HUMAN-BUILDING INTERACTION: SUPPORTING STUDENTS' PERFORMANCE AND WELLBEING THROUGH BUILT ENVIRONMENTS ON CAMPUS

A Dissertation
Presented to
The Academic Faculty

by

Yujin Kim

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Building Construction

Georgia Institute of Technology
May 2022

HUMAN-BUILDING INTERACTION: SUPPORTING STUDENTS' PERFORMANCE AND WELLBEING THROUGH BUILT ENVIRONMENTS ON CAMPUS

Approved by:

Dr. Eunhwa Yang, Advisor
School of Building Construction
Georgia Institute of Technology

Dr. Daniel Castro-Lacouture
School of Building Construction
Georgia Institute of Technology

Dr. Ruth Kanfer
School of Psychology
Georgia Institute of Technology

Dr. Susan Chung
Senior Research Program Manager
HKS Inc.

Dr. Xinyi Song

Date Approved: [April 20, 2022]

ACKNOWLEDGEMENTS

I would like to thank many people who helped me to finish my Ph.D. journey. First of all, I am grateful in many ways to my committee. I am sincerely thankful to my advisor, Dr. Eunhwa Yang, for all the supports, encouragement, and advice. Her passion in research always inspired me in all the time of my Ph.D. study. My other committee members, Dr. Daniel Castro, Dr. Xinyi Song, Dr. Ruth Kanfer, and Dr. Susan Chung, brought different areas of expertise to my dissertation and expanded my thinking all the time. I have learned so much from them. I would like to extend my thanks to the School of Building Construction for a great support academically and financially.

I need to acknowledge the supports from my friends and family, who were always by my side. I would like to thank my friends and colleagues – Sungil Hong and Jung Hyun Lee – for valued time spent together in and outside the Caddell building. Finally, I am deeply grateful to my family for their tremendous understanding and encouragement in the past five years. The love and support from my parents enabled me to complete my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CR	composite reliability
FM	Facility Management
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
POE	Post Occupancy Evaluation
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling

SUMMARY

Facility management aims to ensure buildings' quality and components to support occupants in achieving their goals and objectives. Campus environments play a vital role in student success by providing supportive spaces for learning, living, resting, and socializing. However, studies about the built environment of higher education have mainly focused on the ways of learning and teaching instead of physical components, and built environments on campus and their effects on students have been little studied. This study aims to 1) propose and investigate a theoretical framework on the relationship between built environments and students' outcomes (i.e., academic performance and wellbeing) in higher education and 2) identify the preferred physical and functional environments on campus depending on student activities. This study proposed a theoretical framework based on the socio-materiality theory to explain the complex relationship between materiality and social practice in built environments. The proposed framework was tested in three-fold. First, study 1 investigated how students' space usage of a library changed after the COVID-19 pandemic and was related to indoor environmental features. Data were collected via survey with 66 responses in pre-pandemic and interviews with 12 students during the pandemic. One of the main findings was that, even though students used the library less during the pandemic, they expected to use it as much as pre-pandemic or even more after the pandemic. Furthermore, students required different environmental features depending on their purpose of space usage, and the physical environment cultivated a sense of belonging and community. Second, study 2 tested the restorative effect in indoor settings using an eye-tracking device. Data were collected through a true experiment with 34

students randomly assigned to biophilic vs. non-biophilic design settings. The findings indicated that biophilic design itself was not decisive to restorative effects. Students in both settings selectively looked at nature-like (natural material) and views of nature and reported restoration effects. Lastly, study 3 analyzed how multi-dimensional environments (i.e., physical and functional environments) affected students' outcomes in dormitories. A total of 128 self-reported survey responses revealed that the physical and functional environments were related to each other and directly and indirectly affected students' perceived learning performance and wellbeing. In conclusion, this thesis provides a theoretical framework to explain the iterative process of physical and functional environments on campus and empirical evidence of the importance of built environments for enhancing student experiences and supporting different activities, such as learning, collaborating, socializing, and resting. For this, academic leadership, building managers, and designers should actively adopt the evidence-based design approach to provide appropriate environments and support student activities.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The main objective of Facility Management (FM) is to ensure the function of physical buildings and their components supporting an organization's core business for achieving its goals (Alexander, 1996). FM considers *places* where occupants stay, *people* who use the space, and *processes* which occupants conduct in the place with new, advanced *technologies* simultaneously (International Facility Management Association (IFMA), 2003). From the perspective of FM, it is important to ensure that buildings contribute to enhancing occupant experiences as well as to achieve the objectives of an organization.

A place means an integrated concept of physical and complex social functions (Lefebvre, 1991), causing complex relationships between physical space, complex social construct, and the context in human-made surroundings. Built environments are critical as people in the U.S. spend more than 90% of their time indoors (Leech, Nelson, Burnett, Aaron, & Raizenne, 2002). There has been an interest in investigating the psychological impact of environments over the last four decades, and studies found the built environment significantly affects occupants and their outcomes, including performance (Al Horr, Arif, Kaushik, et al., 2016; Appel-Meulenbroek, Clippard, & Pfnür, 2018; Thatcher & Milner, 2014), satisfaction (Haapakangas, Hongisto, Varjo, & Lahtinen, 2018; Kwon & Remøy, 2020), health and wellbeing (Abisuga, Famakin, & Oshodi, 2016; Al Horr, Arif, Katafygiotou, et al., 2016; Bluyssen, Janssen, van den Brink, & de Kluizenaar, 2011; Evans, 2003). However, relatively little is known about the conclusive relationships

between built environments and their impacts on occupants (Baik, Larcombe, & Brooker, 2019; Hoque & Weil, 2016; Rollings & Evans, 2019).

The purpose of higher education is education, research, and educational services in the community, and the campus must be able to interest, support, and retain students for education (Strange & Banning, 2015). The university campus often consists of many buildings with different spatial functions for education, research, and educational services. Higher education environments are unique in that they provide a space for learning, residence, resting, and socializing simultaneously for students in a single environment (Callender et al., 2011). These buildings support students, one of the primary users, to enhance their learning experiences on campus. However, most universities have difficulties in optimizing the use of their spaces (Ellis & Goodyear, 2016).

The learning environment is critical to students, considering the changes in learning patterns. Team-based learning is a new learning paradigm, shifted from lecture-based and individual learning in the early 2000s (Hills, 2001). The learning process in higher education is similar to knowledge creation processes (Paavola, Lipponen, & Hakkarainen, 2004; Townley, 2001), emphasizing sharing and discovering knowledge through collaboration between a faculty and students or with other students. It allows students to keep learning outside the classroom (Hernández, 2012). As learning can happen anywhere, the campus environment should consider the possibility of a space that supports students' learning ability to enhance the teaching and learning effectiveness, increase communication and creativity, and concentrate on individual study (N. Ibrahim & Fadzil, 2013). Spaces for socializing and relaxing often become an organic learning space where encourages students' casual communication and collaboration. In this vein, a more holistic

view of learning spaces refers to both physical environments and social, psychological environments (Cleveland & Fisher, 2014).

Aligning with the main objective of higher education, enhancing students' academic performance is one of the most important considerations in universities (Fenollar, Román, & Cuestas, 2007). Many studies from the existing literature have defined and examined factors affecting academic performance, including personality traits, motivation factors, learning strategies, approach to learning, and psychological context, in previous studies (Richardson, Abraham, & Bond, 2012), and it is revealed that built environment for learning also affects academic performance (I. Ibrahim, Yusoff, & Sidi, 2011; Marchand, Nardi, Reynolds, & Pamoukov, 2014; Temple, 2009). Traditionally, studies about the relationship between the built environment and academic performance have focused on a classroom on campus, which is the main functional space (I. Ibrahim et al., 2011; Marchand et al., 2014). However, learning happens everywhere, including both formal and informal environments (Ellis & Goodyear, 2016; McLaughlin & Faulkner, 2012). Also, a campus provides various types of buildings, and each building has a different environmental design and features surrounding students depending on the purpose of a building. Therefore, an increasing number of studies started emphasizing the importance of the built environments in academic settings for new learning (Baik et al., 2019; Codinhoto, Tzortzopoulos, Kagioglou, Aouad, & Cooper, 2009).

Expected outcomes of higher education become various, and academic performance is not the only outcome (Ellis & Goodyear, 2016). One of the other expected outcomes is students' health and wellbeing, which are also associated with their academic performance (El Ansari & Stock, 2010). College students are easily and largely exposed to

stressors from academic and personal aspects that can impact mental wellbeing (Collins & Mowbray, 2005). According to the American College Health Association (2019), college students experienced feelings of being overwhelmed (87.4%), exhausted (not from physical activity) (84.7%), very sad (70.8%), overwhelmingly anxious (65.7%), and very lonely (65.6%). Students' health and wellbeing are important as they are, and, to effectively support students' academic and personal success, student health and wellbeing have to be considered on campus.

As mentioned earlier, buildings are important because they affect the behavior and perception of occupants; thus, the built environment on campus poses a great opportunity to support students' activities associated with their academic performance, social and psychological health and wellbeing. Student wellbeing on campus can be improved in various ways, such as learning-related activities, socialization, and student services, and, moreover, students believe that spaces, learning environments, and facilities can enhance their wellbeing (Baik et al., 2019). On the other hand, physical environments can contribute to negative mental health outcomes, such as stress, depression, anxiety, insecurity, fear, panic, and disorientation (Codinhoto et al., 2009). The carefully design and operated built environment on campus can provide safe environments, promote active interactions and healthy relationships, enhance the sense of community and belonging, and, consequently, facilitate students' learning experience. However, there is a knowledge gap as little research has been done to investigate the effects of the built environment on students' wellbeing in university (Fernandez et al., 2016).

1.2 Problem Statement

Despite the growing interest and importance of learning spaces, studies about the built environment of higher education have mainly focused on the ways of learning and teaching instead of physical components (Temple, 2008). The study of spaces in higher education has been little performed (Ellis & Goodyear, 2016), and the academic buildings are often renovated or newly built with little consideration for the impacts of the buildings on occupants (Kuntz, Petrovic, & Ginocchio, 2012). If studies focus on only partial aspects of built environments, it is difficult to understand the way in which they affect occupants and provide appropriate environments to support occupants' activities. A multi-dimensional approach, including physical and functional dimensions of the built environment, is well suited to understand the complex relationships between the various aspects of the built environment on campus and student outcomes. This approach allows us to look at the built environment from different views, including physical properties of the space and how these physical properties evolve with the occupants' use of the space.

1.3 Objectives and Research Questions

This study aims to propose and investigate a theoretical framework on the relationship between built environments and students' outcomes in higher education. The proposed theoretical framework was tested in three different environmental settings and methods (Study 1, 2, and 3). These three studies set the following overarching research questions:

1. What are the needs of spaces on campus depending on student activities?
2. What elements of built environments are related to learning performance and wellbeing in different campus environments?

3. Can the multiple dimensions of built environments affect student outcomes including learning performance and wellbeing?

1.4 Working Definition

1.4.1 Built Environment

A place is an integrated concept of physical spaces and social constructs (Lefebvre, 1991). Physical environments include any physical elements, such as buildings, furniture, equipment, lighting, temperature, noise, air quality, and their configurations (Ayoko & Ashkanasy, 2020). Social construct, on the other hand, includes functional environments, context, activities, and people outcomes. Functional environments mean the environmental support of users' tasks (Vischer, 2008).

Built environments are an abstract concept to describe any physical environments as an alternative to natural environments, form specific building elements to cities, and their functions (Lawrence & Low, 1990). The built environment defines physical boundaries but, as a place, includes social constructs. Therefore, it is important to consider both physical and functional environments when discussing the built environment. The scope of the built environment employed in this study refers to indoor spaces and their physical and functional environments in a building.

1.4.2 Perceived Learning Performance

Performance refers to "actions or behaviors relevant to the organization's goals" (Campbell, 1990, p.704). It does not mean results or outcomes of actions but implies action

itself (Campbell, 1990). When this definition comes to learning, learning performance can be seen as any behaviors and activities related to learning.

1.4.3 Wellbeing

World Health Organization (WHO) (2014, p.1) defines health as "a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity." Wellbeing is a keyword of the definition of health, but there is no consensus on the definition of wellbeing. Wellbeing is regarded as a multi-dimensional construct, including physical, psychological, and social dimensions (Dodge, Daly, Huyton, & Sanders, 2012). Physical wellbeing means a status where people can perform physical activities and carry out social responsibilities without physical and bodily limitations (Capio, Sit, & Abernethy, 2014). Psychological wellbeing refers to the subjective evaluation of satisfaction (Daniels, Watson, & Gedikli, 2017). Lastly, mental wellbeing requires positive mental health that allows people to recognize their abilities, deal with everyday stress, work constructively, and contribute to society (World Health Organization, 2004).

Wellbeing can be used as a measure of context-free experience (Danna & Griffin, 1999). It regards the presence of positive emotions and moods, the absence of adverse effects, and satisfaction with major domains (Diener, 2000). This study employs psychological health and wellbeing, focusing on emotion and mood states.

CHAPTER 2. A REVIEW OF BUILT ENVIRONMENTS ON CAMPUS[1]

2.1 Built Environments for Higher Education

Buildings of higher education are complex in that they must contain multiple interests and values simultaneously (van Heur, 2010). A campus space aims to provide various purposes, such as supporting learning, relaxation, workout, and socializing. Cleveland and Fisher (2014) claimed that using a generic measure for evaluating university facilities is inappropriate because of the different purposes, designs, and contexts of the buildings. Therefore, it is required to have a context-specific approach for built environments of higher education.

Considering contexts, learning environments need to have proper physical and functional environments to effectively support students (Deed & Alterator, 2017; Ellis & Goodyear, 2016; Harrop & Turpin, 2013). Studies on built environments of higher education should consider physical environments and social constructs at the same time. In an early study, Weinstein (1979) emphasized the effects of physical, psychological, and social components in a classroom as they affect student learning experiences, such as achievement, behavior, and attitudes. In her review paper, she defined seating position, presence of window, classroom design and furniture arrangement as physical variables and density and crowding, privacy, and noise as psychological variables.

[1] This chapter is a modified version of "Theoretical understanding of sociomateriality in workplace studies" published in Facilities and has been reproduced here with the permission of the copyright holder.

Even though a growing number of researchers are getting the importance of physical environments in learning and academic settings, physical environments have been little studied (Cleveland & Fisher, 2014; Kuntz et al., 2012). Built environment studies on higher education still have been focused on either physical environments (Chiu & Cheng, 2017; Hill & Epps, 2010; Hoque & Weil, 2016; Pearshouse et al., 2009; Peker & Ataöv, 2020) or social aspects, including functional environments (Freeman, Anderman, & Jensen, 2007; Lee & Schottenfeld, 2014), so the studies failed to link the physical and functional environments in learning settings (Maxwell, 2016; Temple, 2009; Woo, Serenko, & Chu, 2019).

In order to understand the complex relationships in built environments, a theoretical model is required. Theory-based research is lacking, especially in the field of built environments (Jamieson, 2003; Y. Kim & Yang, 2020).

2.2 Socio-materiality

Socio-materiality is a theory that explains the relationship between materiality and social practice in the organization workplace (Leonardi, 2013; Orlikowski, 2007). This theory emphasizes the coexistence of social and material in the workplace and their effects on each other. All materiality is created, used, and interpreted through social practice, and all social practices are influenced by materiality (Leonardi, 2012). Hence, an organization is constructed by the interaction between material forms and human agency (Orlikowski, 2007). The physical environment of the workplace has material characteristics, and social practices including workers and their work differ depending on workplaces. Therefore, in

order to comprehensively understand what happens in the workplace, consideration for both material and social perspectives is required.

Materiality and social practice are the main components of the theory. Materiality refers to any non-human elements that act in their own functions (Leonardi, 2012). The material components include not only visible forms such as furniture, buildings, and devices but also invisible forms like data and electricity (Leonardi, 2012; Orlikowski, 2007; Parmiggiani & Mikalsen, 2013). Orlikowski and Scott (2008) pointed out that the studies on workplace materiality tended to focus on technologies as a material component and ignore other material elements.

The concept of social practice, on the other hand, is very broad and means anything but materiality (Bavdaz, 2018; Leonardi, 2013; Orlikowski, 2007). For example, human, organization, behavior, concepts, norms, policies are included in social practice (Leonardi, 2012). The social practice also refers to perception as a reaction to materiality (Leonardi, 2012).

Socio-materiality has been discussed in two main streams based on the perspective of Ontologies (Bavdaz, 2018). Agential realism, led by Wanda Orlikowski, assumes the inseparability of material and human agencies. This perspective regards that material and humans are intertwined, so organizations exist based on constitutive entanglement of these agencies (Orlikowski, 2007). Critical realism, on the other hand, led by Paul Leonardi, separates materiality and social practice and emphasizes repetitive and cumulative imbrications between the agencies (Leonardi, 2013). Social and material agencies are independent of each other, and they become socio-material by putting them together. By separating two agencies, critical realism enables researchers to observe how each entity

affects the organization. This study follows critical realism in order to understand how material and social entities reconfigure each other in an organization.

2.2 Socio-materiality in Built Environment Studies

The concept of a place is integrated with a physical space and social function (Lefebvre, 1991), so it is possible to consider that built environments are composed of not only the physical environment but also humans that occupy the physical environment (Fischer-Kowalski & Weisz, 1999). The impact of environments is complex and dynamic in that many psychological mechanisms also occur and affect occupants in addition to physical environments (Appel-Meulenbroek, Janssen, & Groenen, 2011), so theory-based approach is helpful to understand the relationship. Based on this perspective, it is possible to understand workplaces based on the socio-materiality theory. When built environment studies adopt socio-materiality, the components of built environment studies can be interpreted using major components of the socio-materiality theory. A physical environment of the built environments is included in a material agency, and occupants and their activity, behavior, and outcomes are regarded as a social practice. However, socio-materiality studies tended to focus on technology in terms of materiality and ignored physical environments as a materiality component (Orlikowski & Scott, 2008). In order to comprehensively understand how built environments work, considering both materiality and social practice is necessary (van den Ende, Willems, & van Marrewijk, 2020).

To understand the complex relationships in the workplace, workplace studies need to consider both social practice and materiality, as both aspects affect each other and are the main components of the workplace. The socio-materiality theory suggests the reciprocal interactions between materiality and social practices; hence, it allows workplace

studies to consider both perspectives. A framework of socio-materiality in the FM study is proposed for facilitating a better understanding of the workplace [Figure 1].

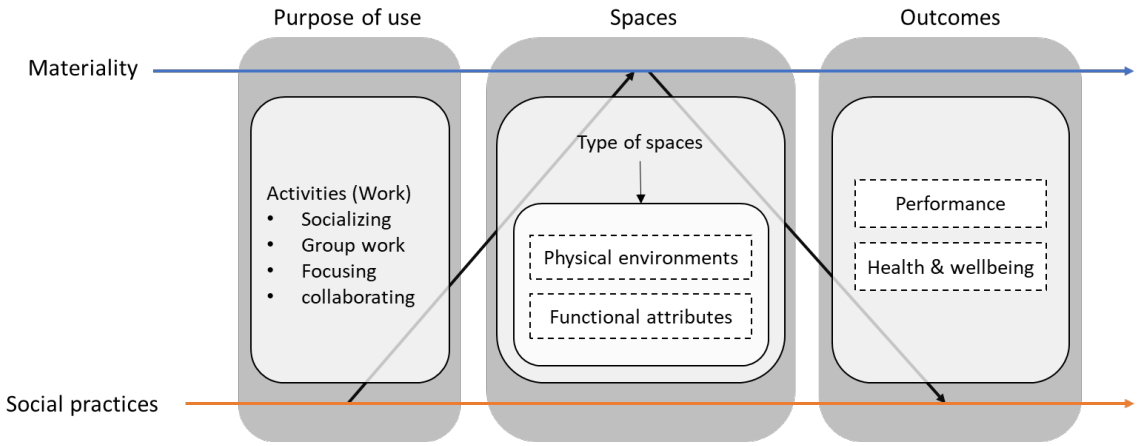


Figure 1 - A theoretical model of socio-materiality for workplace studies (Y. Kim & Yang, 2020)

In socio-materiality, cumulative effects between material and social agencies recur sequentially, which in turn, creates effects on each other. In workplace studies, the first path associated with the social aspect affecting materiality is a type of work. For knowledge workers, work types can be based on the knowledge creation process. As workers decide their workplace depending on their work responsibilities, their outcome can be nested into their workplace. The second path explains the workplace and its component originating from materiality affect workers, which is a social practice. Each workplace provides different indoor environments and configurations, and previous studies found that the built environment influences performance, health and satisfaction of workers. Based on the proposed theory, it is possible to analyze the effects between material and social agencies in the organization from the socio-materiality perspective.

The proposed model aims to explain the built environment of the workplace, so the model for higher education should be adjusted accordingly considering the context. For the built environments of higher education, the structure of the model can be the same as the one for the workplace, but the considerations should differ from the one for the workplace.

2.2.1 Materiality in Built Environments for Higher Education

Socio-materiality studies have traditionally focused on technology and its effects as a material perspective. When FM researchers adopt socio-materiality to built environment research, physical environments and their components can be regarded as materiality. Since the environment influences occupants and their outcomes, including performance and wellbeing, it is essential to evaluate the features of the environment. The effect of physical environments can be found in higher education as well.

2.2.1.1 Type of Spaces

University buildings encompass spaces for teaching, learning, and research, so the built environment mainly aims to enhance the performance of such activities. For this, researchers examined the built environments of higher education, focusing on the classroom environment (Hill & Epps, 2010; Scott-Webber, Strickland, & Kapitula, 2013). However, a learning environment encompasses various environments, including not only traditional classrooms but also learning commons and informal spaces. The informal space means a space where students meet up, socialize, and learn without teachers' supervision, usually outside classroom (Ellis & Goodyear, 2016; Strange & Banning, 2015). Universities are required to provide a variety of space options supporting different activities, including social spaces such as student centers, learning commons, libraries, and

other hospitality, restorative areas (Jamieson, 2003). This study mainly focuses on informal learning spaces, including learning commons in libraries, lounge spaces, and dormitories. Other spaces that are not in the scope of this research are classrooms, studios, machine rooms, auditoriums, dining halls, and student centers.

Considering the change in learning paradigm, a growing number of studies have been focused on informal learning spaces. N. Ibrahim and Fadzil (2013) examined the preference and use of informal spaces in university depending on learning activities. They found students preferred informal spaces for computer-assisted learning, networking, and socializing. Similarly, Harrop and Turpin (2013) found out students' needs and use of informal learning spaces based on nine considerations: destination, identity, conversation, community, retreat, timely, human factors, resources, and refreshment. However, those studies mainly focused on learning space itself as a type of space and did not consider other components in physical environments.

2.2.1.2 Spatial Settings

Analysis of the built environment on campus based on socio-materiality benefits the understanding of the environment and its effects because a campus provides various types of spaces with different features. The physical environments play a role in limiting and defining the range of analysis of the systems (Moffatt & Kohler, 2008), so each environmental setting can be the unit of analysis, which influences occupants.

A study by Scott-Webber et al. (2013) found that design changes of the classroom for active learning in higher education can increase the quality of learning through the between-group experiments in old- and new-classroom environments. The study

emphasized the importance of classroom design but did not provide design differences between two environments and any environmental evidence and intervention. Similarly, Hill and Epps (2010) identified students preferred upgraded classrooms with the perception on tiered seating, lighting, and noise control. However, their study did not find any link between the classroom environments and students' outcomes.

Riddle and Souter's study (2012) focusing on the design of informal learning spaces in higher education suggested that users' comfort is the primary design principle of learning spaces, which includes high quality of furniture configuration and indoor environmental quality. The other design principles included aesthetics, equity (universal design), blending (technology support), affordance (action possibility), and repurposing.

On campus, each space has its own objectives, and the space provides different spatial settings and environments depending on the purpose of space use. As the spaces have different goals and intentions of use, it is important to know if spaces provide appropriate environments with different functions.

2.2.1.3 Indoor Environmental Quality

FM research can also consider Indoor Environmental Quality (IEQ) as the materiality of the built environment. IEQ is one of the main components of the physical environment and defines the building condition inside to provide a comfortable environment for occupants (WBDG, 2018). IEQ is important because IEQ as a materiality entity affects social practices, including satisfaction (Haapakangas, Hallman, Mathiassen, & Jahncke, 2018), productivity (Al Horr, Arif, Kaushik, et al., 2016; Thatcher & Milner, 2014), physical health (Abisuga et al., 2016), and emotional state and perceived wellbeing

(Bluyssen et al., 2011). Studies have utilized different IEQ criteria depending on their objectives, but some factors are commonly mentioned; thermal comfort, indoor air quality, noise, and lighting (Al Horr, Arif, Kaushik, et al., 2016; P. Li, Froese, & Brager, 2018).

Many studies were performed to find the relationship between IEQ and learning performance in classroom environments in higher education. Key IEQ elements that were positively related to academic performance was thermal comfort (Bae, Martin, & Asojo, 2020; Hoque & Weil, 2016; Marchand et al., 2014), acoustic comforts (Marchand et al., 2014), lighting (Bae et al., 2020), and Indoor Air Quality (IAQ) (Bae et al., 2020). Additionally, Choi, Rosenthal, and Hauser (2013) conducted a path analysis to find the relationship between satisfaction with IEQ and student outcomes. Satisfaction with thermal, acoustic, lighting, furnishing, aesthetics, and view conditions were significantly and positively associated with the overall satisfaction with the classroom environments, and the satisfaction with the environmental IEQ affected students' perceptions on the effect of IEQ on learning experience and indirectly course satisfaction. Furthermore, Bae et al.'s study (2020) resulted in dissatisfaction with lighting, IAQ, and temperature significantly decreased the perceived health.

As the previous studies found, IEQ is the main environmental components that have an impact on student learning performance and wellbeing. The previous studies examining students' perception on IEQ comfort did not consider spatial settings or functional environments. However, the built environments contain multiple dimensions and can affect each other. As a result, it is critical to consider various environmental elements at the same time.

2.2.2 Social Practice in Built Environments for Higher Education

2.2.2.1 Activity

Campus buildings have always been places for learning, even though the physical shape and learning paradigm have changed (Strange & Banning, 2015). Traditionally, learning had focused on a lecture in a classroom (Hill & Epps, 2010; Hoque & Weil, 2016; Marchand et al., 2014). However, learning actually refers to any activity performed to gain knowledge by not only individual studying but also collaboration (Jamieson, 2003; Lee & Schottenfeld, 2014; Temple, 2009). Learning spaces must be able to provide support socialization among students. Some researchers emphasized the importance of providing study and gathering places for academic purposes in support facilities such as dormitory (Amole, 2005) and library (Beckers, van der Voordt, & Dewulf, 2015; Bryant, Matthews, & Walton, 2009; J. A. Kim, 2016).

Even though colleges and universities mainly aim to provide a place for learning, it is important to consider various activities that possibly coincide on campus. In addition to learning, students also use spaces on campus for socializing with friends, relaxing, and eating. People choose their spaces where can support their activity effectively. When they use an appropriate space according to their activity, people will perceive the environmental support/ fit of the space. Therefore, considering other activities on campus and examining whether the campus appropriately support those activities are important.

Learning on campus constantly leads sustained attention and mental fatigue. Relaxation allows students to recover from fatigue due to studying, and campus environments play an important role of refreshing and recharging (Felsten, 2009). Students

prefer different relaxation activities such as watching something, meeting and hang out with friends, and having some quiet time (Waxman, Clemons, Banning, & McKelfresh, 2007). There is no specific space for relaxing on campus, but students often take a break between classes. Studies found students get relax and benefit from green spaces (Felsten, 2009; Hipp, Gulwadi, Alves, & Sequeira, 2016; McFarland, Waliczek, & Zajicek, 2008) or indoor common spaces on campus (Waxman et al., 2007).

Additionally, student housing is an essential building on campus to assist student academic and residential needs. Students' experience in the dormitory can be referred as living. This term is very general and covers a variety of activities including sleeping, studying, socializing with friends, and relaxing (Amole, 2009).

2.2.2.2 Functional Environments

Built environments include their functional environments as well as physical environments. Functional attributes refer to suitability that occupants have for their activities in a place (Kwon, Remøy, & van den Dobbelsteen, 2019). They are inseparable and should be considered simultaneously because the physical environments significantly affect the quality of functional attributes. Physical environments influence occupants' outcomes through perception such as perceived support to environmental satisfaction (Haapakangas, Hongisto, et al., 2018) and psychological attributes (Kwon & Remøy, 2020) on the environments.

A campus needs to provide appropriate spaces with functional attributes for enhancing academic performance and wellbeing as student experience on campus (Jamieson, 2003). The requirements of functional environments are different depending on

the purpose and context of the building. For example, learning spaces require an environment supporting focus and collaboration while relaxing spaces need restorative environments. The space supporting functional demands can enhance social relationships in the space, encourage students to spend their time on campus, and consequently increase academic performance (Bennett, 2007). However, few studies exist for defining and examining functional environments in higher education (Jamieson, 2003; Temple, 2009).

2.2.2.3 Outcomes

Lastly, occupant outcomes are the components of social practice. For university buildings, the main objectives are to support students' academic activities to enhance their performance and to provide a healthy space for students' quality of life. Students believe that built environments on campus can affect their learning (Muhammad, Sapri, & Sipan, 2014). Also, the built environment should be able to support students recovering from stress (Turner, Scott-Young, & Holdsworth, 2017). Each physical and functional environment affects individual outcomes such as performance and health.

Studies on factors that affect students' academic performance are not novel but finding the relationship between built environments and academic performance has not been conducted enough (Scott-Webber et al., 2013; Temple, 2009; Weinstein, 1979). It is difficult to objectively define and measure the performance of knowledge-intensive areas (Haynes, 2007). As a result, subjective, self-reported performance can be used to evaluate the performance, and the self-reported measure is also used in academic performance (Cassady & Johnson, 2002).

Muhammad, Sapri, and Sipan (2014) found stressors of student wellbeing in higher education related to building aspects through group interviews: environmental comfort, followed by health and safety, access and quality of facilities, space provision and adequacy, participation and inclusiveness, and interaction. The most important item was furniture/ furniture comfort, followed by internet access, thermal comfort and control, drink water/ refreshment facilities, and personal workstation/ study room. It means both physical environment and social constructs can affect student wellbeing on campus.

Wellbeing is a relatively short-term and emerging responses while mental health is a long-term, acute symptoms. For the built environment studies, especially in case of examining temporary use of spaces, short-term measures such as mood status and immediate stress relief are more appropriate to evaluate the effect of the environments. Wellbeing has been measured using various perspectives such as psychological wellbeing (Baik et al., 2019), emotional states and stress (Bluyssen et al., 2011), and job and life satisfaction (Daniels et al., 2017; Danna & Griffin, 1999)

2.3 Theoretical Model

The proposed framework can be utilized as a theoretical analysis framework for investigating the relationship between materiality and social practice in higher education settings [Figure 2]. In order to adopt socio-materiality, this study defines social practice and materiality through built environments of higher education and addresses how the environments can be interpreted within the concept of socio-materiality. This framework enables researchers to understand how the purpose of building (type of use), physical environments, functional environments, and the outcomes of students affect to each other

cumulatively, by defining the fundamental relationships between the components in the built environment.

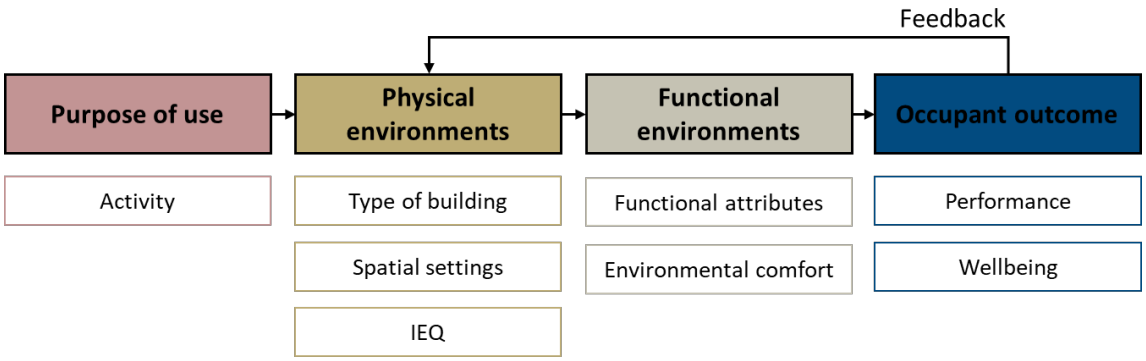


Figure 2 - Theoretical model for human building interaction

CHAPTER 3. STUDY 1 – SPACES USAGE AND STUDENT ACTIVITIES IN ACADEMIC LIBRARY[2]

3.1 Chapter Introduction

A library is one of a university's most important physical attributes (Mulrooney & Kelly, 2021). The concept of modern academic libraries is changing to informal learning spaces that encourage active interactions and collaboration among users. The main users of the academic library, students, perform various activities in a library, including individual focus work, group projects, social gatherings, and relaxation (Lee & Schottenfeld, 2014; Waxman et al., 2007). It is required to provide proper spaces and environments for each activity because appropriate environmental support can enhance the perceived performance of users (Y. Kim et al., 2021). However, little has been explored about what environmental factors can explain students' learning performance and wellbeing in library spaces.

The COVID-19 pandemic caused changes in human behaviors, especially indoors. Some rules were required indoors, such as social distancing and wearing face masks, and space usage was very limited in terms of operation hours and capacity. These restrictions were also observed with academic buildings. Due to COVID-19, physical gatherings were temporarily prohibited on campus; lectures were delivered online, and buildings were closed or had limited use (Crawford et al., 2020). As a result, the form of collaboration

[2] This chapter is a modified version of "Academic library spaces and student activities during the COVID-19 pandemic" published in the Journal of Academic Librarianship and has been reproduced here with the permission of the copyright holder

among students changed from physical, in-person meetings to online meetings (Byrnes et al., 2021), and space settings and uses are expected to differ from those before the COVID-19 outbreak (Wexler & Oberlander, 2021). This case study focuses on academic library settings in higher education and aims to 1) examine how the COVID-19 pandemic changed space use of the library spaces and users' experience and 2) investigate the needs and expectations of an academic library after the pandemic. With these research objectives, three research questions are developed:

RQ1. Do students choose the spaces according to their activities in the academic library during the pandemic?

RQ2. What indoor environmental features do students value in each space of the library?

RQ3. What environmental features explain students' perceived performance and wellbeing in library spaces?

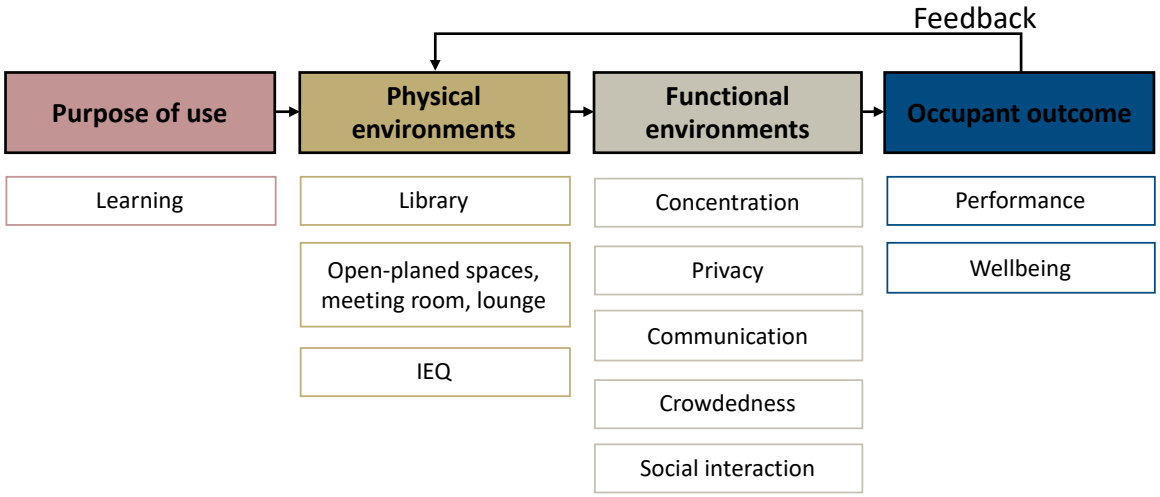


Figure 3 - Theoretical model of built environments for learning

3.2 Theoretical Backgrounds

3.2.1 Type of Learning in a Library

The emphasis on learning has shifted from traditional classroom-based lectures to team-based learning. While traditional learning focuses on the one-way delivery of knowledge from a teacher to students, team-based learning emphasizes knowledge acquisition through active communication between a teacher and students or among students (Beckers et al., 2015). This shift expanded the concept of learning space and changed students' activities associated with learning. This new learning paradigm requires collaboration and discussion outside the classroom (Beckers et al., 2016a). In order to support new learning, colleges and universities provide informal learning spaces for students. Informal learning spaces refer to "non-discipline specific spaces frequented by both staff and students for self-directed learning activities and can be within and outside library spaces" (Harrop & Turpin, 2013, p.59). An academic library is one of the informal learning spaces on campus with attractive interior design and includes various functional spaces, such as cafés, lounge spaces, learning spaces, and meeting rooms. Libraries are evolving to reflect a new learning paradigm by providing various types of space.

To explain the knowledge creation process in knowledge work, Nonaka (1994) developed a theory using two dimensions of explicit and tacit knowledge. Explicit knowledge means the knowledge that we can explain in formal language. It is considered as a part of the entire knowledge someone has. On the other hand, tacit knowledge is hard to deliver or formalize and can be communicated through a specific context (Nonaka, 1994). Lee and Schottenfeld (2014) emphasized the similarity between the student learning process and the knowledge creation process in the workplace as higher education aims to enhance students' collaboration skills according to industrial needs. Based on Nonaka's knowledge creation model (1994), Lee and Schottenfeld (2014) proposed students'

collaborative work settings and defined related knowledge exchange/creation activities for each work setting: focusing (from explicit to tacit), group learning (from tacit to explicit), collaborating (from explicit to explicit), and socializing (from tacit to tacit). Each process of knowledge creation is achieved by different activities. First, focusing transfers explicit knowledge to tacit knowledge. Focusing includes individual studying, researching, or information processing. The next activity is group work, which changes from tacit knowledge to explicit knowledge, is performed by constructing knowledge through teaching and training. Next, collaboration creates new knowledge through individuals exchanging explicit knowledge. Examples are class assignments/projects or research completed in a group. The main difference between group work and collaboration is that students create content as a group when collaborating, while students study together when doing group learning. The last activity is socializing, which happens when people exchange tacit knowledge with one another. The activities of socializing focus on the casual exchange of ideas by chatting, discussing, and social networking.

Most studies tended to focus on learning spaces in a library, but students also utilize libraries to relax and socialize (Waxman et al., 2007; Xu & Yang, 2018). Socializing is an important part of learning, and students also need to take a break or hang out with their friends in a library. Therefore, it is important to provide relaxing and socializing spaces in addition to learning spaces for enhancing student wellbeing and academic performance.

3.2.2 Type of Spaces in a Library

Modern academic libraries provide various types of space in order to satisfy users' needs based on the new learning process, which emphasizes the importance of informal

learning through collaboration and socialization with other students (Beckers et al., 2015). For this, library spaces have to play a role in connecting people (Simens, 2008) and encouraging informal face-to-face meetings (Bryant et al., 2009).

Beckers et al. (2015) proposed a conceptual model to explain how learning spaces align with learning processes in higher education. Based on the levels of self-regulation and social interaction, four space concepts were suggested: 1) classroom settings (low self-regulation and low social interaction), 2) collaboration settings (low self-regulation and high social interaction), 3) individual study settings (high self-regulation and low social interaction), and 4) informal learning settings (high self-regulation and high social interaction). Beckers et al. (2016a) suggested that libraries need to provide at least two types of space to support individual study: busy, open space and quiet, closed space. Students use spaces that can better support their learning activities between the spaces for individual study and collaboration (Hong et al., 2021; Lundström et al., 2016). Furthermore, providing appropriate space for different activities increases satisfaction with the spaces in an academic setting (Hong et al., 2021). However, it is still unknown students' space usage depending on their learning activities. Based on Beckers' theory, understanding which space is appropriate for various activities is important to effectively support students' learning in a library.

3.2.3 Physical and Functional Environments

The learning space can be characterized by its physical features and the perceived quality of social and functional features of the environment (Beckers et al., 2016a). The

alignment of physical and functional environments with students' activities consequently supports students' performance and wellbeing (Y. Kim et al., 2021).

Research has shown that learning can be influenced by the physical environment where students perform their tasks (Tanner, 2000), and students prefer spaces that can support their learning activities (Beckers et al., 2016a). Studies have defined the attributes of physical environments as including satisfaction with indoor environmental quality (IEQ), window views, and spatial arrangements [**Error! Reference source not found.**]. IEQ has been explored in terms of temperature, noise, lighting, and air quality. A study by Lee (2014) found that students were satisfied with the IEQ differently depending on their collaboration activities. However, Lee's study (2014) focused on collaborative activities only and did not consider functional environments in a library.

Functional environments refer to the suitability of environments to occupants' purposes (Kwon et al., 2019). Academic libraries must provide appropriate spaces for learning, socializing, and relaxing activities. An open-plan space setting, which is actively applied to academic libraries to support collaboration among users, raises several issues in functional environments. In addition to spaces that encourage collaboration, students need quiet, individual study areas offering privacy in libraries (Beckers et al., 2016b; Ellison, 2016). Both undergraduate- and graduate-level students reported that space for allowing quiet study is more important than group study and work (Association of Research Libraries, 2019; Ramsden, 2011). Open-plan spaces have been considered inappropriate for work requiring concentration because of distractions and noises (Haapakangas et al., 2018; Yoo-Lee et al., 2013). Crowding is also frequently regarded as a problem in academic libraries that creates noise and distractions (Cha & Kim, 2020; DeClercq &

Cranz, 2014). Some studies have argued that an open-plan office could be utilized for individual focus work if enough spaces are provided and managed by controlling distraction (Block et al., 2009), but it is still debatable. Socializing refers to any social situation, including communicating with others and being with others in the same place, and it is regarded as a part of learning. Therefore, the role of a library is emphasized as both a learning and social space (Bryant et al., 2009). In order to satisfy various needs, libraries should be able to provide physical and functional environments that connect people with study sources (Simens, 2008) and encourage informal face-to-face meetings/encounters (Bryant et al., 2009). These functional environments are affected by physical environments and vice versa; students can perceive different types and levels of functional environments in different spaces. In order to support students' learning in a library, it is important to understand how physical and functional environments are related to perceived learning performance and wellbeing in various spaces in a library.

Table 1 - Physical and functional environments of a library in literature

Environmental type	Features	Beckers et al., 2016a	Cha & Kim, 2015	Hassanain & Mudhei, 2006	Choy & Goh, 2016	Lee, 2014	Mahyuddin & Law, 2019
Physical environment	Window view	✓	✓				
	Background noise	✓		✓			
	Quietness	✓	✓	✓	✓	✓	✓

Table 1 continued

	Lighting	✓	✓	✓	✓	✓	✓
	Furniture	✓	✓		✓	✓	✓
	Resources	✓	✓		✓		
	Temperature	✓	✓	✓		✓	
	Air quality	✓	✓		✓	✓	✓
Functional environment	Concentration	✓			✓		
	Privacy	✓	✓	✓		✓	
	Collaboration	✓	✓		✓		
	Crowdedness	✓	✓				
	Socialization	✓	✓		✓	✓	

3.2.4 Effect of the COVID-19 pandemic on places

Devine-Wright et al. (2020) argued that the power of the pandemic changes the perception of places. The pandemic has unexpectedly restricted people to their homes while it has displaced people from everyday places (Devine-Wright et al., 2020). One of the notable changes was how people use physical spaces (Jens & Gregg, 2021b). After the lockdown, universities mandated lectures to be provided entirely or partially online (Crawford et al., 2020). As a result, students were isolated from their schools and needed to remain at their homes and experience a wholly virtual learning environment in terms of lectures, in-class activities, group projects, and social interaction. In addition, they needed

to be mindful of the physical distance between people regardless of the type of activities (Wexler & Oberlander, 2021). These changes in space use possibly affect students' learning process and performance because they need to adapt their learning strategy to physical spaces. They also might experience social isolation because of the loss of social interaction opportunities with other students in both direct and indirect ways in physical spaces, negatively influencing their wellbeing. However, there is a lack of studies exploring students' activities in academic libraries during the pandemic. Some studies have suggested the possibility that their experiences during the pandemic would affect modification to the meaning of places for the post-pandemic (Low & Smart, 2020; Wexler & Oberlander, 2021). Therefore, understanding students' activities and outcomes in the library is important to support students' learning performance and wellbeing through built environments.

3.3 Methodology

This study uses a mixed-method approach. The first data collection was a survey, and the second data collection was interviews with students. Figure 4**Error! Reference source not found.** shows the data collection process and library operations related to the COVID-19 pandemic in a timeline.

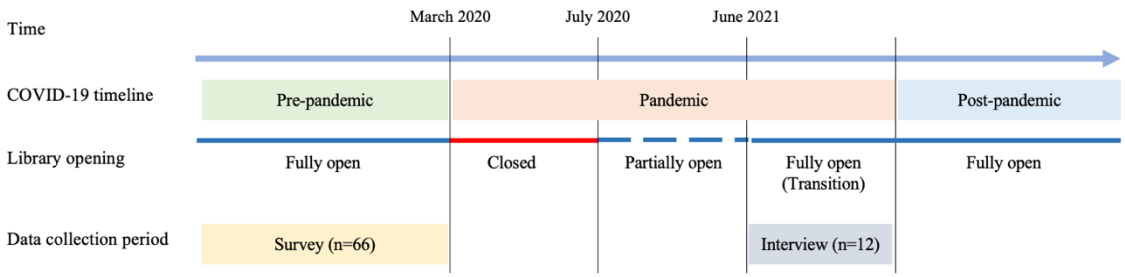


Figure 4 - Data collection process

3.3.1 Survey

The survey aimed to examine activities of the students in an academic library. The survey asked about the type of space and where they stayed in the subject library. The type of space usage included (a) solitary, (b) work as a group, and (C) using the space alone but together, which means students come to a space together but work on their own tasks. Respondents were asked to choose where they stayed between 1) open-plan space for individual study and 2) open-plan space for group work. The last part consisted of demographic questions, including gender, age, position, residence (living in a dorm), ethnicity, and years in the school.

The authors conducted a survey about student activity and perception of the new library settings. The survey was administered via an online survey platform, Qualtrics. Participants were asked to answer the questions by scanning a QR code on a survey flyer linked to the online survey. The sheets were located on tables in open-space study areas on the second, sixth, and seventh floors, so students could participate while they were using the library. Data were collected from Monday, October 21, 2019, to Friday, October 25, 2019. A total of 66 responses were collected [Table 2].

Table 2 - Respondent characteristics

Demographic	%	Demographic	%
Gender		*Ethnicity*	
Male	50.00	White	39.39
Female	50.00	Black or African American	9.09
Age		Hispanic or Latino	6.06
18 – 24	87.88	Asian/ Pacific Islander	43.94
25 – 29	10.61	Other	1.52
30 – 34	1.52	*Years in the school*	
Position		Less than 1 year	54.55
Undergraduate student	74.24	1 ~ 2 years	15.15
Graduate student	25.76	3 ~ 4 years	19.70
		5 years or more	10.61

3.3.2 Interview

A qualitative approach can be helpful to gather rich data on user experience (Navarro-Bringas, Bowles, & Walker, 2020; Sankari, Peltokorpi, & Nenonen, 2018). Semi-structured interviews were conducted between July 2021 and September 2021, and 12 students participated in the interview. For recruitment, the researchers invited students at Georgia Tech to participate in the interview via email and Reddit and recruited other participants using a snowball sampling method. The researcher transcribed and reviewed contents after each interview and found data saturation after 12 interviews, where there

was no more new information was found. Interviews were performed either online or in-person in one of the meeting rooms in the library, according to the interviewees' preference. In order to clarify the spaces that the interviewer and interviewees mentioned, photos of the library spaces were provided as supplementary materials during the interview. Before starting each interview, the interviewer informed the objectives of the study, consent, and anticipated benefits from the interview. Each interview was between 30 and 60 mins and was recorded. A $10 gift card was given as compensation.

Table 3 - Interviewee information

Interviewee	Position	College	Year	Gender	Interview location
1	Graduate student	Liberal Arts	6	Female	Online
2	Undergraduate student	Engineering	3	Female	Online
3	Undergraduate student	Engineering	4	Female	Online
4	Undergraduate student	Engineering	4	Male	In-person
5	Graduate student	Engineering	4	Male	In-person
6	Undergraduate student	Engineering	4	Male	In-person
7	Undergraduate student	Engineering	4	Female	In-person
8	Undergraduate student	Engineering	4	Female	Online
9	Undergraduate student	Design	2	Male	Online
10	Undergraduate student	Engineering	4	Female	Online
11	Undergraduate student	Engineering	4	Female	Online
12	Undergraduate student	Science	4	Male	Online

The interviews aimed to understand students' library space use during the pandemic and their intentions to use the space after the pandemic. The questions focused on students' learning activities, library space types, physical and functional features of the library, and

desired outcomes of the students in the library. Interviews are an effective method to know space usage because they enable the researchers to know students' learning activities beyond the type of space usage (i.e., solitary and group use). The example list of activities included the four different types of collaborative knowledge creation activities of college students suggested by Lee and Schottenfeld (2014): focusing, group learning, collaborating, and socializing. Library spaces were categorized into five types: 1) open-plan spaces for individual study, 2) open-plan spaces for group work, 3) individual study spaces with carrels, 4) meeting rooms, and 5) lounge spaces. Students were asked to identify and describe the spaces that they used previously.

Table 4 - Interview questions

Category	Interview questions
Activity-space	For each activity in the list, can you choose where you would like to do each work in the library post-pandemic? Activity: Socializing, Focusing, Collaborating, and Group working
Physical and functional environments	I will give you several keywords related to your experience at the library. Please describe each space using the keywords that are associated. - Physical environments: Furniture, window view, temperature, quiet/noisy, background noise, lighting, resources - Functional environments: Collaboration, crowdedness, concentration, visual privacy, acoustic privacy
Overall experience	What do you like about the environment of the library? What do you dislike about the environment of the library?
COVID-19-related	During the pandemic, have you ever used the spaces in the library? What spaces did you use in the library? How was it? Do you have any reason that you chose those spaces? Are you going to use the library differently compared to pre-pandemic?

3.3.3 Context

Two targeted buildings of the library are Crosland Tower Library and Price Gilbert at Georgia Institute of Technology. They were fully renovated in 2019 and 2021, respectively, and the two buildings are connected. The library sought to create spaces for active collaboration, providing open-planned spaces without partitions for most of the spaces. The spaces were categorized into five different types, based on the physical learning environment taxonomy suggested by Beckers et al. (2015) [Table 5]. As classrooms in the library can be used for reserved events only, they are excluded from the scope of this study. Photographs of the library spaces are provided in the Appendix.

Table 5 - Features of library spaces

Type	Description	Learning features	
		Self-regulation	Interaction
Open-plan spaces for individual study	Multiple students share a big table in an open-plan space. Chairs have back-support. It is easy to observe each other and to hear others' conversations, but active conversation is not encouraged in the space.	High	Low
Open-plan spaces for group work	The space provides a big table with various types of chairs such as stools and benches. The size of the tables is conducive to group discussions. The space also offers whiteboards and screens to facilitate discussions, and students can freely talk to each other.	Low	High
Individual study areas with carrels	The space is designed as a quiet space. The finishes use noise-absorbing materials, and group meetings are not allowed. The chairs are ergonomically designed for prolonged periods of use.	High	Low
Meeting rooms	Separate rooms intended for group meetings include a whiteboard and a screen that facilitate discussion.	Low	High
Lounge spaces	The space encourages socializing and relaxing. This type of space is easily accessible and open.	High	High

The library was closed between March 2020 and July 2020 because of the pandemic and has been open since August 2020 with some restrictions regarding social distancing, requirement for wearing face masks, card-only access, limited space availability, reduced occupant capacity, and contactless services. Since June 2021, the library has been fully open without any restrictions.

3.3.4 Analysis

Survey data was shown in a contingency table with Chi-square analysis to examine if the students use the spaces differently depending on their activities. Student activities were (a) solitary, (b) work as a group, and (C) using the space alone but together, and the spaces were (a) open-plan spaces for individual study and 2) open-plan spaces for group work.

Interview data were transcribed using Microsoft Word and analyzed using NVivo 12. The transcribed data were analyzed in the first and second cycles, as suggested by Saldaña (2016). In the first cycle, descriptive coding was conducted to label data with summarized words. In this process, a deductive approach was carried out to find space uses depending on their activities as well as physical and functional environmental features. The label was based on a literature review, including the type of spaces, possible activities, and keywords of indoor environmental features. In the second cycle, pattern codes were generated to identify any sentimental arguments about the environment. For inductive coding, only topics mentioned at least two times were used for analysis and provided in this paper. The interviewees only talked about spaces they had used before. The number of responses for each space was reported in parentheses in Figure 5.

3.4 Results

3.4.1 Academic Library Uses before Pandemic

Before the pandemic, students used different types of spaces depending on their space use types ($\chi^2 = 15.19$, df = 2, $p < .05$) [Table 6]. Most (38/48) students who used a space alone chose an open-plan space for individual study, while 7 out of 8 individual students used an open-plan space for group use. Students who were alone but together used the open-plan spaces equally regardless of the purpose of the spaces.

Table 6 - Space types depending on space use

Variable		Space use		
		Solitary	In a group	Alone, but together
Space type	Open-plan spaces for individual study	38 (79.17%)	1 (12.5%)	5 (50%)
	Open-plan spaces for group work	10 (20.83%)	7 (87.5%)	5 (50%)
Total		48 (100%)	8 (100%)	10 (100%)

3.4.2 Academic Library Usage during and post-pandemic

Even though there were some restrictions to use resources, such as computer stations, whiteboards, and screens, most students (10 out of 12) reported that they used the spaces in the library during the pandemic. However, they commonly stated that they came to the library less frequently than before the pandemic and mostly used the spaces individually. The students also mentioned that it was convenient to find spaces they liked because of fewer users in the library than the pre-pandemic period. The reasons that

students used the library less were because they were not on campus, and there was a fear of COVID-19 infection. On the other hand, the reasons they came to the library during the pandemic were for a change of scenery, to get out of their rooms, or to go to a café in the library. For the post-pandemic use, all students except one graduating student responded that they would use the library similar to the pre-pandemic, coming back to the library to use physical spaces with other people like pre-pandemic times or even more often.

For the post-pandemic use, all students except one graduating student responded that they would come back to the library to use physical spaces with other people like pre-pandemic times or even more often. They reported specific spatial preferences for each activity [Figure 5**Error! Reference source not found.**]. They chose library spaces depending on their intention/activities, and those who identified themselves as active users tended to use multiple spaces in the building. For individual study, students mostly preferred the open-plan space for individual study but would use any spaces. For group learning and collaborating, students preferred either meeting rooms or open-plan spaces for group learning. They also preferred major-specific academic buildings outside the library. The interviews found that meeting rooms were used for various purposes, such as meetings, group study, individual study, presentation rehearsals, podcast recording, and instrument lessons. On the other hand, two students stated they would choose online meetings as an alternative to in-person meetings.

> *It is multi-functional use, so whenever I need a place, the library is always the best place for me to be looking for because they have got everything I need and every functional space that I need. [Interviewee 1]*

For socializing, students would go to lounges. However, some students did not consider a library as a space for socializing even though they came and used the library with their friends. They would go somewhere else to socialize but also needed a space to go when they unexpectedly met someone in the library. If they need to use the library for socializing, they would go to lounges. Similarly, relaxing was not why students found the library, but space and furniture for relaxing seemed helpful for students to spend a long time studying. Views to the outside provided students time to relax. Some students mentioned that having coffee and food from the café helped them stay in the library longer.

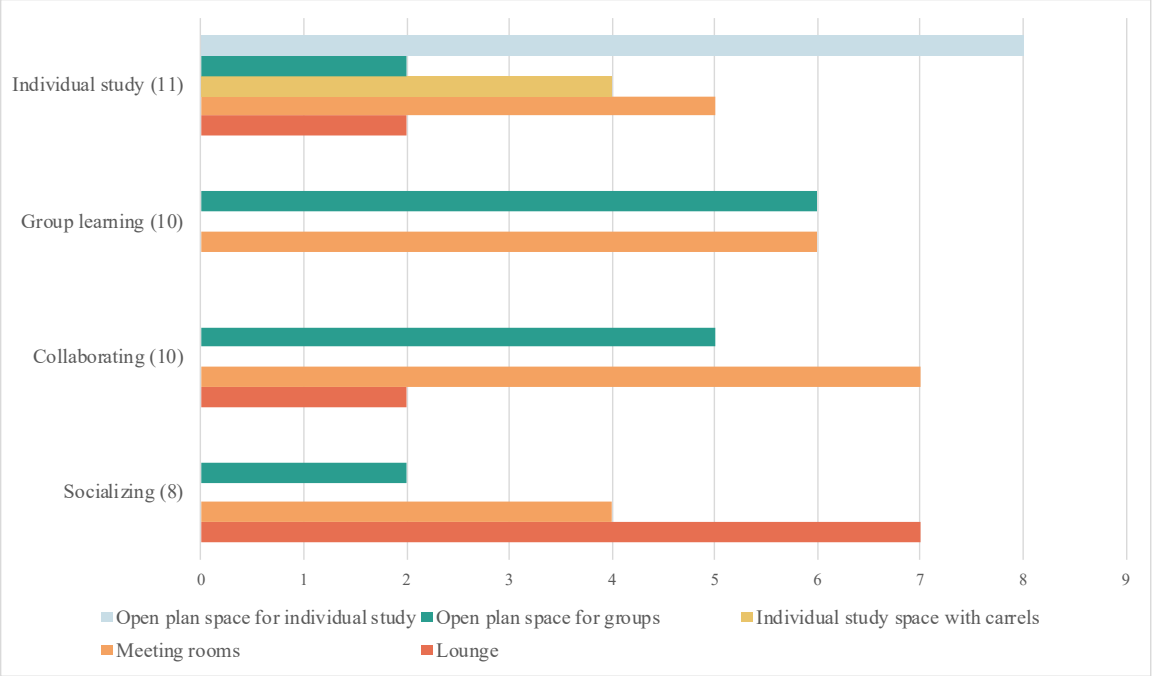


Figure 5. Preferred spaces in the library depending on activities (n=12)

* Numbers in each parenthesis mean the number of interviewees who performed a certain activity in the library during the pandemic. Some interviewees reported multiple spaces for each activity.

3.4.3 Physical Environments of the Library

Students described each space using six physical environmental features based on the list provided by the researchers. Physical environments were identified differently depending on the type of spaces [Table 7]. In addition to the features provided, students also mentioned outdoor seating in general for both studying and relaxing.

Table 7 - Physical environment features in each space type

Physical environments	Space type	Opinion	Interview example	Related outcomes
Window view	Open-plan space (individual)	▲▲▲	*When I was sitting there (individual study space with carrels), I really liked to sit towards the edge so I could see out the window, just because looking in one small box for a long time is like at night. It is hard for me. [Interviewee 10]*	P, W
	Open-plan space (group)	NA		
	Carrel space	▲▲▼		
	Meeting room	▲▲		
	Lounge	▲▲▲		
Background noise	Open-plan space (individual)	▲▲▼	*You have to be quiet. I tend to avoid quiet spaces even if I want to work quite and do hard work. Because, what if I accidentally drop a pencil or something? I don't want to be that guy. [Interviewee 6]*	P
	Open-plan space (group)	▲▲		
	Carrel space	NA		
	Meeting room	▼▼		
	Lounge	▲		

Table 7 continued

Quietness	Open-plan space (individual)	▲▲▲	*If I was working in a group where we had to interact a lot, constantly talking out loud and sharing our ideas, I would probably choose a space that's a little bit louder, so we're not distracting to other people. [Interviewee 10]*	P
	Open-plan space (group)	▼▼►►►		
	Carrel space	▲▲		
	Meeting room	▲▲▲		
	Lounge	▼▼▼		
Lighting	Open-plan space (individual)	▲▲	*I just like the bright lights and stuff with lots of big windows and outdoor lighting. It naturally makes you feel more ready to do work and be productive. [Interviewee 2]*	P, W
	Open-plan space (group)	NA		
	Carrel space	▲		
	Meeting room	NA		
	Lounge	▲		
Furniture	Open-plan space (individual)	▲▼	*In terms of furniture, it is great because of all kinds of variety. You have the movable furniture, the fixed furniture, the tall and the short ones. So, there is something for everyone, which I think is a plus for the library. [Interviewee 4]*	P, W
	Open-plan space (group)	▲▲▲		
	Carrel space	▲▲		
	Meeting room	▲▲▲		
	Lounge	▲►▼▼		

Table 7 continued				
Resources	Open-plan space (individual)	▲▼▼	*I have used these spaces (meeting rooms) quite a bit to work on homework with other people where you can collaborate on the homework or group projects. The whiteboards were super helpful for that, having a large whiteboard space. [Interviewee 10]*	P, W
	Open-plan space (group)	▲▲▲		
	Carrel space	▼		
	Meeting room	▲▲▲ ▲▲		
	Lounge	▲		

Note: ▲ Positive; ▼ Negative; ► Neutral; Performance (P); Wellbeing (W)

3.4.3.1 Window View

The interviewees positively mentioned window views. For open-plan spaces for individual study, the students described that window views helped them feel "productive," "happy," "relaxed." Even though there were big windows in the open-plan space for group work, no one mentioned window views in that space. For individual study spaces with carrels and meeting rooms, the window view was very limited, but the students emphasized that having a view was important because they could feel relaxed. Similarly, one student mentioned that placing natural plants indoors would be helpful for their mental health in the library.

3.4.3.2 Background noise

The students reported an appropriate level of background noise in the open-plan spaces for individual study and group work as well as lounge space. However, they also mentioned that there was no background noise in the quiet zone for individual study, and sometimes small sounds distracted them.

3.4.3.3 Quietness

Opinion about quietness differed depending on the type of space. Students were satisfied with the noise level for the individual study space, while they mentioned that the space for group work and lounge was sometimes noisy. Some students said that the space for group work was not quiet but not distracting either. Otherwise, people who did not prefer the library wanted to have a quiet space. Traditional libraries were likely to be quiet, encouraging focus and individual study and providing physical resources such as books, while the concept of the modern academic library encourages active communication in the building.

3.4.3.4 Lighting

Lighting was mentioned in two different aspects: 1) amount of lighting and 2) natural lighting. Students emphasized the importance of proper lighting for their study, while natural lighting is important for both their positive mood and performance.

3.4.3.5 Furniture

Even though the preferred furniture type was different for each student, they liked the variety of furniture provided in the library. The students mentioned furniture in two different ways: 1) a variety of types and 2) comfort. For open-plan space for group work, students specifically mentioned various furniture types and availability to move them. However, one of the main complaints that students reported was the unavailability of seats they wanted and that sometimes it was hard to know where they could be found. The comfort of the furniture was important for long-term use. On the other hand, for individual

study spaces with carrels and meeting rooms, the students highlighted ergonomic chairs in the spaces that were appropriate for prolonged use.

> *The chairs are very comfortable with that cushioning. So, these are definitely for longer hours of the intense study compared to the high-top stools that do not have backs or are not cushioning. I like these chairs a lot; they are very ergonomic. [Interviewee 2]*

3.4.3.6 Resources

Students pointed out the limited resources in the open-plan space for individual use as the only resource the space provided was electrical outlets. However, they were satisfied with the availability of outlets in every space in the library. They mentioned that whiteboards in the open-plan space for group work and meeting rooms were useful when studying with friends or working on group projects. Some students noted that there were no books in the library. They wanted the books back as it made them feel relaxed. It was also that books were an important signifier for a library.

> *I do think it is odd that there are so few books. I do not really think of it as a library. It is just weird that it is still called a library. [Interviewee 12]*

3.4.4 Functional Environments of the Library

Students explained the functional features of each space [Table 8]. Like physical environments, functional environments were also differently reported depending on the spaces in the library.

Table 8 - Functional environment features in each space type

Functional environments	Space type	Opinion	Interview example	Related outcomes
Concentration	Open-plan space (individual)	▲▲	*Sometimes I like this when there's a lot going in my head, and I want to be cut off for a while. It's like the environment (Carrel space) is telling me, streamlining our focus as well to concentrate on one thing you come in here for. [Interviewee 4]*	P
	Open-plan space (group)	▲▼		
	Carrel space	▲▲▲▲		
	Meeting room	▲▲		
	Lounge	▼▼▼		
Privacy	Open-plan space (individual)	▲▼	*Part of the reason that goes into public spaces to study is that there is no visual privacy. Too much visual privacy, then I cannot stay on task. [Interviewee 7]*	P
	Open-plan space (group)	▲▼▼		
	Carrel space	▲▲▲		
	Meeting room	▲▲▲▲		
	Lounge	▼▼		
Collaboration	Open-plan space (individual)	▲▼	*I would say there is a lot of collaboration because it (open-plan space for group work) is very friendly setting to use a big table and use all those stools to move around. [Interviewee 9]*	P
	Open-plan space (group)	▲▲▲▲▲		

Table 8 continued

Table 8 continued				
	Carrel space	▼▼		
	Meeting room	▲▲▲▲▲		
	Lounge	▲▼		
Crowdedness	Open-plan space (individual)	▲▲▼	*Honestly, I felt less crowding just because of how spread out the tables are (open-plan space for individual study). [interviewee 8]*	P, W
	Open-plan space (group)	▼▼		
	Carrel space	▼		
	Meeting room	▼		
	Lounge	▲▼▼		
Socialization	Open-plan space (individual)	▲▼	*I would come here and meet up with friends. we wouldn't be studying together on the same subject, but we would be together. [Interviewee 8]*	P, W
	Open-plan space (group)	▲▲▲		
	Carrel space	▼▼		
	Meeting room	▲▲▲		
	Lounge	▲▲▲▲▼		

Note: ▲ Positive; ▼ Negative; Performance (P); Wellbeing (W)

3.4.4.1 Concentration

The ability to concentrate was mostly positive in all spaces except the lounge. In the lounge space, there were too many people walking and passing by, which easily distracted students. For individual study spaces with carrels especially, students commonly mentioned that the space was appropriate for long-term, intense study as the space provides a formal setting. Students also mentioned 'quiet,' 'privacy,' and 'study-friendly atmosphere' when talking about concentration.

3.4.4.2 Privacy

Privacy was discussed from two different perspectives: acoustic and visual privacy. For acoustic privacy, meeting rooms provided enough acoustic privacy as they were a separate, enclosed room, preventing any conversation from traveling outside the rooms. There was no acoustic privacy for the other spaces, but the students reported that they were not concerned with that when studying. For visual privacy, individual study spaces with carrels and meeting rooms provided enough visual privacy. Interestingly, some students were concerned that having a high level of visual privacy could make them too comfortable and spend time browsing the internet and social media.

> *Part of the reason that goes into public spaces to study is that there is no visual privacy. Too much visual privacy, then I cannot stay on task. [Interviewee 7]*

3.4.4.3 Collaboration

Collaboration was required for group learning. Students found the ease of collaboration in the open-plan space for group work and meeting rooms. However, they said having an academic conversation in the lounge was difficult as it was too noisy with

high traffic. Students also hesitated to collaborate in the open-plan space for individual study and individual study space with carrels because those spaces were intended to be quiet.

3.4.4.4 Crowdedness

Students reported crowdedness when many different activities were happening, especially in the open-plan space for group work and lounge spaces. Some students also mentioned crowdedness in meeting rooms when the room was full. As a result, they preferred larger rooms even though the expected number of people in the room was one or two. This consequently led to difficulty in reserving a meeting room, causing another reason for crowdedness.

3.4.4.5 Socialization

Socialization was mentioned mostly regarding the lounge space, but students added that they could not concentrate or study in that space. For individual study spaces with carrels, some students thought the space was not for socialization because of the partitions and quiet atmosphere. For the other spaces, they often use those spaces to study alone but be together and be able to interact with others.

3.4.5 Facilities

In addition to the physical and functional environmental features discussed in the previous sections, the students also mentioned some facility-level factors associated with their performance or wellbeing in the library [Table 9].

Table 9 - Facility-level features of the library

Table 9 continued

Factors	Examples	Outcomes
Available seats	*One issue that I faced was the availability of rooms here. I like to work in a quiet space, and I had issues with booking (meeting) rooms. [Interviewee 5]*	P
Rules	*It is supposed to be a quiet floor, but sometimes there could be better enforcement of that. It is not as quiet there as on the 7th floor. [Interviewee 10]*	P
A variety of space types supporting different activities	*Most of the spaces definitely are very supportive of the vibe that I get from them. So there are places where I know I can focus really well, and it is quiet, and then places where I can collaborate really well. [Interviewee 10]*	P
Purpose of library	*I like how mostly everyone there is there to study or do work, at least the spaces that I go to. It seems like everyone is pretty focused. It is not very loud or noisy, though. I think it is a good place to go if you really need somewhere to go outside of your room to do work. [Interviewee 11]*	P
Sense of belonging	*When I am online, I am usually just sitting in my room; I feel like that is just not great for mental health and stuff. I think that is the only reason I start going back in person and just because I am missing people [Interviewee 3].*	W
Outdoor sittings	*It is really a good place for us to relax a little bit, enjoy drinks, and enjoy the scenery. The seeing there is really relaxing. I guess this is one of the important features for us to enhance well-being and make it more enjoyable to study within the library. [Interviewee 1]*	W

3.4.5.1 Available Seats

Providing enough seats was related to increased convenience of use. Some students commonly required more seats in quiet spaces and more meeting rooms with seating.

3.4.5.2 Rules

Students commonly expected some spaces specifically aimed for certain activities to work as intended, and they complained when the spaces did not. For example, they expected quiet in the quiet zones (some open-plan spaces for individual study) and individual study spaces with carrels. As another example, the meeting rooms were supposed to be used according to the number of users, but small groups sometimes reserved big rooms. It consequently led to two problems; 1) small rooms are left unused and 2) big groups could not use any rooms.

3.4.5.3 A Variety of Space Types Supporting Different Activities

As the library served various functions, students were able to choose where they stayed and studied. They knew what environment they needed, and each environment could support students' expectations.

3.4.5.4 Purpose of Library

The purpose of the library itself affected students' study performance in the building. For example, they said they liked people in the space to study or work concentrating on their own tasks, which they found motivated.

3.4.5.5 Sense of Belonging

Outdoor seating was not mentioned on the list given to the students, but five out of twelve students independently mentioned the benefits of using outdoor seating during the interviews. They said they would study, relax, and enjoy views and natural light outside.

3.5 Discussion

This study explored the physical and functional environments of the academic library and investigated the effect of the COVID-19 pandemic on students' activities in the library. The finding showed the change in activities during the pandemic, including the reduced frequency and type of uses. The students used the physical spaces in the library fewer times during the pandemic. As they had experienced virtual settings for attending classes, meetings, collaborating with other students, and socializing, the decrease in the use of the physical spaces was expected (Low & Smart, 2020; Wexler & Oberlander, 2021). Interestingly, however, the interviews in this study revealed that the students would use the library spaces after pandemic as much as the pre-pandemic period or more often; the most frequently mentioned reason for library use was to defeat social isolation. Even before the COVID-19 pandemic, it was reported that between 20 and 71% of late adolescents and young adults, aging between 15 and 21, experienced feeling lonely sometimes or often and overcame the loneliness by reconnecting and socializing with their friends (Qualter et al., 2015). The pandemic disturbed in-person socialization among students on campus, made them feel isolated and anxious, and accelerated their mental problems in terms of depression (Fruehwirth, Biswas, & Perreira, 2021). A community can be built when people with different interests come to use and share the same space and tools (Schopfel, Roche, & Hubert, 2015), so library spaces on campus can significantly contribute to building a sense of community among students. Engaging with friends and spending time together can increase the perception of enhanced social support and consequently strengthen their mental health (Hefner & Eisenberg, 2009). This study supports that physical spaces on campus play an important role in increasing social support. Therefore, students preferred

to come to the library to use the space physically and be around other people. Even though they used the library during the pandemic, this study observed different space use patterns. The students tended to use the space individually, consistent with the observation study by Jens and Gregg (2021). In addition, the students reported that they could easily find the seats they preferred during the pandemic because there were fewer people in the building. The low number of people in the space possibly enabled them to have enough distance from other people, keeping themselves safer with social distancing.

Students' space usage depending on their needs can be explained by the learning space model (Beckers et al., 2015) and student learning process (Lee & Schottenfeld, 2014). First, students preferred the open-plan space for individual study mostly for focusing, which requires high self-regulation and low social interaction. This preference was observed pre-pandemic as well. Similarly, the individual study spaces with carrels were also used for focusing. Both types of spaces provided the same features in terms of self-regulation and interaction so that students might choose spaces based on their preference for the partition, furniture, or view to the outside. Second, group learning requires high social interaction, so the students used the open-plan space for groups or meeting rooms, depending on the needs of resources and privacy. Third, collaborating requires a high level of social interaction. Similar to group learning, most students preferred the open-plan space for groups and meeting rooms. Lastly, the students used lounge spaces, meeting rooms, and open-plan spaces for groups for socializing. Notably, students did not like to use the library primarily as a space to socialize, but they felt a sense of belonging as they were around other people or came to the library with their friends even though they studied alone but together. Similarly, relaxing is also not the main purpose of the library.

Lounge spaces were not preferred for study, but those spaces could be used for relaxing and socializing and helpful for supporting students' learning in the library. In other words, providing a social and relaxing environment in the library is important for students' learning as well as mental health.

In an open-plan study environment, controlling noise is important for students to provide an appropriate environment as it influences cognitive ability and collaboration. Students are also disturbed by background noise frequently when studying for an exam, reading, and writing, while the noise had insignificant effect on brainstorming, consulting, and searching (Braat-Eggen, van Heijst, Hornikx, & Kohlrausch, 2017). Furthermore, there was little difference in collaboration performance between quiet conditions and background noise scenarios (Braat-Eggen, Poll, Hornikx, & Kohlrausch, 2019). In this study, the students were satisfied with background noises in all open-plan study spaces regardless of the target activities of the spaces. For example, in the spaces for group works, students expect noise from others' conversations and can make noise themselves without concern about disturbing other people. On the other hand, in the quiet zone, students do not expect any loud noise. They sometimes avoided a space which was too quiet because they were worried about making any unexpected noise which might capture others' attention. In other words, based on their expectations, students can perceive the background noise differently. Having explicit rules about space uses (e.g., collaboration space, quiet zone) may support study performance by helping them have an appropriate expectation and behave accordingly.

Seats by the window are preferred areas in a library (DeClercq & Cranz, 2014). Most of the students in this study also positively mentioned the presence of windows.

Interestingly, their need for windows manifested differently according to the types of spaces. Even though both spaces for individual study and group work had a window wall, the students rarely mentioned the window in the space for group work, whereas students using the space with carrels or meeting rooms tended to appreciate window views much more. One of the possible reasons is that both types of spaces had a relatively small workstation size with closed partitions or walls providing higher privacy. Having windows in an enclosed and small space possibly made the students feel that the rooms were more spacious. In addition, natural light is an important source to maintain circadian rhythms (Aguilar-Carrasco, Domínguez-Amarillo, Acosta, & Sendra, 2021), but it is hard to get exposure to natural light in the spaces with carrels and meeting rooms. It may consequently lead people to desire more windows. The effect of window presence should be further explored, taking into consideration occupant activities and space arrangements. Windows are also an important source of allowing natural lights indoors. An appropriate amount of lighting enhances performance in the workplace (Brunia, De Been, & van der Voordt, 2016), but the effect of natural lighting and window views in academic settings is little known. In this study, the students mentioned that natural lighting with window views helped enhance students' wellbeing and performance. This result also provides possible evidence of restoration effects that explain that the exposure to nature through windows enhances the cognitive ability and mood states (Hipp et al., 2016; D. Li & Sullivan, 2016; van Esch et al., 2019). For those reasons, natural lighting and its possible restoration effect, providing windows in study spaces can enhance student performance and well-being in terms of positive moods.

Notably, crowdedness was negatively mentioned in most types of spaces. In open-plan spaces, the students easily noticed people walking around and chatting and reported crowdedness. They reported that too many things were happening around them and they felt too crowded to collaborate on a group work/ project in the open-plan spaces and lounge spaces. Crowdedness is related to privacy and disruption by noise (Kaya & Weber, 2003; D. Kim, Bosch, & Lee, 2020); so, even for the open-plan space, design strategies such as appropriate furniture arrangement and dividing spaces by partitions would be helpful to give them a supportive environment for learning by decreasing the frequency of social encounters. Some students also mentioned the availability of seats in relation to crowdedness. If they could not find preferred or appropriate seats for their activities, the students felt the space was crowded.

This study corroborates that open-plan spaces can support various learning activities of students by adopting different space arrangement strategies in academic libraries. Open-plan spaces are flexible in space arrangement, so they benefit under abnormal situations such as the COVID-19 pandemic (Jens & Gregg, 2021b). It was observed that the space utilization of open-plan spaces is much higher than enclosed spaces in an academic building, while suitability, spatial integration, user satisfaction were similar to each other (Jens & Gregg, 2021a).

There are several limitations to this study. First, this study was designed as a case study; so, the results of this study have a limitation of generalization. Therefore, this study should be repeatedly performed in similar settings to find the generalizability. For example, the same interview questions can be asked to students in other academic libraries as well as informal study spaces (e.g., learning commons) in higher education. Based on the

consistent results, it will be possible to understand the students' environmental needs in supporting their learning. Next, this study used a qualitative approach with the limited number of samples for the second data collection. Even though this approach enabled this study to explore diverse opinions about their library use from the students, the nature of the method inherently has limited ability to test statistical significance. Based on the finding of this study, a survey questionnaire can be developed to collect a larger number of samples, and this quantitative approach will enable researchers to perform further analysis to statistically test the relationship between built environments and students' perception of their learning performance and wellbeing.

Traditionally, academic libraries provide a learning opportunity through physical resources, such as books, journal articles, and other materials, for their users. However, libraries, especially academic libraries, are recently evolving by removing physical books and focusing on providing commons spaces. Even though some people still find the value of the library in physical materials, it is time to realize the meaning and purpose of libraries in their communities, as discussed in this study. Modern library spaces on campus, which often afford various activities, such as focused work, group learning, collaborating on class projects, socializing, and relaxing, can significantly contribute to building a sense of community among college students and help them reconnect with their peers. These modern academic libraries are likely to play a major role in providing a comfortable venue to study, collaborate, and interact with each other throughout their college lives. Additionally, understanding students' activities and preferred spaces is critical for new construction and major renovation of libraries and continuous improvement with smaller changes, such as furniture reconfiguration, space assignment and planning, and user policy

(i.e., collaboration vs. quiet zones). As the size of the building is limited, investigating the needs of space types is required to strategically provide spaces in various sizes and types based on appropriate space programming.

CHAPTER 4. STUDY 2 – EXPLORING RESTORATIVE EFFECTS IN INDOOR ENVIRONMENTS

4.1 Chapter Introduction

Restoration theories argue that environmental settings produce a short-term, psychological impact on humans. There are two well-known psychological restoration theories; one of the major areas of study is the recovery of attention capacity, and another is stress reduction. Attention restoration theory (ART), developed by R. Kaplan & Kaplan (1989), addresses the effect of environments on the human capacity to recover from mental fatigue due to sustained direct attention. The ability to focus on a task requires directed and voluntary attention (S. Kaplan, 1995), so such cognitive activity increases mental fatigue. In order to enhance performance, S. Kaplan (1995) suggests that people can reduce their mental fatigue by exposure to or engagement with natural environments. Stress recovery theory (SRT), proposed by Ulrich (1991), suggests that natural environments can help humans recover from fatigue caused by stress and anxiety. Mental and psychological fatigue should be properly treated because they are directly related to work performance and wellbeing, and natural environments provide the best environment for restorative effects and stress recovery (Hartig, Mitchell, de Vries, & Frumkin, 2014). According to Hartig et al. (1997), the level of restorativeness is the highest in the natural outdoor environment, followed by the natural indoor environment, the outdoor built environment, and lastly, the indoor built environment.

R. Kaplan and Kaplan (1989) defined the use of the word "*nature"* as environments where there is barely human intervention, including green spaces with plants and vegetation as well as brown, yellow, white, and red spaces. The scope of the *natural environment* is not limited to completely natural components (R. Kaplan & Kaplan, 1989). It is hard to separate the natural and built environment precisely (R. Kaplan & Kaplan, 1989), so they can be categorized based on the amount of the environmental components located within such as vegetation or buildings. In other words, the natural and built environmental elements can be located in each other's environment. Generally, restorative studies defined green spaces as natural environments and those with dominant man-made/artificial elements as built or non-natural environments (Berman et al., 2014; Choe, Jorgensen, & Sheffield, 2020; Felsten, 2009; Yin et al., 2020). Furthermore, the indoor-outdoor environment is an important consideration because it affects the perceived extent of the environmental experience (Hartig et al., 1997). Hartig et al. (1997) defined indoor spaces as spaces where the view is limited. Based on previous studies, this study categorized indoor-outdoor and natural-built environments [Figure 6].

Category	Indoor	Outdoor
Natural environment	A space with windows with a view, wood materials, natural form furniture, indoor plants	Nature reserves, parks, landscapes with trees, bushes, flowers, grass
Built environment	An indoor spaces without natural form or patterns	Urban areas, industrial zones, shopping malls, historical centers, housing

Figure 6 - Description of 2 (indoor-outdoor) x 2 (natural-built) environments

As both ART and SRT emphasize the effect of nature, the majority of the studies have focused on analyzing the outdoor natural environment and urban green environment, such as green spaces on campus, parks, nature reserves (Hartig, Evans, Jamner, Davis, & Gärling, 2003; Hipp et al., 2016; Hipp & Ogunseitan, 2011; D. Li & Sullivan, 2016). As a result, the indoor environment has tended to have been disregarded and considered unpreferable environments compared to outdoor environments (Berto, Massaccesi, & Pasini, 2008; Hartig et al., 2003; Jung et al., 2017; Kinnafick & Thøgersen-Ntoumani, 2014; D. Li & Sullivan, 2016; Perkins, Searight, & Ratwik, 2011; Rogerson, Gladwell, Gallagher, & Barton, 2016). However, some studies reported that people also perceived restoration from indoor built environments (Altaher & Runnerstrom, 2018; Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008; Staats, Jahncke, Herzog, & Hartig, 2016). Moreover, Hartig et al. (1997) suggested that some indoor environments could have the same or higher restorative effects as natural outdoor environments. Since individuals spend most of their time inside, improving indoor environments that promote attention restoration and stress reduction can be impactful for our daily lives. Nevertheless, first, there needs to be a clear understanding of the components in indoor environments that can promote restoration effects.

Generally, students report that they do not have enough time to relax on campus (Dada, Babatunde, & Adeleye, 2019) and require persistent directed attention that produces mental fatigue and stress (Felsten, 2009). A restorative environment, especially in indoor settings, can effectively provide an opportunity for students to take a break and refresh their cognitive ability. However, restoration effects on campus have been underexamined. Felsten's (2009) study measured the perceived restoration of college students in indoor rest

areas with different arrangements of window views. Felsten (2009) provided four different settings – no window, no views of nature, views of large buildings, and views of nature – and found the view of nature was associated with a higher level of restorativeness. Hipp, Gulwadi, Alves, and Sequeira (2016) tested the effect of perceived greenness and restorativeness on college student quality of life through perceived restorativeness, and there was a positive relationship between perceived greenness on campus and students' quality of life, mediated by perceived restorativeness. Despite the efforts to find restorative effects in the built environments, the impact of indoor environmental attributes of campus buildings on students is not clearly defined.

Therefore, the main objective of this study is to test restorative effects in indoor environments and analyze the relationships between components of the environment and human outcomes, such as perceived restorativeness, mental bandwidth, and mood states. To achieve this purpose, this study seeks to answer the following research questions:

1. Do students report higher restorativeness in a biophilic design space than in a non-biophilic design space?
2. What is the relationship between environmental components of indoor environments and occupant outcomes?

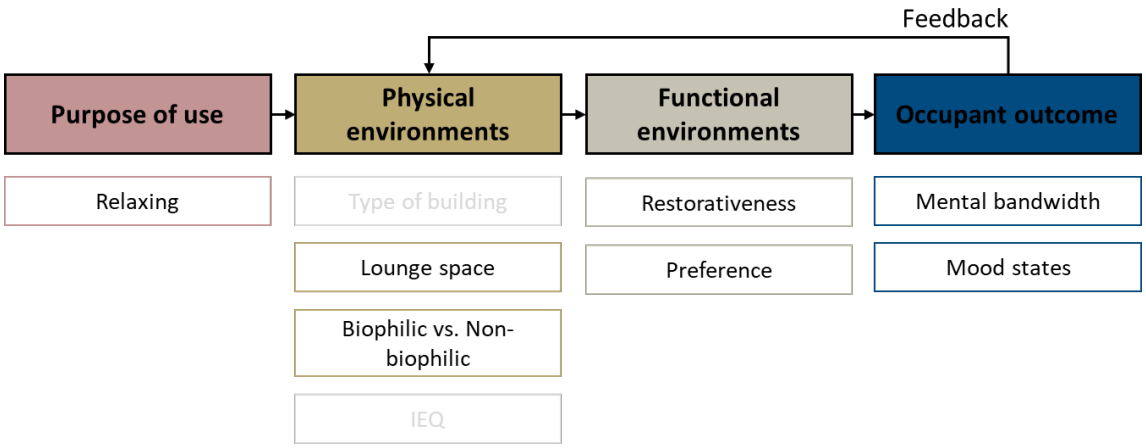


Figure 7 - Theoretical model of built environments for relaxing

4.2 Literature Review

4.2.1 Main Components of Attention Restoration Theory

ART proposes that individuals can benefit from natural environments due to 1) a break from directed attention, 2) fascination, 3) sufficient extent of experience (coherence), and 4) compatible motivation (R. Kaplan & Kaplan, 1989). The first condition, being away, means people need to be apart from the routine and take a break from directed attention (Hartig et al., 1997). The status of being away does not require physical distance, but it does imply being conceptually and mentally free from the activity that needs directed attention (S. Kaplan, 1995). When they have an opportunity for distinct separation from everyday experience, people can experience being away. Second, for receiving restorative effects, people must switch the attention mode from the directed attention, which leads to stress and mental fatigue, to soft fascination. 'Soft' fascination is involuntary, effortless attention, normally given in a natural setting, and provides people with enough mental space. On the other hand, hard fascination barely has any restorative effect because it still

requires directed attention (Basu, Duvall, & Kaplan, 2019). So, not all fascinating environments have a restoration effect (S. Kaplan, 1995). Third, in order to create distance, the elements of the environment must be perceived immediately to a certain extent. The environment needs to be rich enough to be separate or distinct from ordinary environments and be coherent with the environment. The extent of perception does not mean a physically large environment but requires an element that can provide a sense of extent even in a relatively small area (S. Kaplan, 1995). The environment may include a conceptual domain (Hartig et al., 1997). Lastly, compatibility means the consistency between environmental conditions and one's purposes and inclinations (Hartig et al., 1997). People tend to feel more related to and compatible with the natural environments compared to built environments (R. Kaplan & Kaplan, 1989).

4.2.2 Direct Attention and Mental Fatigue

Direct attention is voluntary attention and enables people to concentrate on a task and requires effort. This mental effort draws mental fatigue in the brain and consequently deficits cognitive processing (S. Kaplan, 1995). Mental fatigue is a psychobiological state of the brain and caused by intensive and intentional brain activity such as direct attention and cognitive activity (R. Kaplan & Kaplan, 1989; Marcora, Staiano, & Manning, 2009). For those who are mentally fatigued, processing and focusing on uninteresting information could be difficult. Therefore, mental fatigue directly affects performance, especially cognitive performance. ART argues that spending time in restorative environments promotes recovering from mental fatigue due to directed attention and providing the ability of cognitive abilities (S. Kaplan, 2001).

Mental fatigue can indirectly be measured through mental bandwidth. Mental bandwidth refers to a capacity of information processing in one's head (Basu et al., 2019; Bhargava, 2020). If they are mentally fatigued and hard to process information, it is possible to interpret that people have a low capacity of mental bandwidth. Therefore, mental bandwidth can be a measure of ability of cognitive performance.

4.2.3 Preference

Natural environments are preferred to built environments (R. Kaplan & Kaplan, 1989; van den Berg, Koole, & van der Wulp, 2003), but, besides the restoration effect, being at the preferred place regulates mood and alleviate stress (van den Berg et al., 2003). Preference for a space is positively associated with the perceived restoration (Basu et al., 2019; Korpela et al., 2008; Nordh, 2012; Staats et al., 2016). Therefore, there is a possibility that the preference can mediate the perceived restoration (van den Berg et al., 2003).

4.2.4 Restorative Effects in Built Environments

Restorative effects are observed in indoor environmental components. For example, people in indoor environments with plants showed improved performance in Reading Span Task (RST) (Raanaas, Evensen, Rich, Sjøstrøm, & Patil, 2011) and Response Time Task (J. Kim, Cha, Koo, & Tang, 2018). Yin, Zhu, MacNaughton, Allen, and Spengler (2018) also found high cognitive performance and stress relief in the indoor environment with natural design elements such as an outdoor view and green plants compared to the indoor built environment without such natural elements. On the other hand, a study by Evensen, Raanaas, Hagerhall, Johansson, and Patil (2015) found that people in the indoor environment with natural plants did not show a restorative effect.

Several studies focused on the view from windows. Windows with both building views and natural views had restorative effects, and the proportion of nature from window views significantly affected the wellbeing of the occupants (van Esch, Minjock, Colarelli, & Hirsch, 2019). In contrast with van Esch et al.'s study (2019), another experiment by Li and Sullivan (2016) showed that high school students with a green window view resulted in high attention restoration effects and reduced stress levels compared to those with a barren view window. In addition, Aries, Veitch, and Newsham (2010) reported that natural views from windows indirectly reduce the perceived discomfort through the impressions of the surroundings in the office. Despite efforts to find the effects of indoor built environments, the restorative factors in built environments have been less clearly identified and explored. Overall, the literature examining the view of windows resulted in varying relationships between the type of views and restorative effects, and this might be because other environmental elements that possibly had restorative effects were not examined.

Recently, researchers have shown an increased interest in biophilic design as a source of restorative effects and found its psychological benefits. Biophilic design, which stems from ART and SRT, refers to a design principle adopting natural elements to indoor environments (Kellert, Heerwagen, & Mador, 2008). This design concept aims to provide a positive experience through nature in the indoor environments to the building occupants. Kellert (2008) identified six biophilic design elements: environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships. These six elements include over 70 design attributes. However, most studies testing the effect of biophilic design have focused on green plants and windows. Yin et al. (2020) tested the effect of biophilic design, such

as green plants, water, natural materials, and biomorphic shapes, on stress and anxiety recovery in a virtual reality setting: physiological measures (i.e., heart rate variability, heart rate, skin conductance level and blood pressure) showed better recovery in a biophilic design environment than non-biophilic design, and its effect was strong in the first four minutes of a six-minute recovery process. Hähn et al. (2020) investigated the effect of biophilic design in terms of the presence of plants in offices; placing plants in offices and breakout spaces significantly increased perceived productivity, and removing plants from the office increased the perceived stress of workers. As there are additional biophilic design elements, other elements (e.g., natural materials including wood, natural colors, naturalistic shapes) should be considered to test the impact of biophilic design concepts appropriately.

H1. A group in biophilic design will show higher restorativeness, positive mood, mental bandwidth, and preference than a group in non-biophilic design.

4.2.5 Eye-tracking methods for restoration effect

Many restoration studies were conducted under controlled environments such as experiment laboratories or using real-world photographs (Conniff & Craig, 2016). As the study focus in the existing literature has been limited to the window and green plants, it is unclear if any other components affected the perceived restorativeness. From the previous studies that compared natural and built environments, it is hard to identify which specific components in the indoor environment are related to restorative effects. Considering there are numerous components in environmental settings, specifying the components is critical to understand the relationship.

Eye-tracking devices enable researchers to follow the paths and attention of eyes and provide evidence of how people perceive a scene. Recently, some studies used an eye-tracking device to find restorative effects. The eye-tracking method has a great opportunity of contributing to interpret the environment using data, such as the number of fixations and duration on fixation (Rauthmann, Seubert, Sachse, & Furtner, 2012), and some studies used an eye-tracking device. Most of the studies provided pre-determined photos and identified the restorative components in parks vs. urban environments using an eye-tracking device (Berto et al., 2008; Franěk, Šefara, Petružálek, Cabal, & Myška, 2018; Nordh, 2012). The studies using photographs provided consistent evidence supporting the restorative effects of natural environments. However, the restoration effect in actual environments using an eye-tracking device has been less explored, though it is required to measure mental fatigue or stress of the participants to find a relationship between the environments and their perception (Conniff & Craig, 2016).

4.2.5.1 Fixation

In an eye-tracking method, fixations are important indicators and refer to the amount of attention over the static object of interest (Berto et al., 2008; Duchowski, 2017). The number of fixations in a scene differs depending on the level of restorativeness, especially fascination. Natural environments tend to have high soft fascination compared to built environments, as an environment with soft fascination requires effortless attention. Some experiments with pictures found that the fixation number per minute was significantly lower in the natural environments than in the built environments (Berto et al., 2008; Martínez-Soto, de la Fuente Suárez, Gonzáles-Santos, & Barrios, 2019). However, an experiment by Stevenson, Dewhurst, Schilhab, and Bentsen (2019) found a higher

number of fixation during 30-minute walks in natural environments and pointed out that natural environments with high fascination elicit the desire to explore the environment but not directed attention. A couple of studies explored the types of fixation in natural environments using an eye-tracking device. Nordh et al. (2013) focused on environmental components, such as trees, bushes, grasses, bench, flowers, distributing elements (street lighting), people, and hardscape, using an eye-tracking device on the pictures of parks and found that the time that people stared at green areas (plants, grass, and trees) was related to the level of perceived restorativeness. However, there is still a lack of studies that define fixations and link restorative effects with fixations in built environments.

H2. The number of fixations will be higher in non-biophilic design than in biophilic design.

4.2.5.2 Fixation Duration

Fixation duration refers to the time spent staring at a fixation. The interpretation of the length of duration is inconclusive as a longer duration can be interpreted in two different ways. The first interpretation implies a fixation requires more cognitive effort to process and extract information (Duchowski, 2017), and the other indicates greater interest and attractiveness (Leder, Mitrovic, & Goller, 2016). Stevenson et al. (2019) found the fixation duration was not different depending on the level of fascination, which represented the level of restoration, while Martínez-Soto et al. (2019) and Franěk et al. (2018) reported the low fascination setting had a significantly shorter duration per fixation than the high fascination setting.

H3. The mean duration of fixations on natural components will be longer than non-natural components.

H4. The number and mean duration of fixations on each indoor environmental component will differ in how they relate to restorativeness, mood, and mental bandwidth.

4.3 Methodology

4.3.1 Research Design

This study utilized a randomized design comparing two treatments (biophilic vs. non-biophilic designs). Each participant was randomly assigned to either biophilic design or non-biophilic design. *Setting 1*, biophilic design, had wood materials, organic forms of furniture, and natural light from West facing windows and glass walls. Glass walls were operable and sometimes stayed open. The building was certified by the Living Building Challenge, which means the building satisfied the biophilic design criteria (International Living Future Institute, 2018). On the other hand, *setting 2,* non-biophilic design, had concrete walls and furniture with steel materials. Both settings were similar in terms of their space configurations with a lounge space, main stairs in the buildings, and glass walls with windows on two sides of the space. The pictures of environmental settings for the experiments can be found in APPENDIX C. Environmental Settings for the Experiment in Study 2. The experiments were performed between November 2020 and May 2021. This study was reviewed and approved by the Institutional Review Board (IRB) of Georgia Tech (Title: Restorative effects in built environments, Protocol H20475) on November 4th, 2020.

4.3.2 Experiment Process

Each experiment was conducted for about 30 minutes [Figure 8]. The location of the pre-determined chair was in lounge areas, with the main stairs on their right and window walls with views on their left. Firstly, the researcher explained the overall procedure of the experiment and any possible risks and the participant agreed for participating in the experiment. The first task was a cognitive test to measure capacity to direct attention and expose mental fatigue, enabling this study to control individual differences. The cognitive test was taken using Reading Span Task (RST). RST is widely used in numerous psychology studies and aims to evaluate short-term working memory and cognitive process (Friedman & Miyake, 2004). After the test, the participants put on an eye-tracking device and took a 6-minute break, sitting on a pre-determined chair and wearing the eye-tracking device. Next, the researcher started recording the video through the device and helped calibrate the device at the beginning of the 6-minute break. During the break, world video and eye videos of the eye-tracking device recorded the participants' field of view and eye movements. After the break, the participants filled out a survey about the perceived restorativeness, mental fatigue, and mood states.

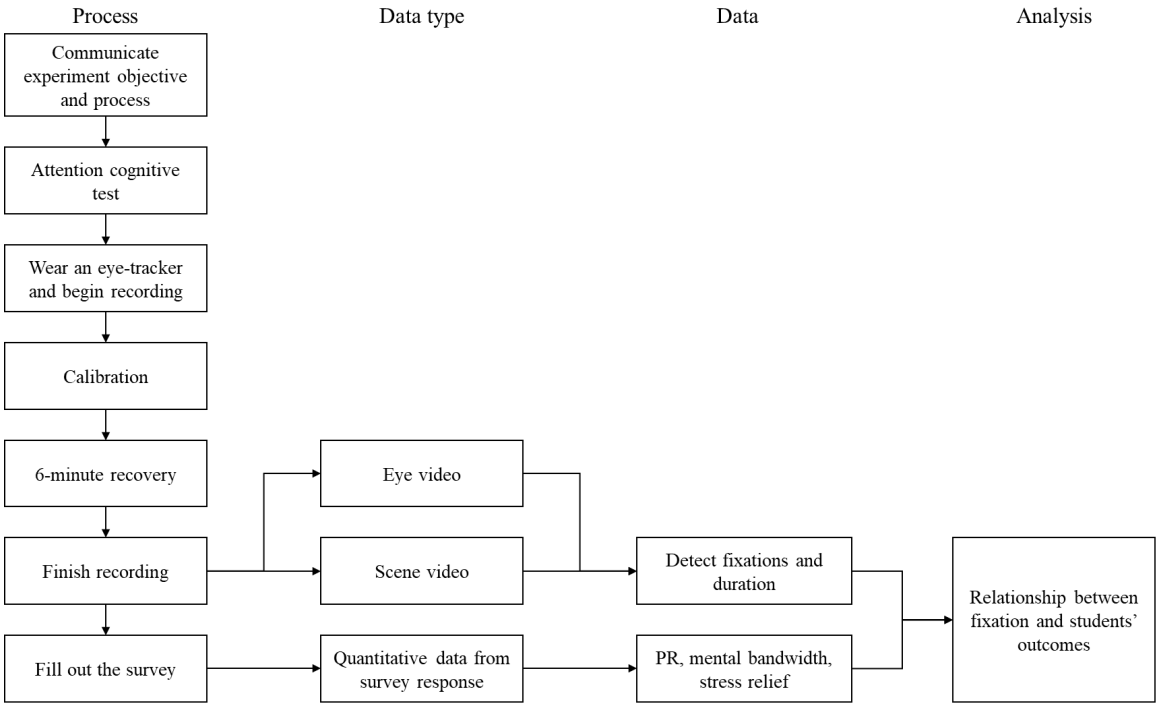


Figure 8 - Experiment process

Some studies found that activities, such as walking, dancing, using a smartphone, and watching television, were also related to the perceived restorativeness (Altaher & Runnerstrom, 2018; Basu et al., 2019; Byrka & Ryczko, 2018; Staats et al., 2016). Therefore, there would be a possibility of the influence of activities on the results of this study if the experiments allowed any movements of the participants. In order to minimize the effect of behaviors and solely test the effect of environments, this study restricted any activity of the participants and asked them to simply sit on a chair.

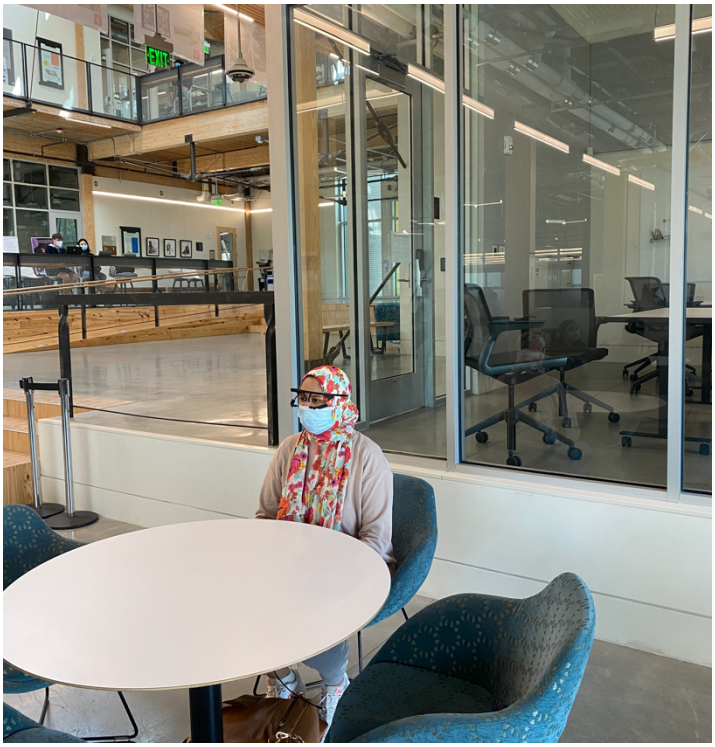


Figure 9 - Experiment setting (in a biophilic setting)

Eye-tracking data was captured with a Pupil Core eye-tracking device, which was developed by Pupil Labs. The wearable device consists of three cameras: two inward-facing cameras track and record eye movements with 200Hz (Hertz), and the other forward-facing camera records the user's surroundings with 120Hz@480p. The unit Hz measures the number of samples per second, and there is no observed problem of sampling errors when an eye camera of an eye-tracking device operates at about 200Hz or faster (Andersson, Nystr, & Holmqvist, 2010). The gaze accuracy, which means the difference between the measured gaze point and the real point, is 0.60°, and precision, which refers to reproduction reliability, is less than 0.02° error.

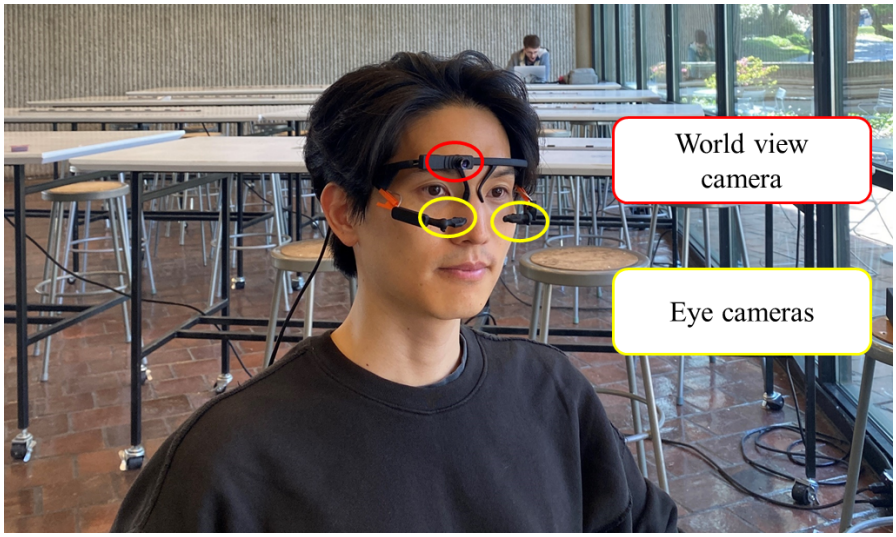


Figure 10 – Pupil Core eye-tracking device (in a non-biophilic setting)

Indoor Environmental Quality (IEQ), which includes temperature, relative humidity, CO2, noise, and lighting level, was measured by the researcher while each participant was taking a break. The devices used for measuring IEQ were Rotronic 1600 CP11 CO_2 Handheld Measuring Instrument for temperature, CO_2, and humidity, Black Globe Thermometer SD-2010 for heat stress, Extech 407732 Type 2 Digital Sound Level Meter for noise, and AEMC CA811 Light Meter for lighting.

4.3.3 Survey

Restorativeness was measured using the Perceived Restorativeness Scale (PRS), developed by Hartig et al. (1997). The survey items were based on the four factors of ART, which are being away, extent - coherence, fascination, and compatibility. The PRS consists of 16 questions under four factors with a 7-point Likert Scale (1: Not at all to 7: Completely). There were two questions on being away, five questions on fascination, four questions on extent (coherence), and five questions on compatibility. Each restorative

factor in this study showed internal consistency, showing Cronbach's alpha between .78 and .86.

Table 10 - Perceived restorativeness for each environment

	Total	Environmental setting		Cronbach's alpha
		Biophilic	Non-biophilic	
Being away	4.65 (1.01)	4.94 (.73)	4.35 (1.18)	.78
It is an escape experience	4.35 (1.15)	4.71 (.77)	4.00 (1.37)	
Spending time here gives me a good break from my day-to-day routine	4.94 (1.20)	5.18 (.95)	4.71 (1.40)	
Fascination	4.82 (1.12)	5.15 (1.08)	4.48 (1.10)	.79
The setting has fascinating qualities	5.09 (1.38)	5.41 (1.37)	4.76 (1.35)	
My attention is drawn to many interesting things	4.65 (1.37)	4.65 (1.46)	4.65 (1.32)	
I would like to get to know this place better	4.82 (1.59)	5.29 (1.16)	4.35 (1.83)	
There is much to explore and discover here	4.68 (1.55)	5.24 (1.39)	4.12 (1.54)	
I would like to spend more time looking at the surroundings	4.85 (1.71)	5.18 (1.55)	4.53 (1.84)	
Extent - Coherence*	5.69 (1.13)	5.66 (1.23)	5.72 (1.05)	.78
There is too much going on	5.62 (1.35)	5.59 (1.58)	5.65 (1.11)	
It is a confusing place	5.68 (1.63)	5.53 (1.70)	5.82 (1.59)	
There is a great deal of distraction	5.21 (1.68)	5.12 (1.62)	5.29 (1.79)	
It is chaotic here	6.26 (1.11)	6.41 (.87)	6.12 (1.32)	

Table 10 continued

Compatibility	4.96 (1.34)	5.34 (1.06)	4.58 (1.51)	.86
I can do things I like here	5.24 (1.52)	5.59 (1.28)	4.88 (1.17)	
I have a sense I belong here	4.23 (1.98)	4.35 (1.87)	4.29 (2.14)	
I have a sense of openness with this setting	5.38 (1.54)	5.71 (1.31)	5.06 (1.71)	
Being here suits my personality	4.56 (1.86)	5.24 (1.44)	3.88 (2.03)	
I could find ways to enjoy myself in a place like this	5.29 (1.43)	5.82 (.73)	4.76 (1.75)	

* Reverse-coded

The questions for *mental bandwidth* in this study were developed by Basu et al. (2019) to measure mental activities as a result of the restorative effect. There were seven questions: two questions for self-awareness (Cronbach's alpha = .50), two questions for daydreaming (Cronbach's alpha = .77), and three questions for planning. One item related to planning was excluded for analysis as it showed low correlation, and, as a result, two items were used for planning (Cronbach's alpha = .90). The scale was a 5-point Likert scale (1: Not at all to 5: Extremely).

Table 11 - Mental bandwidth for each environment

	Total	Environmental setting		Cronbach's alpha
		Biophilic	Non-biophilic	
Daydreaming	3.03 (1.00)	3.06 (.98)	3.00 (1.05)	.77
Lost in thought	2.76 (1.13)	2.76 (1.03)	2.76 (1.25)	

Table 11 continued

Letting your mind wander	3.29 (1.22)	3.35 (1.37)	3.24 (1.09)	
Planning	2.51 (1.32)	2.68 (1.48)	2.35 (1.16)	.90
Thinking about things you need to do	2.59 (1.28)	2.65 (1.50)	2.53 (1.07)	
Making plans for the future	2.44 (1.56)	2.71 (1.69)	2.18 (1.42)	

The questions measuring *mood states* were from a study by Gauvin and Rejeski (2016). Respondents evaluated how they felt of positive engagement (Cronbach's alpha = .72), revitalization (Cronbach's alpha = .70), tranquility (Cronbach's alpha = .80), and exhausted (Cronbach's alpha = .78), using twelve questions with a 5-point Likert scale (1: Not at all to 5: Extremely). For positive engagement, one item was excluded for analysis because of the low Cronbach's alpha.

Table 12 - Mood states for each environment

	Total	Environmental setting		Cronbach's alpha
		Biophilic	Non-biophilic	
Positive engagement	1.98 (.83)	2.26 (.89)	1.71 (.69)	.73
Enthusiastic	2.00 (.95)	2.41 (1.06)	1.59 (.62)	
Upbeat	1.97 (1.03)	2.12 (1.11)	1.82 (.95)	
Revitalization	2.60 (.82)	2.71 (.76)	2.49 (.87)	.70
Refreshed	3.00 (1.10)	3.24 (1.03)	2.76 (1.15)	
Energetic	2.09 (.93)	2.12 (.93)	2.06 (.97)	
Revived	2.71 (1.06)	2.76 (1.03)	2.65 (1.11)	
Tranquility	3.76 (.78)	3.90 (.79)	3.63 (.77)	.80
Calm	3.82 (.76)	3.82 (.64)	3.82 (.88)	

Table 12 continued

Relaxed	3.59 (.99)	3.88 (.93)	3.29 (.99)	
Peaceful	3.88 (1.01)	4.00 (1.17)	3.76 (.83)	
Exhaustion	1.80 (.91)	1.65 (.76)	1.96 (1.04)	.78
Fatigued	1.88 (1.15)	1.65 (.93)	2.12 (1.32)	
Tired	1.97 (1.17)	1.82 (1.13)	2.12 (1.22)	
Worn-out	1.56 (.96)	1.47 (.80)	1.65 (1.11)	

Preference was measured using a single-item question "How much do you like spending time in this space" by a 5-point Likert scale (1: Not at all to 5: Extremely), following other restoration studies (Basu et al., 2019; Nordh, Hartig, Hagerhall, & Fry, 2009; Staats et al., 2016).

Questions about *anxiety due to COVID-19* were asked as the experiment was performed in indoor settings. Four questions were asked using a 5-point Likert scale (1: Not at all to 5: Extremely), for example, "I am worried about being indoors" and "I feel anxious when social distance is not kept in this building." The responses showed high internal consistency (Cronbach's alpha = .91).

4.3.4 Participants

A total of 43 students participated in the experiment. The recruitment and experiment were performed from November 2020 to May 2021. For recruitment, the researcher invited students at Georgia Tech to participate in this study by distributing flyers and sending emails. The participation was voluntary, and a $10 gift card was given as compensation. To enhance the reliability of eye-tracking data, this study excluded seven

participants with gaze confidence less than 60%, which was suggested by Pupil-Labs[3], and two participants who wore glasses during the experiment as wearing glasses with an eye-tracking device cause an approximate 20% increase in accuracy error (Dahlberg, 2010). Therefore, a total of 34 data sets were analyzed; the sample size was medium for eye-tracking studies (Nordh et al., 2013).

Table 13 - Study participants and indoor environmental quality in each setting (Mean (sd) or n (%))

Characteristics	Biophilic design	Non-biophilic design
Number of participants	17	17
Age	24.94 (4.62)	24.59 (4.27)
Gender		
Female	8 (47.06%)	9 (52.94%)
Male	9 (52.94%)	8 (47.06%)
Ethnicity		
White	4 (23.53%)	4 (23.53%)
Hispanic/ Latino	0	1 (5.88%)
Asian/ Pacific Islander	13 (76.47%)	12 (70.59%)
Position		
Undergraduate	6 (35.29%)	7 (41.18%)
Graduate	11 (64.71%)	10 (58.82%)
College		
Computing	2 (11.76%)	4 (23.53%)

[3] Pupil Player v3.3

Table 13 continued

Design	1 (5.88%)	2 (11.76%)
Engineering	9 (52.94%)	9 (52.94%)
Liberal Arts	2 (11.76%)	0
Business	0 (0.00%)	1 (5.88%)
Science	3 (17.64%)	1 (5.88%)
Cognitive ability	25.59 (2.90)	26.29 (3.22)
Anxiety of COVID-19	2.28 (1.06)	1.88 (.85)
Indoor Environmental Quality		
Temperature (°C)	22.83 (.91)	22.18 (.80)
Black Globe Temperature (°C)	22.74 (.94)	21.98 (1.00)
Relative humidity (r%)	40.38 (7.22)	38.79 (8.92)
CO_2 (ppm)	481.24 (22.90)	521.88 (49.07)
Noise (dB)	44.34 (5.91)	55.44 (7.23)
Lighting (plane, lux)	350.31 (92.83)	706.40 (402.22)
Lighting (vertical, lux)	258.25 (175.93)	400.13 (303.58)

4.3.5 Data from Eye-tracking Device

The Pupil Core detects fixations with Dispersion-Threshold Identification (I-DT), which requires two parameters to detect fixations: 1) *duration threshold* and 2) *dispersion threshold* (Salvucci & Goldberg, 2000). The duration threshold requires people to stare at a subject for a certain length of time to detect fixations. For instance, if the minimum duration is too short, false fixations can be detected; on the other hand, if the minimum duration is too long, actual fixations might be ignored (Camilli, Nacchia, Terenzi, & Di Nocera, 2008). The suggested minimum duration for fixation detection using the I-DT

method is between 100msec and 200msec (Salvucci & Goldberg, 2000). Dispersion refers to the spread distance of a fixation point that limits variance and represents the fixation. For example, fixations observed with high tremor might be excluded if the dispersion threshold is too low, whereas different fixations can be merged if the threshold is too high (Salvucci & Goldberg, 2000). Blignaut (2009) suggested a dispersion threshold between 0.7° and 1.3°.

This study extracted two measurements from the eye-tracking device: the number of fixations and the mean duration of each fixation, following the I-DT method. In order to extract the data, this study set the minimum required duration for fixation as 150msec and a dispersion threshold as 1.0°. As a result, the mean confidence of fixation detection was .958.

4.3.6 Statistical Analysis

Statistical analyses were performed using R Studio with dplyr, psych, and CTT packages. First, a test to find individual differences in anxiety and mental ability was performed. As there were no significant individual differences in cognitive ability and anxiety level because of COVID-19, this study did not consider individual differences in cognitive ability and COVID-19 anxiety. Second, Cronbach's alpha was calculated to test the internal consistency of measures. The components showing Cronbach's alpha greater than .70 were used for analysis as suggested by Bland and Altman (1997). Self-awareness was excluded from the analysis due to its low internal consistency. Pearson correlation was calculated and provided between the measures.

To investigate H1 and H2, PRS, mood states, mental bandwidth, the number of fixations, and the mean durations were compared between biophilic and non-biophilic settings using independent t-tests. Before conducting t-tests, normality and homogeneous assumptions were tested and assured. Next, a linear regression analysis using effect codes was used to compare mean durations on each object to test H3. People were set as a reference as it had the least number of fixations. Lastly, H4 was addressed with the Pearson correlation between the number of fixations and durations of each component and the outcomes.

4.4 Results

4.4.1 Biophilic Design vs. Non-biophilic Design

Independent t-tests showed no significant differences in PRS, mental bandwidth, and most mood states between two environmental settings (biophilic vs. non-biophilic) [Table 14]. However, participants in biophilic design showed higher positive engagements ($t(32) = 2.06$, $p<.05$) and preference ($t(32) = 2.75$, $p<.05$) compared to those in non-biophilic design.

Table 14 - Pearson correlation between PRS, mental bandwidth, and mood states

(8)	(9)	(10)	t-test (t(df))
			1.75 (26.57)
			1.80 (32)
			.15 (32)
			1.71 (32)
			.17 (32)
			.71 (32)
			2.06 (32)*
			.77 (32)
.44*			1.03 (32)
-.30	-.23		-1.00 (32)
.44*	.57*	-.33	2.75 (32)*

*p<.05

Table 14 continued

	Mean		(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Biophilic	Non-							
Restorativeness									
Being away (1)	4.94 (.73)	4.35 (1.18)							
Fascination (2)	5.15	4.48 (1.10)	.29						
Extent - Coherence	5.66	5.72 (1.05)	.29	-.12					
Compatibility (4)	5.34	4.58 (1.51)	.29	.39*	.44*				
Mental bandwidth									
Daydreaming (5)	3.06 (.98)	3.00 (1.05)	.18	-.21	.13	-.01			
Planning (6)	2.68	2.35 (1.16)	.19	-.20	.21	.27	.17		
Mood state									
Positive engagement	2.26 (.89)	1.71 (.69)	.26	.43*	.14	.33	.17	-.03	
Revitalization (8)	2.71 (.76)	2.49 (.87)	.21	.39*	.06	.59*	.13	.11	.35*
Tranquility (9)	3.90 (.79)	3.63 (.77)	.23	.16	.07	.47*	.29	.04	-.04
Exhaustion (10)	1.65 (.76)	1.96 (1.04)	-.10	-.44*	.36*	-.11	.21	.34*	-.02
Preference									
Preference (11)	3.82 (.81)	3.00 (.94)	.36	.64*	.16	.71*	.02	.06	.22

4.4.2 Numbers and Types of Fixations

In Table 15, the analyses resulted in no significant difference in the mean number of fixation ($t(32)= -1.00$, $p=.32$) and mean fixation duration ($t(32) = -.81$, $p=.43$) between two environmental settings. However, there were statistically significant differences in the number of fixations on wood materials, furniture, objects, and view to outside. The number of fixations on wood material ($t(17.82) = 4.86$, $p<.05$) and objects ($t(16.25) = 4.46$, $p<.05$)

was higher in the biophilic design setting than the non-biophilic design setting. On the other hand, the non-biophilic setting showed higher number of fixations on furniture ($t(32) = -2.20$, $p<.05$) and view to outside ($t(32) = -3.21$, $p<.05$) compared to biophilic setting.

Table 15 - The number of fixations and mean duration

	Biophilic design	Non-biophilic design	t-test	p
Total fixation	418.12 (190.44)	476.88 (149.33)	-1.00 (32)	.32
Components				
Wood materials	50.35 (35.48)	7.35 (8.48)	4.86 (17.82)*	<.05
Furniture	45.18 (63.56)	95.53 (69.74)	-2.20 (32)*	.04
Wall, floor, ceiling	116.41 (82.08)	127.71 (105.81)	-.35 (32)	.73
Columns, steel structure, pipes	71.12 (86.73)	47.65 (36.69)	1.03 (32)	.31
Objects	50.06 (43.71)	2.59 (3.89)	4.46 (16.25)*	<.05
Lighting	11.35 (11.64)	10.12 (25.73)	.18 (32)	.86
People	5.18 (10.28)	3.59 (6.84)	.53 (27.84)	.60
View to outside	49.06 (59.68)	180.59 (157.82)	-3.21 (32)*	<.05
Mean duration	258.32 (81.88)	283.42 (98.92)	-.81 (32)	.43

*p<.05

4.4.3 Mean Duration on Objects

The result of regression analysis using effect codes found some differences in mean durations from the unweighted grand mean [Table 16]. The model was statistically

significant, and the unweighted grand mean was 208.12. The mean duration on furniture (b=53.53, p<.05), wall, floor, ceiling, window (b=50.75, p<.05), and view to the outside (b=50.67, p<.05) was significantly longer than the grand mean, while those on objects (b=-37.59, p<.05) and lighting (b=-48.30, p<.05) were shorter than the grand mean. There were no differences between the grand mean and the mean durations on wood materials and columns, steel structure, and pipes, respectively.

Table 16 - Mean duration

	Estimates	Std. E	t-value	p
Intercept	208.12	6.728	30.932*	<.05
Wood materials	17.63	17.80	.99	.32
Furniture	53.53	17.80	3.01*	<.05
Wall, floor, ceiling, window	50.75	17.80	2.85*	<.05
Columns, steel structure, pipes	2.27	17.80	.13	.90
Objects	-37.59	17.80	-2.11*	<.05
Lighting	-48.30	17.80	-2.71*	<.05
View to outside	50.67	17.80	2.85*	<.05
$F(7, 264) = 7.882^*, p<.05$				
Adjusted $R^2 = 15.09\%$				

*p<.05

4.4.4 Relationship between Fixation and PRS

Correlations between the number of fixations and PRS, mental bandwidth, and mood states were tested [Table 17]. The total number of fixations was negatively correlated with positive engagement ($r=-.66$, $p<.05$) but not with other variables. For each component, the fixation numbers on the wall, floor, ceiling, and window were negatively associated with fascination ($r=-.41$, $p<.05$) and positive engagement ($r=-.35$, $p<.05$) as well as positively correlated to exhaustion ($r=.47$, $p<05$). The number of fixations on the columns, steel structure, and pipes was negatively correlated to planning ($r=-.38$, $p<.05$) and positive engagement ($r=-.40$, $p<.05$). The number of fixations on objects was positively associated with preference. There was a correlation between the number of fixations on lighting and being away ($r=-.38$, $p<.05$) and a correlation between the fixation numbers on people and revitalization ($r=-.41$, $p<.05$). The number of fixations on wood materials, furniture, objects, and view to the outside did not correlate with any variables.

Table 17 - Correlation between number of fixations on components and PRS, mental bandwidth, mood states, and preference**

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Number of fixations	-.20	-.31	.07	-.15	-.03	.14	-.66*	-.11	.08	.03	-.12
Wood materials	.04	.17	-.23	.07	-.26	-.06	-.03	-.07	.11	-.26	.15
Furniture	-.18	-.07	-.01	-.17	.15	.13	-.32	-.18	.01	-.05	-.01
Wall, floor, ceiling	-.27	-.41*	.05	.05	.20	.26	-.35*	-.16	.15	.47*	-.08
Columns, structure, pipes	-.23	-.06	-.23	-.28	-.16	-.38*	-.40*	-.16	-.08	-.27	-.15

Table 17 continued

Objects	.06	.27	-.21	.17	.11	.07	-.01	.11	.11	-.27	.42*
Lighting	-.38*	-.22	-.00	-.18	-.18	-.27	-.33	-.14	.01	-.24	-.04
People	.10	-.15	.22	-.26	-.21	-.05	.01	-.41*	-.29	.27	-.27
View to outside	.16	-.17	.12	-.05	-.10	.19	-.17	.19	-.04	.07	-.22

* Pearson correlation p<.05

** (1) Being away; (2) Fascination; (3) Extent - Coherence; (4) Compatibility; (5) Daydreaming; (6) Planning; (7) Positive engagement; (8) Revitalization; (9) Tranquility; (10) Exhaustion; (11) Preference.

There were correlations between fixation durations on components and PRS, mental bandwidth, and mood states [Table 18]. The total mean duration was significantly correlated to fascination (r=-.34, p<.05), planning (r=.35, p<.05), and positive engagement (r=-.42, p<.05). The fixation duration on furniture and columns, steel structure, and pipes was negatively correlated to positive engagement, and that on the wall, floor, ceiling, and window was significantly correlated to fascination (r=-.51, p<.05), positive engagement (r=-.37, p<.05), and exhaustion (r=.44, p<.05). There were negative relationships between the mean duration on lighting and being away (r=-.38, p<.05) and between the mean duration on lighting and positive engagement (r=-.34, p<.05). The mean duration on people was negatively associated with compatibility (r=-.35, p<.05), revitalization (r=-.49, p<.05), Tranquility (r=-.36, p<.05), and preference (r=-.35, p<.05). There was no significant relationship between the mean duration on view to the outside and other variables.

Table 18 - Correlation between fixation durations and PRS, mental bandwidth, mood states, and preference**

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mean duration	.12	-.34*	.18	-.21	-.04	.35*	-.42*	-.20	-.01	.05	-.18

Table 18 continued

Wood materials	.01	.05	-.21	-.04	-.31	.01	-.12	-.15	-.02	-.19	.00
Furniture	.01	-.12	.07	-.21	.17	.25	-.36*	-.23	.00	-.03	.01
Wall, floor, ceiling	-.27	-.51*	.08	-.05	.19	.32	-.37*	-.23	.08	.44*	-.22
Columns, structure, pipes	-.21	-.14	-.17	-.31	-.22	-.31	-.40*	-.20	-.15	-.25	-.23
Objects	.03	.23	-.21	.14	.08	.14	-.07	.12	.06	-.26	.35*
Lighting	-.38*	-.23	.01	-.18	-.22	-.26	-.34*	-.14	-.04	-.24	-.08
People	.09	-.18	.25	-.35*	-.19	-.03	-.02	-.49*	-.36*	.32	-.35*
View to outside	.21	-.16	.15	-.03	-.11	.20	-.18	.10	.06	.01	-.14

* Pearson correlation $p<.05$

** (1) Being away; (2) Fascination; (3) Extent - Coherence; (4) Compatibility; (5) Daydreaming; (6) Planning; (7) Positive engagement; (8) Revitalization; (9) Tranquility; (10) Exhaustion; (11) Preference.

4.5 Discussion

Even though most studies have emphasized the restorative effects in outdoor natural environments, it is known that there are restorative effects in indoor environments as well. This study aimed to test the restorative effect in two different indoor environment settings, biophilic and non-biophilic design, using an eye-tracking device. One of the main findings of this study was the restorative effect in both biophilic and non-biophilic design and strongly supported a possibility of restorativeness in indoor environments. Hartig et al. (1997) claimed that the level of PRS would be different between natural/indoor environment and built/indoor environment. However, this study indicated that the level of PRS, mental bandwidth, and mood state except positive engagement did not differ in both

indoor design concepts; even though there was no statistical significance, people tended to show higher levels of PRS, mental bandwidth, and positive mood states (exhaustion was a negative mood state) in biophilic design than in non-biophilic design. Only positive engagement and preference were significantly higher in biophilic design than in non-biophilic design, partially supporting H1. This result could be affected by the window with outside views, which both settings had. People in the non-biophilic design tended to look more at views outside and avoid exploring the indoor environment than those in the biophilic design. In other words, individuals showed a tendency to choose natural views with soft fascination, which balances out the different design concepts. Specifically, the windows in both settings were large glass walls and floor-to-ceiling windows with outside views of plants and vegetation. Interestingly, compared to a previous study (Franěk et al., 2018), the level of fascination and compatibility in both settings in this study was similar to nature, while the level of extent - coherence in both settings was lower than that in nature. This result supports Hartig et al.'s argument (1997) that indoor environments have a limitation to giving occupants a certain level of environmental experience compared to outdoor environments.

A large number of fixations refer to the difficulty of interpreting the fixation information (Loftus & Mackworth, 1978), supported by studies that found a higher number of fixations in the built environment compared to the natural environment (Berto et al., 2008; Franěk et al., 2018; Martínez-Soto et al., 2019). In this study, the mean number of fixations was higher in non-biophilic design than in biophilic design, but it was not statistically significant, rejecting H2. It is possible that glass walls and windows with a

nature view in the non-biophilic design provided the participants with a sense of nature and restorativeness.

This study examined the mean fixation duration on each environmental component and found differences between the mean fixation duration. Interestingly, the mean fixation duration did not depend on the natural component but the size of the components, rejecting H3. The duration tended to be longer on large fixations, including furniture, wall, floor, ceiling, window, and view to the outside than smaller fixations, such as lightings and objects (poster, railing, exit signs, and fire extinguisher). This tendency was also observed in a study by Dupont, Antrop, and Van Eetvelde (2014). Fixation durations depending on the object sizes might be the reason for inconsistent results from the previous studies that focused on environment settings – natural vs. built environments – and did not consider the type of components. As indoor environments can largely differ depending on the design, it is required to examine and interpret indoor environmental components.

Additionally, the identification of fixation of this study allowed a further analysis besides comparing biophilic and non-biophilic design. The number of fixations and mean fixation duration on each component showed different relationships with the PRS, mental bandwidth, mood states, and preference, supporting H4. Firstly, the negative relationship between the number of fixations and outcomes could be inferred by previous studies finding that there were a higher number of fixations in built environments than in natural environments (Berto et al., 2008; Martínez-Soto et al., 2019). The total mean fixation was negatively associated with positive engagement, and each component had a different relationship with outcomes.

Interestingly, the fixation numbers of nature-related components, such as wood materials and view to outside, did not show a link to any outcomes. This result contrasts to studies that insisted on a positive effect of wood materials and windows with nature view (Aries et al., 2010; van Esch et al., 2019). This might be related to the amount of exposure to green. The biophilic design setting provided wood materials only as a natural indoor component. Placing additional natural components possibly helps increase a sense of greenness and consequently enhance the level of restorativeness (Hipp et al., 2016).

Overall, each component's mean fixation duration and fixation durations showed similar patterns to the fixation numbers; the longer fixation duration was associated with lower fascination and positive engagement. The mean duration on components was negatively related to PRS, mental bandwidth, and mood states overall. This result suggests that fixations with longer fixation duration require harder cognitive effort to process information, resulting in reduced cognitive ability and leading to negative mood states. However, it is notable that the mean duration showed a positive relationship with planning. This study also found a positive relationship between the fixation duration on objects and preference for environments. People possibly perceived the objects as decorative elements, showing positive perception (Noland, Weiner, Gao, Cook, & Nelessen, 2017).

Most studies that explored restorative effects using an eye-tracking device examined pictures and found that eye attention tended to focus on the center of the screen (Berto et al., 2008; Noland et al., 2017; Nordh, 2012). The pictures (2D) easily gave a sense of restorativeness and/or green as the view was restricted, leading to significant results. However, human attention in the real world is dynamic and active, where people choose a scene for processing (Henderson, Williams, Castelhano, & Falk, 2003). The significance

of this study is that the experiment was conducted in the real-world setting, which enabled this study to explore human cognitive processing without restrictions of sections and locations of pictures. This study also analyzed the detailed differences in eye movements (number of fixation and duration) on indoor environmental components (i.e., furniture, building components, objects, lighting, wood material, and window) not limiting to windows and plants. Interestingly, this study found no difference in restorative effects in biophilic and non-biophilic design, showing different results from previous studies. In order to provide restorative effects in built environments, it is important to furnish enough components with a certain level of being away, fascination, extent - coherence, and compatibility.

Furthermore, previous studies using eye-tracking devices only provided the number of fixations and fixation duration, which led to the limitation of an opportunity of interpretation according to the components. This study examined and indicated the relationships between each type of component in the settings and restorative effects. Given the results of this study, a few practical implications are suggested. Firstly, a design theme, such as biophilic design, is not decisive in the restorative effect. It would be more helpful to reduce the possibility of the number of fixations by providing spacious spaces. Furthermore, exposed ceiling design might decrease the level of PRS, mental bandwidth, and mood states as it had many components that could lead to more fixations. The implications from this study will help create more stress-relieving and productive environments for both office workplaces and schools.

This study has some limitations. First, the analysis of this study was constrained to correlation analysis because of the limited number of samples. Even though correlation

analysis is commonly used in restorative studies using an eye-tracking device (Franěk et al., 2018; Nordh et al., 2013), a large sample size might allow this study to conduct advanced and various statistical analyses. Finding the effects of environmental elements can give more sense of space. There is another limitation in the number of settings; this study only observed the cognitive processing in two different settings of the built environments. Regardless of the design theme, performing more experiments in various environmental settings would be helpful to understand the restorative effect of indoor environments. Examples include different sizes of the space, different types of spaces (e.g., classroom, learning space), and spaces without windows. Additionally, the data collected during the COVID-19 might have affected the results. There were fewer people in the experiment locations, but having higher occupancy in the post-COVID era can show the different results on the number and duration of fixations and the perceived restoration. Utilizing virtual environments through Virtual Reality (VR) and Augmented Reality (AR) can enable researchers to control the environmental settings of experiments such as the number of people and environmental design.

The evidence from this study highlights the importance of providing appropriate and enough indoor lounge space for enhancing the student experience on campus. It can be applied to workplaces where the occupants require constant cognitive attention. Building owners, managers, and designers can actively adopt evidence-based restoration building components to support student activities. Further research is required in various indoor spaces in terms of space types and design settings so that universities can easily and effectively provide spaces with a restorative effect. Consequently, students will be able to benefit from experiences in indoor environments.

CHAPTER 5. STUDY 3 – MULTI-DIMENSIONAL ENVIRONMENTS OF A DORMITORY

5.1 Chapter Introduction

Students in higher education in the U.S. normally live in private off-campus housing, campus dormitory, or their parental home. According to the U.S. Census Bureau, about 8.16% of students have lived in college/ university student housing (U.S. Census, 2010b, 2010a). Dormitories play a role as a home for students leaving their parental homes (Thomsen, 2007), so dormitories should be able to provide similar physical spaces, social constructs, and mental supports (Lahelma & Gordon, 2003).

For students living in a dormitory, it is their home during the academic year and, as such, presents the immediate and primary built environments in which students live, work, and play. Therefore, students expect the dormitory to provide a stable, predictable, and controllable environment to ensure their safety, help them search for and discover their identity, and encourage social relationships. The objective of student housing is to provide students with an informal space for studying and living (Amole, 2005; Hassanain, 2007). The building should be able to support learning and relaxing simultaneously as well as to separate academic and life boundaries. Students living in a dormitory spend about half of their free awake time in the dorm (Amole, 2005), so the dormitory environment can significantly influence the occupants. Residential satisfaction is closely related to wellbeing and, consequently, quality of life (Rodger & Johnson, 2005; Sirgy, Grzeskowiak, & Rahtz, 2007).

Studies on the impact of dormitory environments started in the 1970s, and quickly become a mainstay of research on campus environments (Devlin, Donovan, Nicolov, Nold, & Zandan, 2008). Studies have focused on density and stress (Baum & Davis, 1980), reaction to noise (Weinstein, 1979), room flexibility (High & Sundstrom, 1977), and social relationships (Case, 1981). Recent studies have focused on environmental satisfaction (‘Ulyani Mohd Najib, Aini Yusof, & Zainul Abidin, 2011; Hassanain, 2007; Thomsen, 2007), the perceived effect of floor height on crowding (Kaya & Erkip, 2001), the perception on bedrooms and coping strategies to reduce the level of stress (Amole, 2005), residential satisfaction (‘Ulyani Mohd Najib, Aini Yusof, & Osman, 2011; ‘Ulyani Mohd Najib, Aini Yusof, & Zainul Abidin, 2011; Amole, 2009), dormitory design (Abu-Obeid & Ibrahim, 2002), and room type preference (Khozaei, Hassan, & Razak, 2011). However, few studies have joint influence of the physical environments and social attributes of dormitories (Abu-Obeid & Ibrahim, 2002; Devlin et al., 2008; Heilweil, 1973). Further, research to date has failed to link environment perceptions to occupants’ learning performance and wellbeing. Considering the role of the dormitory as a place for learning and living, understanding how student perceptions of their living environment relates to students’ outcomes is an important need in order to enhance students’ quality of life.

The main objective of this chapter is twofold: 1) to examine domain-specific perceptions of the dormitory environment (i.e., living, learning, and socializing) and 2) to evaluate the relationships between perceived dormitory environments and student outcomes (i.e., academic performance and wellbeing).

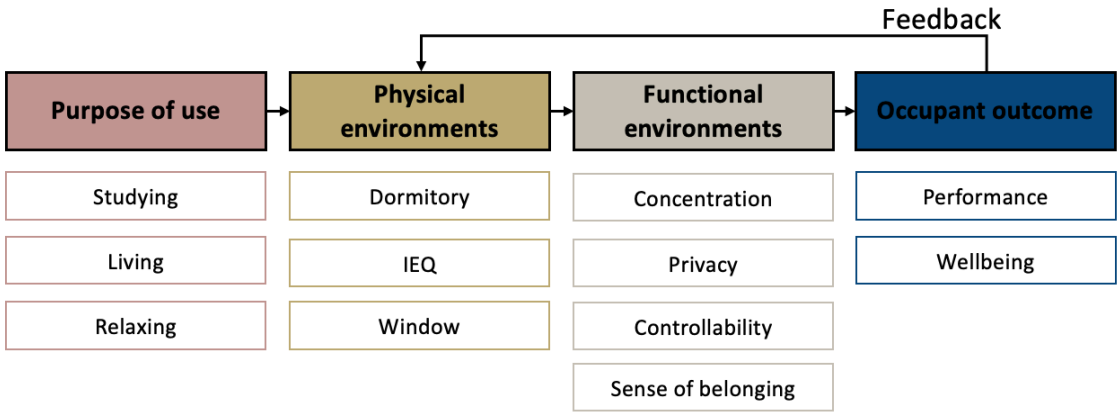


Figure 11 - Theoretical model of built environments for learning and living

5.2 Literature Review

5.2.1 Various Functions of Dormitory

A dormitory is a temporary home for students who live on campus but is different from a parental home in which there are social issues with friends and rules (Thomsen, 2007). Dormitories on campus aim to provide a space for student living, including relaxing, sleeping, entertaining guests, and studying (Amole, 2005), so the physical environment of a dormitory should be able to align with students' activities (Ning & Chen, 2016). As dormitories are typically considered part of the campus physical plant, they have been increasingly viewed as environments that can play a significant role in supporting students' learning performance, satisfaction, and psychological outcomes (Johnson & Cavins, 1996). For example, several studies found that satisfaction with the bedrooms in a dormitory was too low for studying (Amole, 2005; Ning & Chen, 2016), and students prefer to study in the bedroom less than elsewhere in the dorm or outside (Amole, 2011). On the other hand, students living on campus showed evidence of fewer mental health problems in terms of stress, depression, and anxiety than students living off-campus (Beiter et al., 2015).

However, studies failed to link environmental factors of the dorm to students' perception ('Ulyani Mohd Najib, Aini Yusof, & Zainul Abidin, 2011; Hassanain, 2007), and the built environment as a resilience factor was considered at a campus-level (Turner et al., 2017). The relationship between environments and academic performance in dormitories has been rarely examined.

5.2.2 Multi-dimensional Environments in Dormitory

5.2.2.1 The Impacts of the Physical Environment

The parameters of physical environments consist of heating, cooling, ventilation, light, and noise, and they influence the occupants' perception of Indoor Environmental Quality (IEQ), including the amount of lighting, thermal comfort, acoustic comfort, and air quality (Kwon et al., 2019).

Studies that have evaluated student satisfaction with environmental quality using a post occupancy evaluation (POE) method have resulted in inconsistent findings. Hassanain's study (2007) examined the perceived environmental comfort in student housing and found that students were satisfied with thermal comfort, acoustical comfort, visual comfort, and indoor air quality. However, Kocaman, Sezer, and Cetinkol (2017) found that students were satisfied with the temperature, air conditioning use, lighting, color selection, and odor in rooms and common areas but were dissatisfied with indoor acoustical comfort, noise from outside, and natural lighting. Ning and Chen (2016) analyzed student satisfaction with dormitory district, residence, privacy, sense of belonging, acoustic performance, thermal comfort, visual comfort, air quality, and study efficiency in dormitories in China. Students were significantly satisfied with all aspects except study

efficiency. Among the aspects, satisfaction with the dormitory district, air quality, residence, and sense of belonging were significantly related to the overall satisfaction with the dormitory. Bonde and Ramirez (2015) compared students' satisfaction with IEQ between a LEED-certified residence hall and a traditional residence hall. They examined the satisfaction with LEED IEQ criteria, including temperature, air quality, natural and artificial lights. The results showed that the satisfaction with indoor air quality and the temperature had an impact on the indoor environmental comfort and was higher in the LEED-certified building.

Several explanations for the inconsistences among studies may be offered. First, study differences in perceived satisfaction may be due to the different conditions of the buildings in each study. Second, studies varied in the evaluation of different IEQ measures and did not examine any relationship among IEQ criteria or their contribution to outcome measures, thus limiting the generalizability of findings. Finally, and most importantly, studies to date have not examined the effects of the physical dormitory environment on occupant performance or wellbeing.

5.2.2.2 Functional Environments

A dormitory must provide appropriate functional environments to support learning and living effectively. Previous studies have examined the impact of several features of the functional environments, including privacy, controllability, ability to concentrate, and sense of belonging.

Privacy is one of the important issues in a dormitory, as multiple people share one room. Students like to spend most of their free time in their dormitory, but there is typically

very little dedicated space for being alone, resulting in low privacy (Amole, 2005). It is hard to optimize the level of privacy because it is an optimum process between crowding and isolation in a small bedroom (Altman, 1975). Prior studies find that low privacy contributes to poor sleeping quality, entertaining, and studying (Amole, 2005), that in turns is positively related to lower levels of dorm room satisfaction (Kaya & Erkip, 2001).

The ability to concentrate is one of the most important conditions for effective study (Y. Kim et al., 2021). However, students living in a shared room have little opportunity to be alone, so it is sometimes hard to concentrate on studying. Students reported a lack of study efficiency in their rooms (Ning & Chen, 2016). Therefore, providing environments where students can concentrate on studying would be a supportive, functional environment in a dormitory.

A second feature that contributes to functionality pertains to occupant controllability of dorm room contents and arrangements. For example, the limited availability of furniture types and arrangements within a room reduces the opportunity of creating private and isolated spaces. To enhance controllability, students choose to decorate their personal spaces, rearrange the provided furniture, and demarcate personal spaces (Amole, 2005). When they have controllability over the space and situation, students are more likely to use the space for social interaction and spend more time in the room (High & Sundstrom, 1977).

Finally, a sense of belonging in housing can enhance residential satisfaction and social connection with neighbors (Yousefi, Hosseini, Yazdanfar, & Norouzian-Maleki, 2017). Students living in dormitories identify themselves as a part of a group (Rinn, 2004),

and it consequently helps students adjust to university (Bettencourt, Charlton, Eubanks, Kernahan, & Fuller, 1999). Yousefi et al.'s study (2017) found a possibility that a sense of belonging can be affected by architectural design in terms of solidarity, legibility, and view.

5.2.2.3 Relationship between Physical and Functional Environments

Physical and functional attributes are connected and affect occupants systematically, and some studies considered a multi-dimensional perspective of built environments. For example, Ning and Chen (2016) argued that the built environment consists of both physical and functional attributes. Accordingly, they used socio-technical systems theory to examine satisfaction with technical (physical) and social (functional) dormitory environments. Kwon, Remøy, and van den Dobbelsteen (2019) suggested a framework of environmental comforts to enhance environmental satisfaction in workplaces based on a user-focused design approach. Their framework consisted of three layers: physical, functional, and social influences. However, neither of these studies evaluated how physical and functional environments are related to each other. This study proposes that:

> H1. Student satisfaction with the physical dormitory environment will be positively associated with satisfaction with the functional environment.

One of the main purposes of a dormitory is to provide learning environments for students to achieve their academic goals. It is found that students living in a dormitory showed higher academic performance than those living off-campus, but the studies did not consider the environmental features of a dormitory (Turley & Wodtke, 2010). Furthermore, many studies found that the learning environment is related to academic performance on campus, but it has focused on classroom or library environments and has not included

dormitory environments. Therefore, further examination is required about whether the physical and/or functional features of the dormitory environment are related to students' academic performance.

H2. Satisfaction with the physical dormitory environment is positively associated with student academic performance.

H3. Satisfaction with the functional dormitory environment is positively associated with student academic performance.

A supportive campus environment is one of the significant factors that can enhance students' mental health, including physical spaces and social environments (Baik et al., 2019; Turner et al., 2017). In corporate workplaces studies, researchers found that providing appropriate built environments can improve the mental health and wellbeing of workers (Armitage & Amar, 2021; Bluyssen et al., 2011; Evans, 2003) and emphasized the importance of physical environment (i.e., temperature, lighting, noise, and air quality) influencing mental health (Codinhoto et al., 2009; Hoisington et al., 2019). Even though Baik et al.'s study (2019) found that improving the quality of spaces for study and relaxation could enhance the mental health of the students in universities, it has not been clear how the built environment affects the mental health of occupants (Fernandez et al., 2016; Hoisington et al., 2019). This study examines the effect of built environments on mood states as the measure of student wellbeing.

H4. Satisfaction with the physical dormitory environment is positively associated with student positive mood states.

H5. Satisfaction with the functional dormitory environment is positively associated with student positive mood states.

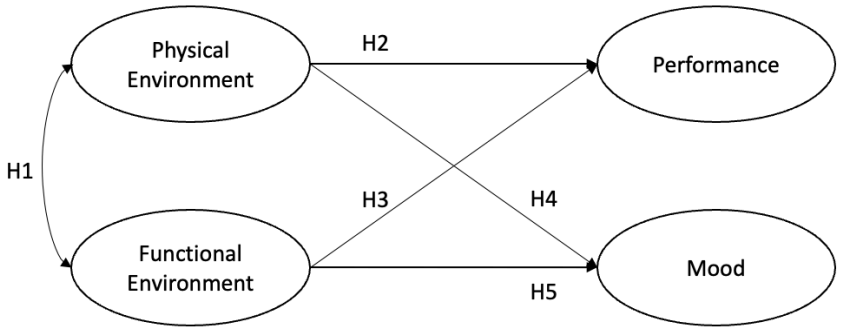


Figure 12 - Hypothesized model

5.3 Methodology

5.3.1 Survey Measure

The survey questionnaire consists of five sections designed to access student perceptions of their built dormitory environments, their perceived learning outcomes, their current wellbeing, and demographic information. Assessment of the physical dormitory environment was locally developed.

The *physical dormitory environment* included five environmental items: the dormitory furniture design, quietness, temperature, clean air quality in the dorm, and dorm lighting. The questions asked participants to rate the importance of their physical dormitory environments for socializing, relaxing, and learning activity as well as the overall comfort of their physical environments using a five-point Likert scale (1: Not important at all to 5: Extremely important). The responses to the importance of the physical dormitory environment were used for identifying what environments were required for each activity

(i.e., socializing, relaxing, and learning) in a dormitory, while the comfort data was used to test the hypothesized model.

Based on the literature review, *functional dormitory environment* was assessed along the dimensions of privacy, controllability, ease of concentration, and sense of belonging, using items suggested by Abu-Obeid & Ibrahim (2002). Abu-Obeid and Ibrahim (2002) developed and used the questions to evaluate the effects of built environments of dormitory buildings on students. Two questions for privacy, five for controllability, five for ease to concentrate, and five for a sense of belonging were used. All questions about functional environments were evaluated with a 5-point Likert scale (1: Strongly disagree to 5: Strongly agree).

The *perceived learning performance* was measured through 1) focused individual work, 2) quality of work, 3) quantity of work, 4) virtual meetings, and 5) creativity using a 5-point Likert scale (1: Very low to 5: Very high). The items except virtual meetings were suggested by Sundstrom, Town, Rice, Osborn, and Brill (1994) to measure the perceived work performance of knowledge workers in office settings. As the learning process of knowledge creation and exchange is similar to knowledge work (Braat-Eggen et al., 2017; Lee & Schottenfeld, 2014), the measures were still valid for students' learning.

The definition of wellbeing has no consensus yet, and it can be measured by subjective satisfaction, happiness, anxiety, or mood states (Turner et al., 2017). In this study, subjective wellbeing was assessed through *mood states* and was measured using the Feeling Inventory developed by Gauvin and Rejeski (1993). The survey items consisted of

12 items with a 5-point Likert Scale (1: Not at all to 5: Extremely), assessing 1) Positive engagement, 2) Revitalization, 3) Tranquility, and 4) Exhaustion.

The last section asked about demographic information, including gender, age, building name, years in the current dormitory, years at Georgia Tech, college, and ethnicity.

5.3.2 Data Collection

An online survey was developed using Qualtrics. The flyers with a QR code linking to an online questionnaire were posted in dormitory buildings and distributed at the dining halls on the G campus. Participants who completed the survey, the participants were automatically eligible for entering a raffle awarding five, $20 gift cards. To be eligible to participate in the survey, students were required to: 1) be Georgia Tech students living in a dormitory, 2) 18 years or older, and 3) an English speaker. The data collection was conducted between March 30th, 2021, and June 28th, 2021. A total of 128 responses were collected and used in subsequent data analyses.

Table 19 - Respondent demographic information (n = 128)

Demographic variables	N (%)
Gender	
Male	69 (53.91%)
Female	57 (44.53%)
Not prefer to answer	2 (1.56%)
Age	

Table 19 continued

18 – 24 years old	120 (93.75%)
25 – 34 years old	4 (3.13%)
35 years old or older	4 (3.13%)
Dormitory building type	
Apartment	58 (45.31%)
Traditional and suite	70 (54.69%)
Ethnicity	
White	67 (52.34%)
Black or African American	4 (3.13%)
Hispanic or Latino	8 (6.25%)
Asian/ Pacific Islander	42 (32.81%)
Mixed	7 (5.47%)
Years living in a dorm	
Less than a year	103 (80.47%)
1 year – less than 2 years	12 (9.38%)
2 years – less than 3 years	9 (7.03%)
3 years or longer	4 (3.13%)
College	
Business	8 (6.25%)
Computing	18 (14.06%)
Design	11 (8.59%)
Engineering	69 (53.91%)
Liberal Arts	9 (7.03%)
Science	13 (10.16%)

5.3.3 Analysis

The data were analyzed using the R studio with *psych* and *lavaan* packages. In order to compare the differences in environmental importance depending on activities, repeated ANOVA was performed. For this analysis, the sphericity assumption was tested by using Huynh-Feldt epsilon and satisfied. Bonferroni tests were performed as post hoc corrections.

CFA and SEM were performed using a Maximum Likelihood method to test H1 through H5 hypotheses. The number of samples should be within an acceptable range to perform SEM. The required sample size for SEM is debatable and is affected by various conditions. There is no one-size-fits-all size, but 100 - 150 samples are generally considered the minimum sample size (Tabachnick & Fidell, 2001). Additionally, the minimum sample size can be calculated by the ratio of observations: estimated parameters *(n:q)*, and the bottom line is that 5 - 10 samples for each parameter (Bentler & Chou, 1987). As the base model of this study had 18 parameters, 90 responses were required at least. There were no missing data in survey responses, so all collected data (a total of N = 128) were used for analysis. The models were evaluated using multiple fit indices, including comparative fit index (CFI) and root mean square error of approximation (RMSEA). The acceptable range of CFI is >.90 (Hu & Bentler, 1995), and that of RMSEA is <.10 with the upper bound of 90% CI lower than .10 (Browne & Cudeck, 1993).

5.4 Results

5.4.1 Required Environments to Support Various Activities in Dormitories

The repeated ANOVA analysis resulted in the different importance levels of environmental features depending on students' activities in a dormitory. The comfortable furniture design was importantly required for all activities, showing the highest importance

for relaxing than the other activities (F=41.32, p<.05). Quietness was the most important for learning, followed by relaxing and socializing (F=175.68, p<.05). The appropriate temperature was significantly important for relaxing, showing the high level of importance for the other activities as well. Clean air quality was important for both relaxing and learning than socializing (F=16.76, p<.05). Lastly, optimal lighting was especially important for learning compared to socializing and relaxing.

Table 20 - Importance of environmental features depending on activities

	Socializing	Relaxing	Learning	F value	Tukey's HSD
Comfortable design of furniture	3.41 (1.02)	4.34 (0.82)	3.73 (1.03)	41.32*	Social-Relax* Social-Learn* Relax-Learn*
Quietness	2.93 (1.22)	4.31 (0.77)	4.55 (0.71)	175.68*	Social-Relax* Social-Learn* Relax-Learn
Appropriate temperature	3.63 (1.10)	4.36 (0.70)	4.21 (0.81)	46.84*	Social-Relax* Social-Learn* Relax-Learn
Clean air quality	3.82 (1.05)	4.26 (0.83)	4.09 (0.86)	16.76*	Social-Relax* Social-Learn* Relax-Learn
Optimal lighting	3.30 (1.05)	3.61 (1.02)	4.33 (0.78)	78.81*	Social-Relax* Social-Learn* Relax-Learn*

* p<.05

5.4.2 Effect of Built Environments on Students' Performance and Wellbeing

5.4.2.1 Measurement Model

Before performing SEM, the measurement model was examined using CFA. The measurement model contained four constructs: physical environment, functional environment, perceived learning performance, and mood (as an indicator of wellbeing). The internal consistency and the reliability of the measurements were validated using Cronbach's alpha and composite reliability (CR), respectively. The results showed the acceptable level, which was over .60 for both. The model fit of the CFA model was χ^2= 192.167 (df = 129), CFI = .915, RMSEA = .062, CI [.043, .080].

Table 21 - The result of the measurement model

Construct		Items	Mean (sd)	Standardized Estimates	Cronbach alpha	Composite Reliability
Physical environment	pe1	Furniture	3.16 (0.93)	.551	.62	.64
	pe2	Quietness	3.53 (1.05)	.527		
	pe3	Temperature	3.27 (1.10)	.402		
	pe4	Air quality	3.58 (0.94)	.641		
	pe5	Optimal lighting	3.30 (1.02)	.386		
Functional environment	fe1	Privacy	3.47 (0.93)	.582	.78	.78
	fe2	Control	3.99 (0.75)	.606		

Table 21 continued

	fe3	Ease of concentration	3.46 (0.81)	.850		
	fe4	Sense of belonging	3.88 (0.85)	.684		
Performance	p1	Focused individual work	3.36 (0.98)	.795	.76	.78
	p2	Quality of work	3.51 (0.89)	.825		
	p3	Quantity of work	3.28 (1.00)	.680		
	p4	Virtual meetings	3.63 (1.01)	.320		
	p5	Creativity	3.11 (1.07)	.547		
Mood	m1	Positive engagement	3.81 (1.17)	.724	.75	.79
	m2	Revitalization	2.42 (0.78)	.795		
	m3	Tranquility	3.23 (0.83)	.761		
	m4	Exhaustion*	2.83 (0.93)	.482		

* Reverse coded

5.4.2.2 Structural Equation Modeling

Based on the measurement model, the proposed model was tested using SEM by adding paths. In the literature review, this paper hypothesized that the physical environments are positively related to the functional environment (H1) and that physical and functional environments were positively associated with learning performance (H2 and H3, respectively). The last hypothesis was proposed that the physical and functional environments were positively related to moods (H4 and H5, respectively). The SEM model

resulted in χ^2= 192.187 (df = 130), CFI = .916, and RMSEA = .061 with CI = [.042, .079]. In order to find a possibility of increasing the model fit, the covariance between positive engagement and revitalization was added in the model based on the modification indices. Therefore, the final model indicated a good model fit with χ^2= 177.576 (df = 129), CFI = .935 and RMSEA = .054 with CI = [.033, .073].

The covariance between physical and functional environments was statistically significant, supporting H1 (b=0.800, p<.05). The physical environment were positively related to mood states, supporting H3, while the physical environment was not associated with performance, rejecting H2. Additionally, the functional environment has a significant influence on performance, supporting H4. However, the functional environment was not related to mood states, leading to a rejection of H5.

Table 22 - Summary of final model results

Hypothesis	Path	Standardized path coefficient	p	Result
H1	Physical environment ~~Functional environment	0.800*	<.001	Supported
H2	Performance ~ Physical environment	-0.561	.052	Rejected
H3	Performance ~ Functional environment	1.175*	<.001	Supported
H4	Mood ~ Physical environment	0.678*	.006	Supported
H5	Mood ~ Functional environment	0.211	.285	Rejected

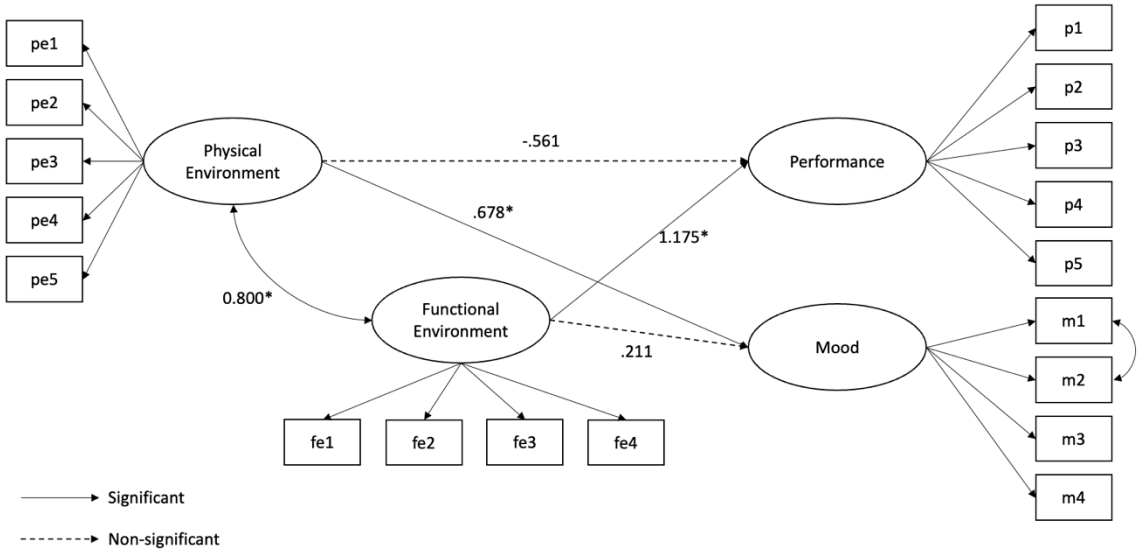


Figure 13 - Structural equation model

In order to examine the high correlation between physical and functional environments in the SEM model, multiple linear regression analyses were further performed. The results showed the relationship between each functional environment (DV) and physical environments (IV) [Table 23]. All models were statistically significant. Furniture was significantly related to all functional environments, showing the range of coefficient between .116 (sense of belonging) and .249 (privacy). On the other hand, temperature and lighting showed no significant association with the functional environments.

Table 23 - Multiple linear regression between physical and functional environment 1

Functional environment	IV1	IV2	IV3	IV4	IV5	Model summary
Privacy	.249*	.286*	.017	.081	.058	R adjusted = .232 F = 8.681* (5, 122)
Control	.154*	.097	.098	.114	.044	R adjusted = .191 F = 5.787* (5, 122)
Concentration	.162*	.135*	.026	.197*	.074	R adjusted = .204 F = 7.508* (5, 122)
Sense of belonging	.116*	.064	.044	.128*	.007	R adjusted = .205 F = 6.273* (5, 122)

IV1: Furniture, IV2: Quietness., IV3: Temperature, IV4: Air quality, IV5: Lighting

*<.05

Table 24 showed the relationship between each physical environment (DV) and functional environments (IV). All models were statistically significant, but the variables showing the significant relationships were limited.

Table 24 - Multiple linear regression between physical and functional environment 2

Physical environment	IV1	IV2	IV3	IV4	Model summary
Furniture	.232*	.079	.124	.315	R adjusted = .168 F = 7.408* (4, 123)
Quietness	.366 *	.018	.107	.275	R adjusted = .173 F = 7.618* (4, 123)
Temperature	.060	.237	.057	.263	R adjusted = .061 F = 3.072* (4, 123)
Air quality	.109	.083	.246*	.390*	R adjusted = .193 F = 8.583* (4, 123)
Lighting	.114	.073	.194	.128	R adjusted = .057 F = 2.912* (4, 123)

IV1: Privacy, IV2: Control., IV3: Concentration, IV4: Sense of belonging

5.5 Discussion

This study tested the students' needs of the built environments depending on activities in the dormitory using a repeated ANOVA analysis and the impact of the environments on the students using SEM. The finding showed that students need different environmental supports for each activity (i.e., learning, socializing, and relaxing), and the result of SEM found the multi-dimensions of physical and functional environments in the dormitory that affect student performance and wellbeing.

Notably, the students reported the importance of physical environments differently depending on activities in dormitories, showing the higher importance of the physical environments for learning and relaxing than for socializing. The environment with quietness and optimal lighting was the most important for learning. This result was consistent with Dusselier, Dunn, Wang, Shelley, and Whalen's study (2005) that argued the importance of noise control for providing a study-friendly environment in a dormitory. Additionally, a similar result was found in other learning settings in higher education, including learning commons and the library (Cha & Kim, 2020; Hong et al., 2021). On the other hand, students especially required the comfortable design of furniture, appropriate temperature, and clean air quality for relaxing. However, students' satisfaction with the dorm environment appeared lower than the importance level, comparing the results in Table 20 and Table 21. There is a great possibility to effectively support students by providing satisfying environments for studying and living, and the focus can be prioritized by finding the gap between the importance and satisfaction. There were the least needs of physical environments for socializing in a dormitory.

The hypothesis that the satisfaction with physical environments is related to that of functional environments (H1) was supported. It has been argued that physical and functional environments are related to each other, but few previous studies tested how they were related to each other and how they affect occupants differently. This study found that the physical and functional environments were highly correlated to each other. Normally, meeting the needs of functional environments is harder than providing satisfying physical environments (Ning & Chen, 2016). The evidence of this study supports that providing satisfying physical environments can leverage the quality of functional environments as well in a dormitory setting. The physical environment included the furniture, noise, temperature, air quality, and lighting, and the functional environment included privacy, controllability, ease of concentration, and a sense of belonging. More importantly, in order to examine the relationship between the environments, the functional environments must be defined appropriately based on the type and purpose of a building because the required functional environments vary depending on the purposes of the building. This study targeted the dormitory buildings in higher education, which aimed to support student academic performance and wellbeing. Depending on the considerations of buildings, the functional environments can differ.

Learning in the dormitory is an important experience for residents as they prefer to study in the dormitory outside the classroom (Dusselier et al., 2005), and the importance of residential environments for academic performance has been emphasized since the 1960s (Rinn, 2004). This study also resulted in the importance of the environment but found the environments had different impacts on learning performance in the dormitory. Interestingly, the SEM result showed the non-significant impact of the physical

environment on students' performance in the dormitory, rejecting H2. On the other hand, the functional environment was related to learning performance in the dormitory, supporting H3. This result should be considered when considering dissatisfaction with study efficiency in dormitories (Ning & Chen, 2016). Little has been explored on this relationship in a dormitory setting, but a similar relationship was found in other settings in higher education. For example, the physical environment was indirectly related to learning performance through environmental supports in a library (Hong et al., 2021; Y. Kim et al., 2021). Regardless of the building types, students require similar environmental support for learning on campus. Therefore, there is a great possibility to enhance students' learning performance in a dormitory when the quality of the functional environment is improved.

Notably, the findings of this study support that the physical environment directly enhances the wellbeing of the students in a dormitory. Physical environments, including lighting, air quality, and noise, impact mental wellbeing at work (R. Cooper, Boyko, & Codinhoto, 2010; Dreyer, Coulombe, Whitney, Riemer, & Labbé, 2018), and the finding of this study argues that providing the appropriate quality of physical environments enhances the perceived wellbeing of the occupants in a dormitory setting. While H4 is supported, functional environments were not directly related to students' wellbeing, rejecting H5. The result on functional environment and wellbeing is in contrast to Turner et al.'s study (2017) that found the impact of the resilience of the environment on the student wellbeing on campus. This inconsistency is possibly caused by the different considerations of functional environments where this study focused on the environments with privacy, controllability, ease to concentrate, and sense of belonging for learning and studying. Therefore, further examination on the impact of the environments on student wellbeing is

required in dormitory settings, defining and taking account of other functional environments.

Despite the significant evidence of built environments was found in this study, several limitations emerged. First, even though the data was collected from multiple buildings, the study was performed on a single campus, and it generates the limitation of the generalization of the findings. With a larger sample size, hierarchical linear modeling (HLM) can be performed to find the effect of each building. This method considers the hierarchy of data that accounts for the shared variance, so it is helpful to understand the effect of individual context as well as a group effect in higher levels of data. Further studies should be able to consider both individual-level and building-level simultaneously. Next, there is a possible variation of design and building features. The dormitory design has less variance compared to other buildings, but each building is still unique. Including measures such as IEQ can help researchers objectively measure the quality of the built environment and to compare between different built environments in terms of physical elements. Third, students chose their rooms and/or roommates based on their needs and preference, so their perceived environments might reflect individual personality and preference. Further study is required to examine if individual personality affects their perceived environments, especially functional environments.

The physical and functional environments can affect each other, so considering both features is important theoretically and practically. The important thing is that functional environments should be considered differently depending on the purpose of the buildings. For example, multi-functional buildings such as dormitories on campus should

be able to provide various spaces to meet occupants needs. Furthermore, a whole campus should be considered to support students' experience and to meet their various needs.

CHAPTER 6. DISCUSSION

The previous chapters tested the proposed theoretical framework in three different academic settings, non-departmental education building, library, and dormitory, in the series of studies. The main consideration was how the built environments, including physical and functional environments, are associated with the humans in the spaces. Despite the emphasis of learning environments on pedagogy, understanding how built environments are related to student learning has not been extensively examined yet (Franz, 2019). For physical environments, this study focused on IEQ and indoor environmental components. The functional environments were considered differently depending on the scope of each study.

The main components and key results are shown in Table 25. Study 1 focused on learning in the library, considering the new concept of learning. As the new learning requires active collaboration with other students and naturally needs social interaction with peers, the functional environments of the library in the second study included privacy, collaboration, crowdedness, and socialization. Next, study 2 focused on relaxing in lounge spaces in two education buildings and tested the restorative effects in indoor environments; the functional environment of the first study focused on perceived restorativeness. Lastly, the functional environments of the dormitory in Study 3 focused on living in the dormitory. Living in a dormitory contains students' academic and social lives in the building, learning and socializing. Therefore, this study defined privacy, controllability, ease of concentration, and a sense of belonging as the functional environments in the dormitory on campus.

Table 25 - Summary of the studies and key findings

	Study 1	Study 2	Study 3
Building	Library	Non-departmental education building	Dormitory
Space	Open-plan space for individual study, open-plan space for group learning, individual study space with carrels, meeting rooms, and lounge spaces	Lounge areas in biophilic and non-biophilic design indoor spaces	Individual dorm unit
Activities	Learning	Learning and Relaxing	Learning, Living, and Socializing
Physical environment	Space types, IEQ	Indoor environmental components	IEQ
Functional environment	Privacy, collaboration, crowdedness, socialization	Restorativeness	Privacy, controllability, ease of concentration, sense of belonging
Outcomes	Academic performance, wellbeing	Mental bandwidth, mood states	Mental bandwidth, mood states
Methods	Survey (n = 66), interview (n = 12)	Experiments (n = 34)	Survey (n = 128)
Key findings			
Relationships between physical and functional environments	NA	Fixation: restorativeness – wall, floor, ceiling (-), lighting (-) Duration: restorativeness – wall, floor, ceiling (-	Correlation (+)

Table 23 continued

		), lighting (-), people (-)	
Factors related to learning performance	Physical environment; Window view, background noise, quietness, lighting, furniture, resources	Fixation: column, steel structure, pipes (-)	n.s.
	Functional environment; ease of concentration, privacy, collaboration, crowdedness, socialization		Privacy, controllability, ease of concentration, sense of belonging
Factors related to wellbeing	Physical environment; Window view, lighting, furniture, resources	Fixation: wall, floor, ceiling (-), column steel structure, pipes (-), people (-)	IEQ (Furniture, quietness, temperature, air quality, optimal lighting)
	Functional environment; crowdedness, socialization	Duration: furniture (-), wall, floor, ceiling (-), column steel structure, pipes (-), people (-), people (-)	n.s.

n.s.: non-significant

Providing different types of spaces is important for students. For activities of students, all three studies found the importance of supporting the learning and relaxing through the built environments on campus. The primary purpose of universities is education, so learning spaces should be the most important spaces provided to students. Importantly, as the learning paradigm changed, several types of spaces are required for learning in addition to traditional classrooms (Hamilton, 2009). The new spaces are mostly based on open-plan settings, encouraging collaboration among students (Hong et al., 2021; King, 2016). In Study 1, even in the same building, the student reported different

perceptions of built environments depending on the type and function of spaces. Similar results were found in previous studies (Beckers et al., 2016b; Lee & Schottenfeld, 2014).

Additionally, this thesis provides the importance of providing spaces for relaxing. Study 1 revealed that having comfortable furniture and spaces to relax is important for learning performance. Furthermore, study 2 found that the lounge spaces had restorative effects and supported enhancing mental bandwidth and reducing stress. Meanwhile, Studies 1 and 3 examined socializing activity in the library and dormitory, but it turned out that socializing was not a primary activity in the subject spaces. In the library, students reported that they would not come to the library for socializing only. Students needed a space to be around other people, even though they did not directly engage with them. Additionally, in dormitories, students reported the lower importance of the physical environments for socializing compared to the environments for learning and relaxing. The spaces must be provided focusing on their primary activities, which are learning and relaxing, but socializing also needs to be considered.

This thesis examined multiple dimensions of built environments, focusing on physical and functional environments. Studies 1 and 2 included both environments in the scope but did not statistically test their relationship with each other. On the other hand, Study 3 tested and found the correlation between the physical and functional environment. However, this study found that they are interdependent, affecting each other. The result of this thesis implies that the relationship between variables should be considered when examining the built environments and their impact on humans.

Notably, the built environments were related to students' academic performance in various ways. In this thesis, some indoor environmental elements such as exposed walls, floor, ceiling, indoor windows, columns, steel structures, and pipes were negatively related to mental bandwidth, which is the ability to learn and study effectively. At the same time, IEQ components were positively associated with academic performance. This result should be considered for designing campus spaces. The human outcomes could be improved if fewer components have negative relationships, arguing that negative images tended to invite attention easily (Noland et al., 2017). The design should aim not to have too many fixations on building components, such as columns, steel structures, or pipes. In Studies 1 and 3, students reported physical environments in the library are related to their academic performance, but the statistical model found no significant relationships. Several studies have reported the effect of specific IEQ elements on learning performance, such as noise (Kaarlela-Tuomaala, Helenius, Keskinen, & Hongisto, 2009; Varjo et al., 2015) and lighting (van Bommel & van den Beld, 2004).

In addition to IEQ, other considerations of physical environments were also associated with occupant performance (Cha & Kim, 2020; Lee, 2014). As found in study 1, window view, furniture, and resources as physical environments should be considered as physical environmental factors. For supporting learning performance, providing appropriate functional environments can be more effective. For example, privacy and ease of concentration were commonly found in dormitories and libraries to enhance learning performance. Privacy is especially important because there is conflict in demand between collaboration and privacy in open-plan space settings (Parkin, Austin, Pinder, Baguley, & Allenby, 2011). Therefore, it is important to provide various types of spaces with different

functional environments to support several types of occupant activities in a building. As the size of the building is limited, investigating the needs of space types is required to strategically provide spaces in various sizes and types based on appropriate space programming. Additionally, establishing rules of space that guide students to use appropriate spaces for their activities uses would be helpful to operate the building properly.

This thesis provides evidence that providing appropriate built environments is important to support the wellbeing of students. Building elements can be negatively associated with mood states, while indoor environmental quality can positively affect students' wellbeing. Furthermore, this thesis found that the physical spaces play an important role in providing social support and a sense of belonging for students. It will consequently enable students to have a sense of community and improve their wellbeing. Similar results were found in a study by (Kariippanon, Cliff, Lancaster, Okely, & Parrish, 2018). They found that physical environments of flexible learning spaces in primary and secondary school can facilitate student learning and were related to students' social and emotional wellbeing as well as physical wellbeing. Therefore, physical environments that can support student wellbeing should be examined and provided further.

6.1 Contribution

There are three perspectives of contributions in this study. First, this study proposes a theoretical model based on the socio-materiality theory to test the complex relationship between physical environments and social elements in built environments. This theory has been developed and used in the field of organizational study. Based on the proposed

theoretical model, testing the model provides evidence of understanding how the environments are associated with humans. Second, this thesis has a methodological contribution in using an eye-tracking device in real-world settings to test the restoration theory in Study 2. Using subjective data for built environmental studies has limitations based on self-report responses. In this thesis, study 2 utilizes an eye-tracking device in the real world that provides objective data. The studies testing restorative theory using eye-tracking devices used 2D pictures instead of real-world environments, so there has been a limitation of providing a sense of surroundings and physical presence. Therefore, this study utilizes the eye-tracking device in real-world settings and provides an opportunity of using objective data for built environment studies. Lastly, the results on environmental effects can provide practical evidence of the importance of supporting campus spaces to space planners, designers, and facility managers. The results also provide design and management considerations for built environments on campus.

6.2 Limitations

This thesis has several limitations. First, there is a limitation of the measures of wellbeing. The definition of wellbeing has no consensus yet, so the measure of wellbeing is also differently used depending on the operational definition of wellbeing. This thesis employed the measure of mood states in order of measuring short-term wellbeing. Therefore, the findings of this thesis could be affected by the measures. Second, this thesis focused on limited types of physical and functional environments, so study 3 did not test a directional effect from physical environments to functional environments. Even though limiting the variable was to control the complexity of the model, it resulted in the limitation. This study focused on IEQ only as physical environments, but the functional environments

can be affected by other factors, such as design (Yousefi et al., 2017), other users (Braat-Eggen et al., 2019), location (Braat-Eggen et al., 2017; Kwon & Remøy, 2020), and maintenance (Braat-Eggen et al., 2017). Lastly, data for this dissertation was collected during the COVID-19 pandemic (except for the survey for Study 1), so there will be a limitation of generalizability. For example, students might have avoided a gathering space or activity rooms for socialization and relaxation in the dormitory due to their anxiety about COVID-19. Also, during the pandemic, the number of people could be lower than before, leading to the low crowding, and this circumstance can make people feel calmer and more comfortable with being in an indoor space.

Georgia Tech, in which the data was collected, has changed its campus according to the 2004 Campus Master Plan. During the entire time of this study's data collection, a student center, a living room on campus for students, was under construction. During this major construction, students might have lacked spaces that naturally guided them to gather. As a result, other buildings, such as the library and learning commons have been used as gathering spaces. The results of this dissertation might be affected by the situation of the whole campus. For example, from the result of this dissertation, students required a library as a space providing a sense of belonging. The students might expect the role of a student center from the library, which led to the high demand of feeling a sense of belonging in the library. After completing of the student center, the need for the library as a gathering space can be declined, but having an environment that provides a sense of belonging can still enhance student wellbeing on campus. Further studies can measure the perceived sense of belonging in different buildings and find the roles of the buildings on campus.

CHAPTER 7. CONCLUSION

This thesis proposes and examines a theoretical framework for understanding built environments on campus using socio-materiality theory that aims to describe the cumulative effects of materiality and social practice in built environments. Campus environments is very complex in order of providing different types of spaces to support various activities of students. This thesis explains the effect of built environments on students' academic performance and wellbeing considering different types of student activity.

The evidence from this thesis highlights the importance of providing appropriate and enough indoor spaces to learning, living, and relaxing for enhancing the student experience on campus. Indoor environments have a role in providing supportive environments to building occupants. Consequently, students will get benefits of enhancing the perceived learning performance and wellbeing through the environments on campus. Understanding students' activities and preferred spaces is critical for new construction and major renovation of libraries and continuous improvement with smaller changes, such as furniture reconfiguration, space assignment and planning, and user policy.

In future studies, the proposed theoretical framework should be tested in other environmental settings in terms of space types and design settings on campus as well as corporate office settings. Every building is unique, and the use and perception of spaces are different in each person. Having further results can concrete the results of this thesis and help designers and facility managers to easily and effectively provide spaces

supporting students. For this, defining functional environments considering the type and purpose of spaces should be preceded.

APPENDIX A. SURVEY: INVESTIGATING OCCUPANT SEATING PATTERNS FOR SHARED SPACE PROGRAMMING AND OPTIMIZATION[4]

The purpose of this survey is to evaluate space use, satisfaction on the spatial features and indoor environment, and functionality of the space in Crosland Library. The following survey should take approximately 15 minutes to complete. We assure you that your answer will be treated in the strictest of confidentiality.

Please answer the following questions based on your 'current' activity and experience.

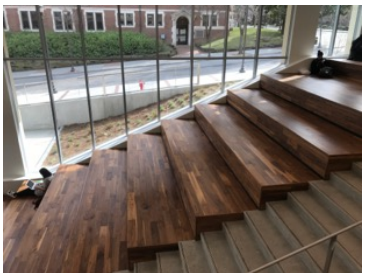
SECTION I. Space use

1. Where are you sitting now?

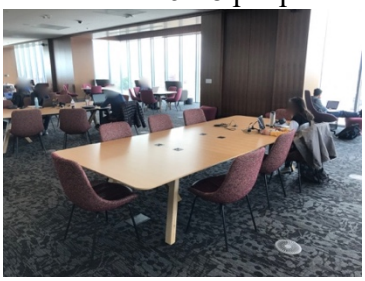
☐ Stairs between ground level and the 1st floor
☐ 2nd Floor
☐ 6th Floor
☐ 7th Floor

2. Which type of furniture are you using? (Choose one)

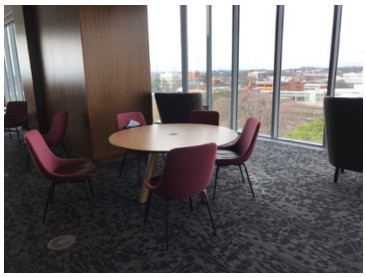
a. Stairs



b. Table for 6 - 8 people



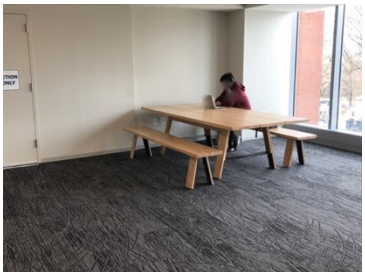
c. Roundtable

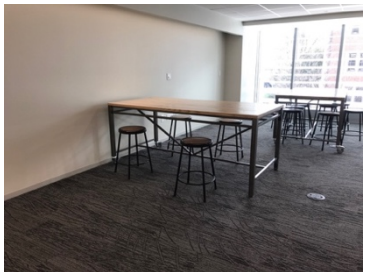


d. Table with benches

e. Table with high-back sofa benches

f. High desk



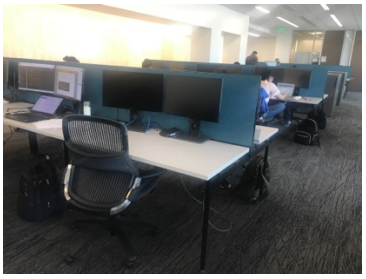


g. Individual sofa

h. Writing desk

i. Sofa with/without a table

[4] This appendix shows a part of the entire survey that was used for the analysis in this thesis.


3. Who are you using the space with?
☐ Alone
☐ In a group (The number of people in your group: _____)
☐ Alone, but together (i.e., friends) (The number of people in your group: _____)

4. Which activity are you doing?
☐ Studying ☐ Lounging/ Resting/ Eating
☐ Group project ☐ Miscellaneous work
☐ Other. Please specify _____

SECTION II. Personal Description
1. What is your gender?
☐Male ☐Female ☐Transgender ☐Genderqueer

2. What is your age?
☐18-24 ☐25-29 ☐30-34 ☐35-39
☐40-44
☐45-49 ☐50-54 ☐55 and over

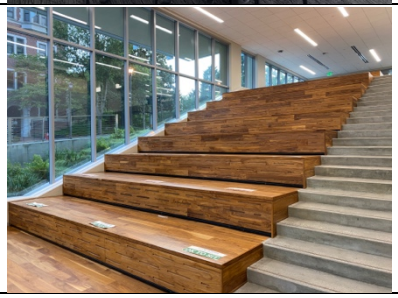
3. How would you describe your position?
☐Undergraduate student ☐Graduate ☐Post Doc

☐Other. Please specify

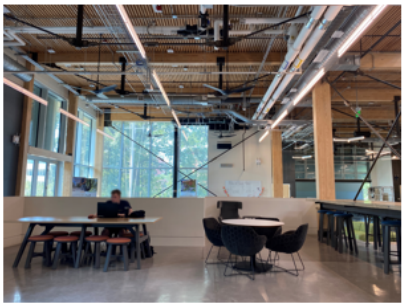
4. What is your ethnicity?
☐White ☐Black or African American
☐Hispanic or Latino ☐Native American
☐Asian / Pacific Islander ☐Other

5. How many years have you been at Georgia Tech?
☐ less than 1 year ☐1 ~ 2 years ☐3~4 years ☐5 years or more

APPENDIX B. EXAMPLE PHOTOGRAPHS OF EACH SPACE TYPEN AT GEORGIA TECH LIBRARY

Type	Example
Open-plan space for individual study	
Open-plan space for group work	
Individual study space with carrels	
Meeting room	
Lounge	

APPENDIX C. ENVIRONMENTAL SETTINGS FOR THE EXPERIMENT IN STUDY 2

Biophilic setting	Non-biophilic setting
a. Overview	
	
b. View to front	
	
c. Side - left (window)	
	
d. Side - right (stairs)	
	

APPENDIX D. RESTORATIEV EFFECTS IN BUILT

ENVIRONMENTS SURVEY FOR STUDY 2

This survey aims to explore how people perceive the built environments and react. The following survey should take approximately 10 minutes to complete. We assure you that your answer will be treated in the strictest of confidentiality.

Section 1. Perceived environment

1. Please evaluate the extent to which the given statement fits your experience.

Scale (1) Not at all; (2) Rarely; (3) Slightly; (4) Neutral; (5) Moderately; (6) Mostly; (7) Completely

Statement	(1)	(2)	(3)	(4)	(5)	(6)	(7)
It is an escape experience							
Spending time here gives me a good break from my day-to-day routine							
The setting has fascinating qualities							
My attention is drawn to many interesting things							
I would like to get to know this place better							
There is much to explore and discover here							
I would like to spend more time looking at the surroundings							
There is too much going on							
It is a confusing place							
There is a great deal of distraction							
It is chaotic here							
I can do things I like here							
I have a sense of I belong here							
I have a sense of openness with this setting							
Being here suits my personality							
I could find ways to enjoy myself in a place like this							

2. How much do you like spending time in this space.

Not at all (1)	A little (2)	Somewhat (3)	A lot (4)	Extremely (5)

3. Which components did you recognize during the break? Please select all applicable choices.

☐ Outside of windows

☐ Stairs

☐ Doors

☐ Furniture (tables, chairs)

☐ People in the space

☐ Others (please specify) _____

4. During the break, what aspects did you like regarding indoor environments?

5. What aspects did you not like regarding indoor environments?

Section 2. Mental bandwidth

Please evaluate the extent to which each statement below describes how you think after the break.

Statement	Not at all (1)	A little (2)	Somewhat (3)	A lot (4)	Extremely (5)
Aware of things going on around you					
Able to take note of thoughts or feelings					
Lost in thought					
Letting your mind wander					
Thinking about things you need to do					
Making plans for the future					
Reflecting on things that happened in the past					

Section 3. Mood states

Indicate the extent to which each word below describes how you feel at this moment in time.

Statement	Not at all (1)	A little (2)	Somewhat (3)	A lot (4)	Extremely (5)
Refreshed					
Calm					
Fatigued					
Enthusiastic					
Relaxed					
Energetic					
Happy					
Tired					
Revived					
Peaceful					
Worn-out					
Upbeat					

Please use the following scale to indicate the extent to which statement describes how you feel in the space because of the COVID-19.

Statement	Not at all	A little	Somewhat	A lot	Extremely
I am worried about being indoors.					
I feel anxiety when the social distance is not kept in this building.					
I feel uncomfortable hanging out with friends indoors.					
I am worried if someone has COVID-19 in the same space as me.					

Section 4. Personal description

1. What is your gender?

☐Male ☐Female ☐Others ☐Prefer not to say

2. What is your age? _____ years old

3. How would you describe your position?

☐Undergraduate student ☐Graduate student ☐Post Doc

☐Other. Please specify_____

4. What is your ethnicity?

☐White ☐Black or African American

☐Hispanic or Latino ☐Native American

☐Asian / Pacific Islander ☐Other

5. How many years have you been at Georgia Tech?

☐ less than 1 year ☐1 ~ 2 years ☐3~4 years ☐5 years or more

6. What is your major? _____

Thank you for your participation and
feel free to contact us if you have any questions!

Yujin Kim, yujin.kim@gatech.edu
Dr. Eunhwa Yang, eunhwa.yang@design.gatech.edu

APPENDIX E. RESULT FIGURES IN STUDY 2

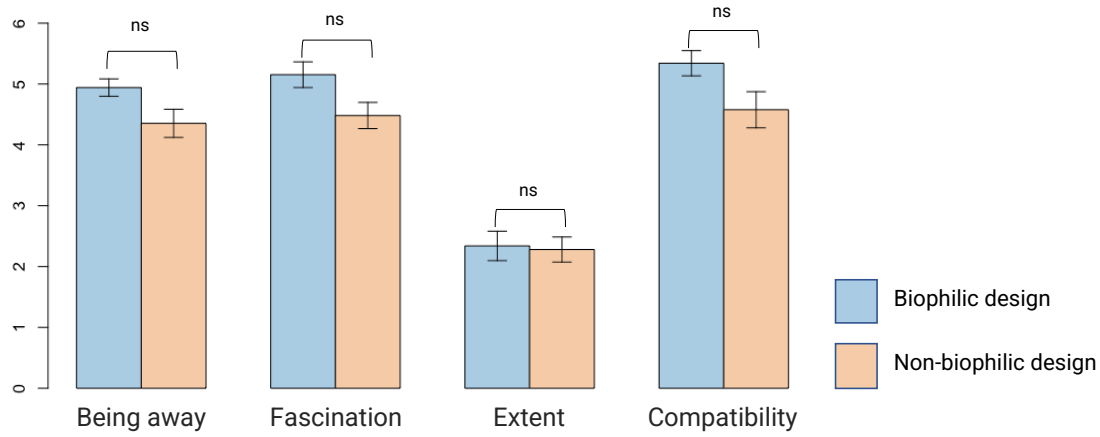


Figure F.1 - Result of independent t-test: Difference in restorative components between biophilic and non-biophilic design (ns: non-significant)

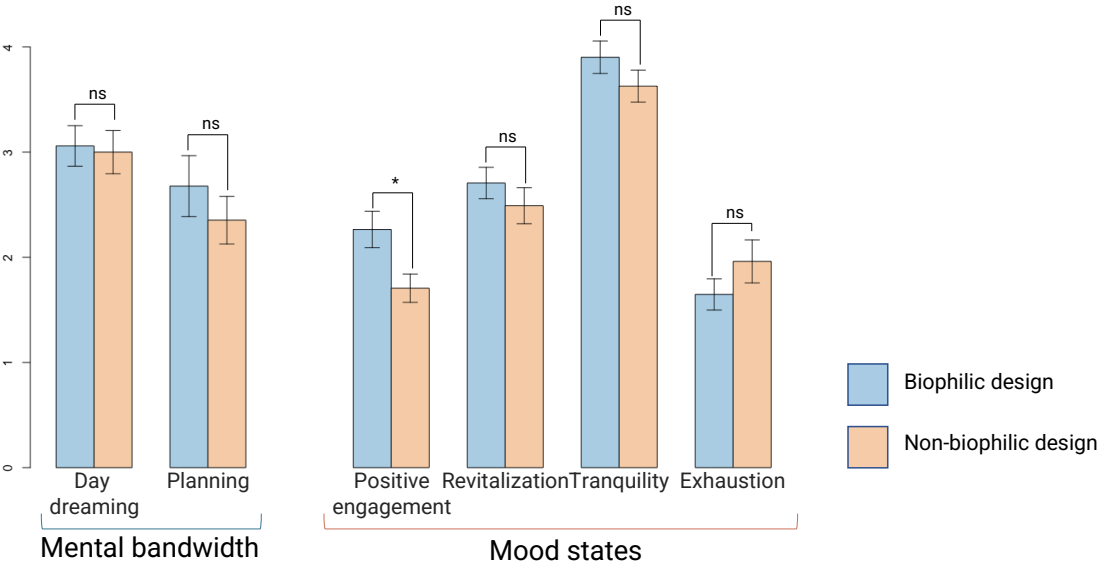


Figure F.2 - Result of independent t-test: Difference in mental bandwidth and wellbeing between biophilic and non-biophilic design (ns: non-significant)

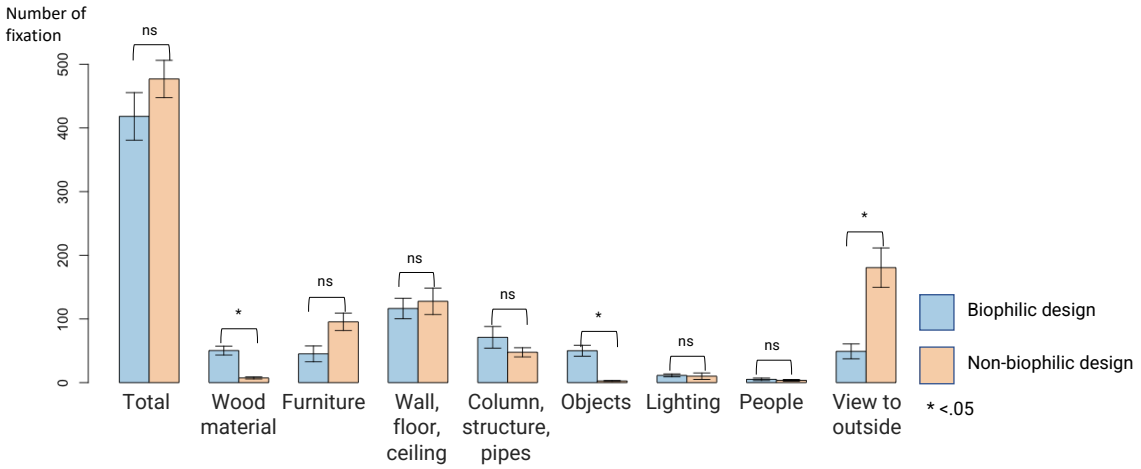


Figure F.3 - Result of independent t-test: The number of fixations between biophilic design and non-biophilic design (ns: non-significant)

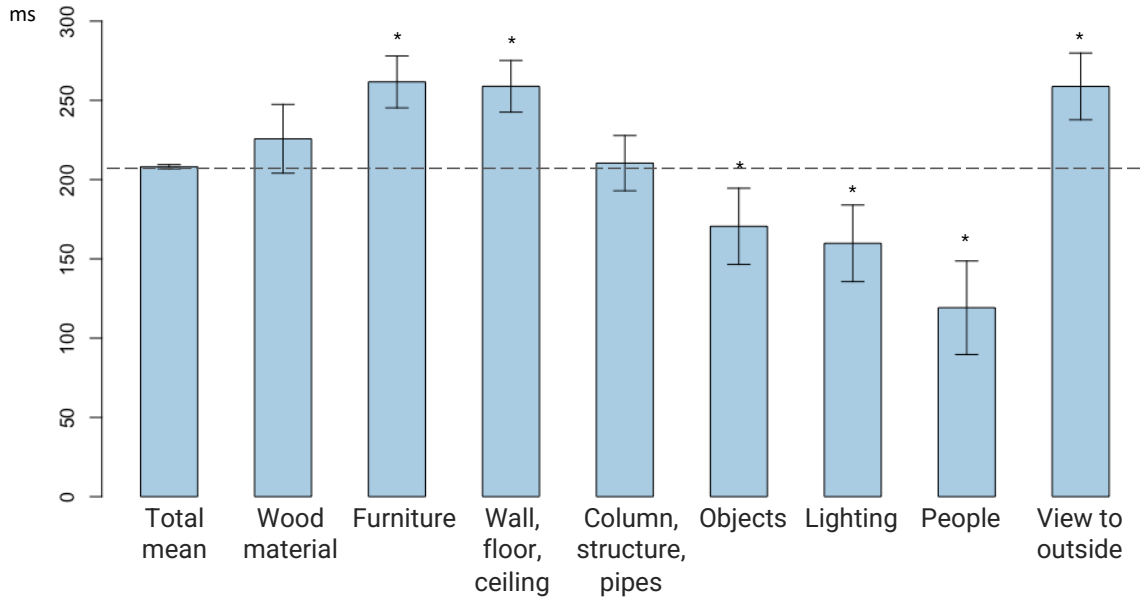


Figure F.4 - Result of regression analysis using effect codes comparing mean fixation duration of each component and total mean duration

Table F.1 - Correlation between number of fixations on components and PRS, mental bandwidth, and mood states

Variables	Restorativeness				Mental bandwidth		Mood states				Preference (11)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Number of fixations	-.20	-.31	.07	-.03	.14	-.66*	-.11	.08	.03	-.12	-.03
Wood materials	.04	.17	-.23	-.26	-.06	-.03	-.07	.11	-.26	.15	-.26
Furniture	-.18	-.07	-.01	.15	.13	-.32	-.18	.01	-.05	-.01	.15
Wall, floor, ceiling	-.27	-.41*	.05	.20	.26	-.35*	-.16	.15	.47*	-.08	.20
Columns, structure, pipes	-.23	-.06	-.23	-.16	-.38*	-.40*	-.16	-.08	-.27	-.15	-.16
Objects	.06	.27	-.21	.11	.07	-.01	.11	.11	-.27	.42*	.11
Lighting	-.38*	-.22	-.00	-.18	-.27	-.33	-.14	.01	-.24	-.04	-.18
People	.10	-.15	.22	-.21	-.05	.01	-.41*	-.29	.27	-.27	-.21
View to outside	.16	-.17	.12	-.10	.19	-.17	.19	-.04	.07	-.22	-.10

(1) Being away; (2) Fascination; (3) Extent - Coherence; (4) Compatibility; (5) Daydreaming; (6) Planning; (7) Positive engagement; (8) Revitalization; (9) Tranquility; (10) Exhaustion; (11) Preference, * p<.05

Table F.2 - Correlation between number of fixations on components and PRS, mental bandwidth, and mood states

Variables	Restorativeness				Mental bandwidth			Mood states			(11)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Total mean duration	.12	-.34*	.18	-.21	-.04	.35*	-.42*	-.20	-.01	.05	-.18
Wood materials	.01	.05	-.21	-.04	-.31	.01	-.12	-.15	-.02	-.19	.00
Furniture	.01	-.12	.07	-.21	.17	.25	-.36*	-.23	.00	-.03	.01
Wall, floor, ceiling	-.27	-.51*	.08	-.05	.19	.32	-.37*	-.23	.08	.44*	-.22
Columns, structure, pipes	-.21	-.14	-.17	-.31	-.22	-.31	-.40*	-.20	-.15	-.25	-.23
Objects	.03	.23	-.21	.14	.08	.14	-.07	.12	.06	-.26	.35*
Lighting	-.38*	-.23	.01	-.18	-.22	-.26	-.34*	-.14	-.04	-.24	-.08
People	.09	-.18	.25	-.35*	-.19	-.03	-.02	-.49*	-.36*	.32	-.35*
View to outside	.21	-.16	.15	-.03	-.11	.20	-.18	.10	.06	.01	-.14

(1) Being away; (2) Fascination; (3) Extent - Coherence; (4) Compatibility; (5) Daydreaming; (6) Planning; (7) Positive engagement; (8) Revitalization; (9) Tranquility; (10) Exhaustion; (11) Preference, * p<.05

APPENDIX F. SURVEY: PHYSICAL ENVIRONMENTS AND FUNCTIONAL ATTRIBUTES FOR LIVING AND LEARNING IN A DORMITORY

Section 1. Physical environments and experience in your dorm

1. What is the major window view in your room?
    a. No window
    b. Green (Tree, grass)
    c. Other residents' window (neighboring building)
    d. Buildings other than neighbors
2. How do you evaluate your satisfaction with the bedroom as a place for socializing? (Very dissatisfied – dissatisfied – neutral – satisfied – very satisfied)
3. How do you evaluate your satisfaction with the bedroom as a place for socializing? (Very dissatisfied – dissatisfied – neutral – satisfied – very satisfied)
4. How much is each aspect important of the bedroom as a place for socializing?

	Not important et al	Slightly important	Moderately important	Very important	Completely important
Comfortable design of furniture					
Quietness					
Appropriate temperature					
Clean air quality					
Optimal lighting					

5. How do you evaluate your satisfaction with the bedroom as a place for relaxing? (Very dissatisfied – dissatisfied – neutral – satisfied – very satisfied)
6. How much is each aspect important of the bedroom as a place for relaxing?

	Not important et al	Slightly important	Moderately important	Very important	Completely important
Comfortable design of furniture					
Quietness					
Appropriate temperature					
Clean air quality					
Optimal lighting					

7. How do you evaluate your satisfaction with the bedroom as a place for learning? (Very dissatisfied – dissatisfied – neutral – satisfied – very satisfied)
8. How much is each aspect important of the bedroom as a place for learning?

	Not important et al	Slightly important	Moderately important	Very important	Completely important

Comfortable design of furniture					
Quietness					
Appropriate temperature					
Clean air quality					
Optimal lighting					

9. How do you evaluate your overall satisfaction with your bedroom? (5-point Likert scale: Very dissatisfied – dissatisfied – neutral – satisfied – very satisfied)
10. How do you evaluate your satisfaction with the bedroom?

	Very dissatisfied	Dissatisfied	Neutral	Satisfied	Very satisfied
Comfortable design of furniture					
Quietness					
Appropriate temperature					
Clean air quality					
Optimal lighting					

Section 2. Perception of the environments

Please evaluate your agreement with the following statements **about your bedroom**.

Statement	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
My room provides privacy from being overheard by others					
My room provides privacy from being overlooked by others					
I have a control over my room					
I have a sense of ownership toward my room					
I can make some changes with furniture in my room					
I can manipulate the items of my room					
My room allows me to do my activities freely					
I feel motivated to act and work					
I can do challenging tasks in my room					
I like my workplace in my bedroom to look like as it is					
My room allows me to satisfy my needs					
I can spend long hours learning in my room					
I feel a sense of belonging to my room					
I am happy to be at my room					
I don't like to see visitors in my room					
I like others to get my permission to get into my room					

I like to meet my friends in my room					

Section 3. Perceived performance in dormitory

Please evaluate your perceived performance when you are learning in your bedroom.

Outcomes	Very low	Fairly low	Moderate	Fairly high	Very high
Focused individual study					
Quality of work					
Quantity of work					
In-person communication and discussion with peers					
Virtual meetings					
Creativity					

Section 4. Mood and emotional state

Please use the following scale to indicate the extent to which each word below describes how you feel when you are in your bedroom at this moment in time.

Feeling	Not at all	A little	Somewhat	A lot	Extremely
Refreshed					
Calm					
Fatigued					
Enthusiastic					
Relaxed					
Energetic					
Happy					
Tired					
Revived					
Peaceful					
Worn-out					
Upbeat					

Section 5. Demographic information

1. What is your gender?
    a. Male
    b. Female
    c. Other (Please specify)
    d. Not prefer to answer
2. How old are you?
    a. 18-24 years old
    b. 25 – 29 years old
    c. 30 – 34 years old
    d. 35 years old or older
3. Where do you live? (Drop down – building name from http://housing.gatech.edu/housing-options)
4. How many years have you lived in your current dormitory on campus?
    a. Less than a year
    b. 1 year – less than 2 years
    c. 2 years – less than 3 years
    d. 3 years – less than 4 years

e. 4 years or more

5. How many years have you spent at Georgia Tech?
    a. Less than a year
    b. 1 year – less than 2 years
    c. 2 years – less than 3 years
    d. 3 years – less than 4 years
    e. 4 years or more
6. What is your classification in the school?
    a. Undergraduate student - Freshman
    b. Undergraduate student - Sophomore
    c. Undergraduate student - Junior
    d. Undergraduate student - Senior
    e. Graduate student
    f. Other (Please specify)
7. What is your college? (Dropdown)
    a. Computing
    b. Design
    c. Engineering
    d. Ivan Allen (Liberal Arts)
    e. Science
    f. Scheller (Business)
    g. Others
8. What is your major? – dropdown
9. How many credits are you taking this semester? _____credits
10. What is your ethnicity?
    a. White
    b. Black or African American
    c. Hispanic or Latino
    d. Native American
    e. Asian/ Pacific Islander
    f. Other (Please specify)
11. Where are you from?
    a. Georgia
    b. Other U.S. states than Georgia
    c. Outside of the U.S.

11-2. If the respondent selects c. outside of the US from the precious question, the survey will ask specific countries – drop down list

12. Would you like to enter a raffle for a change to win a prize? You are eligible to enter a raffle if you complete the survey before April 18, 2021: Yes/No

- If yes, the survey will redirect the participants to another survey asking their name and email address.
- If no, the survey ends.

Thank you for participating in the survey!
If you have any questions, please feel free to contact Yujin (yujin.kim@gatech.edu).

REFERENCES

'Ulyani Mohd Najib, N., Aini Yusof, N., & Osman, Z. (2011). Measuring satisfaction with student housing facilities. *American Journal of Engineering and Applied Sciences*, *4*(1), 52–60.

'Ulyani Mohd Najib, N., Aini Yusof, N., & Zainul Abidin, N. (2011). Student residential satisfaction in research universities. *Journal of Facilities Management*, *9*(3), 200–212. https://doi.org/10.1108/14725961111148108

Abisuga, A. O., Famakin, I. O., & Oshodi, O. S. (2016). Educational building conditions and the health of users. *Construction Economics and Building*, *16*(4), 19–34. https://doi.org/10.5130/AJCEB.v16i4.4979

Abu-Obeid, N. N., & Ibrahim, A. F. (2002). The effect of dormitory type and room view on the perception of privacy and territoriality by female residents. *Architectural Science Review*, *45*(3), 231–241. https://doi.org/10.1080/00038628.2002.9697514

Aguilar-Carrasco, M. T., Domínguez-Amarillo, S., Acosta, I., & Sendra, J. J. (2021). Indoor lighting design for healthier workplaces: natural and electric light assessment for suitable circadian stimulus. *Optics Express*, *29*(19), 29899–29917. https://doi.org/10.1364/oe.430747

Al Horr, Y., Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment*, *5*(1), 1–11. https://doi.org/10.1016/j.ijsbe.2016.03.006

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., & Elsarrag, E. (2016). Occupant productivity and office indoor environment quality: A review of the literature. *Building and Environment*, *105*, 369–389. https://doi.org/10.1016/j.buildenv.2016.06.001

Alexander, K. (1996). Facilities management. In K. Alexander (Ed.), *Facilities management: theory and practice* (pp. 1–12). London and New York: Taylor & Francis.

Altaher, Y., & Runnerstrom, M. G. (2018). Psychological restoration practices among

college students. *Journal of College Student Development*, *59*(2), 227–232. https://doi.org/10.1353/csd.2018.0019

Altman, I. (1975). *The environment and social behavior: privacy, personal space, territory, crowding*. Monterey, CA, CA: Brooks/Cole Publishing Company.

American College Health Association. (2019). American college Health Association - National College Health Assessment II. In *Cornell Internation Affairs Review*. https://doi.org/10.37513/ciar.v12i2.517

Amole, D. (2005). Coping strategies for living in student residential facilities in Nigeria. *Environment and Behavior*, *37*(2), 201–219. https://doi.org/10.1177/0013916504267642

Amole, D. (2009). Residential satisfaction in students' housing. *Journal of Environmental Psychology*, *29*, 76–85. https://doi.org/10.1016/j.jenvp.2008.05.006

Amole, D. (2011). Students' housing preferences in southwestern Nigeria. *Journal of Architectural and Planning Research*, *28*(1), 44–57. Retrieved from https://www.jstor.org/stable/43030926

Andersson, R., Nystr, M., & Holmqvist, K. (2010). Sampling frequency and eye-tracking measures: how speed affects durations, latencies, and more. *Journal of Eye Movement Research*, *3*(3), 1–12. https://doi.org/10.16910/jemr.3.3.6

Appel-Meulenbroek, R., Clippard, M., & Pfnür, A. (2018). The effectiveness of physical office environments for employee outcomes: An interdisciplinary perspective of research efforts. *Journal of Corporate Real Estate*, *20*(1), 56–80. https://doi.org/10.1108/JCRE-04-2017-0012

Appel-Meulenbroek, R., Janssen, I., & Groenen, P. (2011). An end-user's perspective on activity-based office concepts. *Journal of Corporate Real Estate*, *13*(2), 122–135. https://doi.org/10.1108/14630011111136830

Aries, M. B. C., Veitch, J. A., & Newsham, G. R. (2010). Windows, view, and office characteristics predict physical and psychological discomfort. *Journal of Environmental Psychology*, *30*(4), 533–541. https://doi.org/10.1016/j.jenvp.2009.12.004

Armitage, L. A., & Amar, J. H. N. (2021). Person-environment fit theory. In R. Appel-Meulenbroek & V. Danvska (Eds.), *A handbook of theories on designing alignment between people and the office environment* (pp. 14–26). Abingdon: Routledge. https://doi.org/10.1201/9781003128830

Association of Research Libraries. (2019). *LibQUAL2019 Survey*. Washington, DC, DC. Retrieved from https://www.libqual.org/documents/LibQual/notebooks/272_6.pdf

Ayoko, O. B., & Ashkanasy, N. M. (2020). Introduction: Organizational behaviour and the physical environment. In O. B. Ayoko & N. M. Ashkanasky (Eds.), *Organizational Behaviour and the Physical Environment*. London and New York: Routledge.

Bae, S., Martin, C. S., & Asojo, A. O. (2020). Higher education students' indoor environmental quality satisfaction benchmark. *Building Research and Information*, 1–16. https://doi.org/10.1080/09613218.2020.1813012

Baik, C., Larcombe, W., & Brooker, A. (2019). How universities can enhance student mental wellbeing: the student perspective. *Higher Education Research and Development*, *38*(4), 674–687. https://doi.org/10.1080/07294360.2019.1576596

Basu, A., Duvall, J., & Kaplan, R. (2019). Attention restoration theory: Exploring the role of soft fascination and mental bandwidth. *Environment and Behavior*, *51*(9–10), 1055–1081. https://doi.org/10.1177/0013916518774400

Baum, A., & Davis, G. E. (1980). Reducing the stress of high-density living: An architectural intervention. *Journal of Personality and Social Psychology*, *38*(3), 471–481. https://doi.org/10.1037/0022-3514.38.3.471

Bavdaz, A. (2018). Past and recent conceptualisations of sociomateriality and its features: Review. *Athens Journal of Social Sciences*, *5*(1), 51–78. https://doi.org/10.30958/ajss.5-1-3

Beckers, R., van der Voordt, T., & Dewulf, G. (2015). A conceptual framework to identify spatial implications of new ways of learning in higher education. *Facilities*, *33*(1/2), 2–19. https://doi.org/10.1108/F-02-2013-0013

Beckers, R., van der Voordt, T., & Dewulf, G. (2016a). Learning space preferences of higher education students. *Building and Environment*, *104*, 243–252. https://doi.org/10.1016/j.buildenv.2016.05.013

Beckers, R., van der Voordt, T., & Dewulf, G. (2016b). Why do they study there? Diary research into students' learning space choices in higher education. *Higher Education Research and Development*, *35*(1), 142–157. https://doi.org/10.1080/07294360.2015.1123230

Beiter, R., Nash, R., McCrady, M., Rhoades, D., Linscomb, M., Clarahan, M., & Sammut, S. (2015). The prevalence and correlates of depression, anxiety, and stress in a sample of college students. *Journal of Affective Disorders*, *173*, 90–96. https://doi.org/10.1016/j.jad.2014.10.054

Bennett, S. (2007). First questions for designing higher education learning spaces. *Journal of Academic Librarianship*, *33*(1), 14–26. https://doi.org/10.1016/j.acalib.2006.08.015

Bentler, P. M., & Chou, C.-P. (1987). Practical issues in structural modeling. *Sociological Methods & Research*, *16*(1), 78–117. https://doi.org/10.1177/0049124187016001004

Berman, M. G., Hout, M. C., Kardan, O., Hunter, M. C. R., Yourganov, G., Henderson, J. M., … Jonides, J. (2014). The perception of naturalness correlates with low-level visual features of environmental scenes. *PLoS ONE*, *9*(12). https://doi.org/10.1371/journal.pone.0114572

Berto, R., Massaccesi, S., & Pasini, M. (2008). Do eye movements measured across high and low fascination photographs differ? Addressing Kaplan's fascination hypothesis. *Journal of Environmental Psychology*, *28*(2), 185–191. https://doi.org/10.1016/j.jenvp.2007.11.004

Bettencourt, B. A., Charlton, K., Eubanks, J., Kernahan, C., & Fuller, B. (1999). Development of collective self-esteem among students: Predicting adjustment to college. *Basic and Applied Social Psychology*, *21*(3), 213–222. https://doi.org/10.1207/S15324834BASP2103_5

Bhargava, T. D. *Overview: The science of mental bandwidth*. , (2020).

Bland, J. M., & Altman, D. G. (1997). Statistics notes: Cronbach's alpha. *BMJ*, *314*, 572. https://doi.org/10.1136/bmj.314.7080.572

Blignaut, P. (2009). Fixation identification: The optimum threshold for a dispersion algorithm. *Attention, Perception, & Psychophysics*, *71*(4), 881–895. https://doi.org/10.3758/APP.71.4.881

Block, M., de Korte, E., Groenesteijn, L., Formanoy, M., & Vink, P. (2009). The effects of a task facilitating working environment on office space use, communication, collaboration, privacy and distraction. *The 17th World Congress on Ergonomics (IEA 2009)*, 9–14. Beijing, China, China: International Ergonomics Association.

Bluyssen, P. M., Janssen, S., van den Brink, L. H., & de Kluizenaar, Y. (2011). Assessment of wellbeing in an indoor office environment. *Building and Environment*, *46*(12), 2632–2640. https://doi.org/10.1016/j.buildenv.2011.06.026

Bonde, M., & Ramirez, J. (2015). A post-occupancy evaluation of a green rated and conventional on-campus residence hall. *International Journal of Sustainable Built Environment*, *4*(2), 400–408. https://doi.org/10.1016/j.ijsbe.2015.07.004

Braat-Eggen, P. E., Poll, M. K. v.d., Hornikx, M., & Kohlrausch, A. (2019). Auditory distraction in open-plan study environments: Effects of background speech and reverberation time on a collaboration task. *Applied Acoustics*, *154*, 148–160. https://doi.org/10.1016/j.apacoust.2019.04.038

Braat-Eggen, P. E., van Heijst, A., Hornikx, M., & Kohlrausch, A. (2017). Noise disturbance in open-plan study environments: a field study on noise sources, student tasks and room acoustic parameters. *Ergonomics*, *60*(9), 1297–1314. https://doi.org/10.1080/00140139.2017.1306631

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *esting structural equation models* (pp. 136–162). Newbury Park, CA: SAGE Publications.

Brunia, S., De Been, I., & van der Voordt, T. J. M. (2016). Accommodating new ways of working: lessons from best practices and worst cases. *Journal of Corporate Real Estate*, *18*(1), 30–47. https://doi.org/10.1108/JCRE-10-2015-0028

Bryant, J., Matthews, G., & Walton, G. (2009). Academic libraries and social and learning space: A case study of Loughborough university library, UK. *Journal of Librarianship and Information Science*, *41*(1), 7–18. https://doi.org/10.1177/0961000608099895

Byrka, K., & Ryczko, N. (2018). Positive effects of dancing in natural versus indoor settings: The mediating role of engagement in physical activity. *Journal of Environmental Psychology*, *57*, 25–33. https://doi.org/10.1016/j.jenvp.2018.06.002

Byrnes, K. G., Kiely, P. A., Dunne, C. P., McDermott, K. W., & Coffey, J. C. (2021). Communication, collaboration and contagion: "Virtualisation" of anatomy during COVID-19. *Clinical Anatomy*, *34*, 82–89. https://doi.org/10.1002/ca.23649

Callender, J., Fagin, L., Jenkins, G., Lester, J., Smith, E., Baig, B., … Smith, D. (2011). *Mental health of students in higher education*.

Camilli, M., Nacchia, R., Terenzi, M., & Di Nocera, F. (2008). ASTEF: A simple tool for examining fixations. *Behavior Research Methods*, *40*(2), 373–382. https://doi.org/10.3758/BRM.40.2.373

Campbell, J. P. (1990). Modeling the performance prediction problem in industrial and organizational psychology. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of Industrial and Organizational Psychology* (2nd ed., pp. 687–732). Palo Alto, CA, CA: Consulting Psychologists Press, Inc.

Capio, C. M., Sit, C. H. P., & Abernethy, B. (2014). Physical well-being. In *Encyclopedia of Quality of Life and Well-being Research*. Springer. https://doi.org/10.1007/978-94-007-0753-5_2166

Case, F. D. (1981). Dormitory architecture influences: Patterns of student social relations over time. *Environment and Behavior*, *13*(1), 23–41.

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology*, *27*(2), 270–295. https://doi.org/10.1006/ceps.2001.1094

Cha, S. H., & Kim, T. W. (2015). What matters for students' use of physical library space? *Journal of Academic Librarianship*, *41*(3), 274–279. https://doi.org/10.1016/j.acalib.2015.03.014

Cha, S. H., & Kim, T. W. (2020). The role of space attributes in space-choice behaviour and satisfaction in an academic library. *Journal of Librarianship and Information Science*, *52*(2), 399–409. https://doi.org/10.1177/0961000618794257

Chiu, P. H. P., & Cheng, S. H. (2017). Effects of active learning classrooms on student learning: a two-year empirical investigation on student perceptions and academic performance. *Higher Education Research & Development*, *36*(2), 269–279. https://doi.org/10.1080/07294360.2016.1196475

Choe, E. Y., Jorgensen, A., & Sheffield, D. (2020). Simulated natural environments bolster the effectiveness of a mindfulness programme: A comparison with a relaxation-based intervention. *Journal of Environmental Psychology*, *67*(101382). https://doi.org/10.1016/j.jenvp.2019.101382

Choi, S. D., Rosenthal, D., & Hauser, S. (2013). Health and safety issues of older workers surveyed in the construction industry. *Industrial and Systems Engineering Review*, *1*(2), 123–131.

Choy, F. C., & Goh, S. N. (2016). A framework for planning academic library spaces. *Library Management*, *37*(1–2), 13–28. https://doi.org/10.1108/LM-01-2016-0001

Cleveland, B., & Fisher, K. (2014). The evaluation of physical learning environments: A critical review of the literature. *Learning Environments Research*, *17*, 1–28. https://doi.org/10.1007/s10984-013-9149-3

Codinhoto, R., Tzortzopoulos, P., Kagioglou, M., Aouad, G., & Cooper, R. (2009). The impacts of the built environment on health outcomes. *Facilities*, *27*(3–4), 138–151. https://doi.org/10.1108/02632770910933152

Collins, M. E., & Mowbray, C. T. (2005). Higher education and psychiatric disabilities: National survey of campus disability services. *American Journal of Orthopsychiatry*, *75*(2), 304–315. https://doi.org/10.1037/0002-9432.75.2.304

Conniff, A., & Craig, T. (2016). A methodological approach to understanding the wellbeing and restorative benefits associated with greenspace. *Urban Forestry and Urban Greening*, *19*, 103–109. https://doi.org/10.1016/j.ufug.2016.06.019

Cooper, R., Boyko, C., & Codinhoto, R. (2010). The effect of the physical environment on mental wellbeing. In C. L. Cooper, J. Field, U. Goswami, R. Jenkins, & B. J. Sahakian (Eds.), *Mental capital and wellbeing* (pp. 967–1006). Blackwell.

Crawford, J., Henderson, K. B., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., … Lam, S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. *Journal of Applied Learning & Teaching*, *3*(1), 9–28. Retrieved from http://journals.sfu.ca/jalt/index.php/jalt/index

Dada, J. O., Babatunde, S. O., & Adeleye, R. O. (2019). Assessment of academic stress and coping strategies among built environment undergraduate students in Nigerian higher education. *Journal of Applied Research in Higher Education*, *11*(3), 367–378.

https://doi.org/10.1108/JARHE-06-2018-0100

Dahlberg, J. (2010). *Eye Tracking With Eye Glasses* (UMEA University, Sweden). UMEA University, Sweden. Retrieved from http://www.diva-portal.org/smash/get/diva2:306465/FULLTEXT01.pdf

Daniels, K., Watson, D., & Gedikli, C. (2017). Well-being and the social environment of work: A systematic review of intervention studies. *International Journal of Environmental Research and Public Health*, *14*(8). https://doi.org/10.3390/ijerph14080918

Danna, K., & Griffin, R. W. (1999). Health and well-being in the workplace: A review and synthesis of the literature. *Journal of Management*, *25*(3), 357–384. https://doi.org/10.1177/014920639902500305

DeClercq, C. P., & Cranz, G. (2014). Moving beyond seating-centered learning environments: Opportunities and challenges identified in a POE of a campus library. *Journal of Academic Librarianship*, *40*(6), 574–584. https://doi.org/10.1016/j.acalib.2014.08.005

Deed, C., & Alterator, S. (2017). Informal learning spaces and their impact on learning in higher education: Framing new narratives of participation. *Journal of Learning Spaces*, *6*(3), 54–58.

Devine-Wright, P., Pinto de Carvalho, L., Di Masso, A., Lewicka, M., Manzo, L., & Williams, D. R. (2020). "Re-placed" - Reconsidering relationships with place and lessons from a pandemic. *Journal of Environmental Psychology*, *72*, 101514. https://doi.org/10.1016/j.jenvp.2020.101514

Devlin, A. S., Donovan, S., Nicolov, A., Nold, O., & Zandan, G. (2008). Residence hall architecture and sense of community: Everything old is new again. *Environment and Behavior*, *40*(4), 487–521. https://doi.org/10.1177/0013916507301128

Diener, E. (2000). Subjective well-being: The science of happiness and a proposal for a national index. *American Psychologist*, *55*(1), 34–43. https://doi.org/10.1037/0003-066X.55.1.34

Dodge, R., Daly, A., Huyton, J., & Sanders, L. (2012). The challenge of defining wellbeing. *International Journal of Wellbeing*, *2*(3), 222–235. https://doi.org/10.5502/ijw.v2i3.4

Dreyer, B. C., Coulombe, S., Whitney, S., Riemer, M., & Labbé, D. (2018). Beyond exposure to outdoor nature: Exploration of the benefits of a green building's indoor environment on wellbeing. *Frontiers in Psychology*, *9*, 1–17. https://doi.org/10.3389/fpsyg.2018.01583

Duchowski, A. T. (2017). *Eye tracking methodology: Theory and practice* (3rd editio). Springer International Publishing. https://doi.org/10.1007/978-3-319-57883-5

Dupont, L., Antrop, M., & Van Eetvelde, V. (2014). Eye-tracking analysis in landscape perception research: Influence of photograph properties and landscape characteristics. *Landscape Research*, *39*(4), 417–432. https://doi.org/10.1080/01426397.2013.773966

Dusselier, L., Dunn, B., Wang, Y., Shelley, M. C., & Whalen, D. F. (2005). Personal, health, academic, and environmental predictors of stress for residence hall students. *Journal of American College Health*, *54*(1), 15–24. https://doi.org/10.3200/JACH.54.1.15-24

El Ansari, W., & Stock, C. (2010). Is the health and wellbeing of university students associated with their academic performance? Cross sectional findings from the United Kingdom. *International Journal of Environmental Research and Public Health*, *7*(2), 509–527. https://doi.org/10.3390/ijerph7020509

Ellis, R. A., & Goodyear, P. (2016). Models of learning space: integrating research on space, place and learning in higher education. *Review of Education*, *4*(2), 149–191. https://doi.org/10.1002/rev3.3056

Ellison, W. (2016). Designing the learning spaces of a university library. *New Library World*, *117*(5–6), 294–307. https://doi.org/10.1108/NLW-01-2016-0006

Evans, G. W. (2003). The built environment and mental health. *Journal of Urban Health*, *80*(4), 536–555. https://doi.org/10.1093/jurban/jtg063

Evensen, K. H., Raanaas, R. K., Hagerhall, C. M., Johansson, M., & Patil, G. G. (2015). Restorative elements at the computer workstation: A comparison of live plants and inanimate objects with and without window view. *Environment and Behavior*, *47*(3), 288–303. https://doi.org/10.1177/0013916513499584

Felsten, G. (2009). Where to take a study break on the college campus: An attention restoration theory perspective. *Journal of Environmental Psychology*, *29*(1), 160–167.

https://doi.org/10.1016/j.jenvp.2008.11.006

Fenollar, P., Román, S., & Cuestas, P. J. (2007). University students' academic performance: An integrative conceptual framework and empirical analysis. *British Journal of Educational Psychology*, *77*(4), 873–891. https://doi.org/10.1348/000709907X189118

Fernandez, A., Howse, E., Rubio-Valera, M., Thorncraft, K., Noone, J., Luu, X., … Salvador-Carulla, L. (2016). Setting-based interventions to promote mental health at the university: a systematic review. *International Journal of Public Health*, *61*(7), 797–807. https://doi.org/10.1007/s00038-016-0846-4

Franěk, M., Šefara, D., Petružálek, J., Cabal, J., & Myška, K. (2018). Differences in eye movements while viewing images with various levels of restorativeness. *Journal of Environmental Psychology*, *57*, 10–16. https://doi.org/10.1016/j.jenvp.2018.05.001

Franz, J. (2019). Towards a spatiality of wellbeing. In H. Hughes, J. Franz, & J. Willis (Eds.), *School spaces for student wellbeing* (pp. 3–19). Springer. Retrieved from https://doi.org/10.1007/978-981-13-6092-3

Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *Journal of Experimental Education*, *75*(3), 203–220. https://doi.org/10.3200/JEXE.75.3.203-220

Friedman, N. P., & Miyake, A. (2004). The reading span test and its predictive power for reading comprehension ability. *Journal of Memory and Language*, *51*, 136–158. https://doi.org/10.1016/j.jml.2004.03.008

Fruehwirth, J. C., Biswas, S., & Perreira, K. M. (2021). The Covid-19 pandemic and mental health of first-year college students: Examining the effect of Covid-19 stressors using longitudinal data. *PLoS ONE*, *16*(3), e0247999. https://doi.org/10.1371/journal.pone.0247999

Gauvin, L., & Rejeski, W. J. (1993). The exercise-induced feeling inventory: Development and initial validation. *Journal of Sport and Exercise Psychology*, *15*(4), 403–423. https://doi.org/10.1123/jsep.15.4.403

Haapakangas, A., Hallman, D. M., Mathiassen, S. E., & Jahncke, H. (2018). Self-rated productivity and employee well-being in activity-based offices: The role of environmental perceptions and workspace use. *Building and Environment*, *145*, 115–

124. https://doi.org/10.1016/j.buildenv.2018.09.017

Haapakangas, A., Hongisto, V., Varjo, J., & Lahtinen, M. (2018). Benefits of quiet workspaces in open-plan offices – Evidence from two office relocations. *Journal of Environmental Psychology*, *56*, 63–75. https://doi.org/10.1016/j.jenvp.2018.03.003

Hähn, N., Essah, E., & Blanusa, T. (2020). Biophilic design and office planting: a case study of effects on perceived health, well-being and performance metrics in the workplace. *Intelligent Buildings International*. https://doi.org/10.1080/17508975.2020.1732859

Hamilton, C. (2009). Fusion building: New trend with some old roots. *Planning for Higher Education*, *37*(2), 44–51.

Harrop, D., & Turpin, B. (2013). A study exploring learners' informal learning space behaviors, attitudes, and preferences. *New Review of Academic Librarianship*, *19*(1), 58–77. https://doi.org/10.1080/13614533.2013.740961

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, *23*(2), 109–123. https://doi.org/10.1016/S0272-4944(02)00109-3

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research*, *14*(4), 175–194. https://doi.org/10.1080/02815739708730435

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, *35*(1), 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Hassanain, M. A. (2007). Post-Occupancy indoor environmental quality evaluation of student housing facilities. *Architectural Engineering and Design Management*, *3*(4), 249–256. https://doi.org/10.1080/17452007.2007.9684646

Hassanain, M. A., & Mudhei, A. A. (2006). Post-occupancy evaluation of academic and research library facilities. *Structural Survey*, *24*(3), 230–239. https://doi.org/10.1108/02630800610678878

Haynes, B. P. (2007). Office productivity: a theoretical framework. *Journal of Corporate*

Real Estate, *9*(2), 97–110. https://doi.org/10.1108/14630010710828108

Hefner, J., & Eisenberg, D. (2009). Social support and mental health among college students. *American Journal of Orthopsychiatry*, *79*(4), 491–499. https://doi.org/10.1037/a0016918

Heilweil, M. (1973). The influence of dormitory architecture on resident behavior. *Environment and Behavior*, *5*(4), 377–412.

Henderson, J. M., Williams, C. C., Castelhano, M. S., & Falk, R. J. (2003). Eye movements and picture processing during recognition. *Perception and Psychophysics*, *65*(5), 725–734. https://doi.org/10.3758/BF03194809

Hernández, R. (2012). Collaborative learning: Increasing students' engagement outside the classroom. *US-China Education Review*, *9*, 804–812.

High, T., & Sundstrom, E. (1977). Room flexibility and space use in a dormitory. *Environment and Behavior*, *9*(1), 81–90. https://doi.org/10.1177/001391657791005

Hill, M. C., & Epps, K. K. (2010). The impact of physical classroom environment on student satisfaction and student evaluation of teaching in the university environment. *Academy of Educational Leadership Journal*, *14*(4), 65–79.

Hills, H. (2001). *Team-based learning*. Hampshire: Gower Publishing Limited.

Hipp, J. A., Gulwadi, G. B., Alves, S., & Sequeira, S. (2016). The relationship between perceived greenness and perceived restorativeness of university campuses and student-reported quality of life. *Environment and Behavior*, *48*(10), 1292–1308. https://doi.org/10.1177/0013916515598200

Hipp, J. A., & Ogunseitan, O. A. (2011). Effect of environmental conditions on perceived psychological restorativeness of coastal parks. *Journal of Environmental Psychology*, *31*(4), 421–429. https://doi.org/10.1016/j.jenvp.2011.08.008

Hoisington, A. J., Stearns-Yoder, K. A., Schuldt, S. J., Beemer, C. J., Maestre, J. P., Kinney, K. A., … Brenner, L. A. (2019). Ten questions concerning the built environment and mental health. *Building and Environment*, *155*, 58–69. https://doi.org/10.1016/j.buildenv.2019.03.036

Hong, S., Kim, Y., & Yang, E. (2021). Indoor environment and student productivity for individual and collaborative work in learning commons: a case study. *Library Management*. https://doi.org/10.1108/LM-06-2021-0055

Hoque, S., & Weil, B. (2016). The relationship between comfort perceptions and academic performance in university classroom buildings. *Journal of Green Building*, *11*(1), 108–117. https://doi.org/10.3992/jgb.11.1.108.1

Hu, L.-T., & Bentler, P. M. (1995). Evaluating model fit. In R. H. Hoyle (Ed.), *Structural equation modeling: Concepts, issues, and applications* (pp. 76–99). Sage Publications, Inc.

Ibrahim, I., Yusoff, W. Z. W., & Sidi, N. S. S. (2011). Space charging model: Cost analysis on classrooms in higher education institutions. *Procedia - Social and Behavioral Sciences*, *28*, 246–252. https://doi.org/10.1016/j.sbspro.2011.11.048

Ibrahim, N., & Fadzil, N. H. (2013). Informal setting for learning on campus: Usage and preference. *Procedia - Social and Behavioral Sciences*, *105*, 344–351. https://doi.org/10.1016/j.sbspro.2013.11.036

International Facility Management Association (IFMA). (2003). What is Facility Management? Retrieved from International Facility Management Association (IFMA) website: https://www.ifma.org/about/what-is-facility-management#

International Living Future Institute. (2018). *Biophilic design guidebook*. Retrieved from https://living-future.org/wp-content/uploads/2019/01/18-0605_Biophilic-Design-Guidebook.pdf

Jamieson, P. (2003). Designing more effective on-campus teaching and learning spaces: a role for academic developers. *International Journal for Academic Development*, *8*(1–2), 119–133. https://doi.org/10.1080/1360144042000277991

Jens, K., & Gregg, J. S. (2021a). Building performances in open and enclosed spaces: a method for balancing operational costs and space utilization with a focus on user needs and satisfaction. *Architectural Engineering and Design Management*. https://doi.org/10.1080/17452007.2021.1941742

Jens, K., & Gregg, J. S. (2021b). The impact on human behaviour in shared building spaces as a result of COVID-19 restrictions. *Building Research and Information*. https://doi.org/10.1080/09613218.2021.1926217

Johnson, W. G., & Cavins, K. M. (1996). Strategies for enhancing student learning in residence halls. *New Directions for Student Services*, *1996*(75), 69–82. https://doi.org/10.1002/ss.37119967508

Jung, M., Jonides, J., Northouse, L., Berman, M. G., Koelling, T. M., & Pressler, S. J. (2017). Randomized crossover study of the natural restorative environment intervention to improve attention and mood in heart failure. *Journal of Cardiovascular Nursing*, *32*(5), 464–479. https://doi.org/10.1097/JCN.0000000000000368

Kaarlela-Tuomaala, A., Helenius, R., Keskinen, E., & Hongisto, V. (2009). Effects of acoustic environment on work in private office rooms and open-plan offices–longitudinal study during relocation. *Ergonomics*, *52*(11), 1423–1444. https://doi.org/10.1080/00140130903154579

Kaplan, R., & Kaplan, S. (1989). *The experience nature: A psychological perspective*. Cambridge University Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Kaplan, S. (2001). Meditation, restoration, and the management of mental fatigue. *Environment and Behavior*, *33*(4), 480–506. https://doi.org/10.1177/00139160121973106

Kariippanon, K. E., Cliff, D. P., Lancaster, S. L., Okely, A. D., & Parrish, A. M. (2018). Perceived interplay between flexible learning spaces and teaching, learning and student wellbeing. *Learning Environments Research*, *21*(3), 301–320. https://doi.org/10.1007/s10984-017-9254-9

Kaya, N., & Erkip, F. (2001). Satisfaction in a dormitory building. The effects of floor height on the perception of room size and crowding. *Environment and Behavior*, *33*(1), 35–53. https://doi.org/10.1177/00139160121972855

Kaya, N., & Weber, M. J. (2003). Cross-cultural differences in the perception of crowding and privacy regulation: American and Turkish students. *Journal of Environmental Psychology*, *23*(3), 301–309. https://doi.org/10.1016/S0272-4944(02)00087-7

Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. In S. R.

Kellert, J. H. Heerwagen, & M. L. Mador (Eds.), *Biophilic design: The theory, science, and practice of bringing buildings to life* (pp. 3–20). Hoboken, NJ: John Wiley & Sons, Inc.

Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (Eds.). (2008). *Biophilic design: The theory, science, and practice of bringing buildings to life*. Hoboken, NJ: John Wiley & Sons, Inc.

Khozaei, F., Hassan, A. S., & Razak, N. A. (2011). Development and validation of the student accommodation preferences instrument (SAPI). *Journal of Building Appraisal*, *6*(3–4), 299–313. https://doi.org/10.1057/jba.2011.7

Kim, D., Bosch, S., & Lee, J. H. (2020). Alone with others: Understanding physical environmental needs of students within an academic library setting. *Journal of Academic Librarianship*, *46*(2), 102098. https://doi.org/10.1016/j.acalib.2019.102098

Kim, J. A. (2016). Dimensions of user perception of academic library as place. *Journal of Academic Librarianship*, *42*, 509–514. https://doi.org/10.1016/j.acalib.2016.06.013

Kim, J., Cha, S. H., Koo, C., & Tang, S.-K. (2018). The effects of indoor plants and artificial windows in an underground environment. *Building and Environment*, *138*, 53–62. https://doi.org/10.1016/j.buildenv.2018.04.029

Kim, Y., Hong, S., & Yang, E. (2021). Perceived productivity in open-plan design library: Exploring occupant behavior and perception. *Journal of Learning Spaces*, *10*(3), 28–42.

Kim, Y., & Yang, E. (2020). Theoretical understanding of sociomateriality in workplace studies. *Facilities*, *38*(13–14), 927–942. https://doi.org/10.1108/F-10-2019-0112

King, J. G. (2016). Extended and experimenting: library learning commons service strategy and sustainability. *Library Management*, *37*(4/5), 265–274. https://doi.org/10.1108/LM-04-2016-0028

Kinnafick, F. E., & Thøgersen-Ntoumani, C. (2014). The effect of the physical environment and levels of activity on affective states. *Journal of Environmental Psychology*, *38*, 241–251. https://doi.org/10.1016/j.jenvp.2014.02.007

Kocaman, G. Y., Sezer, F. S., & Cetinkol, T. (2017). User satisfaction of indoor environmental quality in student dormitories. *European Journal of Sustainable Development*, *6*(1), 11–12. https://doi.org/10.14207/ejsd.2017.v6n1p11

Korpela, K. M., Ylén, M., Tyrväinen, L., & Silvennoinen, H. (2008). Determinants of restorative experiences in everyday favorite places. *Health and Place*, *14*(4), 636–652. https://doi.org/10.1016/j.healthplace.2007.10.008

Kuntz, A. M., Petrovic, J. E., & Ginocchio, L. (2012). A changing sense of place: A case study of academic culture and the built environment. *Higher Education Policy*, *25*(4), 433–451. https://doi.org/10.1057/hep.2011.29

Kwon, M., & Remøy, H. (2020). Office employee satisfaction: the influence of design factors on psychological user satisfaction. *Facilities*, *38*(1/2), 1–19. https://doi.org/10.1108/F-03-2019-0041

Kwon, M., Remøy, H., & van den Dobbelsteen, A. (2019). User-focused office renovation: a review into user satisfaction and the potential for improvement. *Property Management*, *37*(4), 470–489. https://doi.org/10.1108/PM-04-2018-0026

Lahelma, E., & Gordon, T. (2003). Home as a physical, social and mental space: Young people's reflections on leaving home. *Journal of Youth Studies*, *6*(4), 377–390. https://doi.org/10.1080/1367626032000162104

Lawrence, D. L., & Low, S. M. (1990). The built environment and spatial form. *Annual Review of Anthropology*, *19*, 453–505.

Leder, H., Mitrovic, A., & Goller, J. (2016). How beauty determines gaze! Facial attractiveness and gaze duration in images of real world scenes. *I-Perception*, *7*(4), 1–12. https://doi.org/10.1177/2041669516664355

Lee, Y. S. (2014). Collaborative activities and library indoor environmental quality affecting performance, health, and well-being of different library user groups in higher education. *Facilities*, *32*(3/4), 88–103. https://doi.org/10.1108/F-02-2013-0012

Lee, Y. S., & Schottenfeld, M. (2014). Collaborative knowledge creation in the higher education academic library. *Journal of Learning Spaces*, *3*(1).

Leech, J. A., Nelson, W. C., Burnett, R. T., Aaron, S., & Raizenne, M. E. (2002). It's about

time: A comparison of Canadian and American time-activity patterns. *Journal of Exposure Analysis and Environmental Epidemiology*, *12*(6), 427–432. https://doi.org/10.1038/sj.jea.7500244

Lefebvre, H. (1991). *The production of space*. Oxford: Blackwell.

Leonardi, P. M. (2012). Materiality, sociomateriality, and socio-technical systems: What do these terms mean? How are they different? Do we need them? In P. M. Leonardi, B. A. Nardi, & J. Kallinikos (Eds.), *Materiality and organizing: Social interaction in a technological world.* Oxford university press.

Leonardi, P. M. (2013). Theoretical foundations for the study of sociomateriality. *Information and Organization*, *23*(2), 59–76. https://doi.org/10.1016/j.infoandorg.2013.02.002

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning*, *148*, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015

Li, P., Froese, T. M., & Brager, G. (2018). Post-occupancy evaluation: State-of-the-art analysis and state-of-the-practice review. *Building and Environment*, *133*, 187–202. https://doi.org/10.1016/j.buildenv.2018.02.024

Loftus, G. R., & Mackworth, N. H. (1978). Cognitive determinants of fixation location during picture viewing. *Journal of Experimental Psychology: Human Perception and Performance*, *4*(4), 565–572. https://doi.org/10.1037//0096-1523.4.4.565

Low, S., & Smart, A. (2020). Thoughts about public space during Covid-19 pandemic. *City and Society*, *32*(1), 1–5. https://doi.org/10.1111/ciso.12260

Lundström, A., Savolainen, J., & Kostiainen, E. (2016). Case study: developing campus spaces through co-creation. *Architectural Engineering and Design Management*, *12*(6), 409–426. https://doi.org/10.1080/17452007.2016.1208077

Mahyuddin, N., & Law, J. B. (2019). Indoor environmental quality assessment in a learning space: University of Malaya's main library. *Journal of Surveying, Construction & Property*, *10*(1), 1–15. https://doi.org/10.22452/jscp.vol10no1.1

Marchand, G. C., Nardi, N. M., Reynolds, D., & Pamoukov, S. (2014). The impact of the

classroom built environment on student perceptions and learning. *Journal of Environmental Psychology*, *40*, 187–197. https://doi.org/10.1016/j.jenvp.2014.06.009

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology*, *106*(3), 857–864.

Martínez-Soto, J., de la Fuente Suárez, L. A., Gonzáles-Santos, L., & Barrios, F. A. (2019). Observation of environments with different restorative potential results in differences in eye patron movements and pupillary size. *IBRO Reports*, *7*, 52–58. https://doi.org/10.1016/j.ibror.2019.07.1722

Maxwell, L. E. (2016). School building condition, social climate, student attendance and academic achievement: A mediation model. *Journal of Environmental Psychology*, *46*, 206–216. https://doi.org/10.1016/j.jenvp.2016.04.009

McFarland, A. L., Waliczek, T. M., & Zajicek, J. M. (2008). The relatiobship between student use of campus green spaces and perceptions of quality of life. *HortTechnology*, *18*(2), 232–238. https://doi.org/10.21273/HORTTECH.18.2.232

McLaughlin, P., & Faulkner, J. (2012). Flexible spaces … what students expect from university facilities. *Journal of Facilities Management*, *10*(2), 140–149. https://doi.org/10.1108/14725961211218776

Moffatt, S., & Kohler, N. (2008). Conceptualizing the built environment as a social-ecological system. *Building Research and Information*, *36*(3), 248–268. https://doi.org/10.1080/09613210801928131

Muhammad, S., Sapri, M., & Sipan, I. (2014). Academic buildings and their influence on students' wellbeing in higher education institutions. *Social Indicators Research*, *115*(3), 1159–1178. https://doi.org/10.1007/s11205-013-0262-6

Mulrooney, H. M., & Kelly, A. F. (2021). Belonging, the physical space of the university campus and how it is perceived by students: a quantitative analysis among a diverse student group. *Journal of Learning Spaces*, *10*(2), 1–13.

Navarro-Bringas, E., Bowles, G., & Walker, G. H. (2020). Embracing complexity: a sociotechnical systems approach for the design and evaluation of higher education learning environments. *Theoretical Issues in Ergonomics Science*, *21*(5), 595–613. https://doi.org/10.1080/1463922X.2020.1723037

Ning, Y., & Chen, J. (2016). Improving residential satisfaction of university dormitories through post-occupancy evaluation in China: A socio-technical system approach. *Sustainability*, *8*, 1050. https://doi.org/10.3390/su8101050

Noland, R. B., Weiner, M. D., Gao, D., Cook, M. P., & Nelessen, A. (2017). Eye-tracking technology, visual preference surveys, and urban design: preliminary evidence of an effective methodology. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, *10*(1), 98–110. https://doi.org/10.1080/17549175.2016.1187197

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science*, *5*(1), 14–37.

Nordh, H. (2012). Quantitative methods of measuring restorative components in urban public parks. *Journal of Landscape Architecture*, *7*(1), 46–53. https://doi.org/10.1080/18626033.2012.693780

Nordh, H., Hagerhall, C. M., & Holmqvist, K. (2013). Tracking restorative components: Patterns in eye movements as a consequence of a restorative rating task. *Landscape Research*, *38*(1), 101–116. https://doi.org/10.1080/01426397.2012.691468

Nordh, H., Hartig, T., Hagerhall, C. M., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry and Urban Greening*, *8*, 225–235. https://doi.org/10.1016/j.ufug.2009.06.003

Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies*, *28*(9), 1435–1448. https://doi.org/10.1177/0170840607081138

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals*, *2*(1), 433–474. https://doi.org/10.5465/19416520802211644

Paavola, S., Lipponen, L., & Hakkarainen, K. (2004). Models of innovative knowledge communities and three metaphors of learning. *Review of Educational Research*, *74*(4), 557–576. https://doi.org/10.3102/00346543074004557

Parkin, J. K., Austin, S. A., Pinder, J. A., Baguley, T. S., & Allenby, S. N. (2011). Balancing collaboration and privacy in academic workspaces. *Facilities*, *29*(1), 31–49. https://doi.org/10.1108/02632771111101313

Parmiggiani, E., & Mikalsen, M. (2013). The facets of sociomateriality: A systematic mapping of emerging concepts and definitions. *Scandinavian Conference on Information Systems*, 87–103. https://doi.org/10.1007/978-3-642-39832-2

Pearshouse, I., Bligh, B., Brown, E., Lewthwaite, S., Graber, R., Hartnell-Young, E., & Sharples, M. (2009). A study of effective evaluation models and practices for technology supported physical learning spaces (JELS). In *JISC*. Retrieved from http://www.jisc.ac.uk/whatwedo/projects/learningspaces08.aspx%0ACopyright

Peker, E., & Ataöv, A. (2020). Exploring the ways in which campus open space design influences students' learning experiences. *Landscape Research*, *45*(3), 310–326. https://doi.org/10.1080/01426397.2019.1622661

Perkins, S., Searight, H. R., & Ratwik, S. (2011). Walking in a natural winter setting to relieve attention fatigue: A pilot study. *Psychology*, *2*(8), 777–780. https://doi.org/10.4236/psych.2011.28119

Qualter, P., Vanhalst, J., Harris, R., Van Roekel, E., Lodder, G., Bangee, M., … Verhagen, M. (2015). Loneliness across the life span. *Perspectives on Psychological Science*, *10*(2), 250–264. https://doi.org/10.1177/1745691615568999

Raanaas, R. K., Evensen, K. H., Rich, D., Sjøstrøm, G., & Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology*, *31*(1), 99–105. https://doi.org/10.1016/j.jenvp.2010.11.005

Ramsden, B. (2011). Evaluating the impact of learning space. *Reference Services Review*, *39*(3), 451–464. https://doi.org/10.1108/00907321111161430

Rauthmann, J. F., Seubert, C. T., Sachse, P., & Furtner, M. R. (2012). Eyes as windows to the soul: Gazing behavior is related to personality. *Journal of Research in Personality*, *46*, 147–156. https://doi.org/10.1016/j.jrp.2011.12.010

Richardson, M., Abraham, C., & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin*, *138*(2), 353–387. https://doi.org/10.1037/a0026838

Riddle, M. D., & Souter, K. (2012). Designing informal learning spaces using student perspectives. *Journal of Learning Spaces*, *1*(2).

Rinn, A. (2004). Academic and social effects of living in honors residence halls. *Journal of the National Collegiate Honors Council*, *173*, 67–80. Retrieved from https://digitalcommons.unl.edu/nchcjournal/173/

Rodger, S. C., & Johnson, A. M. (2005). The impact of residence design on freshman outcomes: Dormitories versus suite-style residences. *The Canadian Journal of Higher Education*, *35*(3), 83–99.

Rogerson, M., Gladwell, V. F., Gallagher, D. J., & Barton, J. L. (2016). Influences of green outdoors versus indoors environmental settings on psychological and social outcomes of controlled exercise. *International Journal of Environmental Research and Public Health*, *13*, 363. https://doi.org/10.3390/ijerph13040363

Rollings, K. A., & Evans, G. W. (2019). Design moderators of perceived residential crowding and chronic physiological stress among children. *Environment and Behavior*, *51*(5), 590–621. https://doi.org/10.1177/0013916518824631

Salvucci, D. D., & Goldberg, J. H. (2000). Identifying fixations and saccades in eye-tracking protocols. *Eye Tracking Research & Applications Symposium*, 71–78. https://doi.org/10.1145/355017.355028

Sankari, I., Peltokorpi, A., & Nenonen, S. (2018). A call for co-working – users' expectations regarding learning spaces in higher education. *Journal of Corporate Real Estate*, *20*(2), 117–137. https://doi.org/10.1108/JCRE-03-2017-0007

Schopfel, J., Roche, J., & Hubert, G. (2015). Co-working and innovation: New concepts for academic libraries and learning centres. *New Library World*, *116*(1), 67–78. https://doi.org/10.1108/NLW-06-2014-0072

Scott-Webber, L., Strickland, A., & Kapitula, L. (2013). Built environments impact behaviors: Results of an active-learning post-occupancy evaluation. *Planning for Higher Education Journal*, *42*(1).

Simens, G. (2008). Learning and knowing in networks: Changing roles for educators and designers. *ITFORUM*. ITFORUM. Retrieved from https://eclass.uoa.gr/modules/document/file.php/PPP233/άρθρα βιβλιογραφίας/Siemens 2008.pdf

Sirgy, M. J., Grzeskowiak, S., & Rahtz, D. (2007). Quality of college life (QCL) of students: Developing and validating a measure of well-being. *Social Indicators*

Research, *80*(2), 343–360. https://doi.org/10.1007/s11205-005-5921-9

Staats, H., Jahncke, H., Herzog, T. R., & Hartig, T. (2016). Urban options for psychological restoration: Common strategies in everyday situations. *PLoS ONE*, *11*(1). https://doi.org/10.1371/journal.pone.0146213

Stevenson, M. P., Dewhurst, R., Schilhab, T., & Bentsen, P. (2019). Cognitive restoration in children following exposure to nature: Evidence from the attention network task and mobile eye tracking. *Frontiers in Psychology*, *10*, 42. https://doi.org/10.3389/fpsyg.2019.00042

Strange, C. C., & Banning, J. H. (2015). *Designing for learning: Creating campus environments for student success* (2nd ed.). San Francisco, California: Jossey-Bass.

Sundstrom, E., Town, J. P., Rice, R. W., Osborn, D. P., & Brill, M. (1994). Office noise, satisfaction, and performance. *Environment and Behavior*, *26*(2), 195–222.

Tabachnick, B. G., & Fidell, L. S. (2001). *SAS for windows workbook for Tabachnick and Fidell using multivariate statistics.* Allyn and Bacon.

Tanner, C. K. (2000). The influence of school architecture on academic achievement. *Journal of Educational Administration*, *38*(4), 309–330. https://doi.org/10.1108/09578230010373598

Temple, P. (2008). Learning spaces in higher education: An under-researched topic. *London Review of Education*, *6*(3), 229–241. https://doi.org/10.1080/14748460802489363

Temple, P. (2009). From space to place: University performance and its built environment. *Higher Education Policy*, *22*(2), 209–223. https://doi.org/10.1057/hep.2008.30

Thatcher, A., & Milner, K. (2014). Changes in productivity, psychological wellbeing and physical wellbeing from working in a "green" building. *Work*, *49*(3), 381–393. https://doi.org/10.3233/WOR-141876

Thomsen, J. (2007). Home experiences in student housing: About institutional character and temporary homes. *Journal of Youth Studies2*, *10*(5), 577–596. https://doi.org/10.1080/13676260701582062

Townley, C. T. (2001). Knowledge management and academic libraries. *College and Research Libraries*, *62*(1), 44–55. https://doi.org/10.5860/crl.62.1.44

Turley, R. N. L., & Wodtke, G. (2010). College residence and academic performance: Who benefits from living on campus? *Urban Education*, *45*(4), 506–532. https://doi.org/10.1177/0042085910372351

Turner, M., Scott-Young, C. M., & Holdsworth, S. (2017). Promoting wellbeing at university: the role of resilience for students of the built environment. *Construction Management and Economics*, *35*(11–12), 707–718. https://doi.org/10.1080/01446193.2017.1353698

U.S. Census. (2010a). Educational attainment. Retrieved from https://data.census.gov/cedsci/table?q=college%2F university student 2010&tid=ACSST1Y2010.S1501&hidePreview=false

U.S. Census. (2010b). Population in college/university student housing. Retrieved from https://data.census.gov/cedsci/table?q=student residence&tid=DECENNIALSF22010.PCO8&hidePreview=false

Ulrich, R. S. (1991). Effects on interior design on wellness: Theory and recent scientific research. *Journal of Healthcare Design*, *3*(1), 97–109.

van Bommel, W. J. M., & van den Beld, G. J. (2004). Lighting for work: A review of visual and biological effects. *Lighting Research and Technology*, *36*(4), 255–266.

van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology*, *23*(2), 135–146. https://doi.org/10.1016/S0272-4944(02)00111-1

van den Ende, L., Willems, T., & van Marrewijk, A. (2020). Socio-materiality and the physical environment of organizations. In *Organizational Behaviour and the Physical Environment* (pp. 200–213). Abingdon: Routledge.

van Esch, E., Minjock, R., Colarelli, S. M., & Hirsch, S. (2019). Office window views: View features trump nature in predicting employee well-being. *Journal of Environmental Psychology*, *64*, 56–64. https://doi.org/10.1016/j.jenvp.2019.05.006

van Heur, B. (2010). The built environment of higher education and research: Architecture

and the expectation of innovation. *Geography Compass*, *4*(12), 1713–1724. https://doi.org/10.1111/j.1749-8198.2010.00408.x

Varjo, J., Hongisto, V., Haapakangas, A., Maula, H., Koskela, H., & Hyönä, J. (2015). Simultaneous effects of irrelevant speech, temperature and ventilation rate on performance and satisfaction in open-plan offices. *Journal of Environmental Psychology*, *44*, 16–33. https://doi.org/10.1016/j.jenvp.2015.08.001

Vischer, J. C. (2008). Towards a user-centred theory of the built environment. *Building Research and Information*, *36*(3), 231–240. https://doi.org/10.1080/09613210801936472

Waxman, L., Clemons, S., Banning, J., & McKelfresh, D. (2007). The library as place Providing students with opportunities for socialization, relaxation, and restoration. *New Library World*, *108*(9/10), 424–434. https://doi.org/10.1108/03074800710823953

Weinstein, C. S. (1979). The physical environment of the school: A review of the research. *Review of Educational Research*, *49*(4), 577–610. https://doi.org/10.2307/1169986

Wexler, M. N., & Oberlander, J. (2021). COVID-19 as a super crisis: implications for place management. *Journal of Place Management and Development*. https://doi.org/10.1108/JPMD-09-2020-0093

Whole Building Design Guide (WBDG). (2018). Enhance Indoor Environmental Quality (IEQ). Retrieved from https://www.wbdg.org/design-objectives/sustainable/enhance-indoor-environmental-quality

Woo, E. M. W., Serenko, A., & Chu, S. K. W. (2019). An exploratory study of the relationship between the use of the Learning Commons and students' perceived learning outcomes. *Journal of Academic Librarianship*, *45*(4), 413–419. https://doi.org/10.1016/j.acalib.2019.05.007

World Health Organization. (2004). Promoting mental health: Concepts, emerging evidence, practice: summary report. In *World Health Organization*. Geneva. https://doi.org/10.5840/ncbq201616462

World Health Organization (WHO). (2014). *Constitution of the World Health Organization*. Retrieved from http://apps.who.int/gb/bd/PDF/bd47/EN/constitution-en.pdf?ua=1

Xu, D., & Yang, E. (2018). Library transformation in higher education. *World Workplace 2018*.

Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2020). Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International*, *136*, 105427. https://doi.org/10.1016/j.envint.2019.105427

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment*, *132*, 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006

Yoo-Lee, E. Y., Lee, T. H., & Velez, L. T. (2013). Planning library spaces and services for Millennials: An evidence-based approach. *Library Management*, *34*(6/7), 498–511. https://doi.org/10.1108/LM-08-2012-0049

Yousefi, Z., Hosseini, S.-B., Yazdanfar, S.-A., & Norouzian-Maleki, S. (2017). Promoting the Residents' Sense of Belonging in Housing Design. *Asian Journal of Behavioural Studies*, *2*(5), 33–43. https://doi.org/10.21834/ajbes.v2i5.47