts. This growing body of research underscores the importance of examining the relationship between humans and nature, particularly how a disconnection from natural environments contributes to environmental degradation.

People, societies, and governments are increasingly confronted with environmental and sustainability challenges. In response, researchers have shifted their focus to the relationship between humans and nature to better understand the root causes of environmental problems. As a result, the study of sustainable behaviors has become a significant area of interest (Nisbet et al., 2009; Nisbet & Zelenski, 2013). It is argued that a disconnection from the natural environment may lead to the degradation of the planet (Nisbet et al., 2009). Sustainable behavior, therefore, encompasses a set of actions designed to protect the world

and its resources, embodying a sustainable lifestyle (Corral-Verdugo, Frías, & García, 2010). Engaging in behaviors that simultaneously care for others and protect the biophysical environment is essential for sustainable practices (Bonnes & Bonaiuto, 2002). The goal is to foster environmentally significant behaviors, which can be defined by their impact on the environment—whether through altering the availability of materials or energy, or by changing the structure and dynamics of ecosystems or the biosphere (Stern, 2000).

As environmental protection becomes a critical factor in human decision-making, environmentally significant behavior also takes on the meaning of actions undertaken with the intention of benefiting the environment (Stern, 2000). A common understanding of such behaviors is closely related to consumption and the decisions that follow (Stern, 1997). Generally, these behaviors and decision-making processes are integral to how consumption activities are framed.

Consumption is often viewed as a result of decision-making processes related to behaviors that significantly impact the environment (Corral-Verdugo et al., 2014; Stern, 1997). Decision-making, a key aspect of cognitive functioning, can be categorized into sustainable and environmentally conscious behaviors, including both one-time actions and those that are repeated (McKenzie-Mohr, 2000). This process entails selecting one option from various competing alternatives (Jin et al., 2019; Peters, Dieckmann & Weller, 2011). It involves several stages, such as gathering information, evaluating alternatives, making a choice, and assessing the

results. The decision-making process is shaped by both the characteristics of the situation and the traits of the individual making the decision.

To promote sustainable behaviors, many scientists have dedicated years of research. One study synthesized findings from previous research and recommended design methods that support sustainable behaviors (MacDonald & She, 2012). In conclusion, fostering sustainable behaviors is crucial for addressing the environmental challenges that threaten the future of our planet. By exploring the factors that influence these behaviors, such as values, beliefs, and norms, and by understanding the role of various types of pro-environmental actions, researchers can develop more effective strategies for encouraging sustainable practices. The insights gained from this research are vital for guiding future efforts in environmental protection and sustainability, ensuring that individuals, societies, and governments can work together to preserve the natural world for generations to come.

2.1. Pro-environmental Behavior

Pro-environmental behavior (PEB) is a crucial component in the broader context of promoting sustainable behaviors. This concept refers to actions undertaken by individuals that contribute to the preservation and improvement of the environment, thus supporting the long-term sustainability of ecosystems (Stern, 2000). Understanding and encouraging PEB is essential for addressing the global

environmental challenges posed by climate change, resource depletion, and biodiversity loss (Kollmuss & Agyeman, 2010; Geiger, Geiger & Wilhelm, 2019).

Several theories have been developed to explain and predict PEB, each providing unique insights into the factors that motivate individuals to act in environmentally friendly ways. The Theory of Planned Behavior (TPB), for instance, suggests that behavior is driven by attitudes, subjective norms, and perceived behavioral control. According to TPB, individuals are more likely to engage in PEB when they have positive attitudes toward the environment, perceive social pressure to act sustainably, and believe they have the capability to make a difference (Ajzen, 1991).

Another influential framework is the Value-Belief-Norm theory, which posits that individuals' values shape their beliefs about environmental issues, which in turn form personal norms that drive pro-environmental actions. This theory emphasizes the role of moral obligations and the internalization of environmental values as key drivers of PEB (Stern, 2000).

The significance of PEB lies in its direct impact on reducing environmental degradation and promoting sustainability. Behaviors such as energy conservation, waste reduction, sustainable consumption, and support for environmental policies are all forms of PEB that contribute to the reduction of ecological footprints and the promotion of sustainable development (Farrow et al., 2017).

Encouraging PEB is also vital for creating a culture of sustainability. As more individuals adopt environmentally friendly behaviors, these actions can spread through social networks, creating a ripple effect that amplifies their impact. This is particularly important in the context of climate change, where collective action is necessary to achieve significant environmental benefits (Geiger, Geiger & Wilhelm, 2019).

Moreover, promoting PEB through education, awareness campaigns, and policy interventions can lead to long-term behavioral changes that are essential for sustaining environmental improvements. For instance, increasing public awareness about the consequences of environmental degradation and the benefits of sustainable living can motivate individuals to adopt and maintain pro-environmental behaviors (Farrow et al., 2017).

The Pro-Environmental Behavior Scale (PEBS) developed by Kılınç and Clayton (2013) is a tool designed to measure individuals' engagement in behaviors that positively impact the environment. It aims to assess the frequency and extent of pro-environmental actions taken by individuals in their daily lives.

In conclusion, PEB plays a critical role in achieving sustainability by directly contributing to environmental protection and fostering a societal shift towards sustainable living. By understanding the underlying motivations and barriers to PEB, policymakers and educators can design more effective strategies to promote

these behaviors, ultimately leading to a more sustainable future.

2.2. Environmental Identity

Environmental identity refers to the way individuals perceive themselves in relation to the natural environment, and how this perception influences their behaviors and attitudes toward sustainability (Clayton, 2003). The concept of environmental identity has gained significant attention in the field of environmental psychology, as it provides a deeper understanding of the intrinsic motivations that drive sustainable behaviors. According to Clayton, environmental identity is not just about the actions one takes but also about how these actions are tied to a person's self-image and values. For example, individuals who identify strongly with the environment may feel a personal responsibility to act in ways that are environmentally sustainable. This sense of responsibility often translates into behaviors such as reducing waste, conserving energy, and supporting environmental policies.

Several other approaches complement Clayton's (2003; 2012) framework by exploring how environmental identity intersects with broader psychological theories. For instance, the Value-Belief-Norm theory posited by Stern (2000) suggests that personal values and beliefs about the environment are critical in shaping pro-environmental norms, which then influence sustainable behaviors. In this context, environmental identity can be seen as a reflection of these deeper

values and beliefs, driving individuals to act in ways that are consistent with their environmental ethics.

The connection between environmental identity and sustainable behaviors is well-documented across various studies. For example, individuals with a strong environmental identity are more likely to participate in activities such as recycling, supporting renewable energy initiatives, and engaging in political activism for environmental causes (Whitmarsh & O'Neill, 2010). Clayton (2003) emphasizes that individuals with a strong environmental identity feel a deep connection with the natural world, which translates into a range of pro-environmental behaviors. These individuals are more likely to adopt behaviors such as reducing energy use, purchasing eco-friendly products, and advocating for environmental policies as part of their personal identity. Stets and Biga (2003) conducted a study showing that individuals who identify strongly with environmental values are more likely to engage in behaviors such as water conservation, energy-saving practices, and reduced car use. This strong environmental self-identity motivates behavior that is consistent with protecting the environment. Hinds and Sparks (2008) found that people with a strong environmental identity are more likely to exhibit environmental volunteerism and nature conservation behaviors. Their study also highlighted the role of emotional connection to nature as a motivator for pro-environmental actions. These behaviors are not only motivated by external factors, such as social pressure or economic incentives, but also by an intrinsic desire to maintain consistency with

one’s self-concept as an environmentally responsible person.

Moreover, environmental identity has been linked to long-term commitment to sustainability. Unlike behaviors driven by external rewards or punishments, those rooted in a strong environmental identity are more likely to be sustained over time, even in the absence of external incentives. This is because these behaviors are seen as integral to one’s identity and self-worth (Clayton, 2012).

Understanding environmental identity provides valuable insights into the psychological underpinnings of sustainable behaviors. Clayton’s approach, along with other theoretical frameworks, highlights the importance of integrating environmental concerns into the self-concept to foster long-lasting and meaningful sustainable practices. As environmental challenges continue to grow, strengthening environmental identity across diverse populations may be key to achieving broader sustainability goals.

2.3. Sustainable Consumption Behavior

Sustainable consumption behavior refers to the decision-making processes and actions of individuals that aim to meet their needs while minimizing their impact on the environment, society, and future generations (Stern, 2000). This behavior is essential in addressing global challenges such as climate change, resource depletion, and environmental degradation. Sustainable consumption encompasses

various aspects, including the choice of products, the frequency of consumption, and the methods of disposal, all with the goal of reducing the overall ecological footprint.

Sustainable consumption is grounded in several theoretical frameworks that explain why individuals choose to consume sustainably and how these behaviors can be encouraged. One prominent theory is the Value-Belief-Norm theory, which suggests that individuals' values and beliefs about the environment influence their personal norms and, consequently, their consumption behaviors (Stern, 2000). According to this theory, people who value the environment and believe in the importance of sustainability are more likely to adopt behaviors such as purchasing eco-friendly products, reducing waste, and conserving energy.

In the context of sustainable consumption, TPB suggests that individuals are more likely to engage in sustainable practices if they have a positive attitude toward sustainability, perceive social pressure to act sustainably, and believe they have control over their consumption choices.

Several factors influence sustainable consumption behavior, ranging from individual motivations to broader societal influences. Personal values and environmental awareness play a critical role, as individuals who are aware of environmental issues and hold strong pro-environmental values are more likely to make sustainable consumption choices (Haws et al., 2014). Additionally, social

norms and cultural influences can significantly impact consumption patterns. For example, in communities where sustainable consumption is valued and practiced by peers, individuals are more likely to adopt similar behaviors (Gifford, 2011). Economic factors, such as the affordability and availability of sustainable products, also influence consumption behavior. While some individuals may be willing to pay a premium for eco-friendly products, others may be constrained by financial limitations. Thus, making sustainable products more accessible and affordable is crucial for promoting widespread sustainable consumption (Peattie, 2010).

Moreover, psychological factors, including habits and perceived convenience, play a role in shaping consumption behavior. Sustainable consumption often requires individuals to change their established routines, such as reducing meat consumption or opting for public transportation. These changes can be challenging to adopt, especially if they are perceived as inconvenient or time-consuming (Verplanken & Wood, 2006).

Encouraging sustainable consumption requires a multifaceted approach that addresses the various factors influencing behavior. Education and awareness campaigns are essential for increasing knowledge about environmental issues and the benefits of sustainable consumption. These initiatives can help shift values and attitudes toward sustainability, making individuals more likely to adopt sustainable behaviors (Jackson, 2005). Economic incentives, such as subsidies for

eco-friendly products or penalties for unsustainable practices, can also be effective in promoting sustainable consumption. By reducing the cost barrier and making sustainable options more financially attractive, individuals may be more inclined to choose environmentally friendly products (Thøgersen, 2010).

Besides, policy interventions, such as regulations on product labeling and standards for sustainability, can further support sustainable consumption. Clear labeling that indicates the environmental impact of products can help consumers make informed decisions and choose options that align with their sustainability goals (Leire & Thidell, 2005).

Pro-environmental behavior, environmental identity, and sustainable consumption behaviors are key determinants of sustainable behavior because they reflect the underlying motivations, values, and actions that drive individuals to make environmentally conscious choices. Each plays a distinct but interrelated role in shaping how individuals engage with sustainability: PEB is a direct measure of sustainability because it reflects actual actions taken by individuals to protect the environment. Research suggests that consistent PEB contributes significantly to reducing environmental degradation and promoting long-term sustainability (Stern, 2000). By adopting PEB, individuals contribute directly to reducing resource consumption and mitigating environmental harm. People with a strong environmental identity are more likely to engage in consistent pro-environmental actions, as these behaviors align with their self-concept. Environmental identity

fosters intrinsic motivation, where actions like recycling, conserving energy, or supporting sustainable policies are done out of a sense of moral responsibility or personal fulfillment rather than external pressures (Whitmarsh & O'Neill, 2010). Sustainable consumption behavior is a key aspect of sustainability because it addresses the demand side of resource use. Individual choices about what to buy, how much to consume, and how to dispose of products have significant environmental consequences. By opting for sustainable products and practices, individuals can help reduce waste, pollution, and carbon emissions.

These three elements—pro-environmental behavior, environmental identity, and sustainable consumption behaviors—are interconnected and collectively influence sustainable behavior. Pro-environmental behavior represents the actions taken, environmental identity shapes the motivation behind these actions, and sustainable consumption behaviors reflect how individuals engage with sustainability in their everyday decisions. Together, they form a framework for understanding and promoting long-term environmental sustainability.

In this chapter sustainable behaviors' components were discussed. Pro-environmental behavior, environmental identity and consumption behavior were shown as the determinants of the sustainable behaviors. In the next chapter biophilic approach will be discussed.

CHAPTER III:

BIOPHILIC APPROACH

The biophilic approach is a design and architectural philosophy that focuses on incorporating natural elements into built spaces to enhance the bond between people and the natural world. This concept is rooted in the idea that human beings have an innate affinity for the nature, a term popularized as "biophilia" by Erich Fromm (1964) and later expanded upon by Edward O. Wilson (1984). The biophilic approach not only seeks to incorporate natural features into urban spaces but also aims to create environments that promote well-being, reduce stress, and enhance productivity.

Wilson's "biophilia hypothesis" proposes that humans possess an innate inclination to form connections with nature and other living organisms. This theory implies that the bond between humans and the natural world is essential for our psychological and physical health (Kellert & Wilson, 1993). Following this, Stephen Kellert introduced the concept of biophilic design, which involves “the incorporation of natural elements” and

“processes into the built environment” to enhance the human experience and promote sustainability (Kellert, 2008).

3.1. Biophilic Design

In modern societies, the experience of nature is essential for both physical and mental well-being. Human evolution has been deeply intertwined with the natural environment, contributing to overall well-being and personal fulfillment (Kellert, 2008). Fromm introduced the term "biophilia" to describe a psychological orientation of attraction to all living things (1964; 1973). Building on this, Wilson developed the "biophilia hypothesis," defining it as "the innate tendency to focus on life and lifelike processes" (Fromm, 1964: 1). This hypothesis implies that human reliance on nature extends beyond mere material and physical necessities, encompassing a desire for aesthetic, intellectual, cognitive, and even spiritual fulfillment and meaning. (Kellert & Wilson, 1993: 20). Kellert and Wilson (1993) further integrated biophilia into evolutionary psychology theories. Kellert also introduced the concept of biophilic design, which is integrating natural elements and systems into indoor spaces to foster more sustainable environments (2008).

Kellert described humans as bicultural creatures. In the context of built environment design, biophilia is particularly relevant for long-term sustainability, as it aims to restore and enhance people's positive relationship with nature. This is founded on the idea that positive interactions with natural systems are essential for human performance and well-being (Kellert, 2008:3). A biophilic environment fosters a connection between humans

and nature and is not simply about adding greenery to build spaces (Kellert, Heerwagen & Mador, 2008). Moreover, biophilic environments emphasize the relationship between humanity and nature within the built environment while promoting sustainable and culturally respectful interactions (Kellert, Heerwagen & Mador, 2008). They also encourage a mutual relationship with nature to enrich the human experience in a more respectful manner (Kellert, Heerwagen & Mador, 2008).

Exposure to natural environments is associated with “psychological well-being”, “improved mood”, “pleasure”, and “even better health” (Ulrich, 1984). The role of natural environments in enhancing human effectiveness is significant. Natural environments are restorative and possess characteristics such as 'being away,' 'fascination,' 'extent,' and 'compatibility' (Kaplan, 1995; Hartig et al., 2003). Settings that embody these four characteristics help reduce mental fatigue. The literature often contrasts built and natural environments, with built environments often linked to stress due to their demanding, under-stimulating, and monotonous features (Gillis & Gatersleben, 2015).

Conversely, environments that evoke positive moods enhance attention and help individuals escape from stress and mental fatigue. These environments, often termed restorative (Kaplan, 1995), commonly draw their restorative qualities from nature and natural elements (Gifford & McGunn, 2012). Additionally, individuals connected to nature are more likely to develop and function well psychologically (Pritchard et al., 2020). As a result, built environments generally lack the restorative effects provided by

nature (Karmanov & Hamel, 2008). However, Karmanov and Hamel (2008) found that a well-designed and attractive urban environment could also reduce stress and enhance mood, comparable to an attractive natural environment.

The construction of extensive built environments has distanced humans from nature, contributing to a range of environmental challenges, including unsustainable energy use, biodiversity loss, pollution, and climate change. These issues are often traced back to fundamental flaws in environmental design. To address this, a shift toward restorative environmental design is essential, integrating natural elements into built environments to foster sustainable human-nature interactions (Kellert, 2008).

Restorative environments are natural or built spaces that help individuals recover from mental fatigue and stress, enhancing cognitive functioning and overall well-being. These environments typically exhibit characteristics such as 'being away' (a sense of escape), 'fascination' (engaging stimuli), 'extent' (a coherent, rich environment), and 'compatibility' (alignment with an individual's needs and goals) (Kaplan, 1995).

We need restorative environments because modern urban living and built environments often contribute to mental fatigue, stress, and reduced attention capacities. Exposure to natural settings has been shown to significantly reduce stress, improve mood, and enhance cognitive performance, such as attention restoration and memory improvement (Hartig et al., 2003). Furthermore, environments that incorporate natural elements support

psychological well-being, boost creativity, and promote faster recovery from stress (Ulrich, 1984; Gifford & McGunn, 2012).

Restorative environmental design emerged in response to the decline of natural systems, particularly due to urbanization, which weakens the connection between humans and nature. While sustainable design focuses on minimizing environmental impact, Kellert (2008) argues that biophilic design must complement this approach. This combination aims for resource efficiency, pollution control, biodiversity conservation, and improved indoor environmental quality while fostering a positive relationship between people and nature.

Kellert (2008) categorizes biophilic design into two dimensions: organic (natural elements) and experiential (interaction with space). Natural experiences can be direct (e.g., natural light, ecosystems) or indirect (e.g., potted plants, water elements), while symbolic experiences reflect nature through representations like images or videos. Zou and Ergan (2019) found that features such as window size and access to natural light enhance restorative experiences and positively affect users.

Gillis and Gatersleben (2015) reviewed studies on biophilic design through the lens of restorative environments, highlighting that while natural elements are commonly present, the use of natural materials and processes is often lacking in built environments. They suggest that Kellert's (2015) categorization of biophilic design (Figure 1) “direct

experience of nature, indirect experience of nature, and experience of space and place" provides a solid foundation for further research and application in this area.

Environmental Features	Natural Shapes and Forms	Natural Patterns and Processes
Color	Botanical motifs	Sensory variability
Water	Tree and columnar supports	Information richness
Air	Animal (mainly vertebrate) motifs	Age. change, and the patina of time
Sunlight	Shells and spirals	Growth and efflorescence
Plants	Egg, oval. and tubular forms	Central focal point
Animals	Arches. vaults. domes	Patterned wholes
Natural materials	Shapes resisting straight lines and right angles	Bounded spaces
Views and vistas	Simulation of natural features	Transitional spaces
Façade greening	Biomorphy	Linked series and chains
Geology and landscape	Geomorphology	Integration of parts to wholes
Habitats and ecosystems	Biomimicry	Complementary contrasts
Fire		Dynamic balance and tension
		Fractals
		Hierarchically organized ratios and scales
Light and Space	**Place-Based Relationships**	**Evolved Human-Nature Relationship**
Natural light	Geographic connection to place	Prospect and refuge
Filtered and diffused light	Historic connection to place	Order and complexity
Light and shadow	Ecological connection to place	Curiosity and enticement
Reflected light	Cultural connection to place	Change and metamorphosis
Light pools	Indigenous materials	Security and protection
Warm light	Landscape orientation	Mastery and control
Light as shape and form	Landscape features that define building form	Affection and attachment
Spaciousness	Landscape ecology	Attraction and beauty
Spatial variability	Integration of culture and ecology	Exploration and discovery
Space as shape and form	Spirit of place	Information and cognition
Spatial harmony	Avoiding placelessness	Fear and awe
Inside-outside spaces		Reverence and spirituality

Figure 1. Biophilic design features (Kellert, 2008), drawn by author, 2024.

Browning, Ryan, and Clancy (2014) also categorized biophilic design patterns into 14 items under three main headings: "nature in the space", "natural analogues", and "nature of the space" (Figure 2). They argue that biophilic design has the potential to greatly lower stress levels, boost creativity, enhance overall well-being, and accelerate healing, particularly as urbanization continues to increase globally.

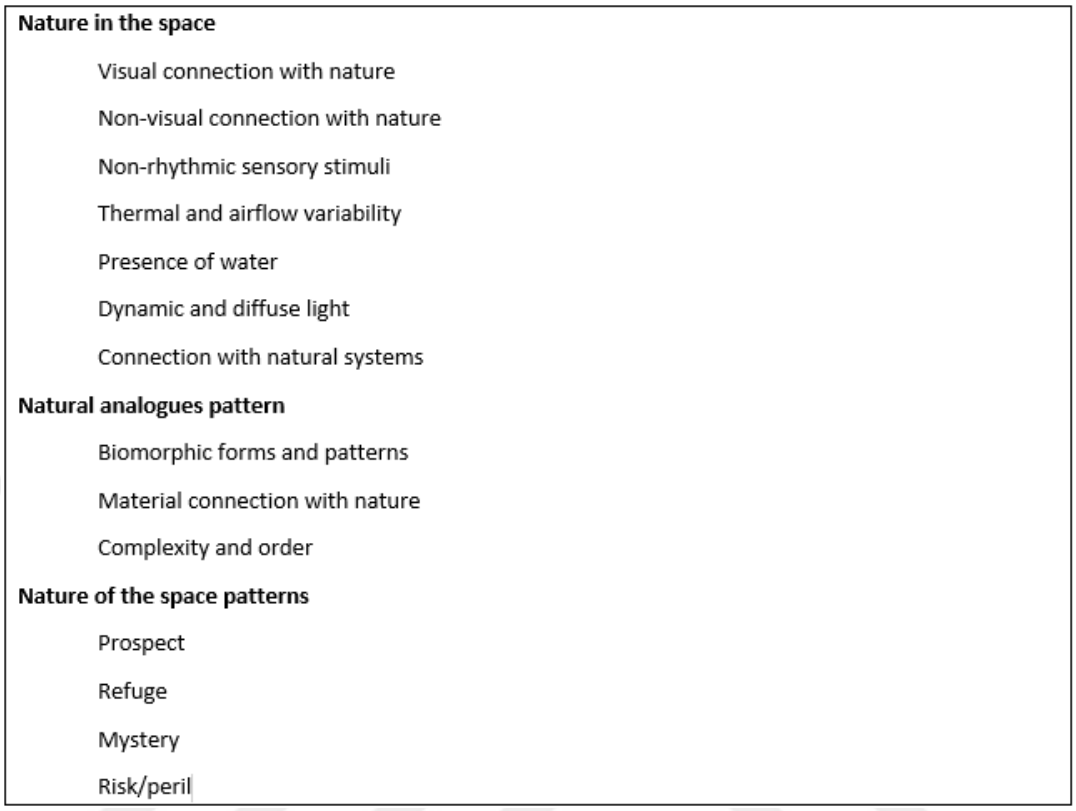

Figure 2. 14 biophilic design patterns (Browning, Ryan & Clancy, 2014), drawn by author, 2024.

Each of these patterns has been shown to foster a connection with nature and enhance physical and psychological well-being. Below is a summary of each biophilic design pattern:

Visual Connection with Nature:

The idea is to provide visual access to natural elements such as plants, water, or landscapes. Views of nature help reduce stress, improve focus, and enhance overall well-being.

Non-Visual Connection with Nature:

This involves engaging other senses—such as sound, smell, or touch—by incorporating natural elements like the sound of water, the scent of flowers, or the texture of wood, which can reduce anxiety and improve cognitive performance.

Non-Rhythmic Sensory Stimuli:

Subtle, unpredictable, and ephemeral elements like rustling leaves or the sound of birds create a calming atmosphere. These stimuli can help restore attention and reduce stress.

Thermal & Airflow Variability:

Natural fluctuations in temperature, humidity, and airflow, similar to what one might experience outdoors, make indoor spaces feel more dynamic and comfortable. This can also enhance occupant comfort and engagement.

Presence of Water:

Water features such as fountains, ponds, or views of rivers and oceans have calming effects, increase concentration, and can positively impact mood and stress levels.

Dynamic & Diffuse Light:

Variability in light conditions, including the use of natural light, can create visual interest and improve mood. This pattern mimics the way sunlight changes throughout the day, creating a sense of time and connection to nature.

Connection with Natural Systems:

This pattern involves recognizing natural processes, such as the changing seasons or weather patterns. Incorporating natural systems fosters an awareness of nature's rhythms and cycles, encouraging a deeper connection to the environment.

Biomorphic Forms & Patterns:

Incorporating shapes, forms, and patterns that resemble those found in nature, such as fractals, spirals, or tree branches, helps create a calming, aesthetically pleasing environment. These forms resonate with the human brain, which is evolutionarily attuned to recognize natural patterns.

Material Connection with Nature:

The use of natural materials like wood, stone, and natural fibers can enhance sensory richness and promote well-being. These materials evoke a sense of authenticity and connection to nature.

Complexity & Order:

This pattern involves creating spaces that exhibit a balanced complexity, where order and variety coexist, similar to natural environments. The presence of both intricate details and harmonious structure helps reduce stress and supports cognitive performance.

Prospect:

Providing expansive views or vantage points allows individuals to feel a sense of openness and control, which reduces stress and enhances comfort. These spaces offer a sense of freedom while allowing for clear sightlines to the surroundings.

Refuge:

Creating small, enclosed spaces within larger environments, where individuals can retreat for privacy or relaxation, evokes feelings of safety and security. These areas help reduce anxiety and provide a psychological escape.

Mystery:

Incorporating elements that suggest something is just around the corner or partially hidden engages curiosity and stimulates exploration. This sense of anticipation can reduce stress and create positive mental stimulation.

Risk/Peril:

Introducing a controlled element of risk or excitement—such as a transparent floor over a height or a precarious-looking bridge—creates a thrill that energizes and engages the senses. This pattern is designed to evoke excitement without causing actual danger.

These qualities make biophilic design increasingly important in contemporary design applications. As a result, this thesis focuses on the 14 biophilic design patterns identified

by Browning, Ryan, and Clancy (2014; 2020), which are further detailed in their book and are foundational to this research.

Biophilic design has been developed in various contexts, such as healthcare environments, where McGee and Marshall-Baker (2015) created the Biophilic Design Matrix. Developed by McGee and Marshall-Baker (2015), this tool is specifically designed to assess biophilic design in healthcare environments. The matrix evaluates spaces based on various biophilic attributes, such as the presence of natural materials, light, air, and water. It helps healthcare facilities improve patient outcomes by incorporating elements that reduce stress and promote healing.

Salingaros (2019) contributed to this field with the Biophilic Index. Biophilic Index is a tool designed to evaluate and quantify the presence and quality of biophilic elements within architectural and urban environments. The concept was introduced by Nikos A. Salingaros, an influential architect and urban theorist, who emphasized the importance of human connections with nature in the design of built environments. His work focuses on how these environments can be structured to promote human well-being through biophilic design principles.

Additionally, frameworks like the WELL Building Standard (International WELL Building Institute, 2020) provides a comprehensive approach to measuring how building features impact human health and well-being. One of its categories, "Mind," emphasizes the importance of biophilia and the integration of natural elements into the built

environment. The WELL standard includes biophilic design strategies as part of its certification process, ensuring buildings promote physical and mental health. The Living Building Challenge (Living Building Challenge, 2020) developed by the International Living Future Institute, sets rigorous performance standards for the design and construction of sustainable spaces. It includes a biophilic environment imperative, which encourages the use of biophilic design principles are integrated from Kellert (2008). This tool emphasizes not only the inclusion of nature but also the cultural and psychological aspects of how people interact with their environments.

The Biophilic Interior Design Index (BIDI) (Yin et al., 2018) is a tool developed to assess the extent and quality of biophilic elements integrated into interior spaces. It was designed to provide a measurable framework for evaluating how well spaces incorporate natural elements, which are known to enhance the human-nature connection and promote well-being. The index is based on the principles of biophilic design, which emphasizes creating built environments that foster a deep connection between humans and nature.

The Biophilic Interior Design Index is built on the 14 patterns of biophilic design, originally identified by Browning, Ryan, and Clancy (2014). Therefore, in this thesis Yin et al.'s (2018) rating tool for Biophilic Interior Design Index is used, because they developed a biophilic index based on 14 patterns of biophilic design (Ryan et al., 2014).

Studies have shown the psychological and physiological benefits of biophilic design. For instance, Wolpe (1978) and Yin et al. (2018) found that biophilic environments reduce

negative emotions and improve positive emotions. Moreover, exposure to nature can improve cognitive performance and reduce stress, with studies showing improvements in short-term memory by 14% (Yin et al., 2018). Cognitive functions, including attention and memory, are positively affected by natural environments (Valtchanov & Ellard, 2015; Fiser & Aslin, 2001; van Lamsweerde et al., 2015).

Lastly, sustainable behaviors are critical for protecting the environment, as highlighted by MacDonald and She (2012) and McKenzie-Mohr (2000). These behaviors are influenced by cognitive processes, and the design of environments can encourage pro-environmental behaviors through informed decision-making and motivation, as discussed by Peters Dieckmann and Weller (2011) and Jin, Ji, and Peng (2019).

3.2. Biophilic Design and Its Relation to Sustainable Behavior

Today's built environment design often reflects a separation of humans from nature through the abstraction and physical division of spaces (Salingaros & Masden, 2008). This separation contributes to unsustainable behaviors (Ives et al., 2018). However, to combat natural disasters, global warming, climate change, and biodiversity loss, sustainable behaviors are essential. The literature reviewed above suggests that exposure to nature enhances restorativeness, and that exposure to biophilic environments, even in gameplay, may foster pro-environmental behaviors as effectively as the physical environment itself. Sustainable behaviors, essential for environmental protection, are shaped by cognitive processes, with design influencing pro-environmental behaviors

through motivation and informed decision-making (MacDonald & She, 2012; McKenzie-Mohr, 2000; Peters, Dieckmann & Weller, 2011; Jin, Ji & Peng, 2019).

Wijesooriya and Brambilla's study (2021) reviews the existing literature on biophilia and explores the strengths, weaknesses, opportunities, and challenges associated with biophilic design in the context of the built environment. The study highlights the potential of biophilic design to change human behavior as an opportunity, as several reviewed studies (Fink, 2011; Africa et al., 2019) indicate that biophilic design promotes pro-environmental behaviors. Additionally, some studies (Marczak & Sorokowski, 2018; Rosa & Collado, 2019; Boiral et al., 2019) suggest that biophilic design can increase environmental awareness. However, Wijesooriya and Brambilla (2021) also note that research on biophilia lacks a comprehensive framework.

Despite the growing awareness and concern for environmental issues over recent decades, corresponding actions to address these concerns have not kept pace, followed suit (Finger, 1994). Thus, researcher arises this question: “how can we encourage pro-environmental behaviors among individuals, including actions intended to minimize environmental harm or improve environmental conditions?” (Scannell & Gifford, 2010). The most prevalent psychological strategy for encouraging pro-environmental behavior centers on altering individual attitudes. This approach typically includes public campaigns, awareness-raising efforts, outreach, or educational initiatives. The underlying assumption is that people do not engage in pro-environmental behavior due to a lack of knowledge and motivation. They might be indifferent, unaware of the negative impacts of

their actions, uncertain about what steps to take, or not sufficiently motivated to act (Schultz & Kaiser, 2012).

Pro-environmental behavior may be influenced by cultivating a more positive attitude toward the psychological benefits of engaging with natural environments. Interactions with nature can improve individuals' recognition of the restorative value these environments offer. Additionally, environmental concern represents the depth of commitment to environmental issues, which serves as a foundation for both environmental knowledge and pro-environmental actions (Hartig, Kaiser & Bowler, 2001). Feelings of emotional affinity toward nature have been shown to be "stronger motivating forces for pro-environmental behaviors than responsibility-related feelings and general environmental beliefs" (Raudsepp, 2005:83).

Built environment design can play a role in promoting pro-environmental behaviors. Biophilic design, which enhances the connection between humans and nature, has the potential to influence human experiences significantly (Ergan et al., 2019). Studies have shown that contact with nature is a key factor in increasing pro-environmental attitudes among children and youth (Collado & Corraliza, 2013; Hartig, Kaiser & Bowler, 2001). Therefore, if a built environment incorporates natural elements—such as those found in biophilic design—it may enhance pro-environmental behaviors. Hartig, Kaiser, and Bowler (2001) revealed that the perception of restorative qualities in the environment is an indicator of ecological behavior and nature protection among university students and Norwegian adults (Hartig, Kaiser & Strumse, 2007).

In this chapter, I discussed biophilic design and its connection to sustainable behavior. In the next chapter, I will introduce the concept of serious games and explain how they can be integrated with sustainable behaviors, along with the use of VR.

CHAPTER IV:

SERIOUS GAME

The concept of serious games was introduced to assess, modify, or influence human behaviors (Aldrich, 2009), particularly in areas such as education, training, defense, and rehabilitation (Tobler-Ammann et al., 2017). Beyond mere entertainment, playing games offers significant advantages—serving as one of the most widespread, lucrative, and impactful forms of entertainment (Squire, 2003). Today, games are utilized across various research domains, including health, cognitive skills development, and educational purposes. While the idea shares commonalities with simulations like flight or medical simulations, it uniquely highlights the added benefits of fun and competition (Plass et al., 2018). Serious games, particularly those in well-designed digital formats, are primarily intended to influence human behavior, cognition, or attitudes by educating, motivating, and engaging users (Johnson et al., 2017). These games are also characterized as interactive computer-based software created for single or multiple players, with objectives that extend beyond mere entertainment (Ritterfeld et al., 2009).

4.1. Effects of Serious Game on Sustainable Behaviors

Indicators of sustainable behavior include practices such as energy conservation, caring for others, recycling, and minimizing consumption. Among these, energy conservation often serves as a central focus of sustainable behavior. Serious games offer users the opportunity to gain knowledge about energy-saving techniques and explore alternative methods for achieving energy efficiency (Orland et al., 2014). Extensive research on serious games has tested energy-saving strategies using both qualitative and quantitative approaches. Some studies have observed behavioral changes during gameplay, while others have noted changes extending into real life. For instance, the games EnerCities (de Vries & Knol, 2011) and EnergyLife (Gamberini et al., 2011) investigated behavioral changes during gameplay. The EnerCities study, which involved 653 participants, revealed a significant improvement in attitudes toward energy saving and the adoption of specific energy-related household behaviors through a quantitative, quasi-experimental design.

Additionally, the EnergyLife mobile application increased awareness of energy consumption among 24 participants. Other games, such as Energy Battle (Geelen, Keyson, Boess & Brezet, 2012), Power Explorer (Gustafsson, Bang & Svahn, 2009), Power Agent (Gustafsson, Katzeff & Bang, 2009), Greenify (Lee, Ceyhan, Jordan-Cooley & Sung, 2013), Power House (Reeves, Cummings, Scarborough & Yeykelis, 2013), and Do It In The Dark (Senbel, Ngo & Blair, 2014), have been shown to positively influence sustainable behaviors in real life. However, in the study by Kimura and Nakajima (2011) on the game EcoIsland, no behavioral changes were observed, nor was

there evidence of an impact on energy-saving motivation among the 20 participants. The aforementioned studies primarily focus on energy saving but also support behavior change in a broader sustainable context.

Quality characteristics of serious games have been studied extensively. These include “game design”, “user satisfaction”, “usability”, “usefulness”, “understandability”, “motivation”, “performance”, “playability”, “pedagogical aspects”, “learning outcomes”, “engagement”, “user experience”, “efficacy”, “social impact”, “cognitive behavior”, “enjoyment”, “acceptance”, and “user interface” (Abdellatif, McCollum & McMullan, 2018:113-115). These characteristics significantly impact users' experiences. For instance, as motivation within the game increases, so does user engagement. Consequently, behavioral changes can be influenced by these characteristics. For example, pro-social individuals are inherently less motivated to participate in competitive social dilemmas (Pletzer et al., 2018). However, van Horen, van der Wal, and Grinstein (2018) noted that competition might not harm motivation when it serves a sustainable goal—fostering outcomes for the common good. Their study also found that competition enhances sustainable behavior when managed by pro-social entities.

Researchers reviewed twenty-five studies on serious games in the field of sustainability (Johnson et al., 2017). Their findings indicate that serious games are valuable for promoting sustainability, positively influencing behavior, cognition, learning, and user experience (Johnson et al., 2017). Overall, they found evidence of positive changes in attitudes toward energy-saving behavior (Johnson et al., 2017). However, one high-

quality study (Gustafsson, Bang & Svahn, 2009) indicated that participants developed a more negative attitude toward the environment overall (Johnson et al., 2017). The researchers explained this finding by citing the occurrence of "cognitive dissonance induced by the aesthetic message of the game" (Gustafsson, Bang & Svahn, 2009:8).

Based on the information above, the environment influences human behavior, which in turn affects the gaming experience. Since this study focuses on environmental design—particularly biophilic design—it will have implications for the gaming experience. Physical affordances and their manipulation, such as lighting levels or the integration of real-world environments into the game, influence users' immersion levels (Nordin et al., 2014). For instance, when awareness of the surroundings is high, it strongly impacts the gaming experience (Nordin et al., 2014). Therefore, it can be stated that the presence of biophilic design elements may influence the game experience and, consequently, its effects on human behavior. To support this, a study that has the 'Save the Planet' simulation-like game significantly enhanced participants' pro-environmental awareness (Ozgen, Afacan & Surer, 2020).

4.2. Use of Serious Game in Virtual Environments

Virtual Environment (VE) is a computer-generated, interactive, and often immersive space that simulates real-world or imagined environments. Users can interact with this environment in real-time, often using input devices like keyboards, mice, or motion sensors (Burdea & Coiffet, 2003). Virtual environments are used in various applications, including simulations, education, training, and entertainment (Sherman & Craig, 2018).

The primary objective of a virtual environment is to generate a sense of presence, enabling users to feel as though they are truly within the simulated world (Johnson et al., 2017).

Virtual Reality (VR) is a technology that offers a fully immersive, computer-generated simulation of a three-dimensional environment, allowing users to interact with it in a way that feels authentic (Cipresso et al., 2018). VR typically involves specialized hardware, such as head-mounted displays and motion-tracking devices, which provide visual, auditory, and occasionally haptic feedback. The aim of VR is to create a strong sense of presence, making users feel as if they are physically situated within the virtual environment (Kimura & Nakajima, 2011).

Immersive Virtual Reality (IVR) refers to an advanced form of VR designed to completely immerse users in a computer-generated environment (Steuer, 1992). By stimulating multiple senses—such as sight, sound, and touch—IVR systems enhance the feeling of being present within the virtual world. The high level of immersion achieved through devices like VR headsets, motion trackers, and haptic feedback tools helps to blur the line between the virtual and the real, making the experience more compelling and realistic (Slater & Sanchez-Vives, 2016; Gustafsson, Katzeff, & Bang, 2009).

The integration of serious games into VEs has become a significant area of interest in various fields, including education, healthcare, and environmental sustainability. Serious games, which are designed for purposes beyond entertainment, provide users with

interactive and immersive experiences that can lead to behavioral changes, skill development, and enhanced learning outcomes (Orland et al., 2014). This chapter explores the role of serious games within virtual environments, highlighting their benefits, applications, and challenges.

Virtual environments create immersive spaces where users can experience realistic scenarios, enhancing their learning and retention. For instance, in healthcare, serious games within VEs allow medical professionals to practice surgical procedures or patient interactions in a risk-free environment, leading to improved skills and confidence (Kimura & Nakajima, 2011). Besides, one of the primary goals of serious games is to influence user behavior. When integrated into virtual environments, these games can effectively promote pro-environmental behaviors, energy conservation, and other positive actions. Studies have shown that virtual environments can simulate real-world challenges and encourage users to adopt sustainable practices in their daily lives (Orland et al., 2014). In addition, virtual environments make serious games accessible to a wider audience, allowing users to engage with educational content from any location. This flexibility is particularly valuable in educational settings, where VEs can be used to create virtual classrooms, laboratories, and training modules (Gee, 2008).

Virtual environments are also used to promote environmental awareness and sustainability through serious games. Games like EnerCities and EnergyLife have been successful in educating players about energy conservation and the importance of

sustainable practices, leading to behavioral changes both in-game and in real life (Gamberini et al., 2011; Geelen et al., 2012).

In this chapter, the concepts of serious games and virtual environments were defined and discussed within the framework of sustainable behavior. The next chapter will systematically explain the research methodology of the thesis.

In the previous chapters, I explored the concept of sustainable behaviors (Chapter II), including pro-environmental behavior, environmental identity, and sustainable consumption behavior. These elements have been established as critical determinants in fostering sustainable behaviors. Furthermore, the biophilic design approach (Chapter III) was discussed as a promising strategy to restore the human-nature connection, which has become increasingly distant due to the rise of industrialization and urbanization.

However, while the literature demonstrates that biophilic design can positively influence pro-environmental behavior, there is a notable gap in understanding how virtual environments, particularly through serious games, can simulate these effects. Current research on biophilic design is primarily limited to real-world applications, with insufficient exploration of its potential within digital environments such as immersive virtual reality (VR). The integration of biophilic design elements in serious games and their influence on sustainable behavior remains underexplored.

To address this research gap, the next chapter will outline the methodological framework used to investigate how biophilic design integrated into serious games can influence sustainable behaviors. Specifically, the chapter will describe how the study was designed to measure the impact of biophilic environments in both real-world and virtual settings, focusing on participant behavior in both contexts.

The methodology will detail the experimental design, including:

Participant selection and group assignment (control vs. treatment groups),
The creation of serious game scenarios incorporating biophilic design elements,
The comparison of sustainable behaviors in real-world biophilic environments versus virtual biophilic environments,
The use of qualitative and quantitative methods (e.g., surveys, and interviews) to assess the impact of these environments on sustainable behavior.
This methodological approach will provide a structured means of answering the research questions presented in the introductory chapters, allowing for a robust analysis of the potential for biophilic design and serious games to promote sustainability.

In the next chapter, I will delve into these methodological details, ensuring a clear understanding of how the research was conducted and how the findings were analyzed.

CHAPTER V:

METHODOLOGY

5.1. Aim, Research Questions and Hypotheses

The aim is encouraging sustainable behaviors through the use of a biophilic environment within a serious game. This research introduces the concept of a serious game as an innovative tool to assess the influence of exposure to a biophilic environment on sustainable behaviors.

This thesis aims to explore the following questions:

RQ1: Is there any difference between exposure to biophilic and non-biophilic environments in real settings regarding sustainable behaviors?

RQ2: Does playing a serious game with biophilic design elements in a biophilic environment change sustainable behaviors compared to a biophilic built environment?

RQ3: What are the contrasting sustainable behaviors observed in real-world settings versus virtual reality environments?

The thesis involves three studies and three hypotheses:

H1: There is a statistically significant difference between the control group (experiencing the non-biophilic built environment) and the treatment group (experiencing the built environment with biophilic design) regarding sustainable behaviors.

H2: Playing serious game with biophilic design elements increases participants' sustainable behaviors more than experiencing the real built environment.

H3: Participants exhibit distinct sustainable behaviors in virtual reality environment compared to real-world settings.

5.2. Settings

In this research I carried out across three distinct environments, resulting in the collection of four corresponding data sets. The environments were as follows: Phase 1 (Figure 3) took place within the Science Faculty (SA building) on Bilkent University's campus covering 5000 acres, with 3000 acres designated as forested areas. Phase 2 (Figure 4) was conducted in a non-immersive computer environment within the same building as Phase 1. Phase 3 (Figure 5) occurred in an immersive VR environment designed and created by the first author. Additionally, Phase 4, a Controlled Experiment Study was conducted to collect data from a control group located in a different building (FF building) on the same

campus. FF building was selected due to its architectural similarity to SA building but with a notable absence of biophilic design elements.

Figure 3. Experiment area of phase 1, SA building, figure captured by author, 2022.

Figure 4. Experiment area of phase 2, SA building, figure captured by author, 2022.

Figure 5. Experiment area of phase 3, figure captured by author, 2023.

The decision to use SA building as the physical setting for the experiment was based on its high score of 43 out of 54 on the Biophilic Interior Design Index (BIDI) (Yin et al., 2018; Ryan et al., 2014) (see Appendix A), as assessed by four architects with approximately 15 years of experience in sustainable design. Similarly, FF building was chosen for the controlled experiment due to its lower BIDI score of 15 out of 54 (Yin et al., 2018; Ryan et al., 2014).

5.4. Participants

Before beginning data collection, I designed the experiment using G*Power to determine the required sample size (Faul et al., 2007). With a medium effect size ($f = 0.25$), an α level of 0.05, and a power ($1-\beta$) of 0.95, the calculation indicated that approximately 43 participants per group, or a total of 172 participants, would be needed. Afterward, I obtained ethical approval from the Bilkent University's ethics council (see Appendix E) and proceeded to collect data from 173 participants. However, 11 participants were excluded from the study for not meeting the research criteria, leaving 162 participants for data analysis. The sample size across groups varied slightly, ranging from 40 to 43 participants. Previous research on serious games in decision-making contexts has reported participant numbers ranging from 15 to 189 (Linehan et al., 2009; Ong & Araral, 2021; Roungas et al., 2020).

I used cluster sampling method to create groups. These groups are; Group 0, Group 1, Group 2 and Group 3. Group 0 is controlled group, Group 1 is the biophilic built environment exposure group, Group 2 is game players in the biophilic built environment group, Group 3 is game players in the VR environment group. Gender distribution, background, level of educations and the number of the participants in each group can be seen in table 1.

Table 1. Distribution and the backgrounds of the participants.

Number of Participant	Group	Phase	Age Range	Gender	Level of Education	Background
41	0	4	18-29	13 men 28 women	1 Ph.D. 2 Master 38 Undergrad	10 ARCH 3 BA 3 CS 18 IAED 2 IE 3 MATH 2 PSYC
42	1	1	19-32	21 men 21 women	3 Ph.D. 3 Master 36 Undergrad	6 CHEM 4 CS 4 IAED 4 IE 2 LAW 7 MATH 5 MBG 2 ME 5 PHYS 3 PSYC
40	2	2	18-35	22 men 18 women	5 Ph.D. 6 Master 29 Undergrad	1 ARCHA 1 BM 3 CHEM 2 CS 2 EE 12 IAED 2 IE 1 LAW 4 MAN 2 MATH 3 MBG 2 ME 4 PHYS 1 PSYC
39	3	3	18-36	25 men 14 women	2 Ph.D. 7 Master 30 Undergrad	1 BIM 2 CHEM 14 CS 1 CTIS 2 EE 4 IAED 1 IE 1 LAW 3 MBG 2 ME 4 PHYS 3 PSYC

Note. ARCH: architecture, ARCHA: archaeology, BA: business administration, BIM: business information management, BM: business management, CHEM: chemistry, CS: computer science, CTIS: computer technology and information system, EE: electrical electronics, IAED: interior architecture and environmental design, IE: industrial engineering, LAW: law, MAN:

management, MATH: mathematics, MBG: molecular biology and genetics, ME: mechanical engineer, PHYS: physics, PSYC: psychology.

I collected data on weekdays between 12:00 PM and 4:00 PM to maximize natural daylight, excluding days with overcast conditions. Williamson and Cummins (1983) define an overcast day as having 1,000 lux and daylight as exceeding 10,700 lux. Using this information, I measured light levels on the experiment days using the Light Meter, Developed and tested by optics scientists and engineers, this app is calibrated using professional equipment, according to the developer. I did not conduct experiments on days with daylight below 1,000 lux. On the days I conducted experiments, daylight measurements were typically around 14,000 lux. There is overcast day, between overcast day and daylight and daylight calculation examples from different experiment days.

5.4. Instruments

This study utilized four instruments to measure participants' responses: the Environmental Identity and Pro-Environmental Behavior Scale (Clayton & Kilinç, 2013), the Sustainable Consumption Behavior Scale (Quoquab et al., 2019), and the Theory of Planned Behavior Question Construction Scale (Ajzen, 1991). To ensure clarity and accuracy, these instruments were translated from English into the participants' native language and then back into English.

5.4.1. Sustainable Behavior Scale

Clayton (2003) suggests that environmental identity, which supports universal values, environmental behaviors, and decision-making, can differ across cultures. In a later study, Clayton and Kilinç (2013) adapted the PEBS to suit the nationality of participants, and this adapted scale was used in this study. The scale included 15 items related to environmental identity (5 items) and pro-environmental behaviors (10 items). Given the growing concern over the environmental impact of sustainable consumption behavior (SCB), this study also adopted a reliable 24-item SCB Scale developed by Quoquab et al. (2019) to understand participants' sustainable behaviors. This scale includes 11 quality of life items and 13 care environmental wellbeing items. Therefore, SBS was created with the help of these adaptations.

5.4.2. Theory of Planned Behavior Question Construction

Ajzen's (1991) Theory of Planned Behavior (TPB) is a psychological framework that outlines how individuals' attitudes, subjective norms, and perceived behavioral control shape their intentions and behaviors. According to the TPB, behavioral intentions are influenced by one's attitudes toward the behavior and the perceived social pressures, or subjective norms, related to that behavior. Ajzen expanded this by adding the concept of perceived behavioral control, recognizing that individuals' perceptions of their ability to perform a behavior also play a crucial role in their intentions and actual behavior. Ajzen (1991) proposed that human behavior is influenced by three constructs: behavioral,

normative, and control beliefs. The perception of behavioral control impacts how behavioral attitude and subjective norms affect intention. To assess participants' perceptions, I adopted self-assessment interview questions based on (see Appendix C) Ajzen's (1991) TPB Question Construction.

5.4.3. Technologies and Devices

For this research, a serious game was developed using the Unity Game Engine. The VR environment was experienced through HTC Vive headsets. The 3D modeling was carried out using Blender 3.6. Besides statistical data analysis was performed with JASP 0.16.2.

5.5. Procedures

This research involved the collection of four experimental datasets, each corresponding to a distinct sub-procedure: Phase 1 represented the pre-game stage, Phase 2 the game stage, Phase 3 the immersive game stage, and finally Phase 4, the Controlled Experimental Stage. All stages of the experimental process are illustrated in Figure 6. The primary objective of the first phase was to explore participants' perspectives on sustainable behavior and biophilic design. Additionally, it investigated the relationship between these two factors and assessed participants' perceptions of various biophilic design elements.

Figure 6. The experimental stages of the four study sets, drawn by author, 2022.

The second phase aimed to establish a framework for a serious game and subsequently design a game that aligned with this framework. The outcomes of the pre-game stage provided the foundation and guiding principles for this development. As a result, the serious game was introduced as a novel variable to explore the impact of biophilic design elements on human behavior.

In the third phase, representing the immersive game stage, three variables were examined: environmental settings (both VR and physical) and the configuration of the biophilic serious game. While behavioral changes were measured by the serious game in the first two phases, in the third phase, differences between reality (i.e., real and virtual environments) were assessed.

The final phase, the controlled experimental stage, served to establish a baseline, enabling the comparison of the effects of biophilic design. This ensured that any observed changes or effects were genuinely attributable to the manipulations in Phases 1, 2, and 3.

The experimental process began with Phase 1, the pre-game stage, during which data on participants' sustainable behavior within the interior space of SA building at the university were collected. Participants experienced the building environment and subsequently completed questionnaires. Based on the results, a design framework was developed for the second study.

Phase 2, the game stage, involved the design and development of the game. After the game was created using the framework, participants played it and completed sustainable behavior tests. Following this, Phase 3 was conducted. Participants engaged with the game in a VR environment and again completed sustainable behavior tests.

Finally, the controlled experimental stage, Phase 4 was conducted in Bilkent University' FF building on the university campus. FF building was chosen as a controlled environment comparable to SA building due to its similar function, design language, and material use, despite differences in biophilic design elements. This choice aimed to ensure similar representations of indoor spaces and evoke a consistent sense of natural space hierarchy (Richter et al., 2011).

5.5.1. Phase 1: Pre-Game

Phase 1 sought to establish a foundational understanding of the impact of biophilic design on user behavior and interaction. To accomplish this, I examined individual perceptions

of biophilic design. This initial phase was essential for shaping the development of the subsequent serious game. The process involved the following steps: First, participants were selected to ensure a diverse range of perspectives on biophilic design who uses SA building more than one semester. They were then invited to experience SA building, chosen for its diverse biophilic design features. Participants completed a structured questionnaire to record their perceptions and reactions to the various biophilic design elements within the building (see Appendix B). Following this, they took part in semi-structured interviews that allowed by TPB, allowing for a deeper exploration of their perceptions and attitudes toward sustainable behavior and biophilic design (see Appendix C). Then, they filled out the SBS questionnaires (see Appendix D).

Finally, the data gathered from the questionnaires and interviews were analyzed to uncover key themes and patterns related to biophilic design and sustainable behavior. This analysis informed the development of a conceptual framework that guided the creation and implementation of the serious game in Study 2.

5.5.2. Phase 2: Game

The second phase focused on investigating how the game environment affects user behavior. The results from the first study were used to develop a biophilic design framework for the serious game. The study compared the effects of real and non-immersive virtual environments on participants' sustainable behaviors while playing the game. The sample groups were divided into two: one group filled out questionnaires

without playing the game in SA building, while the other group filled out the same questionnaires after playing the game. The second group played the “Pop a Coffee Corner” game, which was created based on the data collected from the first study.

The game was designed to incorporate the biophilic design elements found to be the most relatable and perceivable by participants, such as visual connection with nature, dynamic and diffuse light, the presence of water, and mystery elements. The game was developed using the Unity Game Engine 2020.3.34f1, and models were created with Blender 3.6 software.

5.5.2.1. Game Design

The game “Pop a Coffee Corner” was structured into two distinct levels. Players were tasked with making decisions initially, while the second level involved designing a coffee corner. The motivation behind developing this game was rooted in addressing sustainability concerns prevalent in the coffee industry, encompassing issues like coffee cup waste, transportation impact, CO_2 emissions, and rainforest depletion.

In the game, players designed the coffee corner, utilizing 22 items, including bags, cups, and various types of coffee, beverages, and interior design items as tables, and chairs. The gameplay introduced an array of challenges, such as time constraints, the selection of items traversing through the entrance, decision-making, and item placement within the coffee

corner, all of which contributed to the game's complexity. Designed as a clicker game, players must make decisions within two minutes to gain points.

The chosen items were collected within an inventory bag (Figure 7) during gameplay, and these selections can subsequently be positioned within the coffee corner once the allotted time elapses. The game design and flow were elucidated in Figure 8, while the specific design items featured were visually represented in Figure 9.

Figure 7. a. Game screen, b. Inventory screen, figure captured by author, 2022.

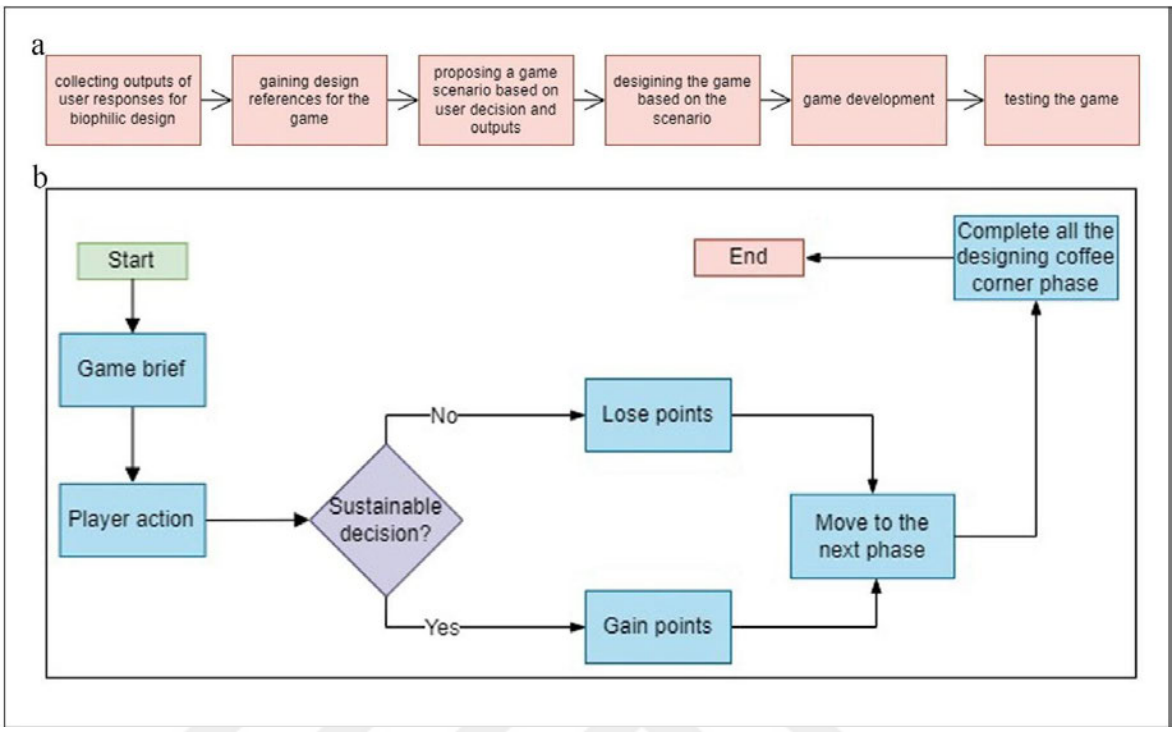

Figure 8. a. Game design pipeline, b. Flowchart, figure drawn by author, 2023.

Figure 9. Coffee-corner design items, figure drawn by author, 2022.

I started to design the game for PC in May 2022. Three games I developed during 3 months but all these three games failed in terms of effectiveness. After that, I consulted game development company and they told it would take too much time to finish and they did not want to help. Then I consulted to Ali Turan who is a developer at Ekinoks Software Company. He is a senior developer in eight years and he knows how to develop a unity game. Therefore, I collaborated with him during the game development process (Figure 10).

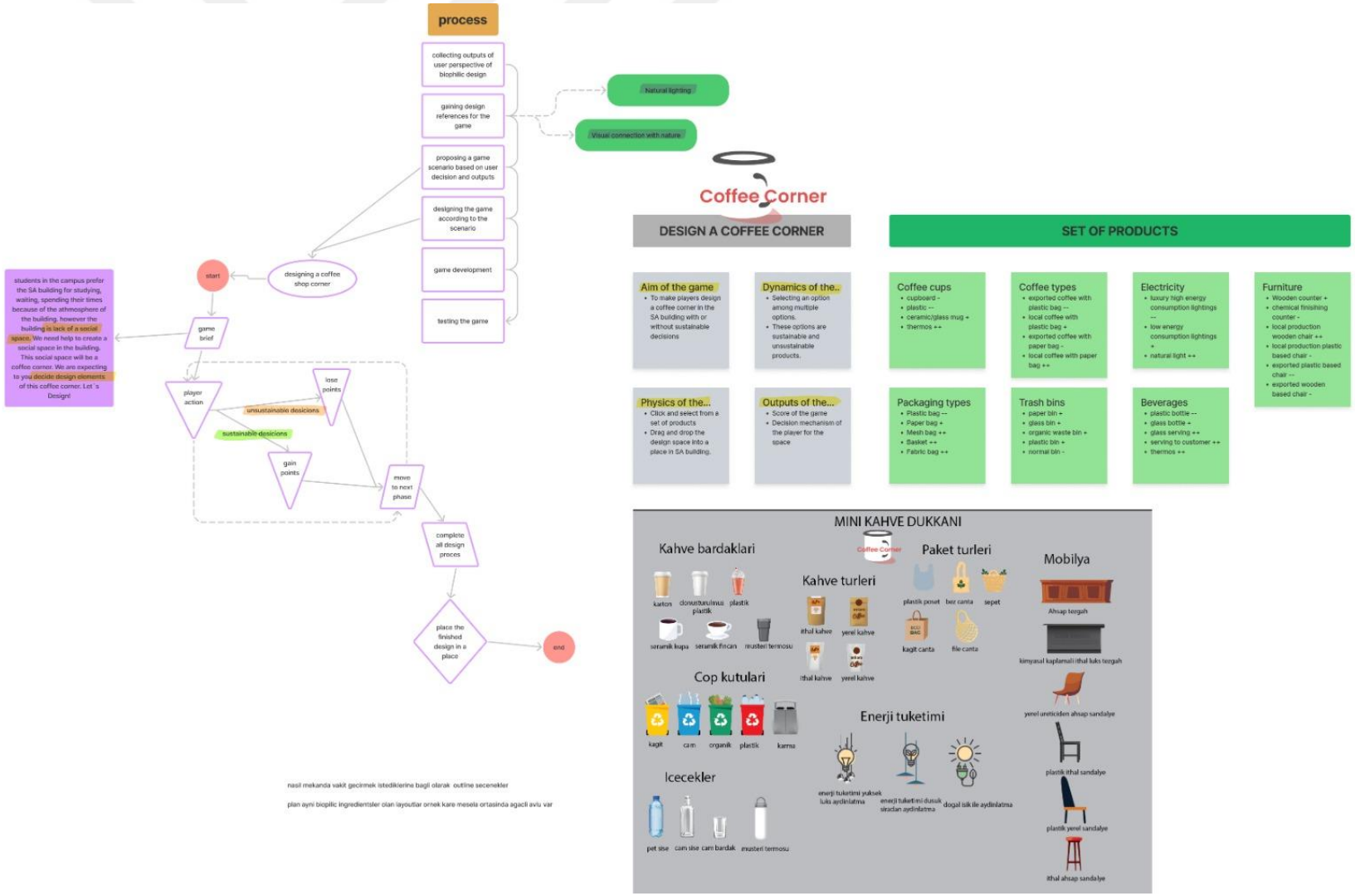

Figure 10. Collaboration process with a developer during game design.

When we were developing the game, we used interior architectural design elements to engage in coffee corner design stage. I integrated different types of furniture with different types of materials and colors as seen in Figure 11 and Figure 12.

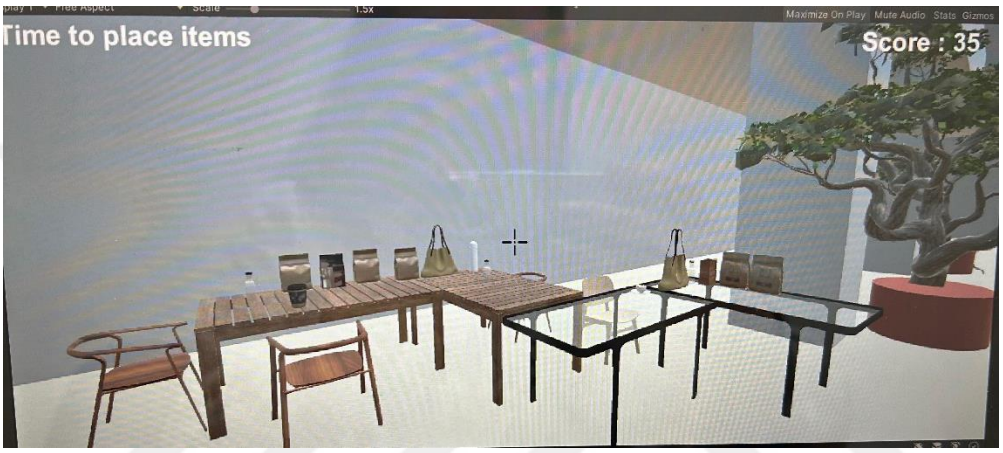

Figure 11. Desktop game player's coffee corner design.

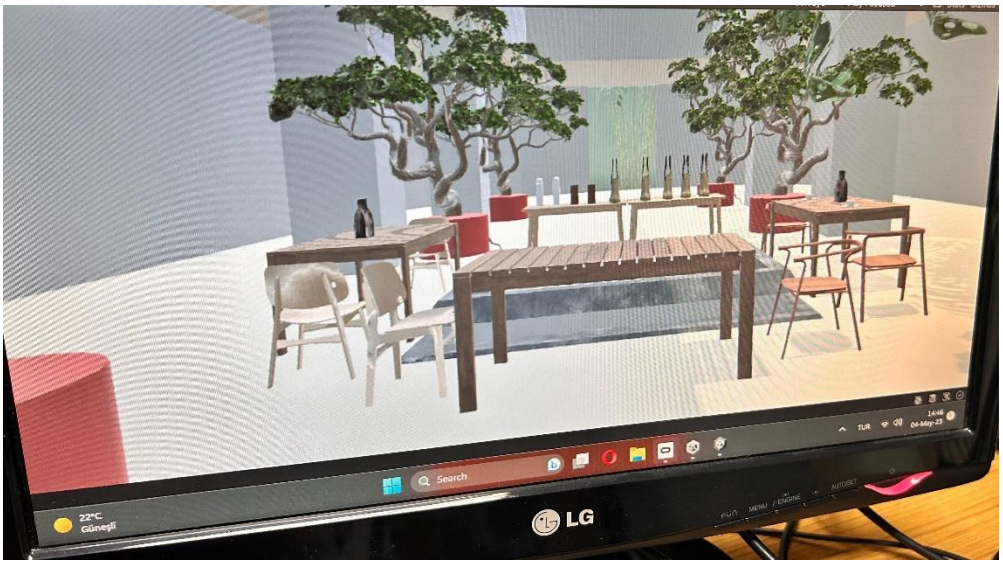

Figure 12. VR game player's coffee corner design.

5.5.3. Phase 3: Immersive Game

Phase 3 compared real and virtual environments to assess potential behavioral changes. This phase of the study employed a between-subjects design. Participants engaged in tasks within a VR environment while playing the serious game "Pop a Coffee Corner," which incorporated biophilic design elements. After completing the game, participants' behavioral information, were measured with SBS. The collected data were then analyzed to identify any correlations, associations, or differences between groups.

5.5.4. Phase 4: Controlled Experiment

In this phase, a control group experiment was conducted to determine whether significant differences existed between the experimental and control groups. Participants from FF building (Figure 13) completed the SBS questionnaire within the indoor space of the same building. The collected data were subsequently compared to those from the other experimental groups.

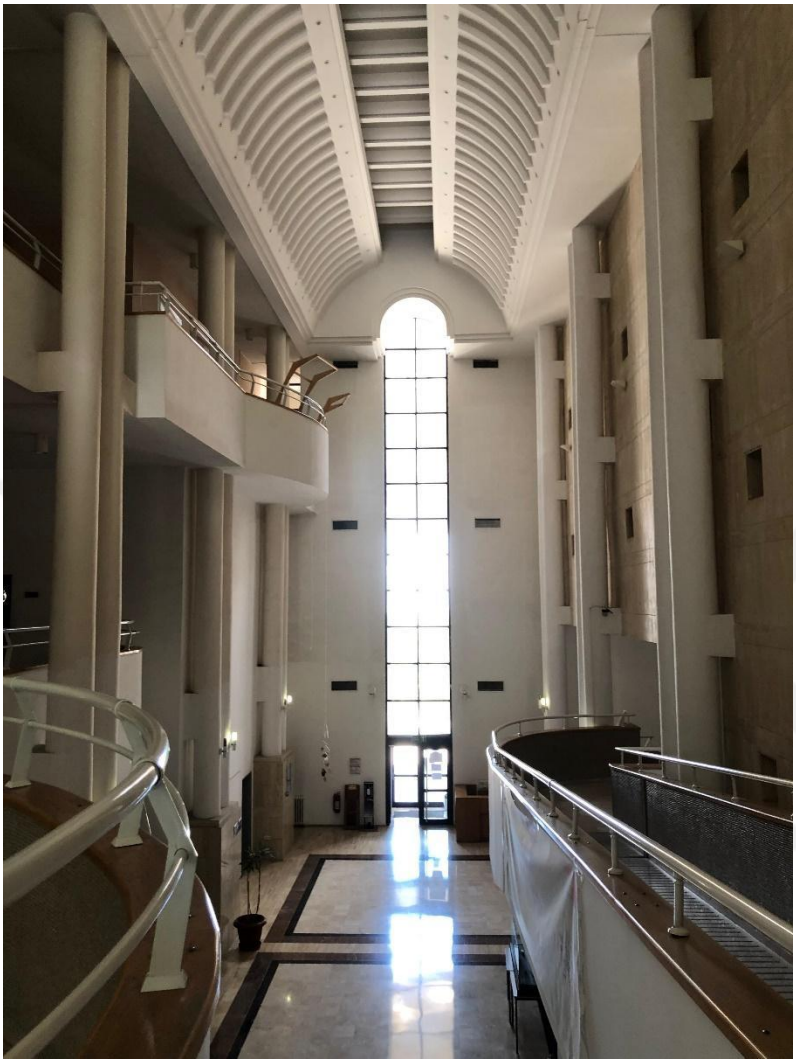

Figure 13. Controlled experiment setting, FF building, figure captured by author, 2022.

5.6. Pilot Study

The pilot study was conducted to show a serious game can affect human's behaviors. Therefore, a serious game was developed without any design interventions. This game was "Save the Planets". I developed this multipurpose serious game to raise environmental awareness among players. The game, modeled as a life simulation, allows players to interact with and learn from a virtual Solar system (Figure 14), and even create

their own customized systems. This customization helps to identify and reflect players' priorities and aspirations regarding environmental stewardship. Each planet have four stages to become mature (Figure 15). This triggers the players caring behaviors.

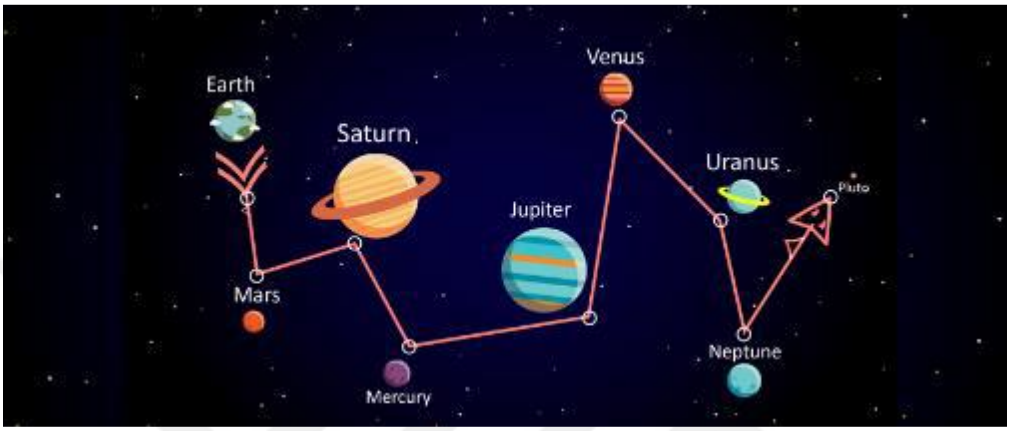

Figure 14. Solar system of the game, drawn by the author, 2020.

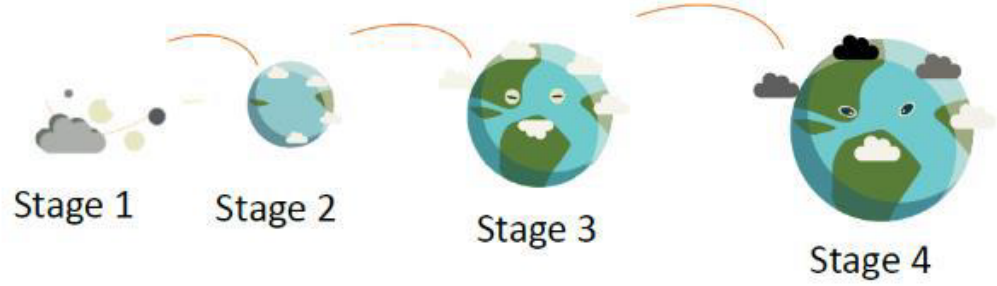

Figure 15. Four stages of a planet, drawn by the author, 2020.

The game features a general map, and the player begins at stage one, starting with Earth. Using drag-and-drop functionality, the player can position planets by moving elements like the Sun, Moon, and humans, which are available as buttons at the bottom of the screen. The player drags humans to place them on Earth (Figure 16). To successfully complete the game, the player must progress through four stages for each planet. Between stages, various tasks must be completed, with the number of tasks increasing as the player advances. As the player progresses, the appearance of the planet changes in

each stage.

Figure 16. User interface of the game, drawn by the author, 2020.

To measure the effectiveness of the game, I employed three different scales (see Appendix F): the Environmental Identity Scale (EIS) (Clayton, 2003), the Pro Environmental Behavior Scale (PEB) (Markle, 2013), and the Environmental Action Scale (EAS) (Alisat, 2015). These scales were used in both pre-test and post-test evaluations of the 22 participants who played the game. The findings demonstrated that "Save the Planets" significantly increased pro-environmental awareness among participants, indicating that such games can be potent tools for motivating individuals to adopt long-term sustainable behaviors (Table 2).

Table 2. Descriptive statistics of pre-test and post-test results.

Pre-Test	Mean	Std. Dev.
EIS	5.33	1.04
PEBS	3.72	0.54
EAS	1.34	0.64
Post-Test	**Mean**	**Std. Dev.**
EIS	5.50	0.92
PEBS	4.18	0.44
EAS	2.31	0.90

The study highlights the potential of serious games not just as entertainment but as powerful tools for education and behavioral change in areas such as environmental conservation. In this pilot, I used different scales and that made the analysis complicated and created doubt in reliability. Therefore, I adapted the Pro-Environmental Behavior Scale (PEBS) by Clayton and Kılınç (2013) for the actual studies, as it was developed in the context of Turkey. Additionally, the Environmental Action Scale (EAS) did not align with the specific sustainable behavior components I focused on, as it primarily measures secondary actions, such as discussing campaigns or attending protests, rather than direct actions that can directly influence sustainable behaviors.

CHAPTER VI:

RESULTS

The study's results were analyzed using descriptive statistics, t-tests, and ANOVA. The data collected from semi-structured interviews during the pre-game stage were analyzed quantitatively. Similarly, the data collected through questionnaires during the game and immersive game stages were also analyzed qualitatively.

6.1. Pre-Game Results

I analyzed the collected data through statistical methods. Within dataset 1, I coded the dimensions and identified 14 distinct biophilic design elements (Table 3)

Table 3. Abbreviation list of 14 biophilic items.

Item category	Item number	Item name
Nature in the space (NIS1)	1	Visual connection with nature
Nature in the space (NIS2)	2	Non-visual connection with nature
Nature in the space (NIS3)	3	Non-rhythmic sensory stimuli
Nature in the space (NIS4)	4	Thermal and airflow variability
Nature in the space (NIS5)	5	Presence of water
Nature in the space (NIS6)	6	Dynamic and diffuse light
Nature in the space (NIS7)	7	Connection with natural systems
Natural analogues pattern (NA1)	8	Biomorphic forms and patterns
Natural analogues pattern (NA2)	9	Material connection with nature
Natural analogues pattern (NA3)	10	Complexity and order
Nature of the space patterns (NOF1)	11	Prospect
Nature of the space patterns (NOF2)	12	Refuge
Nature of the space patterns (NOF3a/b)	13	Mystery
Nature of the space patterns (NOF4a/b)	14	Risk/peril

The data was coded into JASP version 0.16.2 for network analysis. The results are presented in Table 4 and Figure 17. Table 4 provides a summary of the network analysis. Each node in Figure 17 represents a biophilic design item, and the connections indicate their relationships. The thickness of the connection reflects the strength of the association. Blue connections represent positive associations, while red connections represent negative associations. The centrality plot reveals the highest betweenness measures, which include Visual connection with nature (NIS1), Non-rhythmic sensory stimuli (NIS3), Non-visual connection with nature (NIS2), and Presence of water (NIS5) (Figure 18).

Table 4. Summary of Network Analysis.

Number of nodes	Number of non-zero edges	Sparsity
16	120/120	0.000

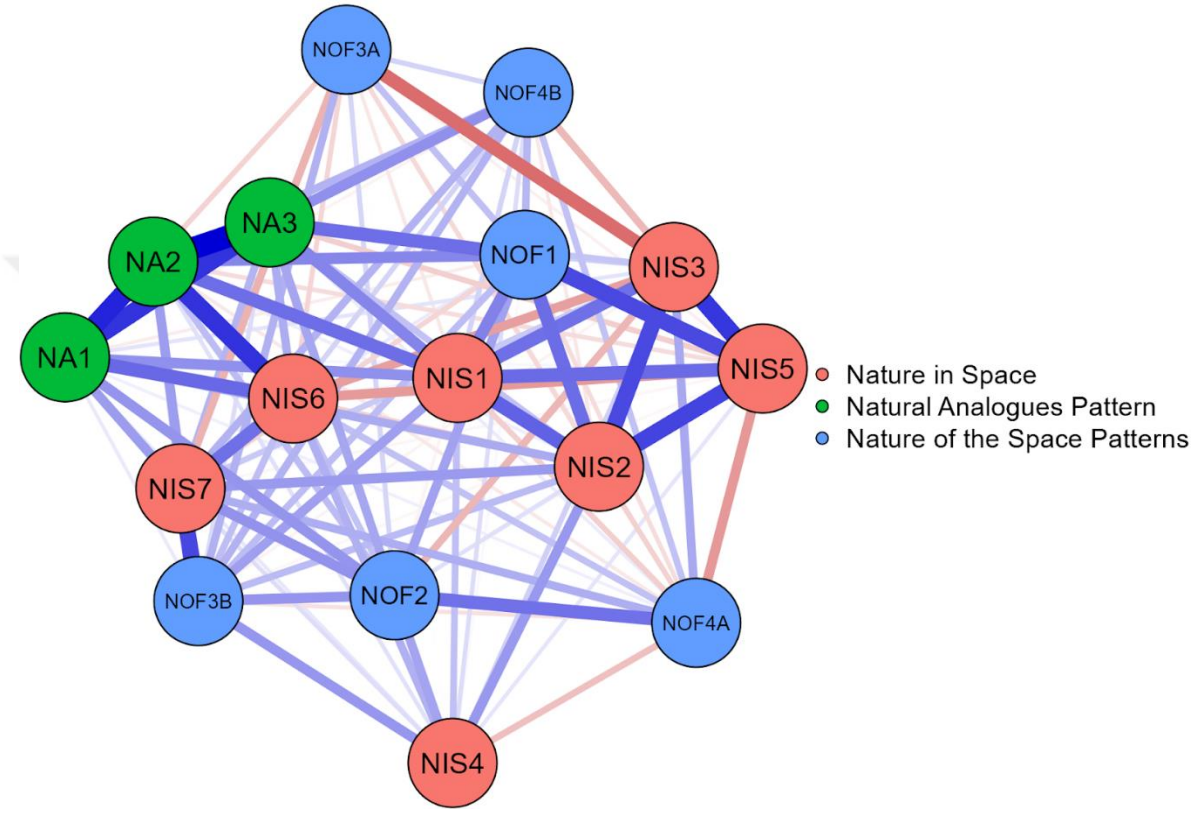

Figure 17. Network analysis diagram of biophilic design items.

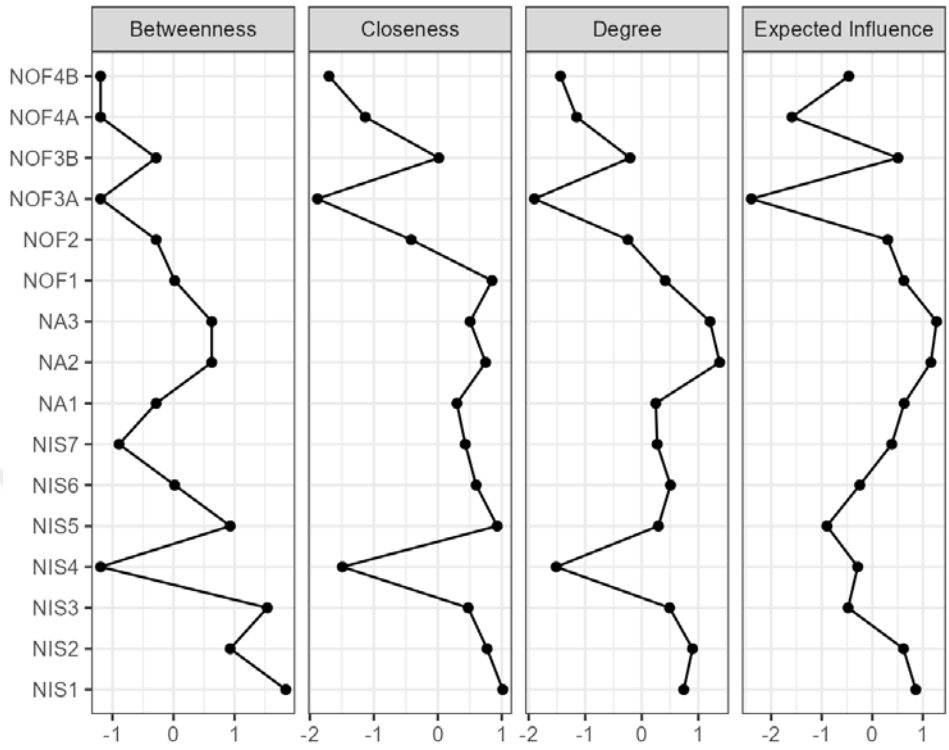

Figure 18. Centrality plot graph.

I conducted a semi-structured interview with 20 participants (11 women and 9 men) and analyzed interview items (1- What do you know about sustainable behaviors?, 2- How do you perceive sustainable behavior?, 3- Do you agree with the definition of sustainable behavior above? Yes or No please explain why?, 4- Do you think that exposing biophilic design items in the building can change your attitude towards nature? Yes or No please explain why?, 5- How do you relate the biophilic design items of this building with sustainable behaviors of yours?, 6- How do you evaluate yourself in terms of environmentally caring actions?, 7- What do you see as the advantage of your working in the building in the future?, 8- What do you see as the disadvantage of your working in the building next times?) (see Appendix C). Additionally, participants provided ratings for the

building's design elements that promote sustainable behavior using a 7-point Likert scale (Which design elements of this building would encourage the sustainable behaviors?)(see Appendix G). Visual connection with nature (item 1) and dynamic and diffuse light (item 6) obtained the highest scores (Table 5).

Table 5. Biophilic design item score by participants.

Items	Score
1 Visual connection with nature	57
2 Dynamic and diffuse light	25
3 Presence of water	21
4 Non-visual connection with nature	8
5 Non-rhythmic sensory stimuli	4
6 Biomorphic forms & patterns	4
7 Thermal & airflow	3
8 Complexity & order	2
9 Mystery	2
10 Refuge	1

The analysis led me to determine that Non-rhythmic Sensory Stimuli, Dynamic and Diffuse Light, Visual Connection with Nature, Non-visual Connection with Nature, and the Presence of Water are the main elements that serve as the foundational components for the serious game design framework in the Study Set 2 (Figure 19). I structured the framework into four categories: Physical, Visible, Non-visible, and Noticeable. Spatial arrangements like openings and layering were essential to embody these categories within the environment. Structural partitions such as windows, doors, the structure itself, and objects are required for the biophilic design to be applied to the environment.

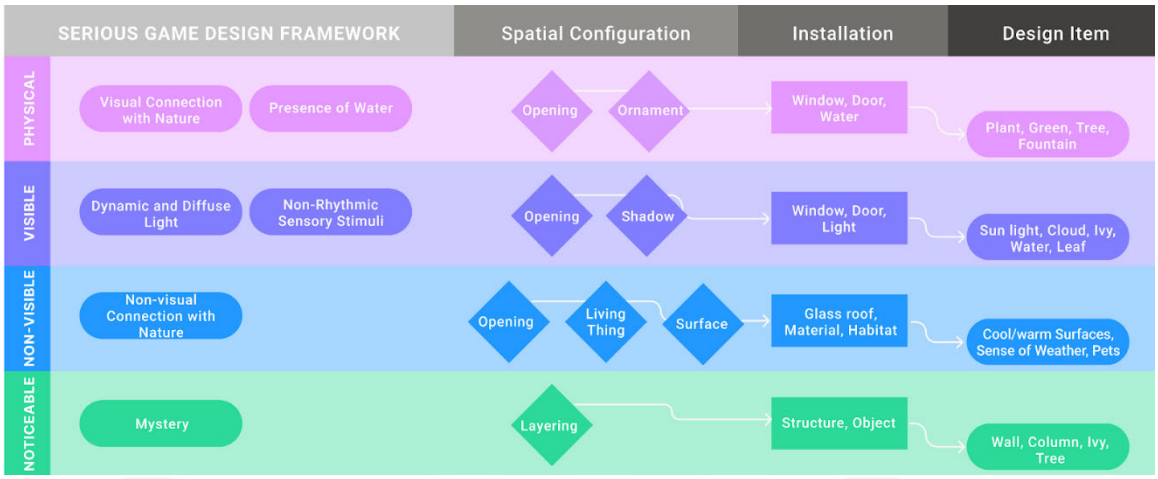

Figure 19. Design framework, drawn by author, 2022.

6.2. Game Results

In this section, experimental groups were represented into table 6: Group 0, Group 1, Group 2, and Group 3. Descriptive statistics were conducted thereafter. Initially, Group 0 and Group 1 were analyzed to test H1, followed by the analysis of Group 1 and Group 2 to test H2. Descriptive statistics indicated that Group 0 and Group 1 were normally distributed, as per the Shapiro-Wilk test results in Table 7.

Table 6. Experiment groups.

Groups	Explanation
Group 0	Control group
Group 1	Only biophilic treatment exposure group
Group 2	Game players in a real environment with a biophilic treatment exposure group
Group 3	Game players in a VR environment with a biophilic treatment exposure group

After conducting descriptive statistics to test hypothesis H1, which posits a statistically significant difference between the control group (experiencing the non-biophilic built environment) and the treatment group (experiencing the built environment with biophilic design) in terms of sustainable behaviors, an independent sample t-test was performed. The results revealed a statistically significant difference between Group 0 and Group 1 concerning the Sustainable Behavior Scale (SBS) (Student's t-test $p < .041$), although no significant difference was observed between the groups regarding the subcategories of the SBS (see Table 8). Therefore, H1 is supported.

Table 7. Descriptive statistics of Group 0 and Group 1.

	QualityofLife		CareEnvWellbeing		EnvIdentity		ProEnBeh		SBS	
	0	1	0	1	0	1	0	1	0	1
Valid	41	42	41	42	41	26	41	26	41	43
Missing	0	1	0	1	0	17	0	17	0	0
Mean	3.86	4.03	3.81	3.89	5.23	5.09	3.51	3.5	3.69	3.85
Std. Dev.	0.57	0.44	0.64	0.66	0.92	1.04	0.54	0.5	0.48	0.37
Skewness	-0.45	-0.13	-0.78	-0.24	-0.71	0.31	-0.17	0.45	-0.26	0.42
Std. Err.of Skewness	0.37	0.37	0.37	0.37	0.37	0.46	0.37	0.46	0.37	0.36
Kurtosis	-0.61	-0.67	0.39	-0.84	-0.6	-0.61	-0.62	-0.51	-0.9	-0.29
Std. Err.of Kurtosis	0.72	0.72	0.72	0.72	0.72	0.89	0.72	0.89	0.72	0.71
Shapiro-Wilk	0.95	0.98	0.95	0.96	0.98	0.96	0.98	0.96	0.96	0.96
P-value of Shapiro-Wilk	0.09	0.52	0.07	0.15	0.53	0.46	0.57	0.39	0.11	0.18
Min.	2.7	3	2.2	2.6	3.2	3.2	2.3	2.6	2.7	3.2
Max.	4.9	4.9	4.9	4.9	7	7	4.5	4.6	4.5	4.7

Note. 0:Group 0, 1:Group 1.
Note. QualityofLife: quality of life is the sub-category of the sustainable consumption behavior scale, CareEnvWellbeing: care environmental wellbeing is the sub-category of the sustainable consumption behavior scale, EnvIdentity: environmental identity, ProEnvBehs: pro-environmental behavior.

Table 8. Independent sample t-tests.

	t	df	*p*
SBS	-1.764	82	0.041*
QualityofLife	-1.460	81	0.074
CareEnvWellbeing	-0.584	81	0.280
EnvIdentity	0.544	65	0.706
ProEnvBehs	0.053	65	0.521

Note. QualityofLife: quality of life is the sub-category of the sustainable consumption behavior scale, CareEnvWellbeing: care environmental wellbeing is the sub-category of the sustainable consumption behavior.

Note. The alternative hypothesis specifies that Group 0 is less than Group 1 for all tests.

Note. Student's t-test.

Furthermore, descriptive statistics (refer to Table 9) were calculated to test the normality of Group 1 and Group 2. The Shapiro-Wilk test results in Table 8 demonstrate that all subcategories of the SBS were normally distributed (Quality of Life: Group 1 $p = .52$, Group 2 $p = .22$; Care Environmental Well-being: Group 1 $p = .15$, Group 2 $p = .06$; Environmental Identity: Group 1 $p = .46$, Group 2 $p = .0454$; Pro-environmental Behavior: Group 1 $p = .39$, Group 2 $p = .87$).

Table 9. Descriptive statistics of Group 1 and Group 2.

	QualityofLife		CareEnvWellbeing		EnvIdentity		ProEnBeh		SBS	
	1	2	1	2	1	2	1	2	1	2
Valid	42	40	42	40	26	40	26	40	43	40
Missing	1	0	1	0	17	0	17	0	0	0
Mean	4.03	4.21	3.89	4.05	5.09	5.91	3.5	3.81	3.85	4.02
Std. Dev.	0.44	0.39	0.66	0.6	1.04	0.66	0.5	0.52	0.37	0.35
Skewness	-0.13	-0.15	-0.24	-0.72	0.3	-0.86	0.45	-0.06	0.42	0.2
Std. Err.of Skewness	0.37	0.37	0.37	0.37	0.46	0.37	0.46	0.37	0.36	0.37
Kurtosis	-0.67	-0.91	-0.84	0.36	-0.61	0.95	-0.51	-0.46	-0.29	-0.16
Std. Err.of Kurtosis	0.72	0.73	0.72	0.73	0.89	0.73	0.89	0.73	0.71	0.73
Shapiro-Wilk	0.98	0.96	0.96	0.95	0.96	0.94	0.96	0.99	0.96	0.98
P-value of Shapiro- Wilk	0.52	0.22	0.15	0.06	0.46	0.04	0.39	0.87	0.18	0.7
Min.	3	3.5	2.6	2.3	3.2	4	2.6	2.7	3.2	3.3
Max.	4.9	4.9	4.9	4.9	7	7	4.6	4.9	4.7	4.9

Note. 1:Group 1, 2:Group 2.
Note. QualityofLife: quality of life is the sub-category of the sustainable consumption behavior scale, CareEnvWellbeing: care environmental wellbeing is the sub-category of the sustainable consumption behavior scale, EnvIdentity: environmental identity, ProEnvBehs: pro-environmental behavior.
Note. Significant results suggest a deviation from normality.
*p<.05

Following descriptive statistics, to test hypothesis H2, which suggests that playing a serious game with biophilic design elements will increase participants' sustainable behavior more than experiencing the real built environment, an independent sample t-test was conducted. The results indicated a significant difference between Group 1 and Group 2 regarding Sustainable Consumption Behavior (Quality of Life: Student's t-test $p = .028$), Environmental Identity (Student's t-test $p < .001$), Pro-environmental Behavior (Student's t-test $p = .009$), and SBS (Student's t-test $p = .022$). The significance and non-significance of the p-values can be viewed in Table 10. These findings support the claim that playing a serious game with biophilic design elements leads to a more significant increase in participants' sustainable behaviors than merely experiencing the built environment; therefore, H2 is supported.

Table 10. Independent sample t-test.

	t	df	*p*
SBS	-2.054	81	0.022*
QualityofLife	-1.947	80	0.028*
CareEnvWellbeing	-1.153	80	0.126
EnvIdentity	-3.902	64	< .001**
ProEnvBehs	-2.408	64	0.009*

Note. QualityofLife: quality of life is the sub-category of the sustainable consumption behavior scale, CareEnvWellbeing: care environmental wellbeing is the sub-category of the sustainable consumption behavior

Note. The alternative hypothesis specifies that Group 1 is less than Group 2 for all tests.

Note. Student's t-test.

6.3. Immersive Game Results

The Sustainable Behavior Scale (SBS) exhibited acceptable consistency with all items and sub-categories (α = .85), and an alpha level of .05 was utilized for all statistical tests. ANOVA was employed to compare the mean scores among Group 1, Group 2, and Group 3. Effect size values, represented by Eta-squared values, are provided in the table for the scores exhibiting statistically significant differences between the groups.

ANOVA coefficient,

$$\text{sum of squares between groups} = \sum (\sum X_i)^2 / n_i - (\sum X_i)^2 / N$$

Where:

X_i = Individual scores in each group

n_i = Number of scores in each group

N = Total number of scores.

Post-hoc analyses were conducted using the Bonferroni test for scores identified with significant differences among the groups, and Table 11 includes information on which specific groups contributed to these differences. The mean scores for Care Environmental Well-being (CareEnvWellbeing) among the groups displayed statistically significant differences (p-value = 0.027 < 0.05). This difference primarily arises from variations between Group 2 and Group 3, indicating that distinct biophilic designs significantly influence the CareEnvWellbeing score (p-value = 0.024 < 0.05).

Table 11. ANOVA tests.

GROUP	Mean	Std. Deviation	Eta-square	F	*p*
SBS					
Group 1	3,82	0,37			
Group 2	4,02	0,35	-	1,975	0.143
Group 3	3,92	0,40			
CareEnvWellbeing					
Group 1	4,03	0,69			
Group 2	4,05	0,60	0,058	3,715	0.027*
Group 3	3,65	0,77			
Group 2 - Group 3					*0.024**
QualityofLife					
Group 1	4,12	0,43			
Group 2	4,21	0,39	-	1,763	0.176
Group 3	4,13	0,47			
EnvIdentity					
Group 1	5,1	1,05			
Group 2	5,91	0,66	0,137	8,311	<.001**
Group 3	5,65	0,74			
Group 1 - Group 2					*<.001***
Group 1- Group 3					*0.018**
ProEnvBehs					
Group 1	3,5	0,51			
Group 2	3,81	0,52	0,062	3,445	0.036*
Group 3	3,7	0,40			
Group 1 - Group 2					*0.030**

Note. 95% confidence interval, *p<.05, **p<.001.

ANOVA results indicate statistically significant differences in Environmental Identity (EnvIdentity) mean scores among the groups (p-value < 0.001). Subsequent post-hoc analyses reveal that Group 1 significantly differs from both Group 2 and Group 3 concerning this score, suggesting that gaming behavior impacts this score, as Group 1 participants, who do not engage in gaming, exhibit lower EnvIdentity Scores compared to Group 2 and Group 3.

Regarding the Pro-environmental Behavior (ProEnvBehs) score comparison among the groups, significant differences were detected (p-value = 0.036 < 0.05). Further post-hoc analysis unveils a statistically significant difference specifically between Group 1 and Group 2 concerning the ProEnvBehs Score (p-value = 0.030 < 0.05).

The statistical analysis above supports H2 but indicates that H3 is rejected.

To demonstrate the relation between SBS and game score or unsustainable-sustainable decisions within Group 2 and Group 3, Pearson's Correlation test was done. The statistics indicated no significant correlation between game scores, unsustainable and sustainable choices, and the SBS scores of the participants (Table 12).

Table 12. Pearson's correlations table.

			Pearson's r	*p*
GameScore	-	SBS	0.106	0.342
GameScore	-	unsustainable	-0.173	0.121
GameScore	-	sustainable	0.006	0.958
SBS	-	unsustainable	-0.087	0.435
SBS	-	sustainable	0.128	0.252
unsustainable	-	sustainable	0.605	<.001**

Note. * p<.05, ** p<.001.

CHAPTER VII:

DISCUSSION

Scientific studies consistently emphasize the role of environmental factors in shaping sustainable behaviors, making this an active area of ongoing research. Given that much of our daily life occurs within built environments, these spaces inevitably influence our behaviors. Within this context, biophilic design has emerged as a key concept, gaining traction for its potential to foster sustainable behavioral patterns. At the same time, serious games have become a prominent research tool for influencing sustainable behaviors, rising in popularity as a research methodology. This thesis utilized the serious game approach as an innovative tool to better understand and assess individuals' sustainable behaviors.

The study involved four experiments to test three hypotheses and explore three research questions (Table 13). The results revealed that biophilic design positively influences individuals' sustainable behaviors. Moreover, engaging with a serious game that

incorporates biophilic design within a similarly treated environment enhances support for sustainable behavior more than exposure to a biophilic environment alone.

Table 13. Hypotheses of this study and their outcomes.

Code	Hypothesis	Result
H1	There is a statistically significant difference between the control group (experiencing the non-biophilic built environment) and the treatment group (experiencing the built environment with biophilic design) in terms of sustainable behaviors.	Supported
H2	Playing a serious game with biophilic design elements increases participants' sustainable behavior more than experiencing the real built environment.	Supported
H3	Participants exhibit distinct sustainable behaviors in virtual reality environment compared to real-world settings	Not supported

The findings partially support H1, showing a significant difference in sustainable behaviors between participants exposed to biophilic and non-biophilic environments, consistent with previous studies (Ryan & Browning, 2020; Wijesooriya & Brambilla, 2021; Zhong et al., 2022). However, when examining specific subcategories of sustainable behavior, no significant differences were found in Environmental Identity, Sustainable Consumption Behavior (SCB), or Pro-environmental Behavior. While participants generally exhibited more sustainable behaviors in a biophilic environment, this did not translate into distinct differences in the individual subcategories.

The study also supports H2, demonstrating that combining a serious game with biophilic design and a biophilic physical environment has a more substantial positive effect on sustainable behaviors than the environment alone. However, H3 was not supported, as no significant differences were found between sustainable behaviors in real and immersive virtual environments, aligning with earlier research (Emamjomeh et al., 2020; Yin et al., 2018). This suggests that immersive VR environments could be a valuable alternative for researchers with limited access to real-world settings.

Before conducting the experiments, correlation was hypothesized between game scores and participants' sustainable behaviors. However, this assumption was not supported by the analysis. Participants tended to prioritize sustainability over high scores when choosing game items, possibly influenced by the nature of serious games as a form of entertainment (Squire, 2003). Although no direct correlation was found between sustainable behaviors and game scores, the group that played the game showed a positive difference in sustainable behaviors compared to the group that did not play.

The findings of this study provide significant insights into the potential of biophilic design, especially when integrated with serious games, in promoting sustainable behaviors. The results align with previous research, affirming the efficacy of biophilic environments in positively influencing human behavior. The integration of both virtual and real biophilic settings in this study is a novel approach that extends the existing body of knowledge in environmental psychology and sustainable design.

The comparison between real and virtual biophilic environments revealed that biophilic elements in immersive VR settings can elicit similar responses as those found in physical environments. These results are consistent with studies by Yin et al. (2018), which showed that exposure to natural elements in virtual environments could reduce negative mood and improve cognitive function, similar to their effects in real-world settings. This finding also supports the work of Browning, Ryan, and Clancy (2014), who suggested that biophilic design could reduce stress and enhance overall well-being in urban spaces.

One of the most important contributions of this study is the exploration of serious games as an educational tool to encourage sustainable behaviors. The literature on serious games, such as the work by Orland et al. (2014) and Johnson et al. (2017), emphasizes their ability to change behavior by simulating real-world challenges in a gamified environment. In this study, the use of a serious game that incorporated biophilic elements was shown to further enhance sustainable behavior, particularly in the virtual setting. This outcome aligns with prior studies that highlight the value of serious games in fostering pro-environmental behaviors (Senbel et al., 2014; de Vries & Knol, 2011).

The study's methodology, combining both qualitative and quantitative approaches, allowed for a robust analysis of how biophilic design and serious games can work synergistically to foster sustainable behaviors. The results from the Pro-Environmental Behavior Scale (PEBS) and Sustainable Consumption Behavior Scale (SCB) confirmed that participants exposed to biophilic design, particularly in virtual reality environments, demonstrated higher engagement in sustainable actions. These findings expand on the

theoretical frameworks proposed by Stern (2000) regarding value-belief-norm theory and its application in the context of environmental education.

Despite the promising results, several limitations should be acknowledged. First, the pilot study used a small sample size, which limits the generalizability of the findings. Future studies should aim to involve a larger, more diverse sample to validate the outcomes. Additionally, while the PEBS and SCB scales provided valuable insights, more comprehensive tools could be used in future studies to explore different dimensions of sustainable behavior, such as long-term behavioral change.

CHAPTER VIII:

CONCLUSION

In conclusion, in this thesis, I proposed that playing a serious game designed with a biophilic approach within a built environment featuring biophilic elements can effectively promote sustainable behaviors. To validate this idea, the first author developed a serious game based on data collected from participants. The results showed that biophilic design positively influenced participants, with the most significant impact observed when participants engaged with the game in such an environment. This was more effective than exposure to either a non-biophilic or biophilic environment alone, or playing the game in a virtual reality (VR) setting. These findings suggest that using serious games, which are less costly and time-consuming, can be a practical alternative to traditional, resource-intensive research setups for studying the effects of environmental factors on human behavior.

The study identifies certain biophilic elements—such as visual and non-visual connections with nature, dynamic and diffuse light, and the presence of water—as having the most significant impact on sustainable behaviors as having the most significant impact on their perceived sustainable behaviors, as confirmed by their interview responses. The numerical data, including Biophilic Index (BI) responses from the same participants, supported these observations. This insight can guide future research and practical applications by suggesting that these elements be prioritized in the design of both physical and virtual environments. Moreover, understanding the specific mechanisms through which these elements influence behavior could lead to more targeted and effective interventions (Ryan & Browning, 2020; Zhong et al., 2022).

For the field of interior architecture, this research opens new avenues for the incorporation of biophilic design principles in not just traditional physical spaces, but also in virtual environments. By demonstrating that virtual reality environments with biophilic elements can evoke similar psychological and behavioral responses as real-world settings, the study suggests that interior designers should consider VR applications as a valid medium for promoting sustainability and well-being. This is particularly relevant in contexts where physical biophilic integration is challenging, such as in densely populated urban areas or restricted spaces like hospitals and industrial zones. This research also supports the idea that digital environments can be thoughtfully designed to mirror the benefits of natural spaces, which expands the role of interior architects in designing immersive, technology-driven spaces.

The potential applications of this research extend beyond traditional educational tools, providing architects and interior designers with innovative methods to engage individuals in sustainable behaviors through the use of technology and immersive design. By bridging the gap between physical and virtual spaces, this study broadens the horizons of biophilic design and reinforces its role in shaping a sustainable future.

Future studies should build on these findings by exploring the long-term impact of biophilic design in virtual spaces, as well as its integration with other digital tools that foster environmental awareness. Through continued research, the fields of interior architecture and architecture can evolve to address the urgent need for sustainable design solutions in both tangible and digital realms.

Moreover, future research should explore these specific elements individually to understand their distinct influence compared to other biophilic factors. The literature indicates that biophilic design significantly affects individuals' behaviors, moods, and cognitive abilities (Emamjomeh et al., 2020; Ryan & Browning, 2020; Wijesooriya & Brambilla, 2021; Yin et al., 2018; Zhong et al., 2022). My study further contributes by evaluating its impact on sustainable behaviors.

8.1. Implication of the Study

The findings from this study have several important implications for the fields of environmental design, sustainability research, and behavioral psychology, particularly in the context of biophilic design and serious games.

First, the integration of biophilic design in built environments: The study underscores the potential of biophilic design to significantly enhance sustainable behaviors in individuals. By demonstrating that environments enriched with biophilic elements can promote pro-environmental behaviors, the research suggests that incorporating biophilic design principles in built environment could be a powerful strategy for fostering a deeper connection between individuals and the natural world. This has direct implications for architects, designers, and policymakers who aim to create built environments that encourage environmentally responsible behavior. The use of biophilic design could also be strategically applied in educational and institutional settings to instill sustainable practices in larger populations (Browning et al., 2014; Kellert, 2008).

Second, the use of serious games as a research tool: The successful application of a serious game to measure and influence sustainable behaviors presents a cost-effective and innovative alternative to traditional research methods. Serious games offer a dynamic and engaging platform for participants to interact with complex environmental scenarios, which can lead to more profound and lasting behavioral changes than passive observation or instruction alone. This finding highlights the potential for serious games to be used not

only as a research tool but also as an educational and training mechanism to promote sustainability (Schuller et al., 2013; Johnson et al., 2017).

In summary, this study contributes to the growing body of evidence supporting the integration of biophilic design in built environments and the innovative use of serious games as tools for promoting sustainable behaviors. These findings have broad implications for how we design our spaces, educate future generations, and develop policies aimed at fostering a sustainable relationship between humans and the environment.

8.2. Limitations of the Study

The strengths collectively enhance the credibility and potential impact of the thesis. However, it is important to recognize the study's limitations to provide a balanced evaluation. There are five main limitations in this thesis' experimental study. First, limitation is contextual specificity. The findings may have limited generalizability due to the specific context of the Bilkent University's Science Building and the use of a serious game. The controlled environment in which participants' responses were collected may not fully reflect behaviors in more diverse real-world settings. Second limitation is participant selection and exclusion. Some participants were excluded due to motion sickness during VR gameplay and unfamiliarity with the experimental setup. Moreover, the study primarily focuses on short-term behavioral changes immediately following

exposure to biophilic design elements, which may not fully capture long-term sustainable behaviors.

Moreover, third limitation is short-term focus of the study. The study primarily focused on assessing immediate behavioral changes following exposure to biophilic design elements. As a result, the findings may not capture the long-term sustainability of these behaviors. Longitudinal studies are needed to understand how these behaviors evolve over time and whether the initial impacts of biophilic design persist. Forth limitation is limited scope of biophilic elements. Although the study identified specific biophilic design elements that influence sustainable behaviors, it did not explore the full range of possible elements or combinations thereof. The impact of other biophilic features that were not included in the serious game or the built environment remains unexplored.

The last limitation of the study is virtual vs. real world comparisons. While the study compared behaviors in virtual and real environments, it did not fully investigate the nuances between these two settings, particularly how different types of virtual environments might influence behavior differently. The study's findings on the effectiveness of VR environments in promoting sustainable behaviors may be limited by the specific VR setup used.

8.3. Suggestions for Future Studies

Future research could address these limitations to build upon the findings and further

explore the relationship between biophilic design and sustainable behaviors:

Future studies should aim to apply the experimental design in more diverse real-world settings, beyond controlled environments such as university buildings, to assess the generalizability of the results. Expanding the study to different types of environments, including urban, rural, and commercial spaces, would provide a more comprehensive understanding of the influence of biophilic design.

To enhance the robustness of future studies, researchers should consider including participants who may experience motion sickness or discomfort in VR settings by using alternative virtual setups or less immersive technologies. A larger and more diverse participant pool could offer more generalizable results.

Future research should consider longitudinal designs that examine the long-term effects of exposure to biophilic design elements on sustainable behaviors. This would allow researchers to assess the persistence of behavioral changes over time and evaluate the long-term impact of both real-world and virtual biophilic environments.

Future studies could expand the scope of biophilic elements considered in both real and virtual environments. This could include investigating the effects of a wider variety of natural features, such as water elements, sounds of nature, or organic materials, to determine their potential influence on sustainable behaviors.

More nuanced comparisons between virtual and real-world environments should be explored, particularly by varying the types of virtual environments (e.g., more immersive or less immersive) and studying how these variations influence behavior. Investigating different VR setups, such as varying the level of immersion or using mixed-reality environments, could offer deeper insights into how virtual biophilic environments impact sustainable behavior.

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APPENDICES

Appendix A. Biophilic Interior Design Index: Questionnaire

Q1 Can you see any natural elements (e.g. plants, flowers, soil, water, etc.)?

No, not at all
Yes, a few
Yes, a lot

Option: 0-10

How much ...

Q2 Except for visual connection to nature, do you have some non-visual connections with nature? (e.g. hearing the sounds of birds/water, smelling the natural scents of plants/flowers, touching the real plants/water, feeling the surface warm from sunlight, etc.)

No, not at all
Yes, a little
Yes, very much

Display This Question:

If Can you see natural elements (e.g. plants, flowers, water)? No, not at all Is Not Selected

Or Except for visual connection to nature, do you have non-visual connections with nature? (e.g. hearing the sounds of birds/water, smelling the natural scents, touching the real plants etc.) No, not at all Is Not Selected

Q3 Do the natural elements change dynamically (e.g. swaying plants, flowing water, living animals, birdsong, weather,etc.)?

No, not at all
Yes, a little
Yes, very much

Q4 Does this space has natural ventilation (i.e. operable windows, doors to open spaces, etc.)?

No, not at all
Yes, a little
Yes, a lot

Q5 Is there any water (e.g. water wall, fountain, pool, aquarium, etc. except for bottle water) in this space?

No, not at all
Yes, a little
Yes, a lot

Q6 Does this space have dynamic light (e.g. natural daylight, dynamic artificial light)?

No, not at all
Yes, a little
Yes, a lot

Q7 Do you think you can observe seasonal changes (light intensity and color, plant cycles, ambient scents) of natural view from this space?

No, not at all
Yes, a few
Yes, a lot

Q8 Are there any biomorphic forms (e.g. fabric, carpet, and wall paper designs based on the imitation of nature elements, columns shaped like tress, etc.) in this space?

No, not at all
Yes, a few
Yes, a lot

Q9 Can you observe natural materials used in this space (e.g. wood, stone, bamboo, etc.)?

No, not at all
Yes, a few
Yes, a lot

Q10 How about the visual complexity in this space (e.g. material texture, figures in wallpaper and carpet, exposed building structure and mechanical system, etc.)?

Nothing is complex
There are a few things with complex patterns
There are a lot of things with complex patterns

Q11 Do you have a long distance view from this space?

No, the focal length of major view is within 20 feet (6 meters)
Yes, the focal length of major view is between 20 feet (6m) and 100 feet (30m)
Yes, I can see views over 100 feet

Q12 Does this space have refuge places (i.e. a place for withdrawal from environmental conditions, in which the individual is protected from behind and overhead)? (e.g. seats with speech and visual privacy, spaces reserved for reflection, meditation, rest, relaxation, reading, etc.)

No, not at all
Yes, a few
Yes, a lot

Q13 How about the mystery condition (i.e. obscuring of the boundaries and a portion of the focal subject, thereby enticing the user to anticipate the full extent of the subject and explore the space further) of this space?

All the edges of this space are clear (1)
One edge of the focal subject is obscured (2)
Two or more edges of the focal subject are obscured (3)

Is there any part of this space that you want to explore further (e.g. obscured/curved boundaries, dramatic shade and shadows)?

No, not at all
Yes, one part
Yes, two parts or more

Q14 How about the risk condition (i.e. A present danger, which is inert and unable to cause harm due to a trusted element of safety) of this space? ()

Feel no risky (1)
High-level risk (2)
Low-level risk (3)

Can you observe an identifiable threat coupled with reliable safeguard (e.g. views from a higher room into the lower courtyard, transparent railing or floor plane)?

No, not at all
Yes, a little
Yes, a lot

Appendix B. Biophilic Design Evaluation Form

Biophilic Design Evaluation Form

This questionnaire was prepared within the scope of 'Biophilic Design Approach for a Serious Game and Its Effects on User' study. Before fill in the questions, please look around and try to experience the environment of SA Building. To get more information about each design statements, please see the attachment that includes examples of various designs.

Name	Age	Education	Department	Gender

NATURE IN SPACE

"Nature in the Space addresses the direct, physical and ephemeral presence of nature in a space or place. This includes plant life, water and animals, as well as breezes, sounds, scents and other natural elements. Common examples include potted plants, flowerbeds, bird feeders, butterfly gardens, water features, fountains, aquariums, courtyard gardens and green walls or vegetated roofs. The strongest Nature in the Space experiences are achieved through the creation of meaningful, direct connections with these natural elements, particularly through diversity, movement and multi-sensory interactions."

1 There is visual connection with nature in this building

"A view of elements of nature, living systems, and natural processes."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

2 There is non-visual connection with nature in this building

"Auditory, haptic, olfactory or gustatory stimuli that engender a deliberate and positive reference to nature, living systems or natural processes."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

3 There is non-rhythmic sensory stimuli in this building

"Stochastic and ephemeral connections with nature that may be analyzed statistically but may not be predicted precisely."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

4 There is access to thermal & airflow variability

"Subtle changes in air temperature, relative humidity, airflow across the skin and surface temperatures that mimic natural environments."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

5 There is presence of water in this building

"A condition that enhances the experience of a place through seeing, hearing or touching water."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

6 There is dynamic & diffuse light in this building

"Leverages varying intensities of light and shadow that change over time to create conditions that occur in nature."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

7 There is connection with natural systems in this building

"Awareness of natural processes, especially seasonal and temporal changes characteristic of a healthy ecosystem."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

NATURAL ANALOGUES

"Natural Analogues addresses organic, non-living and indirect evocations of nature. Objects, materials, colors, shapes, sequences and patterns found in nature, manifest as artwork, ornamentation, furniture, décor, and textiles in the built environment. Mimicry of shells and leaves, furniture with organic shapes, and natural materials that have been processed or extensively altered (e.g., wood planks, granite tabletops), each provide an indirect connection with nature: while they are real, they are only analogous of the items in their 'natural' state. The strongest Natural Analogue experiences are achieved by providing information richness in an organized and sometimes evolving manner."

8 There are biomorphic forms & patterns

"Symbolic references to contoured, patterned, textured or numerical arrangements that persist in nature."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

9 There is material connection with nature

"Materials and elements from nature that, through minimal processing, reflect the local ecology or geology and create a distinct sense of place."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

10 There is complexity & order

"Rich sensory information that adheres to a spatial hierarchy similar to that encountered in nature."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

NATURE OF THE SPACE

"Nature of the Space addresses spatial configurations in nature. This includes our innate and learned desire to be able to see beyond our immediate surroundings, our fascination with the slightly dangerous or unknown; obscured views and revelatory moments; and sometimes even phobia inducing properties when they include a trusted element of safety. The strongest Nature of the Space experiences are achieved through the creation of deliberate and engaging spatial configurations commingled with patterns of Nature in the Space and Natural Analogues."

11 There are prospect aspects in this building

"An unimpeded view over a distance, for surveillance and planning"

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

12 There are refuge aspects in this building

"A place for withdrawal from environmental conditions or the main flow of activity, in which the individual is protected from behind and overhead.'

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

13 There are mystery aspects in this building

"The promise of more information, achieved through partially obscured views or other sensory devices that entice the individual to travel deeper into the environment."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

14 There are risk/peril aspects in this building

"An identifiable threat coupled with a reliable safeguard."

Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree

*all quotations are taken from Terrapin`s *14 Patterns of Biophilic Design* book

Appendix C. Theory of Planned Behavior Survey

Theory of Planned Behavior Construction Scale

Please mark the scales considering the gaps in the statements and which one is the closest to you.

1) It would be ..... for me to work in a way to spend time in a building with biophilic design.

Bad:	1	2	3	4	5	6	7	:Good
Unpleasant:	1	2	3	4	5	6	7	:Pleasant

2) Most people who are important to me approve of working in a way to spend in a building with biophilic design.

Disagree:	1	2	3	4	5	6	7	:Agree

3) Most people like me work in a way to spend time in a building with biophilic design.

Unlikely:	1	2	3	4	5	6	7	:Likely

4) I believe that I can work in a way to spend time in a building with biophilic design in the future.

False:	1	2	3	4	5	6	7	:True

5) Working in a way to spend time in a building with biophilic design in the future is up to me.

Disagree:	1	2	3	4	5	6	7	:Agree

6) I intend to work in a way to spend time in a building with biophilic design, in the future.

Unlikely:	1	2	3	4	5	6	7	:Likely

7) In the past times I have worked in a way to spent time in a building with biophilic design.

False:	1	2	3	4	5	6	7	:True

Please write your answers under the questions.

1) What do you see as the advantage of your working in a building with biophilic design in the future?

2) What do you see as the disadvantage of your working in a building with biophilic design next times?

3) What else comes to mind when you work in a building with biophilic design in the future?

4) Please list any factor or circumstances that would make it easy or enable you to work in a building with biophilic design in the future.

5) Please list any factor or circumstances that would make it difficult or prevent you to work in a building with biophilic design in the future.

Long Answer Questions

Definition of sustainable behavior:

Sustainable behavior is the set of actions planned for protecting the world and its resources (Corral-Verdugo, Frías, & García, 2010) as a sustainable lifestyle. Engaging in actions that aim to care for others, simultaneously protecting the biophysical environment are the requirements of sustainable behaviors (Bonnes & Bonaiuto, 2002). It aims to create environmentally significant behaviors.

1) What do you know about sustainable behaviors?

2) How do you perceive sustainable behavior?

3) Do you agree with the definition of sustainable behavior above? Yes or No please explain why?

4) Do you think that exposing biophilic design items in the building can change your attitude towards nature? Yes or No please explain why?

5) How do you relate the biophilic design items of this building with sustainable behaviors of yours?

6) How do you evaluate yourself in terms of environmentally caring actions?

7) Which design elements of this building would encourage the sustainable behaviors? Please rate them from 1 to 10 in terms of importance level for you. (1: least important, 10: most important)

Appendix D. Sustainable Behavior Scale

				SBS		
		PEB & Environmental Identity Scale Adapted from Clayton & Kilinç, 2013 *The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Susan Clayton*				
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below				
		1		4		7
		Not at all true of me		neither true nor untrue		completely true of me
1	_____	I believe that other organisms exist so that human beings can utilise them.				
2	_____	If I have a chance, I would like to participate in tree planting programs.				
3	_____	I like picnicking in nature.				
4	_____	I believe that other living beings have the same right to live as human beings.				
5	_____	I believe we should not consume natural resources excessively.				
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below				
		1		3		5
		Not at all true of me		neither true nor untrue		completely true of me
6	_____	I turn the computer off when it is not planned to be used for a few hours				
7	_____	I try to reduce the use of a personal automobile				
8	_____	I purchase foodstuffs and other products with minimal packaging				
9	_____	I use long-lasting lamps				
10	_____	I adjust the heating level to keep the house cooler during the cold months				
11	_____	I use reusable plates, cups, and cutlery rather than disposable ones				
12	_____	I give unwanted products such as furniture and clothes to people who can use them				
13	_____	I purchase used furniture, clothes, etc. when available				
14	_____	I use both sides of the paper for copying				

15	_____	I donate to environmental organisations				
		Sustainable Consumption Behavior Scale adopted from Quoquab, Mohammad and Sukari, 2018				
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below				
		1	2	3	4	5
		never	rarely	sometimes	usually	frequently
16	_____	I always try hard to reduce miss-use of goods and services (e.g. I switch off light and fan when I am not in the room)				
17	_____	I recycle daily newspaper (e.g. use as pet's litter box, etc.)				
18	_____	I avoid being extravagant in my purchase				
19	_____	I avoid over use/consumption of goods and services (e.g. take print only when needed)				
20	_____	I reuse paper to write on the other side				
21	_____	While dining in restaurant, I order food(s) only the amount that I can eat in order to avoid wasting food				
22	_____	I choose to buy product(s) with biodegradable container or packaging				
23	_____	I don't like to waste food or beverage				
24	_____	I recycle my old stuffs in every possible ways (e.g. distribute old clothes among needy people)				
25	_____	I reuse shopping bag(s) every time go for shopping				
26	_____	I plan carefully before I purchase product of service				
27	_____	I do care for the natural environment				
28	_____	I use eco-friendly products and services				
29	_____	I purchase and use products which are environmentally friendly				
30	_____	I often pay extra money to purchase environmentally friendly product (e.g. organic food)				
31	_____	I am concerned about the shortage of the natural resources				
32	_____	I prefer to use paper bag since it is biodegradable				
33	_____	I love our planet				

34	_____	I always remember that my excess consumption can create hindrance for the future generation to meet up their basic needs
35	_____	I care for the need fulfilment of the next generation
36	_____	I often think about future generation's quality of life
37	_____	I try to control my desire of excessive purchase for the sake of future generation
38	_____	I am concerned about the future generation
39	_____	I try to minimise the excess consumption for the sake of preserving environmental resources for the future generation

Appendix E. Bilkent University Ethics Committee Approval

Bilkent Üniversitesi
Akademik İşler Rektör Yardımcılığı

Tarih : 24 Mayıs 2023

Gönderilen : Dilay Seda Özgen

Danışman : Yasemin Afacan

Gönderen : H. Altay Güvenir
İnsan Araştırmaları Etik Kurulu Başkanı

Konu : *"Biophilic ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 24 Mayıs 2023 tarihli görüşme sonucu, *"Biophilic Design Approach for a Serious Game and Its Effects on User"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Kovid-19 salgını nedeniyle konulmuş olan kısıtlamaların yürürlükte olduğu süre içinde, tüm komite toplantıları elektronik ortamda yapılmaktadır; aşağıda isimleri bulunan Bilkent Üniversitesi Etik Kurulu Üyeleri adına bu yazıyı imzalama yetkisi kurul başkanındadır.

Etik Kurul Üyeleri:

Ünvan / İsim	**Bölüm / Uzmanlık**	
Prof.Dr. H. Altay Güvenir	Bilgisayar Mühendisliği	Başkan
Prof.Dr. Erdal Onar	Hukuk	Üye
Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	Üye
Doç.Dr. Işık Yuluğ	Moleküler Biyoloji ve Genetik	Üye
Dr. Öğr. Üyesi Burcu Ayşen Ürgen	Psikoloji	Üye
Dr. Öğr. Üyesi Didem Özkul McGeoch	İletişim ve Tasarımı	Yedek Üye
Dr. Öğr. Üyesi A.Barış Özbilen	Hukuk	Yedek Üye

Kurul karar/toplantı No: 2023_05_24_02

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

Bilkent Üniversitesi İnsan Araştırmaları Etik Kurulu Hakkında:

- Kurul aşağıda ünvan, isim, uzmanlık alanı/bölümü belirtilen 5 asli ve 2 yedek üyeden oluşur:

  Prof.Dr. H. Altay Güvenir (Başkan), Bilgisayar Mühendisliği
  Prof.Dr. Erdal Onar, Hukuk
  Prof.Dr. Haldun Özaktaş, Elektrik ve Elektronik Mühendisliği
  Doç.Dr. Işık Yuluğ, Moleküler Biyoloji ve Genetik
  Dr.Öğr. Üyesi Burcu Ayşen Ürgen, Psikoloji
  Dr. Öğr. Üyesi Didem Özkul Mcgeoch (Yedek Üye), İletişim ve Tasarımı
  Dr.Öğr. Üyesi Arif Barış Özbilen (Yedek Üye), Hukuk

- Kurul toplantılarına katılamayan asli üyelerin yerine yedek üyeler görevlendirilir.
- Kurul en az 3 üye ile toplanabilir.
- Bir başvurunun onay alması konusunda olumsuz oy kullanan üyeler bunu onay belgesindeki isimlerinin yanına muhalefet notu düşerek belirtirler.
- Bir başvurunun onay alabilmesi için en az 3 üyenin olumlu oy kullanması gerekir. Onay belgesinde isimlerinin yanında muhalefet notu bulunmaması, o üyelerin olumlu oy kullandıkları anlamına gelir.

(Form Student_EN[1*])

Ethics form for graduate and undergraduate students - human participants

Note - group projects fill in one copy with all your names on it. Consult your project supervisor for advice before filling in the form.

Your name(s): Dilay Seda Özgen,
Project Supervisor: Assoc.Prof. Dr. Yasemin Afacan

A. Write your name(s) and that of your supervisor above.
B. Read section 2 that your supervisor will have to sign. Make sure that you cover all these issues in section 1. Discuss what you are going to put on the form with your project supervisor.
C. Sign the form and get your project supervisor to complete section 2 and sign the form.

1. Project Outline (to be completed by student(s))

(i) Full Title of Project:

Biophilic Design Approach for a Serious Game and Its Effects on User

(ii) Aims of project:

As Assoc. Prof. Dr. Yasemin Afacan from I.D. Bilkent University and Assist. Prof. Elif Surer from METU and Ph.D. Student Dilay Seda Özgen from I.D. Bilkent University, we are a research/design team currently studying on serious games. Therefore, we aim to change people's behaviours and attitudes towards nature by supporting sustainable behaviours among college students by `Pop a Coffee Corner` game, which is created by Dilay Seda Özgen. This game was developed in Unity engines.

The mechanics of the game is selecting the items that are required in the design process of the coffee corner. Therefore during the first stage of the game players are making decisions to collect these items. Players get scores when they make sustainable decisions and loose scores when they make unsustainable decisions. After the decision making, players are designing the coffee corner with the items that are selected. This game was built for an immersive virtual reality environment and non immersive virtual environment. Players are experiencing both environments.

In order to understand how this game alters players` attitudes and knowledge we are planning to observe their decisions they are making during the game. Besides, in order to better understand their sustainable behaviours and cognitive outcomes about environmental attitudes, we are planning to give them questionnaires after the gameplay.

This study aims to collect data on players' environmental behaviours considering their experience in game play and attitude alteration towards the environment. The answers will be collected anonymously by Dilay Seda Özgen. Players will be chosen from Bilkent University students who have taken classes from the SA building or used the study area for different periods. The study will be conducted in English.

(iii) What will the participants have to do? (brief outline of procedure; please draw attention to any manipulation that could possibly be judged as deception; *for survey work, a copy of the survey should be attached to this form*):

They will be asked to play `Pop a Coffee Corner` serious game in the virtual reality environment mentioned above and answer the questionnaires.

(iv) What sort of people will the participants be and how will they be recruited? In the case of children state age range. (*Any participant who has not lived through his/her 18th birthday is considered to be a child!*)

They will be students of I.D. Bilkent University. All participants are above 18 years old.

*If you are testing children or other vulnerable individuals, state whether all applicants have CRB[2]** clearance*

1* Adapted from *www.york.ac.uk/depts/psych/www/research/ethics/HumanProjForm.doc*

2* * Criminal Records Bureau – Please attach relevant clearance documentation.

D.S.Ö YA.

(v) What sort stimuli or materials will your participants be exposed to? Tick the appropriate boxes and then explain the form that they take in the space below, please draw attention to any content that could conceivably upset your participants).
Questionnaires[x]; Pictures[ ]; Sounds [ ]; Words[ ]; Caffeine[ ]; Alcohol[ ]; Other[x].

They will play a video game using the head mounted display for an immersive virtual reality environment and they will answer questionnaires after gameplay.

(vi) Consent Informed consent must be obtained for all participants before they take part in your project. The form should clearly state what they will be doing, drawing attention to anything they could conceivably object to subsequently. It should be in language that the person signing it will understand. It should also state that they can withdraw from the study at any time and the measures you are taking to ensure the confidentiality of data. If children are recruited from schools you will require the permission of the head teacher, and of parents. Children over 14 years should also sign an individual consent form themselves. When testing children you will also need Criminal Records Bureau clearance. Testing to be carried out in any institution (prison, hospital, etc.) will require permission from the appropriate authority. (Please include documentation for such permission.)
Who will you seek permission from?

Please attach the consent form you will use. Write the "brief description of study" in the words that you will use to inform the participants here.

INFORMED CONSENT

Dear participants,
This is the study of Biophilic Design Approach for a Serious Game and Its Effects on User research. Aim of this study is to change people's behaviours and attitudes towards nature by supporting sustainable behaviours. Within this scope, participants are asked to play the video game and answer questionnaires that measure sustainable behaviours. This study aims to collect data on players' environmental behaviours to support people`s sustainable behaviours with a serious game in a biophilic environment.

Your answers will be collected anonymously. Your responses will remain confidential.

We do not foresee any risks or discomfort from your participation in the study.

Your participation in the study is on a voluntary basis and you have the choice not to participate. Your identity will remain anonymous; your choice will not have an impact on any relationship to the investigator (Dilay Seda Özgen) and will not affect the research outcome.

You may contact with Dilay Seda Özgen (dilayozgen@bilkent.edu.tr) for any further questions.

(vii) Debriefing - how and when will participants be informed about the experiment, and what information you intend to provide? If there is any chance that a participant will be 'upset' by taking part in the experiment what measures will you take to mitigate this?

They will be informed about the study through the announcement through BAIS. After they read the consent form, they are asked whether they continue or quit the experiment and allow them to quit if they want.

(viii) What procedures will you follow in order to guarantee the confidentiality of participants' data? Personal data (name, addresses etc.) should only be stored if absolutely necessary and then only in such a way that they cannot be associated with the participant's experimental data.

There is no name or address needed in gameplay and questionnaire and also all given answers anonymously taken by participation.

(ix) Give brief details of other special issues the ethics committee should be aware of.

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(x) Tick any of the following that apply to your project

[x] it uses Bilkent facilities;
[ ] it uses stimuli designed to be emotive or aversive;
[ ] it requires participants to ingest substances (e.g., alcohol);
[x] it require participants to give information of a personal nature;
[ ] it involves children or other vulnerable individuals;
[ ] it could put you or someone else at risk of injury.

D.S.Ö YA

Student's signature: ..... date: 25/5/23

(all students must sign if this is a group project, please initial all other pages)

The signatures here signify that researchers will conform to the accepted ethical principles endorsed by relevant professional bodies, in particular to

Declaration of Helsinki (WMA):
http://www.wma.net/en/30publications/10policies/b3/index.html

Ethical Principles of Psychologists and Code of Conduct (APA):
http://www.apa.org/ethics/code2002.html

Ethical Standards for Research with Children (SCRD):
http://www.srcd.org/about-us/ethical-standards-research

2. **Supervisor's assessment (supervisor to complete - circle yes or no)**

Yes/No - I confirm that I have secured the resources required by this project, including any workshop time, equipment, or space that are additional to those already allocated to me.

Yes/No - The design of this study ensures that the dignity, welfare and safety of the participants will be ensured and that if children or other vulnerable individuals are involved they will be afforded the necessary protection.

Yes/No - All statutory, legislative and other formal requirements of the research have been addressed (e.g., permissions, police checks)

Yes/No - I am confident that the participants will be provided with all necessary information before the study, in the consent form, and after the study in debriefing.

Yes/No - I am confident the participant's confidentiality will be preserved.

Yes/No - I confirm that students involved have sufficient professional competency for this project.

Yes/No - I consider that the risks involved to the student, the participants and any third party are insignificant and carry no special supervisory considerations. If you circle "no" please attach an explanatory note.

No/Yes - I would like the ethics committee to give this proposal particular attention. (Please state why below)

Supervisor's signature: ..... date: 25/5/23

Please e-mail an electronic version of this word processed form (without signatures) along with other application material to the committee to start the evaluation process. Paper copies of all application material, (properly signed where indicated, and initialled on all other pages) should be sent after possible modifications suggested by the committee are finalized.

Bilkent University does not allow the use of students of research investigators as participants. Students who have the potential of being graded by the investigators during or following the semester(s) in which the study is being carried out should not participate in the study. Students may not receive any credit for any university course, with the exception of the GE250/GE251 courses, for their participation. The GE250 and GE251 (Collegiate Activities I and II) courses include an optional activity which encompasses volunteering as a participant in a research project.

D.S.Ö. YA.

(Form Staff_EN[1*])

Staff Application Form for Experiments with Human Participants

(A separate application form must be completed for each experiment and staff member.)

Please check one: ___ *I need a formal approval letter for an external agency (TÜBİTAK, etc.)*

__X_ *An internal communication letter informing me of the approval will be sufficient*

1. Name of applicant (graduate students should indicate their supervisors)

Assoc. Prof. Dr. Yasemin Afacan

2. Funder of grant/studentship if any:

3. Full title of experiment/project

Biophilic Design Approach for a Serious Game and Its Effects on User

4. When do you wish to start data collection: __20.05.2023_____

5. Aims of project:

As Assoc. Prof. Dr. Yasemin Afacan from I.D. Bilkent University and Assist. Prof. Elif Surer from METU and Ph.D. Student Dilay Seda Özgen from I.D. Bilkent University, we are a research/design team currently studying on serious games. Therefore, we aim to change people's behaviours and attitudes towards nature by supporting sustainable behaviours among college students by `Pop a Coffee Corner` game, which is created by Dilay Seda Özgen. This game was developed in Unity engines.

The mechanics of the game is selecting the items that are required in the design process of the coffee corner. Therefore during the first stage of the game players are making decisions to collect these items. Players get scores when they make sustainable decisions and loose scores when they make unsustainable decisions. After the decision making, players are designing the coffee corner with the items that are selected. This game was built for an immersive virtual reality environment and non immersive virtual environment. Players are experiencing both environments.

In order to understand how this game alters players` attitudes and knowledge we are planning to observe their decisions they are making during the game. Besides, in order to better understand their sustainable behaviours and cognitive outcomes about environmental attitudes, we are planning to give them questionnaires after the gameplay.

This study aims to collect data on players' environmental behaviours considering their experience in game play and attitude alteration towards the environment. The answers will be collected anonymously by Dilay Seda Özgen. Players will be chosen from Bilkent University students who have taken classes from the SA building or used the study area for different periods. The study will be conducted in English.

6. What will the participants have to do? (Provide a brief outline of procedure, *for survey work, a copy of the survey should be attached to this form.*) Please indicate if the participants may be exposed to stimuli which may upset them:

They will be asked to play `Pop a Coffee Corner` serious game in the virtual reality environment mentioned above and answer the questionnaires.

7. What sort of people will the participants be and how will they be recruited? In the case of children state age range. (*Any participant who has not lived through his/her 18th birthday is considered to be a child!*)

They will be students of I.D. Bilkent University. All participants are above 18 years old.

8. Arrangements for consent and debriefing (attach information sheet and consent form)

They will be informed about the study through the announcement through BAIS. After they read the consent form, they are asked whether they continue or quit the experiment and allow them to quit if they want.

1* Adapted from *www.york.ac.uk/depts/psych/www/research/ethics/StaffPGEthicsForm.doc*

YA.

(Form Staff_EN[1*])

Staff Application Form for Experiments with Human Participants

(A separate application form must be completed for each experiment and staff member.)

Please check one: ___ *I need a formal approval letter for an external agency (TÜBİTAK, etc.)*

__X_ *An internal communication letter informing me of the approval will be sufficient*

1. Name of applicant (graduate students should indicate their supervisors)

Assoc. Prof. Dr. Yasemin Afacan

2. Funder of grant/studentship if any:

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Biophilic Design Approach for a Serious Game and Its Effects on User

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6. What will the participants have to do? (Provide a brief outline of procedure, *for survey work, a copy of the survey should be attached to this form.*) Please indicate if the participants may be exposed to stimuli which may upset them:

They will be asked to play `Pop a Coffee Corner` serious game in the virtual reality environment mentioned above and answer the questionnaires.

7. What sort of people will the participants be and how will they be recruited? In the case of children state age range. (*Any participant who has not lived through his/her 18th birthday is considered to be a child!*)

They will be students of I.D. Bilkent University. All participants are above 18 years old.

8. Arrangements for consent and debriefing (attach information sheet and consent form)

They will be informed about the study through the announcement through BAIS. After they read the consent form, they are asked whether they continue or quit the experiment and allow them to quit if they want.

1* Adapted from *www.york.ac.uk/depts/psych/www/research/ethics/StaffPGEthicsForm.doc*

YA.

Consent Form

Name of the participant:

Information of a contact person in any emergency situation:

Name of the study: *Biophilic Design Approach for a Serious Game and Its Effects on User*

This is the study of Biophilic Design Approach for a Serious Game and Its Effects on User research. Aim of this study is to change people's behaviours and attitudes towards nature by supporting sustainable behaviours. Within this scope, participants are asked to play the video game and answer questionnaires that measure sustainable behaviours. This study aims to collect data on players' environmental behaviours to support people`s sustainable behaviours with a serious game in a biophilic environment.

Your answers will be collected anonymously. Your responses will remain confidential.

We do not foresee any risks or discomfort from your participation in the study.

Your participation in the study is on a voluntary basis and you have the choice not to participate. Your identity will remain anonymous; your choice will not have an impact on any relationship to the investigator (Dilay Seda Özgen) and will not affect the research outcome.

You may contact Dilay Seda Özgen (dilayozgen@bilkent.edu.tr) for any further questions.

I _____, understood the objectives of this study and I want to participate voluntarily. My sign is proof of my approval.

Signature: Date:

I, Dilay Seda Özgen, explained the aim, expectation and the methodology of this study, and also I will keep participant information in confidential.

Signature: Date:

D.S.Ö. 7A.

Appendix F. Pre and Post Test of the Pilot Study

		Pre-Test									
		Environmental Identity Scale Adapted from Clayton, 2003									
		The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Susan Clayton									
		Gender:	Female	Male	Not prefer to say	(use x for one)					
		Living location:	Campus	Urban	Rural	(use x for one)					
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	2	3	4	5	6	7			
		Not at all true of me			neither true nor untrue			completely true of me			
1		I spend a lot of time in natural settings (forest, mountains, lakes, seaside)									
2		Engaging in environmental behaviours is important to me									
3		I think of myself as a part of nature, not separate from it									
4		If I had enough time I would work for environmental causes									
5		When I am upset or stressed I can feel better by spending some time in nature									
6		Living near nature is important to me; I would not want to live in a city all the time									
7		I like to garden									
8		Being a part of ecosystem is an important part of who I am									
9		Behaving responsibly towards the earth -living a sustainable lifestyle- is part of my moral code									
10		Learning about the natural world should be an important part of every child`s upbringing									
11		I would rather live in a small house with a nature landscape view than a bigger house with a view of other buildings									
12		I really enjoy camping or/and hiking outdoors									
		Pro Environmental Behavior Scale adapted from Markle, 2013									
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	2	3	4	5					
		never	rarely	sometimes	usually	always					
13		How often do you turn off the lights when leaving a room?									
14		How often do you switch off standby modes of appliances or electronic devices?									
15		How often do you cut down on heating or air conditioning to limit energy use?									
16		How often do you turn off the TV when leaving a room?									
17		How often do you limit your time in the shower in order to conserve water?									
18		How often do you wait until you have a full load to use the washing machine or dishwasher?									
19		How freaquently do you watch television programs, movies, or internet videos about environmental issues?									
20		How often do you talk to others about their environmental behavior?									
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	3	5							
		hot	warm	cold							
21		At which temprature do you wash most of your clothes?									
		please indicate the extend to which each of the following statements describes you by using the appropriate answer from the below									
		Yes	No								
22		Are you currently a member of any environmental, conservation, or wildlife protection group?									
23		During the past year have you contributed money to an environmental, conservation, or wildlife protection group?									
24		During the past year have you increased the amount of organically grown fruits and vegetables you consume?									
		please indicate the extend to which each of the following statements describes you by using the appropriate									
		1	3	5							
		never	occasionally	frequently							
25		During the past year how often do you have car pooled?									
26		During the past year how often have you used public transportation?									
27		During the past year how often have you walked or cycled instead of driving									
		Environmental Action Scale adopted from Alisat and Riemer, 2015									
		The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Susan Alisat									
		please indicate the extend to in the last six month, how often, if at all, have you engaged in the following environmental activities and actions by using the appropriate number from the scale below									
		0	1	2	3	4					
		never		sometimes		frequently					
28		Educated myself about environmental issues (e.g., through media, television, internet, blogs, etc.)									
29		Participated in an educational event (e.g., workshop) related to environmental issues									
30		Talked with others about environmental issues (e.g., friends, parents, etc.)									
31		Used online tools (e.g., Instagram, Youtube, Twitter, etc.) to raise awareness about environmental issues									
32		Personally contact with a politician/government official about an environmental issues									
33		Became involved with an environmental group or political party (e.g., volunteer, summer job, etc.)									
34		Financially supported an environmental cause									
35		Took part in a protest/rally about an environmental issues									
36		Consciously made time to be able to work on environmental issues (e.g., choosing environmental activities over other leisure activities)									
37		Participated in nature conservation efforts (e.g., planting trees)									
38		Spent time working with a group/organization that deals with the connection of the environment to other societal issues such as justice or poverty									

		Post-Test									
		Environmental Identity Scale Adapted from Clayton, 2003 The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Clayton									
		Gender:	Female	Male	Not prefer to say	(circle one)					
		Living location:	Campus	Urban	Rural	(circle one)					
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	2	3	4	5	6	7			
		Not at all true of me			neither true nor untrue			completely true of me			
1		I would spend a lot of time in natural settings (forest, mountains, lakes, seaside)									
2		Engaging in environmental behaviours would be important to me									
3		after play the game I think of myself as a part of nature, not separate from it									
4		If I had enough time I would work for environmental causes									
5		When I am upset or stressed I would feel better by spending some time in nature									
6		Living near nature would be important to me; I would not want to live in a city all the time									
7		After play the game I may spend time for gardening									
8		After play the game I thought being a part of ecosystem would be an importa									
9		Behaving responsibly towards the earth -living a sustainable lifestyle- would be part of my moral code									
10		After play the game I started to think, learninSg about the natural world should be an important part of every									
11		I would rather live in a small house with a nature landscape view than a bigger house with a view of other buildings									
12		After play the game I would really enjoy camping or/and hiking outdoors									
		Pro Environmental Behavior Scale adapted from Markle, 2013 *The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Gail Markle*									
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	2	3	4	5					
		never	rarely	sometimes	usually	always					
13		How often will you turn off the lights when leaving a room?									
14		How often will you switch off standby modes of appliances or electronic devices?									
15		How often will you cut down on heating or air conditioning to limit energy use?									
16		How often will you turn off the TV when leaving a room?									
17		How often will you limit your time in the shower in order to conserve water?									
18		How often will you wait until you have a full load to use the washing machine or dishwasher?									
19		How freaquently will you watch television programs, movies, or internet videos about environmental issues?									
20		How often will you talk to others about their environmental behavior?									
		please indicate the extend to which each of the following statements describes you by using the appropriate number from the scale below									
		1	3	5							
		hot	warm	cold							
21		At which temprature will you wash most of your clothes?									
		please indicate the extend to which each of the following statements describes you by using the appropriate answer from the below									
		Yes	No								
22		Are you currently consider to be a member of any environmental, conservation, or wildlife protection group?									
23		After play the game do you consider to contribute money to an environmental, conservation, or wildlife protection grou									
24		After play the game do you consider to increase the amount of organically grown fruits and vegetables you co									
		please indicate the extend to which each of the following statements describes you by using the appropriate									
		1	3	5							
		never	occasionally	frequently							
25		After play the game how often would you consider will you car pooling?									
26		After play the game how often would you consider will use public transportation?									
27		After play the game how often would you consider will walk or cycle instead of driving?									
		Environmental Action Scale adopted from Alisat and Riemer, 2015 *The originators of the below questionnaire were contacted, and the permission to use the questionnaire has been obtained from Susan Alisat*									
		please indicate the extend to in the last six month, how often, if at all, have you engaged in the following environmental activities and actions by using the appropriate number from the scale below									
		0	1	2	3	4					
		never		sometimes		frequently					
28		I will educate myself about environmental issues (e.g., through media, television, internet, blogs, etc.)									
29		I will participate in an educational event (e.g., workshop) related to environmental issues									
30		I will talke with others about environmental issues (e.g., friends, parents, etc.)									
31		I will use online tools (e.g., Instagram, Youtube, Twitter, etc.) to raise awareness about environmental issues									
32		I will personally contact with a politician/government official about an environmental issues									
33		I will become involve with an environmental group or political party (e.g., volunteer, summer job, etc.)									
34		I will financially support an environmental cause									
35		I will take part in a protest/rally about an environmental issues									
36		I will consciously make time to be able to work on environmental issues (e.g., choosing environmental activities over other leisure activities)									
37		I will participate in nature conservation efforts (e.g., planting trees)									
38		I will spend time working with a group/organization that deals with the connection of the environment to other societal issues such as justice or poverty									

Appendix G. Interview Data

scale	1	2	3	4	5
subject	q1	q2	q3	q4	q5
	What do you know about	How do you perceive sustainable	Do you agree with the definition of	Do you think that exposing biophilic design	How do you relate the biophilic design
1	my knowledge is limited to the information I gathered from my friends and colleagues who are nature activist	I am aware of its importance for the future of our species and others. However I am not optimistic about teaching these behavior to most of the human population.	Yes, I agree since for us to sustain ourselves we have to make sure the environment we live in is sustained too.	Although I think biophilic design items are important to create an environment that lets the people get closer to nature which can help them mentally and physically I am skeptical about wether this would alter an uneducated person`s behaviors towards being more sustainable.	I do not belive there to be a connection
2	It is important to protect and preserve our environment for both us and future. Sustainable behaviors can help us to fulfill these aims	I think it is important to apply our lives to make world better. However, it is hard to complete this aim because of the comsumerist society.	yes it gives more understandable approach for the sustainable behavior.	it is more semphatic and warm design items. This makes me more positive attitude towards the building and places.	I do not have an idea about the relation between biophilic design and sustainable behavior. However, both of them gives sense of cozy home environment.
3	Sustaible behaviors can be involved into different areas of our daily life. They are about living more sustainble, eco friendly. For instance reusing shopping bags. Carrying your own thermos are easy but effective chages.	I always research about sustainable behaviors and I try to find new sustainable products that I can use instead of unsustainable things.	yes because by embracing sustainable behaviors, you show that you are not only care about yourself or your generation but also about the world and the future generations. But only caring is not enough so you start to live a more sustainable lifestyle.	no I think nature and biophilic design are different than each other. The nature experience and its feelings can only change in nature.	I do not relate them.
4	as I know sustainable behaviors purpose is protecting the environment	they are very important to save the world for the next generations	yes	yes because such places make me feel more peaceful and relaxed.	biophilic design in building can make people calm. Therefore people might would like to see more natural elements around them. So more people may try to protect the environment
5	to prevent horrific results of global warming and climate change, all individuals must take action to increase their sustainable behaviors	it is greatly necessary	yes	biophilic design items might increase my love towards nature because we are not able to see natural landscapes very often these days. These items might be helpful to remember I should protect the nature.	dynamic and diffuse light is connected with my light use habbits. Because as a programmer myself I prefer to work in daylight as often as possible. this kind of lightening might help me.
6	I know that refracting from using	I think everyone should adhere to	yes I agree with that. this definition	yes seeing natural elements as a part of	Personally I try to behave sustainably due
7	yasamin devami icin gerekli olan	faydali	katiliyorum hoyratca davranmak her	belki biraz. Etrafimizda gormek belki dogayla	cevremdeki bitkiler bana dogayi hatirlatip
8	gunumuzde hizla azalan dogal	I perceive sustainable behavior as	yes I belive that sustainability is	yes	there is a naturally occuring creeper here
9	etrafimizdaki kaynaklari daha bilincli	mesela kagitlarin geri donusumunu	yes because I also beileve the key	yes because nowadays most of the people	dogal yasami hatirlatir
10	keeping your manners of handling things to such regards as not to spend excess recoursces	good for the future	yes as I agree. Climate change is a serious issue for the future generations	might possibly yes, if there were some examples or some really thought provoking designs. Like presence of water, diffusion of natural light, and stairs and walls in form of nature patterns	I do not feel that much close, the biophilic design of the building could have been better
11	sustainable behavior is when we	I perceive it to be very important but	yes I aggree but I do not agree on its	yes I really like biophilic design in interior	reminds me to be sustainable in my
12	I do not know much about	by protecting the sources of the earth.	yes because sustain means that to	yes people usually live and spend time in	in this building as biophilic design items I
13	it may be a neccessity for the future	I appreciate the people behave that	yes it macthes with the description	no I do not associate stuff like that a change	do not think there is a relation
14	any behavior that limit exessive	it is important for a better world,	yes but also education should be part	people may realise the nature brings joy\calm	I do not think there is in the building so I
15	it is getting harder to perseu, just	using extra money, the estimated	yes caring and thinking for other is	yes observing living things while working,	I do not think that it is to relatable. There
16	I know that they are kind of eco-		yes I agree. I love being eco-friendly	it makes me feel more happy and more relax.	it makes me relax
17	sustainable behaviors is taking	I am thinking the same way as I	I agree with the definition above	evet degistirir. Bu itemler doganin minyatur	bu binadaki bitkilerin insani rahatlatmak

6	7					
q6	q7	tpbq1	tpbq2	tpbq3	tpbq4	tpbq5
How do you evaluate yourself in terms of	Which design elements of this building would	1) What do you see as the	2) What do you see as the	3) What else comes to mind	4) Please list any factor or	5) Please list any factor or
even though I do not do everything I can do, I believe my level of caution to be enough.	the windows that see a view of plants, I think this feature would be the most effective. The plants in the building, since these plants are cared for I think their impact on sustainability would be limited.	working under natural light is better and easier for our eyes.	It is a public space and it is far from my home.		Heaters	cold weather, crowdness
I try to more sensitive about this problem. For example I do not prefer plastic based items.	1-visual connection with nature, 2-presence of water, 3-dynamic and diffuse light 4-mystry.	the advantage of working under the natural lights is feeling more energetic, motivated what you do	it can be distracting when working	open space, cozy	lab conditions is not suitable for the natural light for those chemicals or machines	chemicals and machines can be broken and destroyed when contacting with the light. That is why labs generally do not have windows a lot.
I try to live as sustainable as I can. To achive this I am trying to change my daily life habits. I stopped consuming meats. I can carrying my own thermos with me everyday. And also I changed my habits when I am having my period. Overall rather than recycling things I am trying not to waste unsustainbale products at my daily life.	1-non visual connection with nature, 2-presence of water, 3-dynamic and diffuse light, 4- visual connection with nature.	natural light makes me feel happier and freer. So it increases my concentration	since it changes it can be hard to arrange yourself for every different natural light through the day.	open space, freedom	changing lab conditions or I can change the work area that I want to work in	since I am studying chemistry. I will nor think labs that I will be working will have natural light a lot.
although I have no time to participate environmental actions I do my best to protect the environment	there are plants insight this building and they might encourage the sustainable behaviors.	it might be good for our eyes	I think that there is no disadvantage of working under the natural light	It would be peaceful	if there are a lot of windows on all the wall of the building and if they can filter harmful sunlight it will be easy to work	too much sunlight would make it difficult to work
I do not think I do a lot of actions to help the nature. I am not happy about it. I know the good habits to protect the nature but sometimes I am unable to do them	1-dynamic and diffuse light, 2-presence of water, 3-visual connection with nature	it helps me to take enough vitamin D because I usally do not stay under sunlight ver often.	it sometimes disturb my eyes because I am not very comfortabel with sunlight because of allergic		it would help me to decrease brightness	
I try to act in regard of sustainability,	1-visual connection, 2-non rythmic sensory	reading from a paper under	if that is the only light	none	if the building has designated seating	some designs of buildings (or
kendi copumu yere atmamak ve geri	1-mechanical flow of a body of water, 2-	icim aciliyor daha kolay	herhangi bir dezavantaj	mutluluk huzur	gunes isigi olmayan yerlerde depresif	labaratuvarlarda calisiyor
average because I need to make more	1-light,2-plants 3-air system, 4-high ceiling	it can improve my productivity	there is no disadvantage	it can increase my awakeness	satisfaction, awakeness, productivity,	my vertigo situation
I am modarete. Dogayi korumak istiyorum	1-giristeki agaclarin varligi dogal bir ortam	yapay isikla calismanin gozleri	dogal isik iyidir. ileride de	nothing	isik geciren pencere gibi seylerin sayisi	agaclarin buyumesi ile iceri
I often try not to overlook actions that are not beneficial for the environment	1-the branches droppng from the 3rd floors and 2-spiral staircase. They both seem engaging too look at. But only the branches\flowers give sense of a sustainable behaviors.	illumination wakes you up from natural light and I feel refreshed	the sunglare directly to the eyes and dust might be an issue	bright and ambiance-rich environment	more available spaces	very hot days
as a student I try to be as environmentally	more greenery free drinkable water refills	it is sustainable to work usign	no disadvantage, I can	it is always nicer to work in	more available spaces to work in the	crowdness and niose due to
I try my best to care environment but I do	1-windows. They make saving energy possible	first of all it saves energy. And	when the weather is	I would enjoy doing most of	big windows and right angels would be	small windows, wrong angles,
I do as much as I can for nature but	I do not think design elements really effects	less energy consumption	cloudy days has more	it is just nice	cannot think of any	do not believe there is any
I do care but I do not change my lifestyle if	I do not think any of it can but maybe plants	it can reduces the stress and	I do not see any	I like to work where I can see	if any seating with appropriate table ,	if it is too cold and too crowded
I do not do any contribution to any group	the trees that put in several places represent	you do not feel disconnected	when you are working	pass	working for an environmental factory it	working for an evil corporation
I want to support environmental actions	there is some tree which are big and beautiful	it could be healthier than	it spends less energy		more window and may better kinf of	sometimes it makes places very
elimden geldigince doga dostu hareket		I do not see any disadvantage				