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THE USE OF BIOMIMICRY IN INTERIOR ARCHITECTURE EDUCATION: CASE STUDY; JORDANIAN UNIVERSITIES

M.Sc. THESIS

Deya Aldeen Hakamat ALREFAI

Nicosia

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Approval

We certify that we have read the thesis submitted by Deya Aldeen Alrefai titled **"The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities"** and that, in our combined opinion, it is fully adequate, in scope and quality, as a thesis for the degree of Master of Interior Architecture.

Examining Committee	Name-Surname	Signature
Head of the Committee:	Assoc. Prof. Dr. Ayten Özsavaş Akçay	....
Committee Member*:	Assoc. Prof. Dr. Guita Farivarsadri	....
Supervisor:	Dr. Elnaz Farjami	....

Approved by the Head of the Department

4 / 10/2023

....

Prof. Dr. Zihni Turkan

Head of Department

Approved by the Institute of Graduate Studies

/ /2023

Prof. Dr. Kemal Hüsnü Can Başer

Head of the Institute

Declaration

I declare that all information, documents, analysis, and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. As required by these rules and conduct, I also declare that I have fully cited and referenced information and data not original to this study.

Deya Aldeen Hakamat Alrefai

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Abstract

The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities

Alrefai, Deya Aldeen

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Abstract:

In the rapidly evolving landscape of design and sustainability, integrating biomimicry principles into education has emerged as a beacon of innovation and hope. As our world grapples with increasingly complex environmental challenges, it becomes imperative to nurture a new generation of designers who can create aesthetically pleasing spaces and champion sustainability, creativity, and holistic problem-solving. This thesis investigates integrating biomimicry concepts within interior architecture education in Jordanian universities. It aims to evaluate students' and academics' awareness and knowledge levels regarding biomimicry and its potential impact on creativity, problem-solving, and sustainability awareness.

The study employs a mixed-methods approach, combining quantitative and qualitative surveys to gather insights from students and academics. The results reveal varying levels of familiarity with biomimicry among students from different universities and academic levels. In contrast, academics are more aware of biomimicry's relevance in interior architecture education. Furthermore, qualitative research uncovers challenges in assimilating biomimicry concepts into the design process. Key obstacles include the Challenge of Scaling Transfer, emphasizing the need for interdisciplinary collaboration, and the Knowledge Gap, highlighting the importance of analogical thinking in biomimicry education.

This research underscores the importance of incorporating biomimicry into interior architecture education to foster creativity, problem-solving skills, and sustainability awareness. The findings include the lack of awareness of biomimicry among academics and students, the scarcity of sources and research related to biomimicry in interior architecture, and the underutilization of biomimicry as an educational tool in interior design and architecture departments of Jordanian universities. In conclusion, this research calls for integrating biomimicry instruction into interior architecture design education across Jordanian universities and beyond. It emphasizes the role of biomimicry education in addressing complex environmental challenges and advancing sustainable design practices globally.

Keywords: Biomimicry, Interior Architecture, Interior Design, Education, Analogical Reasoning, Jordanian Universities.

Öz

İç Mimarlık Eğitiminde Biyomimikri Kullanımı: Örnek Olay; Ürdün Üniversiteleri

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Öz

Hızla gelişen tasarım ve sürdürülebilirlik ortamında, biyomimikri ilkelerinin eğitime entegre edilmesi bir yenilik ve umut ışığı olarak ortaya çıkmıştır. Dünyamız giderek daha karmaşık hale gelen çevresel sorunlarla boğuşurken, estetik açıdan hoş mekanlar yaratabilen ve sürdürülebilirliği, yaratıcılığı ve bütüncül problem çözmeyi savunan yeni nesil tasarımcıların yetiştirilmesi zorunlu hale gelmektedir. Bu tez, Ürdün üniversitelerindeki iç mimarlık eğitimine biyomimikri kavramlarının entegre edilmesini araştırmaktadır. Öğrencilerin ve akademisyenlerin biyomimikri konusundaki farkındalık ve bilgi düzeylerini ve bunun yaratıcılık, problem çözme ve sürdürülebilirlik bilinci üzerindeki potansiyel etkisini değerlendirmeyi amaçlamaktadır.

Çalışma, öğrencilerden ve akademisyenlerden içgörü toplamak için nicel ve nitel anketleri birleştiren karma bir yöntem yaklaşımı kullanmaktadır. Sonuçlar, farklı üniversitelerden ve akademik seviyelerden öğrenciler arasında biyomimikri ile ilgili farklı düzeylerde aşinalık olduğunu ortaya koymaktadır. Buna karşılık, akademisyenler biyomimikrinin iç mimarlık eğitimindeki öneminin daha fazla farkındadır. Ayrıca, nitel araştırma biyomimikri kavramlarının tasarım sürecine dahil edilmesinde karşılaşılan zorlukları ortaya çıkarmaktadır. Temel engeller arasında disiplinler arası işbirliği ihtiyacını vurgulayan Ölçeklendirme Transferi Zorluğu ve biyomimikri eğitiminde analojik düşüncenin önemini vurgulayan Bilgi Boşluğu yer alıyor.

Bu araştırma, yaratıcılığı, problem çözme becerilerini ve sürdürülebilirlik bilincini geliştirmek için biyomimikrinin iç mimarlık eğitimine dahil edilmesinin öneminin altını çizmektedir. Biyomimikri entegrasyonunun gereksiz olduğu hipotezini çürütmekte ve iç

mimarlık eğitiminin temel bir bileşeni olması gerektiği fikrini desteklemektedir. Sonuç olarak bu araştırma, biyomimikri eğitiminin Ürdün üniversitelerinde ve ötesinde iç mimarlık tasarım eğitimine entegre edilmesi çağrısında bulunuyor. Biyomimikri eğitiminin karmaşık çevresel zorlukların ele alınmasındaki ve sürdürülebilir tasarım uygulamalarının küresel olarak ilerletilmesindeki rolünü vurgulamaktadır.

Anahtar Kelimeler: Biyomimikri, İç Mimarlık, İç Tasarım, Eğitim, Analojik Muhakeme, Ürdün Üniversiteleri.

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List of Abbreviations

YU: Yarmouk University.

UJ: University of Jordan.

GJU: German Jordanian University.

CHAPTER I

INTRODUCTION

1.1 Introduction:

In the twentieth century, interior architecture became an artistic specialization premised on rules, systems, and sciences. Interior architecture is the interdependence between architecture and interior design; this discipline deals with building elements and their constructive components, such as architecture and interior design, which deal with interior spaces and their relationships (Fakhimi, 2009). Interior architecture is a subject that encompasses the analysis and understanding of existing buildings and proposed spaces, the nature and qualities of interior space, and an intimate examination of the characteristics of interior decoration (Brooker and Stone, 2007). It involves creating functional, safe, and aesthetically pleasing environments that meet the needs of the people who will use them. Interior architecture contains many spaces, including residential, commercial, and public buildings (Pennanen et al., 2010). Besides functional and aesthetic considerations, interior architects prioritize sustainability and the environment in their designs. This includes using energy-efficient systems, eco-friendly materials, and incorporating natural elements and biomimicry principles (Gamage and Hyde, 2011). Designers and architects collaborate with elements of nature like bees, fungi, bacteria, algae, and plants to develop innovative technologies for advancing the field. They aim to extend the lifespan of materials, reduce the need for frequent renovations, and choose sustainable materials and products (Ahmed and Ola, 2022).

Biomimicry is the study of nature's designs and processes and the use of those designs and processes to solve human problems (Vierra, 2011). A fundamental biomimicry approach in architectural design is developing new design methods that combine the model of behavior and the materialization process in addition to environmental factors. This situation requires understanding form, material, and structure (Yetkin, 2021). The primary purpose of using biomimicry in architecture is to create building designs inspired by the adaptations of living organisms or natural systems to their environments (Ergün and Aykal, 2022; Sheikh and Asghar, 2019).

The abilities in nature to regenerate, sustain, overcome, and proffer sustainable solutions to their challenges, which are like what the human environment is grappling with, is what the biomimicry concept is premised upon (Oguntona and Aigbavboa, 2023). It is a field that is growing in popularity and importance as more people become aware of the need to find more sustainable and environmentally friendly solutions (Nkandu and Alibaba, 2018). Biomimicry is a term that refers to the practice of developing sustainable solutions by drawing inspiration from nature's designs and processes (Pawlyn, 2016). It involves studying and emulating the strategies, structures, and functions found in the natural world to create innovative and environmentally friendly designs by observing strategies in natural organisms examined and adapted by early humans to meet their housing, security, health, food production, and agricultural needs (Murr, 2015). Biomimicry seeks to apply those strategies to solve human challenges in a sustainable and regenerative manner. This approach encourages a shift towards harmonizing human technologies with the natural world, aiming to create more efficient, resilient, and eco-friendly solutions.

The term biomimicry appeared for the first time in scientific research in 1982 (Vincent et al., 2006). Biomimicry has improved sustainability and efficiency, especially in design and construction (Pawlyn, 2011). A new form of design was introduced several years ago, which requires modern man to look at the biological functions or processes found in nature for inspiration (Heil, 2023). Many examples of biomimicry exist in various fields, including engineering, architecture, and product design. For example, finding and using more durable local building materials, such as the self-cleaning properties of a lotus leaf (Figure 1), can be used to design surfaces resistant to dirt and grime (Singh, 2020).

Figure 1: Lotusan paint inspired by lotus flower properties (Singh, 2020).

In several architectural examples, designers used the idea, based on the shading properties of cactus spines, to design the exterior facade of the Ministry of Municipal Affairs and Agriculture (MMAA) building in Qatar, inspired by the cactus plant by Aesthetics Architects in Bangkok (Figures 2 and 3). This structure contains awnings that can adjust the amount of sunlight entering the room by automatically rising and falling in response to the temperature inside. The blinds in front of the windows are designed as a collapsible system to adapt to variable temperatures (Yetkin, 2021).

Figure 2: Cactuses. Retrieved from (URL 1).

Figure 3: MMAA Building: Innovative interface inspired by Cactuses. Retrieved from (URL 2).

Nature is a design inspiration that imitates its models and systems to solve unsolved problems. Biomimicry architecture is a contemporary architectural philosophy that seeks solutions for sustainability in nature, not by replicating natural forms but by understanding the rules that govern those forms (Baumeister et al., 2014). Biomimicry helps discover new and sustainable solutions in architecture that can be implemented in other ways to meet human needs (Verbrugghe et al., 2023). Janine Benyus first articulated the principles of biomimicry in her book published in 1997 (Biomimicry: Innovation Inspired by Nature). Since then, designers, engineers, and scientists have widely adopted these principles, seeking to develop more sustainable and efficient solutions.

Benyus, as discussed by (McGregor et al., 2003), presents nine functional principles derived from nature that can serve as valuable models for human behavior and design. These principles highlight the fundamental characteristics of ecosystems and emphasize the importance of incorporating them into designs to promote ecological sustainability. They include the role of sunlight in sustaining continuity in nature, the efficient use of energy, the alignment of form and function, the recycling of resources, the significance of biodiversity, the benefits of cooperation, and the importance of local expertise and adaptation. These principles provide valuable guidance for creating designs that are harmonious with the natural world and promote sustainable practices.

- "Nature as a model, studying nature and inspiring from its designs and processes to solve human problems."
- "Nature as a measure, an ecological standard to judge the 'rightness' of our innovations."
- "Nature as a mentor, a new way of viewing and valuing nature, not what we can extract from but what we can learn from" (Benyus, 1997, pp. 2–9)

Following these principles can create innovative solutions that are sustainable, efficient, and harmonious with the natural world.

In recent years, the biomimicry approach to design has gained interest among designers, engineers, and end users. However, there are difficulties in introducing biomimicry concepts into university curricula (Santulli and Langella, 2011). Pankina and Zakharova (2015) stated that in the future, biomimicry design will become more prevalent in architecture. There has been an increasing interest in introducing biomimicry in interior architecture education in some universities worldwide in the last few years, as reported by (Khalil and Cheng, 2019; and Amer, 2019). Interior architecture and interior design education may benefit from understanding how nature functions and how to emulate natural systems in the twenty-first century.

DeKay (1996) also suggests, "To educate designers for ecologically and socially responsible practice, design schools are needed to be radically redesigned in their structure, content, and methods" (DeKay, 1996, p. 1). Yeler (2015) suggested that an enhanced appreciation for nature can be nurtured by reconfiguring educational programs to facilitate students' comprehension of natural processes; in turn, it enables the integration of its patterns and biological principles into their understanding of design.

Roshko (2010) suggests, "To create a dialog between design and nature, our design epistemology requires a fundamental change. Not only our design praxis but also our design pedagogy is still based on 19th-century Beconian principles within which the notion of "domination over nature" constitutes the foundational thought process" (Roshko, 2010, p. 548).

Integrating biomimicry into interior architecture education can give students a new perspective on sustainable design solutions. Khalil and Cheng (2019) suggest that this approach promotes innovative thinking by encouraging students to consider alternative solutions that are aesthetically pleasing, functional, and environmentally responsible. By learning from nature, students can design spaces that are not only visually pleasing but also functionally and environmentally sound (Asojo and Vo, 2021). This approach holds enormous potential for creating innovative and sustainable interior architecture solutions.

The gap between biomimicry and its application in interior architecture can be attributed to several factors. One main reason is that the biomimicry approach is still relatively new. Wilson (2008) identifies three specific reasons for this gap: a significant analogy distance between biomimicry and traditional interior architecture practices, a lack of knowledge and understanding of biomimicry within the domain, and the ongoing challenge of identifying relevant biomimetic strategies for interior architecture (Wilson, 2008). In summary, the gap exists due to the novelty of biomimicry, limited knowledge and understanding, and the need for further exploration and identification of relevant biomimicry strategies specific to interior architecture.

1.1.1 Problem Statement:

Learning biomimicry is becoming increasingly necessary as the world faces complex and pressing environmental challenges. The study highlights the importance of biomimicry in teaching interior architecture and emphasizes that it needs to be given the recognition it deserves.

The research problem addressed in this study revolves around the need for the integration of biomimicry in the field of interior architecture education in Jordanian universities and the need for sources and research related to biomimicry in interior architecture; these issues hinder the effective utilization of biomimicry as an educational tool in these departments.

The motive is to bridge this educational gap faced by students and academics to overcome obstacles while applying biomimicry, examine the awareness of students and academics, and discover the main factors that can help students and academics apply the concept of biomimicry. Find educational curricula that help them solve problems in sustainable and innovative ways and learn to decipher and translate functions from nature to design.

1.1.2 Aim and Objective of the Study:

This thesis endeavored to underscore the significance of incorporating biomimicry into educational curricula within Jordanian universities, explicitly focusing on interior architecture and interior design programs. Furthermore, it investigates educational methods and approaches employed to impart knowledge about biomimicry in the context of interior architecture. The study aims to assess the knowledge level of students and academics in Jordanian universities concerning biomimicry. Additionally, it aims to identify the reasons for biomimicry's underutilization in teaching interior architecture in Jordanian universities.

In general, biomimicry can be a powerful approach to teaching interior architecture; an essential focus of the study is to highlight the significance of biomimicry as a valuable educational tool and advocate for its integration as a compulsory course in the interior architecture curriculum offered by Jordanian universities. The objective is to raise awareness among students and academics about biomimicry and address their challenges when applying biomimicry principles to their designs.

1.1.3 The main Research Questions and Sub-Questions:

What is the current level of awareness of biomimicry among academician and students in Jordanian universities' interior design and Interior architecture departments?

Sub-Questions:

Sub-question 1: What is the extent of available sources and research related to biomimicry in the context of interior architecture within Jordanian universities?

Sub-question 2: How can biomimicry be effectively incorporated as an educational tool in interior design and architecture programs at Jordanian universities?

Sub-question 3: To what extent does analogical reasoning influence the understanding of biomimicry among students and academics?

1.1.4 Methodology:

The beginning will be using the qualitative methodology to understand biomimicry thoroughly in interior architecture and interior design, including approaches and levels of biomimicry. This research focuses on the educational curricula used in teaching biomimicry techniques and their practical applications in interior architecture at Jordanian universities. The study will investigate teaching materials and resources relevant to biomimicry education to identify appropriate methodologies for imparting knowledge about interior architecture. Furthermore, the importance of analogical reasoning as a teaching tool for students and teachers in clarifying complex biomimicry concepts will be examined. Finally, the study will show how this pedagogical approach can be applied and the methods used to analyze natural elements for design purposes.

The second part of the methodology, which is the quantitative method, will conduct questionnaires, and three universities in Jordan will be selected as a sample for the study, which includes departments that study interior architecture and interior design. Questionnaires will be utilized to measure the knowledge of biomimicry among students and academics. To gather information regarding their knowledge of applying and teaching biomimicry in interior architecture, to clarify methods of teaching biomimicry, and to highlight reasons for the non-use of biomimicry in interior architecture in Jordanian universities.

1.1.5 Limitations:

This study has several limitations that should be considered when interpreting its findings. First, the sample was limited to three Jordanian universities, and the results may need to be more generalizable to other universities or regions. Additionally, the study was conducted only among students and academics in the Department of Interior Architecture and Interior Design.

Additionally, the language issue may have affected the collection and analysis of data, mainly as some universities teach interior architecture and interior design in Arabic, which may require additional time and resources for translation.

Finally, the study revealed a need for more knowledge among students and academics about biomimicry in interior architecture, which may suggest the need for further education and awareness-raising initiatives in this field.

1.1.6 Chapter Outline:

Having introduced the thesis topic and objectives in this chapter, Chapter 2 includes the literature review, encompassing precedent studies, the definition and approaches of biomimicry, biomimicry in interior architecture, and biomimicry in interior architecture education. Literature Review Findings identify the evolving methodologies in interior architecture and biomimicry and the application strategies that could provide the most transferrable framework for interior architecture curricula. The chapter discusses biomimicry strategies for interior architecture education curriculum development and accreditation criteria.

Chapter 3 The chapter explains the study methodologies used in this thesis. The qualitative methodology focused on obtaining a comprehensive understanding of biomimicry in interior architecture and interior design, including approaches and levels of biomimicry. Examination of educational curricula employed to teach biomimicry techniques and their practical implementation within interior architecture in university contexts. Additionally, it involves exploring teaching materials and resources related to biomimicry education to ascertain suitable methodologies for effectively conveying knowledge in interior architecture education.

The second part of the methodology is the quantitative approach, which targets students and academics of interior architecture and interior design in Jordanian universities. Three universities in Jordan were selected as a sample for the study, including interior architecture and interior design departments. The chapter includes the compulsory courses of three Jordanian universities.

Chapter 4 is titled "Results and Evaluations," which provides a condensed overview of the outcomes derived from questionnaires administered to educators and students of interior architecture and interior design in Jordanian universities. These questionnaires were utilized to gauge the degree of understanding among students and instructors about biomimicry. The primary objectives encompass comprehending the scope and context of their awareness regarding the application and pedagogy of biomimicry within interior architecture. Furthermore, the chapter seeks to elucidate the reasons underlying biomimicry's limited utilization within the curriculum of interior architecture in Jordanian universities.

Finally, Chapter 5, "Conclusions," encapsulates the research findings and recommendation synthesis. This culminating chapter also outlines potential directions for future research, offering a glimpse into the prospective trajectory of biomimicry in shaping approaches to interior architecture education within Jordanian universities. Within this chapter, propositions are advanced that underscore the essentiality of introducing a compulsory biomimicry course into the curricula of interior architecture.

CAPTER II

Literature Review

2.1 Biomimicry:

The growing recognition of the importance of energy efficiency and conservation has driven the exploration and adoption of various design approaches and solutions to mitigate energy-related challenges. Among these strategies, biomimicry has emerged as a prominent approach. Biomimicry entails studying natural designs, systems, and processes to derive inspiration for solving human problems (Singh and Nayyar, 2015). Consequently, biomimicry emerged as a technique that produced fruitful outcomes and was adopted by various professions (Kuday, I., 2009). This innovative approach offers insights into systems, components, methodologies, architectures, and aesthetics found in nature. Biomimicry is beyond mere replication of nature; it involves utilizing natural principles to enhance the understanding of analogous technological inquiries. Rather than a direct imitation of natural materials and functions, biomimicry aims to leverage these principles to solve complex problems by employing optimized technologies (Amer, 2019).

Biomimicry marks a shift from an age of resource extraction from nature to a period of gleaning insights from its structures, mechanisms, and tactics (Oguntona and Aigbavboa, 2023). Nature's system has worked for millions of years; biomimicry is a way of learning from nature (Nasir, 2022). Throughout time, the natural world has cultivated remarkable traits to thrive, function efficiently, and excel—a valuable reservoir that biomimicry seeks to harness in pursuit of its central aim of sustainability (Oguntona and Aigbavboa, 2023). Biomimicry represents a novel paradigm and an emerging frontier within architecture, yet it encounters various challenges that impede its progression.

2.1.1 Definition of Biomimicry:

Over the years, nature has developed outstanding attributes for its survival, efficiency, and performance, which a rich source of biomimicry aims to tap into to achieve its overarching goal of sustainability (Oguntona and Aigbavboa, 2023). Otto Schmidt first coined the term "biomimetic" in 1982 (Vincent et al., 2006), and Janine Benyus revived it in 1997 (Benyus, 2009).

Biomimicry is of Greek linguistic origin from the words bios (life) and mī́mēsis (imitation), meaning "imitation of life" or "imitation of life" (Benyus, 1997). The researchers mentioned that biomimetics and biomimicry aim to solve problems by examining first and then imitating or drawing inspiration from existing natural models. They defined the concept of biomimicry as a term used to describe materials, equipment, mechanisms, and systems that humans use to mimic natural systems and designs. Biomimicry is an innovation method that seeks sustainable solutions by mimicking nature's time-tested patterns and strategies (Shahda et al., 2014). Biomimicry aims to establish products, processes, and policies that are exceptionally well-suited for sustainable living on Earth over the long haul. Biomimicry has gained prominence in reducing human impact on our environment since Janine Benius, a biology writer, gave a name and purpose to this innovative concept (Yahya and Mossman, 2006). Janine M. Benyus defines it as creating sustainable designs and solutions through studying and consciously emulating natural forms, processes, and ecosystems (Benyus, 2011; Singh and Nayyar, 2015). Pawlyn's book Biomimicry in Architecture defines biomimicry as a promising emerging research field defined as a solution for design problems inspired by natural models, systems, and elements (Pawlyn, 2019).

Furthermore, it can be categorized as a design discipline, a problem-solving approach, an environmentalist stance, or a new viewpoint on valuing and respecting biodiversity (Goss, 2009). Knippers et al. define biomimicry as a field of science and an interdisciplinary approach that has the potential to provide sustainable solutions in collaboration with biologists, physicists, chemists, engineers, and architects, and describe biomimicry as an idea that takes inspiration from nature and helps solve human problems and design more sustainably (Knippers et al., 2016).

2.1.2 The Principles of Biomimicry:

Biomimicry is an approach to design that draws inspiration from nature to create environmentally sustainable solutions that harmonize with the natural world. By taking nature cues and using them as a model, measure, and mentor, biomimicry seeks to establish a strong connection between the constructed and natural environments. This approach is grounded in the belief that the more we emulate the functioning of the natural world, the more likely we are to create solutions compatible with the planet's ecosystems (Benyus, 2002). If we can mimic all three forms, processes, and ecosystems, we will learn how to adapt and create "life-friendly" conditions (Baumeister et al., 2014). The recommendation to introduce the approach in the initial stages of the design process before ideas are formed is made clear.

According to Kennedy (2017), biomimicry effectively tackles these challenges by transposing biological mechanisms into engineering concepts. It draws inspiration from nature both as a model for design and as a measure during design evaluation while also assuming the role of a guiding mentor that underscores nature's innate value throughout the design process. Benyus (2009) describes it this way: Benyus explains these three ways:

- **Nature as a model:**

Biomimicry is a new science that studies models of nature and then imitates or draws inspiration from these designs and processes to solve human problems

- **Nature as a measure:**

Biomimicry uses an environmental criterion to judge the "correctness" of our innovations. After 3.8 billion years of evolution, nature has learned what works and what does not, what lasts.

- **Nature as a mentor:**

Biomimicry is a new way of viewing and valuing nature. Introduces an era based not on what we can extract from the natural world but on what we can learn from it (Benyus, 1997).

Biomimicry encompasses sustainable methodologies within design education by following three essential elements: nature as a model, nature as a measure, and nature as a mentor (Stevens et al., 2019). She suggests three essential questions: "What does nature do here (Nature as a model), what does nature not do here (Nature as a measure), and why or why not? (Nature as a mentor). This approach allows us to gain deeper insights and inspiration from nature's wisdom and apply them to our designs. Deriving architectural inspiration from nature is contingent upon architects incorporating the in-between step of abstraction (Amer, 2019).

Consequently, the utilization of biomimetics entails a sequential triad: Research – Abstraction – Implementation (Pohl, 2015). Yan et al. (2021) defines biomimicry as a promising framework to offer innovative and environmentally sustainable solutions, achieved through emulating nature's ingenious forms, principles, and models. Therefore, a successful abstraction and application of the biomimicry thinking concept necessitate establishing a multifaceted relationship with nature, encompassing model, measure, and mentor (Oguntona, 2023). The abstraction phase is always the most challenging for non-experts in biology (Faragalla and Asadi, 2022).

2.1.3 Biomimicry Approaches:

Biomimicry aims to produce innovative and sustainable design solutions inspired by nature's designs by integrating design and designers into the biomimicry process (Eryilmaz, 2015). Nagel et al., (2019) emphasize the importance of integrating biological principles into design processes and outline two main approaches to biomimicry: the problem-driven approach (Design to Biology) and the biology-driven approach (Biology to Design).

Macnab (2011) introduces the Biomimicry Design Spiral, comprising segments like Biology to Design and Challenge to Biology. The Biomimicry Design Spiral serves as a practical framework for integrating nature's principles at various levels, including form, process, and ecosystem, ensuring that the final design mimics nature efficiently. The design spiral serves as an iterative tool reflecting the evolution processes found in nature. This visual tool assists designers from various disciplines in following biomimicry steps (Figures 4 and 5). Designers, whether they are from different disciplines such as engineering, architecture, industrial design, or natural sciences, can practice biomimicry by following the basic steps explained through these design spirals (Kuday, 2009).

A design spiral is a tool designed to make the biomimicry process visually understandable for designers (Taghavi, 2016). The biomimicry design process leads to the integration of biomimicry into the design process through two main processes defined by (Coban and Costu, 2021).

- The problem-driven approach (Challenge to Biology) The process of identifying and defining a design problem and then exploring nature to find suitable solutions, Figure 4.
- The biology-driven approach (Biology to Design) the process of studying and understanding the strategies and behaviours of organisms in nature, and subsequently applying that biological knowledge to the design projects, Figure 5.

This tool facilitates the utilization of innovative ideas from nature in design challenges by providing a clear step-by-step process.

2.1.3.1 Challenge to Biology Approach:

The authors discuss examples of approaches and the benefits of using biomimicry in design and illustrated there are two main approaches to the design process in biomimicry: the problem-based approach and the solution-based approach (Vincent et al., 2006; Benyus, 1997). The approach is often called the direct method (Challenge to Biology Spiral), The process consists of the following stages: 1-Identify, 2-Define, 3-Biologize, 4-Discover, 5-Abstract, 6-Emulate, and 7-Evaluate (Attia, 2015; Iouguina, 2013). This approach begins with the identification of a design problem and subsequent exploration of nature to discover solutions aligned with the challenge (Figure 4). El Ahmar (2011) stated that through this approach, reaching potential biomimicry solutions is possible without collaborating with a biologist or ecologist or without an in-depth scientific understanding. However, the effectiveness of this method hinges on the designer's understanding of the subject matter and their capacity to translate biological knowledge into practical design. This approach is seen as a potential means to transition the built environment from an unsustainable paradigm to a more effective one (McDonough and Braungart, 2002).

By integrating knowledge from Yetkin (2021) and Knippers et al. (2019), designers have the opportunity to tap into nature's wisdom and embrace a biomimicry approach to addressing human challenges sustainably. This method takes inspiration from the variety of solutions found in nature, encouraging the creation of designs that align with ecological principles and contribute to a more sustainable future. It operates non-linearly and incorporates iterative feedback loops, fostering continuous improvement (Helms et al., 2009).

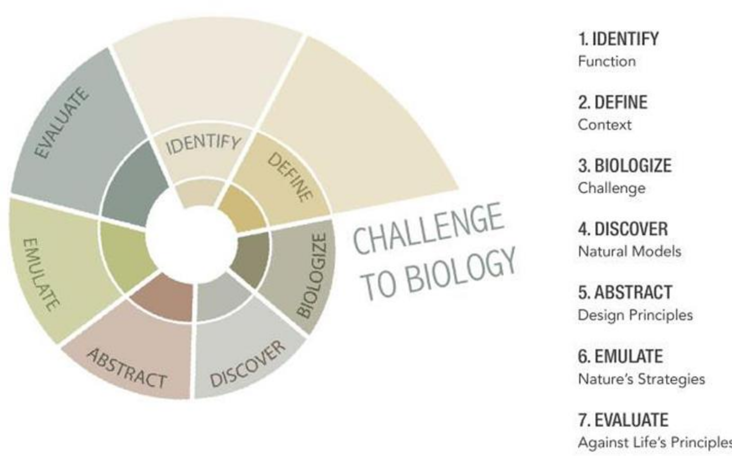

Figure 4: The Challenge to Biology Design Spiral (Macnab, 2011).

2.1.3.2 Biology to Design Approach:

The solution-based approach, also known as "Biology to Design," involves starting with a biological principle or phenomenon and using it as the source for design ideas. In this approach, designers directly mimic strategies, behaviours, or systems found in nature by using analogical translation systems. On the other hand, the indirect approach involves designers abstracting ideas and concepts as principles from nature's designs. According to Heil (2023), This methodology operates under a solution-focused paradigm, where biology influences design (biology-influencing design). In this framework, biological insights shape human design, led by individuals possessing scientific familiarity with nature, who explore potential design applications grounded in biological knowledge. Overall, both approaches to biomimicry encompass the acquisition and comprehension of natural organisms' functionalities, underpinned by the concept of the intricate interrelation between human and earth systems. Biomimicry represents a profound understanding of the processes performed by natural organisms. Such understanding is based on learning such processes in detail, resulting in a design that connects humans to earth systems (Aamer, 2021).

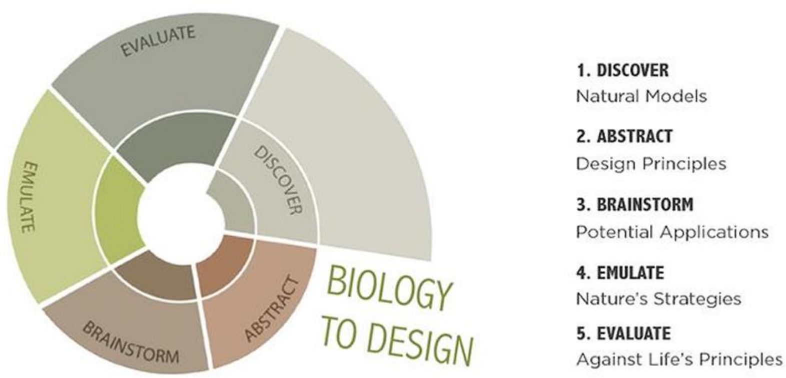

Figure 5: Biology to Design Spiral (Macnab, 2011).

According to McGregor (2013) and Aamer (2021), Benyus discusses a set of nine functional principles found in nature that can serve as valuable models for human behaviour. These principles encompass the fundamental characteristics of ecosystems and emphasize that the integration of these principles in designs can lead to the development of ecologically sustainable products,

▪ The continuity of nature is provided by sunlight.

▪ Nature uses only as much energy as it needs.

- In nature, form, and function match.
- Nature recycles everything.
- Nature depends on diversity.
- Nature rewards cooperation.
- Nature demands local mastery.
- Nature prevents excessive need.
- Nature pushes the limits of power.

These principles resonate that nature runs on sunlight; nature recycles everything; nature uses only the energy it needs; nature fits form to function; nature demands local expertise; nature banks on diversity; nature taps the power of limits; nature rewards cooperation; and nature curbs excesses from within (Neill, 2018).

In conclusion, the first approach, referred to as the indirect method, draws inspiration from the natural world and relies on the expertise of biologists or ecologists to identify relevant biological features applicable to human design. In this approach, known as the "Biology to Design Spiral," designers or students observe the strategies and adaptations found in nature and utilize that biological knowledge as a guiding force in their design projects. However, a drawback of this method is that designers have limited control over the design parameters right from the beginning of the process. Despite this limitation, the indirect method holds the potential to revolutionize human design but necessitates strong interdisciplinary collaboration.

Also, the second approach, known as the direct method, involves a designer formulating a design problem, followed by a biologist searching for a design solution in nature that addresses that particular problem. Using the "Challenge to Biology Spiral," the designer or student initially identifies a design problem and then explores the natural world to discover solutions that effectively tackle the challenge. In this scenario, the designer maintains control over the initial design objectives. However, if the designer lacks a deep understanding of the subject matter or fails to effectively translate biological knowledge into design, the resulting human design may remain superficial and fail to fully harness the potential of scientific research.

Biomimicry, as a comprehensive approach, can be understood through three dimensions. Firstly, biomimicry views nature as a model, criterion, and guide, offering inspiration and a means to evaluate the effectiveness of human innovations. Secondly, the practice of biomimicry follows a design spiral, which acts as a cyclical process guiding the application of biomimicry principles in problem-solving and design. Lastly, it involves nine principles of life that provide a framework for understanding and emulating nature's strategies.

2.1.3.3 Biomimicry Approach by (Biomimicry 3.8):

This section explores the Biomimicry 3.8 platform for biomimetic design, focusing on the importance of principles derived from nature. Biomimicry version 3.8 introduced "Thinking Biomimicry" in 2013, which improved the tools and steps used in biomimicry. This online platform provides education, inspiration, methodologies, methods, and information related to biomimicry to everyone. These principles have been transformed into a versatile tool by Biomimicry 3.8, providing guidelines and design evaluation criteria based on fundamental principles found in the natural and life sciences (Stevens et al., 2019). This platform also provides a clearer explanation of previous biomimicry approaches and how to apply them.

The Biomimicry Institute developed Design Spiral an approach for designers across scientific fields. It mirrors nature's reiterative design process, known as evolution, which seeks the most efficient mechanisms suited to the environment and path of least resistance. In Figure 6, Design Spiral guides designers through a sequence of steps, including defining, biologizing, discovering, abstracting, emulating, and evaluating (Verbrugghe et al., 2023).

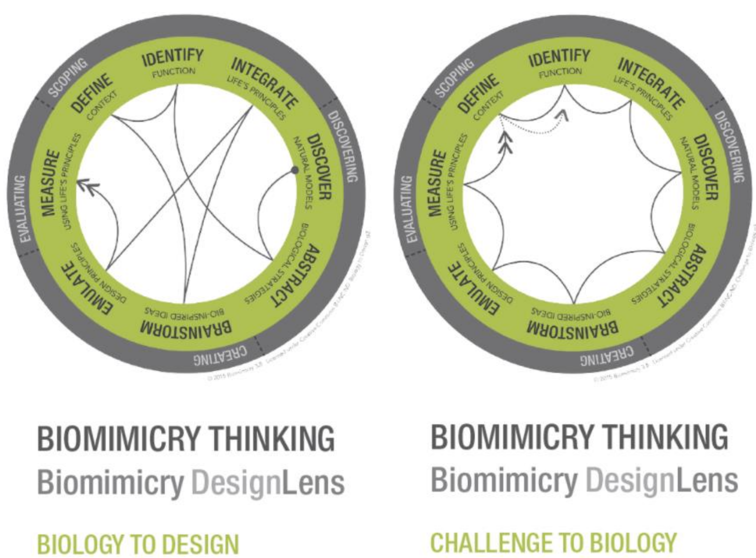

Figure 6: Biomimicry Thinking Tools: (1) Challenge to Biology and (2) Biology to Design (Source: Biomimicry Institute, URL 3).

The Biomimicry 3.8's design process involves eight iterative steps according to Stevens et al. (2019): define (context), identify (function), integrate (life's principles), discover (natural models), abstract (biological strategies), brainstorm (bio-inspired ideas), emulate (design principles), and measure (using life's principles). This process commences by defining the problem's context and identifying the core function required for the design challenge. It integrates Life's Principles to enhance function, resilience, and regeneration. Designers seek inspiration from diverse natural models and abstract underlying principles, fostering creative idea generation through brainstorming. They then emulate nature's strategies, structures, and systems in their design. Finally, the design solution is measured and evaluated using Life's Principles to ensure alignment with sustainability, resilience, efficiency, and adaptability.

The Nature Principles diagram introduced by Biomimicry 3.8 (2014), serves as a guide for innovators to develop sustainable solutions by drawing inspiration from nature's proven strategies (URL 3). Life's Principles are vital for effective biomimicry communication, encompassing six benchmarks that represent key principles observed in natural systems applicable to design practices and problem-solving, as can be seen in Figure 7. These benchmarks include adaptability to changing conditions, use of life-friendly chemistry, optimization over maximization, integration of development with growth, evolutionary adaptation, and resilience through diversity (Taghavi, 2016; Helmrich et al., 2020).

Figure 7: The Nature Principles: Six Sustainable Benchmarks Inspired by Nature (URL 4).

Taghavi provides a concise graphical summary of all the aforementioned details on the tools and stages involved in biomimicry design in Figure 8 (Taghavi, 2016).

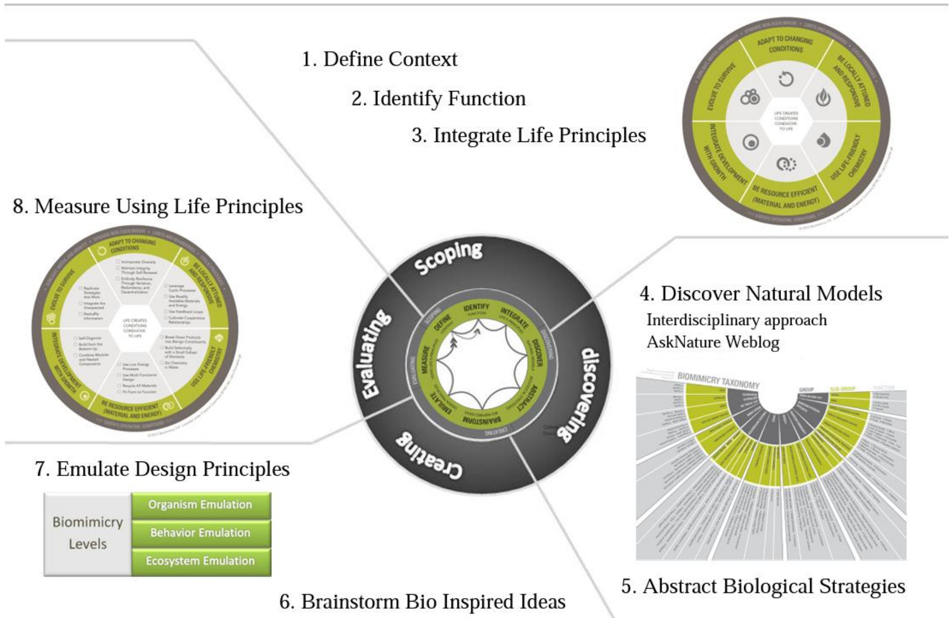

Figure 8: illustrates the design phases, methods, and tools of biomimicry in a concise manner (Taghavi, 2016).

2.1.4 Levels of Biomimicry:

Several authors stated There are three main levels of biomimicry: Nature serves as the source of inspiration for creation, the imitation of organismal behaviour, and the replication of ecosystems (Benyus, 1997; Zari, 2007; El Ahmar, 2011; El-Zeiny, 2012; Tavzan et al., 2015). The first level pertains to individual organisms such as plants or animals, involving the replication of either specific parts or the entire organism. The second level involves emulating behaviours, encompassing the translation of how organisms act or interact within a broader framework. The third level involves the emulation of complete ecosystems, encompassing the fundamental principles that enable their successful functioning, and it is the most extensive level of imitating nature (Ahmar 2011; Aamer, 2021; Ergün, and Aykal, 2022).

Benyus distinguishes three levels of biomimicry: organism, behaviour, and ecosystem. These are used and apply to all fields. A design can mimic some parts of an organism, the response of an organism in its context, or a function of an ecosystem. Zari added dimension to biomimicry for researching biological analogies tailed towards architectural applications, which are: form, material, construction, process, and function (Verbrugghe et al. 2023). Benyus (2008) highlights that complete simulation of nature in biomimicry requires considering these three levels of mimicry. This approach offers potential solutions for addressing human problems by leveraging nature's wisdom across these levels. The section will present implemented architectural examples from around the world, carefully chosen to identify and analyse interior architecture aspects in line with these biomimicry principles. In this section, after defining each level, a series of implemented examples from around the world will be presented. These architectural examples were chosen to allow for the identification and analysis of interior architecture aspects.

2.1.4.1 Organisms Level:

Every organism present on Earth holds immense potential as a valuable design resource. Within this context, designers have access to a diverse array of information sources that have emerged through the process of evolution. Verbrugghe et al. (2023) have characterized the organism level as primarily a wellspring of inspiration for shaping a building's form, configuration, or structural attributes. Consequently, comprehending the interactions among organisms at this level of biomimicry provides us with the unique opportunity to imitate not only the characteristics of an individual organism but also the entire natural system (Nasir and Kamal, 2022). By gaining a deeper understanding of these interactions, designers can incorporate nature's brilliance into their designs and harness its efficiency to address various challenges and enhance the quality of their creations.

The basis of biomimicry is to be inspired by organisms or processes in nature (Ergün and Aykal, 2022). Hershcovich et al. (2021) delve into the realm of material biomimicry, focusing specifically on the organism level. An example is the "Bumpy Body Beetle" found in desert environments, by elevating its back into the air, the Namibian beetle adeptly collects fog, allowing droplets to accumulate. Emulating this innovative fog-collection approach offers the potential to introduce fog-collecting structures in tents and building surfaces, effectively retaining water (Aamer, 2021; Awadalla, 2022), which served as inspiration for the design of a fog-catching system implemented at the Hydrological Centre of Namibia University (Figure 12).

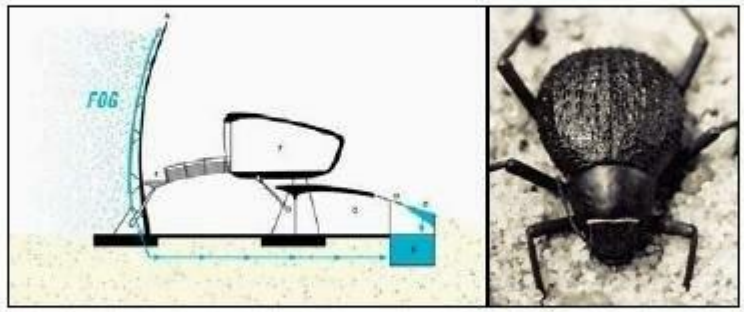

Figure 9: Matthew Parkes' Hydrological Centre, the steno Cara beetle. adapted by (Zari, 2007).

Researchers are actively studying the water-harvesting strategies of Darkling beetles in the Namib Desert, renowned for its arid conditions, to comprehend how they collect water from sources like dew and ocean fog using their body surfaces (Ulhøi, 2021; URL 5). This involves a holistic examination of the beetles' physical attributes, chemical properties, and behavioural patterns, with the ultimate goal of deciphering the secrets behind their successful water capture. The knowledge acquired from these investigations holds the potential to drive the creation of advanced biomimicry materials and surfaces that emulate the Darkling beetles' efficient water harvesting.

The organism level in biomimicry corresponds to the replication of shape or surface characteristics of a living organism (Singh, 2020). However, in the realm of interior architecture, many examples at this level tend to focus more on imitating forms rather than truly mimicking them. Additionally, the emphasis often lies on mimicking a single item rather than replicating the entire system, which can limit the potential for achieving high sustainability levels (Zari, 2007; El Ahmar, 2011). Nevertheless, nature offers significant potential for mimicking technological elements and objects at this level. However, due to limited biological knowledge about organisms, the design process may remain at a basic stage, lacking in-depth understanding and exploration. It is important for designers to further develop their understanding of biological principles to enhance the effectiveness and sustainability of their designs at the behavioral level in interior architecture.

2.1.4.2 Behaviours Level:

At the behaviour level of biomimicry, the focus is not on directly mimicking the physical characteristics of an organism but rather on emulating its behaviour. Instead of directly replicating the organism, the aim is to imitate the relationships and interactions observed between organisms or species (Reap et al., 2005). By exploring and understanding these behavioural dynamics, biomimicry offers the potential to replicate and incorporate such patterns into human design and daily life (Zari, 2007). By studying and understanding how organisms behave and interact in their natural environment, designers can derive insights and principles that can be applied to solve human problems or improve systems and processes (Aamer, 2021). Many organisms encounter similar environmental challenges as humans do. Still, these organisms try to solve their problems within limits of energy and material availability and continue to develop solutions even with the change of the Challenges of the environmental conditions; this broader perspective allows for incorporating natural systems and processes into human-made designs, promoting harmony and efficiency inspired by nature's intricate interconnections (Shahda et al., 2014).

A notable example of biomimicry at the behaviour level is the design of a sustainable and environmentally-friendly shopping centre, inspired by the construction behaviour of African termites in their mounds. This particular building, located in Harare, Zimbabwe and designed by Mick Pearce, closely mimics the cooling system observed in termite mounds Figure 10 (Awadalla, 2022). Termites build their mounds with channels at the base to draw in fresh air while allowing hot air to escape through chimneys at the top, maintaining a cool interior for their high activity levels. Taking inspiration from this natural air circulation system, the shopping centre utilizes a similar approach to cool the building during hot summer days in Harare, minimizing the need for energy consumption (Nasir and Kamal, 2022). As a result, the building's energy costs are 20% lower compared to similar structures, translating to annual savings of 3.5 million dollars for the owners (Rankouhi, 2011; Alshami et al., 2015; Fehrenbacher, 2012).

Figure 10: Eastgate building, Zimbabwe, Simulation of termite's mounds (Shahada et al., 2014).

2.1.4.3 Ecosystems Level:

Mimicking the ecosystem is an integral part of biomimicry (Benyus, 1997). The concept of eco-mimicry encompasses the imitation of ecosystems in design and is often associated with sustainability. This level of biomimicry offers several advantages, including the ability to integrate it with other levels of biomimicry, such as organism and behaviour. The aim of mimicking ecosystem is to support a movement towards a green life to use in the future (Maglic, 2012).

Figures 14 and 15 showcase the Earthship, a sustainable home designed according to the principles of biomimicry at the ecosystem level (Anous, 2015). This innovative building incorporates six natural design principles, including the use of recycled and local materials, natural cooling and heating systems, rainwater harvesting inspired by the Namibian beetle, renewable energy generation through photovoltaic cells and wind generators, gray water recycling for botanical cells, and food production through indoor and outdoor botanical planters (Mansour, 2010).

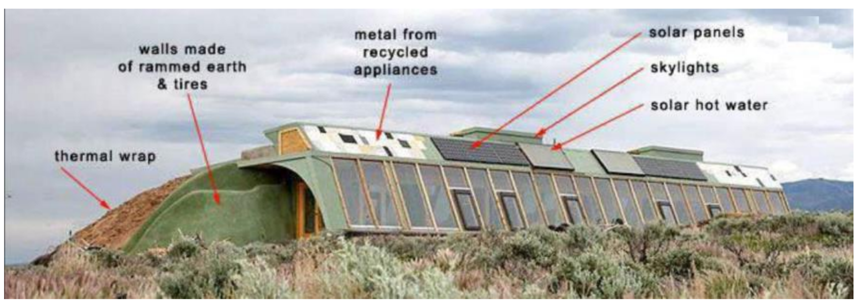

Figure 11: Eco-friendly house The Earthship inspired by nature (Anos, 2015).


Figure 12: The Earthship's inside plants and photovoltaic solar cells (Anous, 2015).

Additionally, eco-mimicry aligns with the principles of sustainability, emphasizing the importance of creating designs that are environmentally friendly and promote ecological balance. On the ecosystem level, design may draw from the entire ecosystem of an organism and its surrounding. It emphasizes natural process and cycle of the greater environment (Tavzan et al., 2015).

The natural ecosystem provides significant value and benefits to the human environment through a variety of services it offers. According to Youmatter (2020), the natural ecosystem provides four primary services: regulating services. provisioning services. cultural services. and supporting habitat services. Drawing from the multitude of sustainable features displayed by the natural ecosystem, there is great potential to extract innovative ideas for addressing human challenges through the inspiration, imitation, or emulation of nature. By achieving ecological sustainability and conserving native biodiversity (Kuuluvainen, 2009), open up a wide range of opportunities to derive innovative solutions to human challenges through inspiration, imitation, or emulation of nature. Therefore, the abundant sustainable features offered by the natural ecosystem serve as a valuable source for extracting innovative ideas and addressing various human challenges.

Jácome Pólit (2014) highlights that nature's principles, known as Nature or Life's principles, offer valuable insights for sustainable coexistence within the natural ecosystem. By adopting biomimicry approaches based on these principles, the built environment can contribute to ecosystem well-being and regeneration. Zari (2007) defines ecosystem principles, as encompassing aspects such as reliance on sunlight, system optimization, adaptation to local conditions, diversity in components and relationships, creation of conditions conducive to life, and adaptation and evolution at various levels and rates. Zari (2014) further emphasizes how biomimicry enables the built environment to mimic and contribute to resilient, sustainable, and adaptable designs, fostering regeneration in the natural environment and bolstering climate change adaptation. Through the translational process of biomimicry, functional concepts from nature are applied to human contexts, offering thoughtful solutions for human needs. Architects utilize the five dimensions of the biomimetic approach mimicking ecosystem form, materials, construction methods, processes, and functions as benchmarks to incorporate biomimicry principles into their design and architecture, resulting in environmentally sound, sustainable, and efficient buildings (Jamei and Vrcelj, 2021).

Biomimicry operates at three levels: organism, behaviour, and ecosystem, as designers explore nature to inspire innovative and sustainable solutions (El-Zeiny, 2012; Biomimicry Institute, 2013). By examining organisms at multiple levels, valuable insights and solutions can be derived for biomimetic design (El-Zeiny, 2012).

Within each level are five biomimicry dimensions: form, material, construction, process, and function. These dimensions allow designers to examine and mimic various aspects of a design, such as its appearance, composition, manufacturing techniques, operational mechanisms, and capabilities. Table 1, adapted from Pedersen Zari (2007), describes the differences between each type of biomimicry and illustrates how various aspects of a termite or its ecosystem could be mimicked.

Table 1: Levels and Mimicry Dimensions for the Application of Biomimicry, Adapted from Pedersen Zari (Zari, 2007).

levels of biomimicry	**Mimicry Dimensions**	**Example: Building the mimics termites**
1-Organism level (Mimicry of a specific organism)	Form	The building looks like a termite.
	Material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	Construction	The building is made in the same way as a termite; it goes through various growth cycles for Example.
	Process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	Function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
2- Behavior level (Mimicry of how an organism behaves or relates to its larger context).	Form	The building looks like it was made by a termite; a replica of a termite mound for example.
	Material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	Construction	he building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	Process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.

	Function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example. It may also function in the same way that a termite mound does in a larger context.
3- Ecosystem level (Mimicry of an ecosystem).	Form	The building looks like an ecosystem (a termite would live in).
	Material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	Construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	Process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.
	Function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilizing the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc. in a similar way to an ecosystem for example.

2.2 Biomimicry in Interior Architecture:

Biomimicry in interior architecture is a design approach that draws inspiration from nature's strategies, forms, and processes to create sustainable and innovative interior spaces (Benyus, 1997; Zari, 2007; Pawlyn, 2011; Jácome Pólit, 2014; Knippers et al., 2016). It involves applying biological strategies, forms, and functions observed in natural organisms to enhance the functionality, efficiency, and aesthetic qualities of interior spaces (Hensel et al., 2013). It is necessary to imitate nature and transfer it from nature for a sustainable life (Yetkin, 2020). Since the area of interior architecture encompasses a variety of design features and dimensions, including spaces, objects, elements functions, etc. The dissemination of biomimicry can assist in addressing design issues in this area. By emulating nature's solutions, interior designers can address various challenges related to energy efficiency, material selection, waste management, and occupant well-being (Xia, 2016).

In interior architecture, biomimicry goes beyond mere replication of nature's physical forms and patterns (Pawlyn, 2011). One aspect of biomimicry in interior architecture is the use of advanced engineering materials that mimic the structural and functional properties found in nature. These materials can provide strength, flexibility, and self-healing capabilities, among other desirable attributes (Xia, 2016). By studying how nature solves life's problems through millions of years of evolution, designers can apply these principles to develop sustainable and regenerative interior spaces (Jácome Pólit, 2014).

In recent years, biomimicry has emerged as a popular approach among architects, offering the promise of creating a more sustainable environment by emulating nature's design principles (Rankouhi, 2011). Although all architects find this promise very tempting, few examples of biomimicry are applied to buildings in any way, shape, or form. Buildings may be designed that fully realize this promise thanks to the advancement and successful application of biomimicry at all levels and complete approaches (Rankouhi, 2011). The integration of biomimicry principles in interior architecture enables the creation of spaces that are not only aesthetically pleasing but also functionally efficient and environmentally responsible (Zari, 2007). Designers can explore concepts such as energy efficiency, natural ventilation, daylighting, material selection, and waste management, inspired by nature's ingenious solutions (Knippers et al., 2016). Printing technologies, such as 3D printing, offer new opportunities for implementing biomimetic design strategies in interior architecture. By digitally fabricating intricate and complex forms, designers can replicate natural patterns and textures, creating visually stunning and functional interior elements (Rael and San Fratello, 2018). Rainwater harvesting techniques, inspired by the water-harvesting strategies of organisms such as the Namibian beetle, can be incorporated into interior spaces for sustainable water management (Anous, 2015), illustrated in the previous section in Figure 9.

Furthermore, biomimicry in interior architecture promotes a deeper connection between humans and the natural world (Pawlyn, 2011). By incorporating natural elements, patterns, and processes into interior spaces, occupants can experience a sense of biophilia, which is the innate human affinity for nature (Knippers et al., 2016). This connection to nature has been shown to enhance well-being, productivity, and overall satisfaction with the built environment. The design process in biomimetic interior architecture often involves interdisciplinary collaboration between architects, biologists, engineers, and material scientists (Pohl and Nachtigall, 2015). This collaboration allows for a deeper understanding of biological systems and their adaptation strategies, enabling designers to translate these principles into functional and aesthetically pleasing interior solutions.

In conclusion, the systematic review of biomimicry design in architecture highlights the potential of biomimicry to drive innovation and shape the future of interior architecture. Biomimicry in interior architecture offers a transformative approach to design that embraces sustainability, innovation, and human well-being. By learning from nature's wisdom and applying it in the design process, interior architects can create spaces that reflect the beauty of the natural world and also contribute to its preservation and regeneration.

2.2.1 A framework for comprehending how biomimicry is used in interior architecture:

In the context of biomimicry in interior architecture, a framework has been provided to understand how nature's design strategies can be applied. Nature's design strategies offer many opportunities for creating sustainable, functional, and aesthetically pleasing interior spaces. By drawing inspiration from the efficiency and adaptability of natural ecosystems (Vincent et al., 2006), interior architects can incorporate biomimicry principles into their design process. By incorporating biomimicry principles, interior architects can integrate natural elements, such as biomorphic shapes, fractal patterns, or organic textures, to create captivating and harmonious interior designs (Joye, 2007; Zari, 2007). Understanding and applying nature's design strategies can inspire innovative storage solutions that maximize space while minimizing waste and creating sustainable interior spaces that minimize resource consumption and environmental impact, as emphasized by (Zari 2007; El-Zeiny 2012).

Furthermore, researchers McDonough and Braungart (2010) and El-Zeiny (2012) presented a framework for applying the problem-based biomimetic approach. The literature also identifies two basic approaches to applying biomimicry in design: defining design problems and examining nature's solutions (top-down approach). Meanwhile, the other involves identifying specific biological traits and translating them into human design solutions (the bottom-up approach), as explained by El-Zeini (2012) and Zare (2007). As confirmed by various studies (Zari, 2007; Knippers, 2009; El-Zeiny, 2012; Pandremenos et al., 2012; Yurtkuran et al., 2013), the problem-based biomimetic approach seeks to transform the built environment from an unsustainable environment to a sustainable and resilient one by providing solutions to existing challenges. Olusegun and Clintonat (2018) at their study supported the potential of the problem-based approach for achieving sustainability if employed by professionals and designers in the construction industry.

El-Zeiny (2012) developed comprehensive frameworks in interior architecture, categorizing biomimicry into three levels: Organism Features, Organism-Community relationships, and Organism-Environment relationships, providing valuable insights for designers to derive inspiration from nature's designs. Additionally, a framework illustrated in Figure 13 redefines biomimicry levels and approaches, empowering designers and architects to select suitable approaches by categorizing and defining various types of biomimicry through a literature review. Pedersen Zari (2007) introduced a framework for applying biomimicry in architectural design, supported by visual aids in Figures 14 and 15, enhancing understanding and guiding designers in incorporating biomimicry principles for increased sustainability in architectural design. Students can engage in design exercises utilizing the biology-influencing design approach (El-Zeiny, 2012), which involves a series of steps: (1) identifying an arthropod for a solution-based approach, (2) defining the biological solution, (3) extracting biological principles, (4) reframing the solution, (5) searching for a problem, (6) defining the problem, and (7) applying the biomimetic principles to the design problem (Yurtkuran et al., 2013).

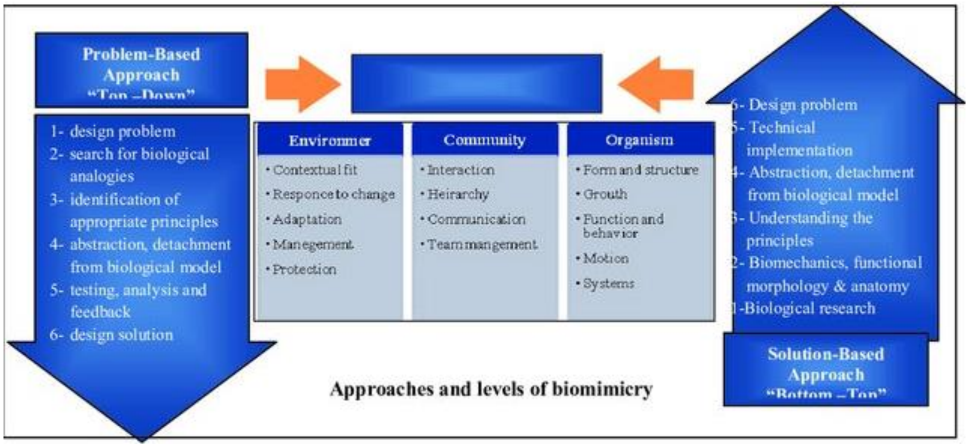

Figure 13: A framework to comprehend the various facets of biomimicry (El-Zeiny, 2012).

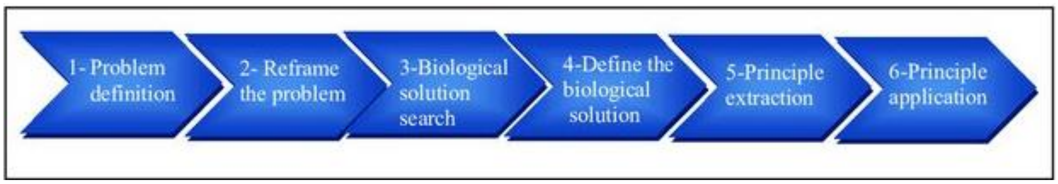

Figure 14: The steps of problem- based approach (El-Zeiny, 2012).

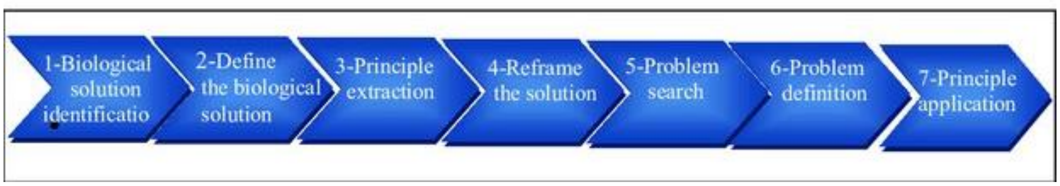

Figure 15: The steps of solution- based approach (El-Zeiny, 2012).

These previous studies provide further guidance and inspiration for designers and architects interested in integrating biomimicry principles into their interior design practice. By leveraging nature's design strategies and incorporating biomimicry principles, interior architects can create interior spaces that are visually appealing, And also sustainable, functional, and in harmony with the natural environment. This holistic approach to interior design promotes a balance between human needs and environmental stewardship, leading to a more sustainable future (Vincent et al., 2006; Joye, 2007; Zari, 2007; Askar et al., 2021).

2.2.2 Examples of Biomimicry in Interior Architecture:

Biomimicry in interior architecture is a ground breaking approach that leverages the brilliance of nature to create innovative and sustainable interior spaces (Jácome Pólit, 2014; Knippers et al., 2016; Pawlyn, 2011). This approach involves harnessing advanced engineering materials inspired by nature's structural and functional properties (Pohl and Nachtigall, 2015) and integrating energy-efficient concepts like natural ventilation and daylighting (Nagy and Osama, 2016). By observing and replicating nature's efficiency, functionality, and elegance, designers have revolutionized the field of interior design (Mazzoleni, 2013).

Biomimicry in interior architecture goes beyond superficial mimicry of nature's forms and patterns. It involves a deep understanding of biological systems and their adaptation strategies, enabling designers to translate nature's principles into practical design solutions (Kellert et al., 2011). Through interdisciplinary collaboration between architects, biologists, engineers, and material scientists, biomimicry in interior architecture has unlocked transformative possibilities (Pohl and Nachtigall, 2015,). The incorporation of biomimetic design strategies has led to the creation of aesthetically pleasing, functional, and environmentally responsible interior spaces that foster a profound connection between humans and the natural world (Kellert, 2008; Zari, 2007).

Examples of biomimicry in interior architecture abound, demonstrating the diverse applications and benefits of this approach. biomimicry lighting designs allow for adaptive energy consumption, mimicking the efficient lighting strategies observed in nature (Sommese et al., 2022). The use of natural materials, inspired by nature's wisdom, enhances biophilic design and creates a soothing and biophilic environment (Kellert et al., 2011). Space optimization techniques inspired by nature's efficient use of space maximize functionality and promote efficiency (Zari, 2007). Acoustic design principles derived from natural sound-absorbing and diffusing mechanisms contribute to optimal sound quality in interior spaces (Barron, 2009). Adaptable building skin designs, influenced by nature's self-regulating mechanisms, enhance sustainability by optimizing energy efficiency and thermal comfort (Matheou et al., 2020). Additionally, incorporating biophilic design principles, which mimic the patterns and elements of nature, creates a harmonious and calming environment that fosters well-being and connectivity with the natural world (Kellert et al., 2011). These following examples highlight the transformative potential of biomimicry in interior architecture and provide a glimpse into the innovative design solutions that can be achieved by drawing inspiration from nature's genius. By embracing biomimicry, interior architects can create visually appealing spaces, functional, sustainable, and conducive to human well-being.

2.2.2.1 The Biomimicry Chair designed by Lilian Van Daal:

Designed by Lilian van Daal, draws its inspiration from the cellular structures found in nature, particularly plant cells known for their ability to offer a blend of softness and flexibility along with structural strength and rigidity (Tavsan and Sonmez, 2015). This 3D printed chair is constructed using elongated units that closely resemble the visual appearance of plant cells. In areas requiring greater structural support and firmness, these units are oriented vertically, while in areas where flexibility and softness are needed, they are positioned horizontally. The chair is crafted using polyamide material, strategically distributed to ensure that certain parts remain soft while others provide essential structural integrity (Taghavi, 2016).

Figure 16: Biomimicry Chair (Tavsan and Sonmez, 2015).

2.2.2.2 Vertebrae Staircase Inspired by The Spine of Whale:

Andrew McConnell’s staircase takes its form the spine of a whale. However, upon closer examination of each piece, this biomimetic makes sense as each section is interlocked with its adjacent pieces to create a continuous and rigid structure. Just like a whale’s spine, the staircase makes use of a central structural steel support extending through all the individual pieces, from which each tread of the stair extends. The result is spiral staircase that seems to float, just like a whale (URL6).

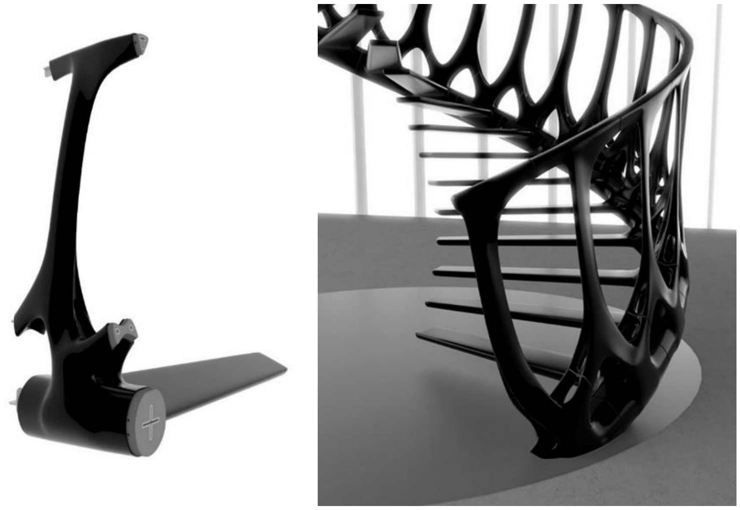

Figure 17: Vertebrae Staircase, (URL6).

2.2.2.3 The Ambio Light Inspired by bioluminescent microorganisms:

Developed by the designer Teresa van Dongen, the Ambio light employs bioluminescent microorganisms to generate light in an air-tight glass tube filled with a liquid that acts as seawater for these organisms. As a result, a soft teal blue light is generated each time the light fixture moves or swings, mimicking the movement of the waves in the ocean. Not only does the design look to nature for inspiration, but it also employs nature itself as a source of energy, according to the designer's statement on her website (URL6).

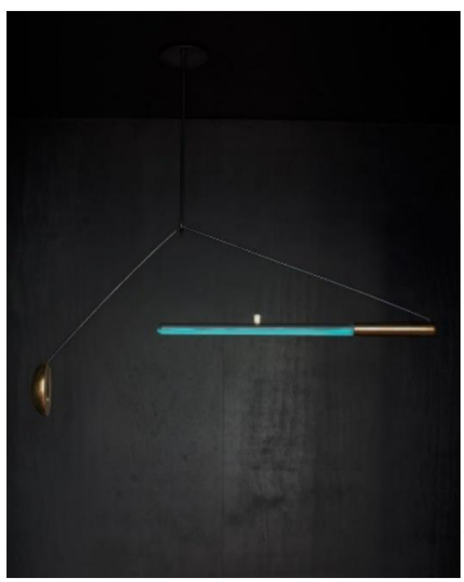

Figure 18: The Ambio Light, (URL6).

2.2.2.4 The Bullitt Building in Seattle:

The Bullitt Building is located on Capitol Hill in Seattle. Architect Miller Hull drew inspiration from the living processes of Douglas fir forests in Western North America when designing the building Figure 19 (Radwan and Osama, 2016). This innovative building is designed to mimic the amazing ecosystem of the forest, utilizing its natural processes to conserve water and energy (Taghavi, 2016). With 600 solar panels, the building generates all the energy it needs in a year. Additionally, a cistern collects rainwater to meet the building's water needs, and wastewater is recycled for toilet systems and a garden (Bryars, 2016). This sustainable design earned the Bullitt Building the title of the greenest commercial building in the United States in 2013. Robert Peña, a project consultant, highlights the building's efficiency, stating that it is 80 percent more efficient than a typical commercial structure. This not only addresses energy issues but also helps mitigate the impacts of climate change (Taghavi, 2016).

Figure 19: The Bullitt building was inspired by a living process in the forest (Taghavi, 2016).

2.2.2.5 Shanghai Natural History Museum in China:

The Natural History Museum draws its architectural inspiration from the nautilus shell, a geometric form found in nature. Designed by Perkins and Will, the museum showcases a distinctive feature known as the "Cell Wall" within its structure, crafted from glass and aluminium. This three-layered lattice formation visually mirrors the characteristics of plant and animal cells, effectively responding to and filtering natural light and temperature, thereby naturally regulating the interior climate. Functioning as a bioclimatic building, it intelligently utilizes a building skin to maximize daylight and minimize solar heat gain. Additionally, an oval courtyard pond facilitates evaporative cooling, while a geothermal system, harnessing energy from the Earth, is employed for heating and cooling purposes. Rainwater is collected from the green roof and, along with recycled greywater, stored in the pond as part of its sustainable water management approach (Khatch, 2023).

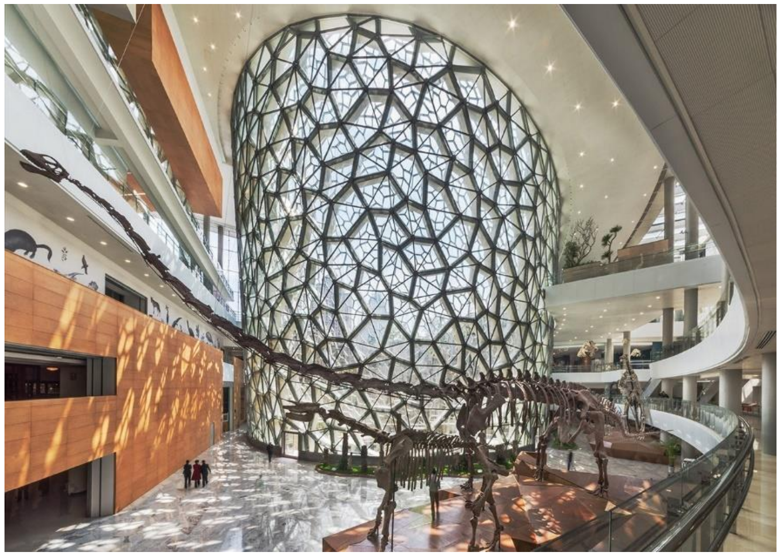

Figure 20: Shanghai Natural History Museum, (URL 6).

2.2.2.6 The Eastgate Centre in Zimbabwe:

The Eastgate Centre taking inspiration from termite mounds. Termites, with their natural ability to regulate nest temperature through vertical chimneys, influenced the building's design Figure 21. This shopping and office complex was constructed with vertical atriums that pull heat up and out. The concrete slabs of the building are kept cool when the night air is pulled in through intake fans. Bonanate explains that though the building doesn’t have a conventional air conditioning or heating system, it expends 90 percent less energy to heat and cool by using a ventilation system that cost about one-tenth the price of an air conditioning system in a comparable sized building (Bonanate, 2015). The Eastgate Centre in Zimbabwe serves as a notable demonstration of biomimicry by emulating the ventilation systems observed in termite mounds. By replicating the mound's capacity to regulate temperature through natural convection and heat exchange, the building achieves passive cooling and reduces energy consumption, even in the hot African climate (Symeonidou and Efstathiadis, 2019).

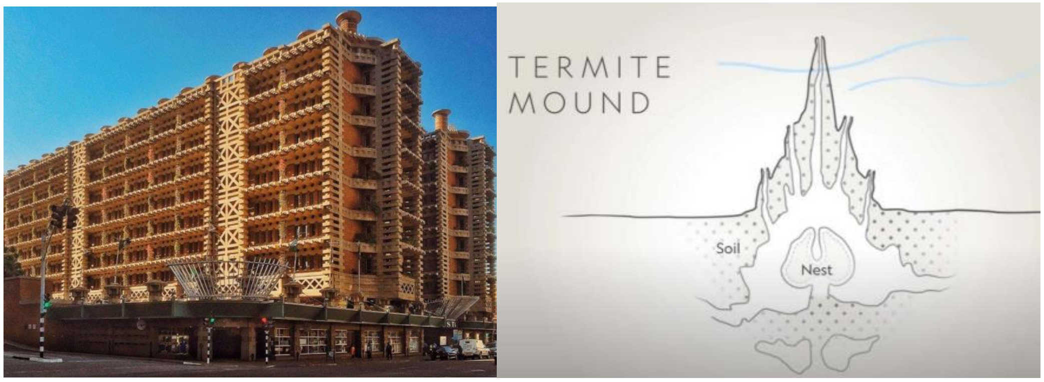

Figure 21: The Eastgate Centre in Zimbabwe, and termite mounds (Köse Batuhan, 2023).

These instances demonstrate how biomimicry is used in interior architecture in real-world settings. Interior architecture students may learn the advantages of embracing nature as an inspiration source when designing living environments by incorporating biomimicry principles into design courses. Designers may create creative, sustainable solutions that advance the area of interior architecture by integrating biomimicry (Mueller, 2008). The subsequent chapter will also look at the biomimicry of interior architecture education.

2.3 Biomimicry in Interior Architecture Education:

Looking to nature for inspiration while attempting to address design problems is one of the novel techniques that ought to be promoted in interior architecture education. The emerging field of biomimicry and learning to design with and for nature has expanded in recent years through a diversity of educational programs (Stevens, et al. 2019). Designers often seek inspiration from various sources to tackle complex design problems. One of the methods they employ is studying nature and understanding its strategies for addressing environmental challenges (Yurtkuran et al., 2013). Exploring nature and deriving solutions from it hold great value for designers. By carefully selecting suitable materials for design and incorporating recycling practices that align with local conditions, nature serves as a vast resource of durable and aesthetically pleasing solutions (Tavzan et al., 2015)

The biomimicry approach, which encourages creative and innovative design solutions through critical thinking, is closely related to sustainability, ecology, technology, and science (Yağlı and Altun, 2022). It goes beyond merely focusing on form and function, making it highly impactful in interior architectural education and the field of architecture. Embracing this approach can help interior architects develop the capacity for collaborative design processes and tackle global-scale challenges effectively.

Biomimicry education involves studying contexts from Nature and applying them to design, by understanding how organisms operate, biomimicry education explores how these functionalities can be utilized in the design field (Amer, 2019). Striving for buildings with "zero" environmental impact in terms of energy, carbon, waste, and water is an ambitious but worthwhile objective. However, the future of built environments necessitates transcending the realm of sustainability to attain net-positive environmental consequences (Aamer, 2021). The foundation of the biomimicry concept rests upon nature's capacities to regenerate, sustain, surmount obstacles, and provide enduring solutions to the challenges it encounters, which closely parallel the predicaments faced by the human environment (Oguntona and Aigbavboa, 2023). A solution to the issues affecting our environment is provided by biomimicry. Because of its potential to produce a more regenerative built environment, biomimicry serves as a source of inspiration for prospective innovations (Nasir and Kamal, 2022). As a result, it is of significance that educational institutions globally are integrating nature-inspired methods into their academic programs.

The role of interior architectural education is under scrutiny to produce professional architects and designers capable of offering sustainable solutions. UNESCO and the International Union of Architects recognize the importance of ecologically sustainable design, environmental awareness, and scientific research techniques in architectural education (UIA, 2014). According to Vitruvius, the architect should comprehensively understand various disciplines, ranging from literature, geometry, history, and philosophy to music, medicine, law, and astronomy. He emphasized that architecture lies at the crossroads of science and art, highlighting its interdisciplinary nature encompassing both theoretical knowledge and practical application (Vitruvius, 1993: 4,5). In the present day, architects and designers are expected to prioritize socio-cultural, economic, and ecological sustainability in their work. They must align their practices with nature and actively address challenges such as climate change and energy issues.

Common problems identified in interior architectural education include the need for increasing interdisciplinary approaches and studies, fostering critical thinking and multidimensional creativity, supporting original and creative solutions based on scientific knowledge and research, utilizing modern technological possibilities, and targeting lifelong learning (TMMOB, 2020). The Biomimicry approach aligns well with these principles and can contribute significantly to the education of architects.

In various universities worldwide, nature-based design processes are being incorporated into formal interior architectural education at different scales, with many workshops and training on biomimicry being offered in informal education. In the context of interior architectural education in Jordan, there is a lack of emphasis on "nature" and "biology" as notions in the studies. Overall, there is a need for more research and attention to the Biomimicry approach in interior architectural education, particularly in terms of its interdisciplinary working methods and its potential impact on the architectural design process. Currently, the Biomimicry approach remains an underexplored field in interior architectural education studies.

The integration of the biomimicry approach in architectural education has gained traction in recent years, with various universities worldwide adopting this innovative method. Several studies have explored the impact of biomimicry on students' thinking skills and perception of nature, providing valuable insights into its potential benefits.

For instance, Alawad and Mahgoub (2014) conducted a study with middle school students, finding that teaching biomimicry enhances students' awareness of nature and its meaningful functions. In addition, biomimicry has been shown to affect early learning positively. The research also revealed that biomimicry has a lasting impact on students' skills, leading to the development of self-reflection, critical and creative thinking, and problem-solving techniques. As a result, Alawad and Mahgoub (2014) recommended considering biomimicry as a key component of the design education system (Alawad and Mahgoub, 2014).

Likewise, Tavsan et al. (2015) implemented biomimicry concepts in an architectural design course for second-grade students at Karandeniz Technical University in Turkey. Their research indicated that the use of analogies in the course aroused students' interest and wonder, increasing their motivation to explore nature-inspired design solutions. As students engaged with the concepts, they developed their analytical abilities and learned that many architectural challenges have solutions in nature (Tavzan et al., 2015).

In a study by Mansour (2010) at the University of Dammam in Saudi Arabia, interior architecture students were encouraged to draw inspiration from the genius of the natural world, fostering new paths for sustainable living on Earth. Mansour emphasized that teaching biomimicry as a tool for innovation could lead to a more harmonious integration of the built environment with nature (Mansour, 2010).

Yağlı and Altun (2022) in their article "A Bio design Education Program Proposal for Architects", emphasize the need for a paradigm shift in architectural education, urging universities and institutions to adopt the proposed bio-design education program to shape a new generation of architects committed to creating a greener and more resilient world (Yağlı and Altun, 2022). Awadalla (2023) suggests in his recommendations that interior design faculties should encourage students to explore and utilize natural functions in their design processes while integrating technology in harmony with nature. He emphasizes the importance of fostering students' understanding of how to simulate biological systems in their design concepts, not only in terms of aesthetics but also in functionality. By teaching about biological systems and processes in nature and incorporating bio-design principles, students can learn to simulate and apply these concepts effectively in architecture and engineering (Awadalla, 2023).

In architectural and industrial design education context, noteworthy insights emerge from two distinct case studies. Amer (2019) examines the effects of a "Biomimicry in Architecture" course at MSA University in Cairo. Through action research methodology, this study reveals that the course effectively introduces students to nature-inspired design approaches, enhancing their comprehension of the intricate interplay between design and the natural world. The active learning environment cultivates problem-solving skills, analytical thinking, creativity, and self-reflection, showcasing the lasting impact of biomimicry on students' capabilities (Amer, 2019; Avci, 2019). In the field of industrial design, Gamze Avci (2019) emphasizes biomimicry's significance and assesses its integration and awareness at Izmir universities. The study underscores the necessity for educators to bridge the connection between biomimicry and sustainability in the design process, enabling students to fully grasp its purpose. Amer (2019) further emphasizes the importance of embedding biomimicry as a foundational component in design education (Amer, 2019). These case studies collectively underscore the promising trajectory of integrating biomimicry into design education, with implications for both architectural and industrial design domains.

Taghavi (2016) provides valuable insights into applying biomimicry in interior architecture. The research emphasizes the importance of drawing inspiration from nature's strategies, forms, and processes to create sustainable and innovative interior spaces. By incorporating biomimicry-applying principles, interior designers can address various challenges, including energy efficiency, material selection, waste management, and occupant well-being (Taghavi, 2016). The study highlights that biomimicry in interior architecture extends beyond replicating physical forms and patterns found in nature, encompassing advanced engineering materials that mimic nature's structural and functional properties. This approach results in visually appealing and functional spaces and fosters a deeper connection between occupants and the natural world. Taghavi's research underscores the potential of biomimicry to drive innovation, promote sustainability, and enhance human well-being in interior architecture.

Overall, the case studies showcase the positive impact of the biomimicry approach in engaging students and instilling the principles of biomimicry as a systematic and scientific design methodology in architectural education. the researchers encourage institutions to further incorporate biomimicry into their curricula, promoting innovative and sustainable design solutions in the field of architecture.

2.4 The Role of Analogical Reasoning in Biomimicry Education in Interior Architecture:

Analogical reasoning is all about finding similarities between two ideas or concepts. This process of abstracting and transferring knowledge from one concept to another is a fundamental aspect of generating new and innovative design ideas. Goel (1997), concurs that analogical reasoning is a crucial element in the realm of creative design. In biomimicry or biologically inspired design, designers employ analogical reasoning to draw comparisons between biological phenomena and design challenges. They then apply similar strategies from nature to develop solutions for their designs. However, it's worth noting that, as noted by Shu et al. (2011), despite the many innovative solutions inspired by biology in engineering, there are ongoing challenges in creating comprehensive methods for biomimicry design. Cheong et al. (2014) share the view that analogical reasoning in the context of biomimicry design remains not entirely comprehended.

In the realm of biomimicry design thinking, the integration of analogical reasoning has emerged as a pivotal avenue for enhancing innovation and problem-solving. As demonstrated by studies such as those conducted by Stevens et al. (2019), Cheong et al. (2014), and Vendetti et al. (2015), the application of analogical transfer facilitates the bridging of knowledge between distinct domains, enabling designers to draw inspiration from nature's patterns, systems, and strategies to craft novel design solutions. These research endeavours collectively emphasize the significance of analogical reasoning as a cognitive tool that fuels creativity and offers a framework for translating biological concepts into tangible design principles.

Moreover, Stevens, et al. (2019) present a compelling case for the successful integration of analogical reasoning within a Design-Based Learning framework, providing students with a compelling rationale for learning, fostering engagement, offering opportunities for application and practice, and encouraging reflection and iteration an approach aligned with Kolodner's (2003) perspective on analogical leaps across diverse contexts. Collaborative group work, trend discovery, communication, and continuous reflection are inherent components of this process.

Cheong, et al. (2014) shed light on the potential cognitive biases affecting analogical reasoning, notably fixation's pronounced influence on the design process, which, according to their observations, may surpass the influence of analogical reasoning itself. Aligning with Brown's (2010) notion of studying transformational creativity through an inductive, bottom-up approach, Cheong et al. advocate for heightened awareness of fixation's impact on identifying analogies a fundamental requirement for effective analogical reasoning in biomimicry design.

Further reinforcing the importance of analogical reasoning in biomimicry, biomimicry design practitioners, as stipulated by Biomimicry 3.8 (2014) and ASU (2016), are expected to embody specific elements in their solutions, including accurate emulation of biological strategies, sustainability integration, adherence to biological forms, processes, and ecosystems, interdisciplinary collaboration, and a deep sense of gratitude and respect for the organisms that inspire their designs.

The role of analogical reasoning in biomimicry education is underscored by its three core processes: recalling relevant knowledge, determining its applicability, and applying an approach congruent with the principles of abstracted design and the nature technology summary. Didactical approaches, such as iterative feedback loops and the incorporation of hand drawing, further facilitate students' comprehension and the effective application of analogical reasoning.

Stevens (2021) concludes that analogical reasoning enriches students' grasp and application of biological models, while biomimicry tools like Life's Principles and visual conceptual mapping provide a common language for sustainability assessment and foster a deeper understanding of complex systems. Implementing biomimicry's analogical reasoning in the classroom enhances learning engagement also equips students with valuable tools to contribute to sustainable solutions, promoting a heightened appreciation for nature and scientific engagement.

In line with Cheong et al.'s (2014) qualitative and inductive study, which unearthed observations regarding novice designers' tendencies to focus on superficial similarities and the influence of fixation, Stevens (2021) corroborates these findings. Stevens notes that biomimicry students often struggle with translating biological mechanisms into design principles, a critical step in generating biomimicry solutions. To address this, Stevens recommends dividing the Nature's Technology Summary exercise into sections with intermediate feedback sessions, emphasizing the value of hand drawing to enhance students' understanding, and sequentially addressing forms, processes, and system analogies in biomimicry design education, potentially improving students' comprehension.

In conclusion, analogical reasoning plays an important role in biomimicry design, facilitating the transfer of knowledge and strategies from the biological realm to innovative design. While this approach has shown great potential for enhancing creativity and problem-solving in biomimicry, designers must be aware of and address ongoing challenges. The integration of analogical reasoning in biomimicry education is vital, as it equips students with valuable tools for sustainability assessment and a deeper understanding of complex systems, ultimately promoting a profound appreciation for nature and scientific engagement. Furthermore, the practical application of analogical reasoning in biomimicry design is essential to ensure the accurate emulation of biological strategies, sustainability integration, interdisciplinary collaboration, and respect for the organisms that inspire these innovative solutions. In summary, analogical reasoning is fundamental in bridging the gap between biology and design, thereby nurturing a comprehensive approach to biomimicry that offers the potential for a more sustainable future.

CHAPTER III

METHODOLOGY

3.1 Method of The Study:

The method of study used in this case consists of two main parts. The first part involved administering questionnaires to academics in the Department of Interior Architecture at Jordanian universities. Similarly, the second part involved a separate questionnaire for students in the Department of Interior Architecture and Interior Design at these universities. The details of these two parts will be discussed in the following sections.

For the student part, the research sample was selected from the architecture and design departments. The data collection process began by selecting samples of students enrolled in design studios at different levels within the Interior Architecture and Interior Design departments because students in the first and second years specialize in architecture and design in general. Accordingly, the number of the total sample was determined. Out of 283 students approached, 98 agreed to participate in the survey. The students were allowed to complete the questionnaire in hard copy or through an online link using Google Surveys. Many of them chose the online option. A brief explanation of the term was included with the questionnaire to aid those unfamiliar with the concept of biomimicry. An example of the questionnaire can be found in Appendix A.

As for the academic part, full-time academics in the Interior Architecture and Interior Design departments from these universities were chosen as samples. Out of 15 academics approached, 11 agreed to participate in the survey. Like the students, the academics were given the choice to complete the questionnaire in hard copy or through an online link using Google Surveys. All of them opted for the online method. A brief explanation of biomimicry and Analogical reasoning was included with the questionnaire to assist those who might not be familiar with the topic. An example of the questionnaire can be found in Appendix B.

3.1.1 The Aim of The Case Study:

- To assess the level of awareness among students and academics regarding biomimicry.
- To determine the extent to which biomimicry is applied in Interior Architecture and Interior Design in Jordanian universities.

- To explore the relationship between awareness levels and the application of the biomimicry method in Interior Architecture.
- To identify the reasons behind the limited use of biomimicry as a compulsory course in design studio academics at Jordanian universities.

3.1.2 The Categories of Questions:

The student's questionnaire includes sixteen questions, and the academics questionnaire includes twenty-four questions, divided into three categories:

Personal awareness questions aimed to gauge the knowledge of academics and students about biomimicry.

Opinion-based questions were designed to gather perspectives on the relationship between sustainability and biomimicry and its usage in interior architecture. Additionally, these questions aimed to understand the reasons for the limited integration of biomimicry in interior architecture design studios and the role of analogical reasoning in biomimicry education.

These experience-based questions were designed to gain insights into the practical application of biomimicry and its integration into the university curriculum. By understanding their previous experiences and knowledge of biomimicry, the study sought to paint a comprehensive picture of biomimicry awareness and implementation in the Interior Architecture and Interior Design field in Jordanian universities. Because most Jordanian universities teach interior architecture and interior design in Arabic, the entire study was conducted in Arabic and translated into English after data collection.

3.1.3 Statistical Analysis and Tools:

This study used the statistical package for social sciences [SPSS] v27 to analyse data. SPSS is one of the most commonly used packages in various social sciences disciplines to analyse data; this package provides many tools and tests that assist data analysis. Below is a list of tools and tests used in this study to gather data:

- Descriptive Analysis: This involves presenting summary statistics like counts and percentages to provide an overview of sample personal information and assessments. Mean and Standard Deviation (STD) are used to show the average agreement levels on various aspects in the survey.

- Chart Graphs: Visual representations such as Pie and Cluster Bar Graphs are used to help illustrate the survey results clearly and concisely, making it easier for readers to understand the data.
- Independent Samples T-Test: This statistical test is employed to compare the mean values of two groups, helping to determine whether significant differences exist between them.
- One-way Analysis of Variance (ANOVA): ANOVA is used to compare mean values among three or more groups. It is particularly useful for identifying significant differences between these groups [according to university and age]. post-test Scheffe analysis is conducted following a significant ANOVA to pinpoint the specific sources of differences.
- Cross Tabs: This technique is used to examine how respondents' selections differ based on their personal information. It helps identify patterns or trends in the data based on specific demographics or characteristics.
- Total Unduplicated Reach and Frequency Analysis (TURF): TURF analysis is employed to determine which assessments are the most frequently chosen among multi-check assessments. This method helps identify the most popular or commonly selected options among respondents [multi-check assessments].

3.2 Case Studies Jordanian Universities:

There are four government universities and six institutional universities with interior architecture and interior design undergraduate and postgraduate programs in Jordan. To assess the current state of biomimicry concepts in interior architecture education and the level of awareness among students and academicians, a research study was conducted in three universities, which included Yarmouk University in the city of Irbid, the University of Jordan in the capital, Amman, and the German Jordanian University in the city of Madaba; to ensure the comprehensiveness of the study on different regions of Jordan. Official approvals were obtained from these universities, and necessary measures were taken to ensure participants' anonymity and voluntary participation. This study aimed to gauge the awareness levels of biomimicry among students and academics, analyse the extent of its inclusion in curricula, examine the link between awareness and its practical application in Interior Architecture, and uncover the reasons behind its limited integration as a compulsory element in design studio courses at Jordanian universities. The study involved two surveys, with students and academicians from these universities' interior architecture and interior design departments, aiming to provide insights into the subject and address the research questions.

3.2.1 Yarmouk University (YU):

Yarmouk University is one of the leading universities in Jordan, located in Irbid. It was established in 1976 and is known for its strong academic programs and diverse faculties. The university offers a wide range of undergraduate and postgraduate programs, including in the fields of arts, sciences, engineering, humanities, and social sciences.

In terms of interior architecture education, Yarmouk University provides students with a comprehensive curriculum that covers various aspects of interior design, architectural theory, and practical design skills. The university's Interior Design Department aims to equip students with the knowledge and expertise needed to excel in the field of interior design (URL 7).

As part of the study mentioned earlier, Yarmouk University was selected as one of the sample universities to assess the level of awareness and application of biomimicry concepts in interior architecture education. The survey conducted at Yarmouk University aimed to gain insights into how biomimicry is perceived and integrated into the curriculum, and how students and academicians respond to this innovative approach in their educational journey. Yarmouk University has a commitment to promoting research and innovation, and it actively encourages its students and faculty members to engage in research activities (URL 7).

The Design Department's curriculum spans four years, including compulsory and elective courses and design studios. During the initial two years, students undertake courses that are shared among all departments within the faculty. Following this, students specialize in either interior design or graphic design programs. The department is staffed by three full-time instructors and one part-time trainer, responsible for educating a student body comprising over 300 individuals. Specifically, in the Interior Design Department at Yarmouk University, there are a total of 112 students, with 54 consenting to participate in the survey.

3.2.2 University of Jordan (UJ):

The University of Jordan, located in Amman, is one of the oldest and most prestigious universities in Jordan. It was established in 1962 and has since become a prominent centre of higher education in the country. The university offers a wide range of undergraduate and postgraduate programs in various disciplines, including arts, sciences, engineering, social sciences, and humanities (URL 8).

In the context of interior architecture education, the University of Jordan's Interior Design Department provides students with a comprehensive and rigorous curriculum. The department aims to nurture creative and skilled interior designers who are equipped to address contemporary design challenges.

As part of the study mentioned earlier, the University of Jordan was selected as one of the sample universities to assess the level of awareness and implementation of biomimicry concepts in interior architecture education. The survey conducted at the University of Jordan sought to understand how biomimicry is perceived and integrated into the curriculum, as well as how students and academicians respond to this innovative design approach. The University of Jordan is known for its research and academic excellence commitment. The university encourages its students and faculty members to engage in research activities and innovative projects. This focus on research and academic inquiry may provide a conducive environment for exploring new approaches, such as biomimicry in design, within the field of interior architecture and design education (URL 8).

The Department of Visual Arts curriculum spans four years, including compulsory and elective courses and design studios. During the initial two years, students undertake courses that are shared among all departments within the faculty. Following this, students specialize in the interior design field, or Sculpture field, or Multimedia field, or Photography and painting programs. The department is staffed by four full-time instructors responsible for educating a student body comprising over 600 individuals. Specifically, in the Interior Design Department at the University of Jordan, there are 109 students, with 31 consenting to participate in the survey.

3.2.3 Jordanian German University (GJU):

The German Jordanian University (GJU) is a unique and innovative institution in Jordan, established in partnership with German universities. It was founded in 2005 and is located in Madaba, Jordan. The university follows the German higher education system and offers a range of undergraduate and postgraduate programs across various disciplines, including engineering, natural sciences, business, and design (URL 9).

In interior architecture education, the German Jordanian University provides its students a comprehensive and interdisciplinary curriculum. The Interior Architecture Department at GJU aims to foster creative thinking and design skills while integrating cutting-edge technology and sustainable practices into learning (URL 9).

As part of the study mentioned earlier, the German Jordanian University was selected as one of the sample universities to assess the level of awareness and implementation of biomimicry concepts in interior architecture education. The survey conducted at GJU sought to understand how biomimicry is incorporated into the interior design curriculum and how both students and academicians perceive and apply this approach in their educational and professional practices.

GJU is known for promoting a culture of innovation, research, and international collaboration. The university encourages students and faculty members to engage in research projects and industry partnerships, providing a dynamic learning environment that fosters creativity and critical thinking. This emphasis on innovation and interdisciplinary collaboration may offer opportunities for exploring and integrating biomimicry principles in interior architecture education at the university (URL 9).

The Architecture Department curriculum contains many compulsory and elective courses and design studios offered over five years. In the first and second years, students study courses common to all departments in the faculty. After that, the student begins studying interior design or graphic design programs. This department has seven full-time teachers teaching interior Architecture to over 300 students. The total number of students in the Interior Design Department at German Jordanian University is 17, 13 of whom agreed to participate in the survey.

3.3 Curriculum:

There are four public universities and six institutional universities with interior architecture and interior design undergraduate and postgraduate programs in Jordan. As a result, following a review of university colloquiums, the compulsory courses from three state government universities have been included in the tables below. Note that these universities do not offer courses related to biomimicry.

3.3.1 Compulsory requirements of Interior Design at Yarmouk University:

The Bachelor of Interior Design program at Yarmouk University consists of 132 credit hours. The compulsory specialization requirements in the Interior Design program are 21 credit hours directly related to interior design. Other compulsory requirements are divided into three categories: University requirements of 27 credit hours, College requirements of 21 credit hours, and Department requirements (stream requirements) of 48 credit hours, 15 hours (elective courses). It provides its students with an organized study plan that helps them acquire skills and knowledge in general and interior design. Table 2 displays the compulsory courses for the YU Bachelor of Interior Design program. Table 3 displays the mandatory master's program requirements in the design of 33 credit hours with the thesis, divided into two categories: a compulsory department requirement of 24 credit hours and an elective department requirement of 9 credit hours at Al Yamamah University.

Table 2: Compulsory requirements for Interior Design program at YU (URL 7).

Course No.	Course Title	Hrs.
DES 331	Space Planning and Lighting	3
DES 333	Furniture Design	3
DES 430	Interior Design 1	3
DES 431	Interior Design 2	3
DES 432	Interior Design 3	3
DES 498	Advanced Studies for the Graduation Project	3
DES 499D	Graduate Project (Interior Design)	3

Table 3: Compulsory requirements for Master of Design at YU (URL 7).

Course No.	Course Title	Hrs.
DES 601	Research Methods in Design	3
DES 603	Studies in Visual Culture	3
DES 604	Communication Theories and Design	3

DES 631	Design and Architecture Sustainability.	3
DES 633	Lighting Design Technology	3
DES 634	Furniture Design Techniques	3
DES 681	Design and Environment	3
DES 696	Creative Thinking in Design	3
DES 697	Practical Design Project	3
DES 699	Thesis	6

3.3.2 Compulsory requirements of Interior Design at University of Jordan:

To earn a bachelor's degree in interior design from the Department of Visual Arts at the University of Jordan, students are required to complete a total of 132 credit hours. The compulsory specialization requirements in the Interior Design program are 39 credit hours directly related to interior design. Other compulsory requirements are divided into three categories: University requirements of 27 credit hours, School requirements of 24 credit hours, and Department requirements (stream requirements) of 33 credit hours, 9 credit hours (elective courses). It provides its students with a structured study plan that helps them acquire skills and knowledge in general design and interior design. Compulsory Interior Design Requirements 39 credits hours, Table 4 presents the compulsory courses for the Bachelor of Interior Design program at UJ.

Table 4: Compulsory requirements for Interior Design program at UJ (URL 8).

Course No.	Course Title	Hrs.
2001181	History of Interior Design	3
2001182	Interior Design Techniques	3
2001281	Furniture Design	3
2001282	Interior Design 1	3
2001283	Interior Design 2	3
2001284	Interior Design 3	3
2001381	Lighting and Acoustics	2
2001382	Sustainability Design	2
2001383	Design Psychology	2

2001384	Engineering Drawing 1	3
2001385	Engineering Drawing 2	3
2001386	Workshop	3
2001418	Graduate Project 1	2
2001419	Graduate Project 2	4

3.3.3 Compulsory requirements of Interior Architecture at German Jordanian University:

The Interior Architecture stream at the German Jordanian University is one of a program as it is the first and only program in Jordan offering an engineering degree in interior architecture. The program of Interior Architecture consists of 187 credit hours. The compulsory specialization requirements in the Interior Architecture program are 52 credit hours directly related to interior architecture. Other compulsory requirements are divided into three categories: University requirements of 27 credit hours, School requirements of 37 credit hours, and Department requirements (stream requirements) of 71 credit hours. its students a curated study plan that helps them acquire the skills and knowledge of architecture. Table 5 introduces the compulsory courses for the Bachelor of Interior Architecture program at GJU.

Table 5: Compulsory requirements for Interior Architecture program at GJU (URL 9).

Course No.	Course Title	Hrs.
ARCH 140	Understanding the Built Environment	3
ARC 221	Architectural Design: Methods and Typologies	5
ARCH 221	Modern Foundations of Architecture	3
ARC 231	Computer Visualizations I	2
ARC 232	Computer Visualizations II	2
ARCH 261	Structural Systems I	3
ARCH 262	Utility Planning and Design I	3
ARCH 353	Land Surveying	2
ARCH 150	Physics for Architects	3
ARCH 350	Local Internship	0

ARCH 255	Interior Construction Works I	3
ARCH 355	Interior Construction Works II	3
IARC 355	Interior Working Designs	3
IARC 213	Space Planning for Temporary Uses	5
IARC 214	Retail Design Studio	5
IARC 215	Shopfront and Display Design	5

In Chapter 3 conclusion, the research methodology for the case study involves two main components: administering questionnaires to academics and students in the Interior Architecture and Interior Design departments at Jordanian universities. The chapter outlines the fourfold aim of the case study, which includes assessing awareness levels, exploring biomimicry's application, understanding the relationship between awareness and application, and identifying reasons for its limited integration.

The questions in the questionnaires are categorized into three groups: personal awareness questions, opinion-based questions, and experience-based questions. The case study examines institutions such as Yarmouk University, The University of Jordan, and the German Jordanian University, employing surveys to gauge the extent of biomimicry awareness and utilization among students and academicians in interior architecture and design. Furthermore, the chapter introduces the research question regarding, to what extent are Jordanian interior architecture students and academics aware of biomimicry.

The chapter concludes by detailing the courses offered by Jordanian universities with interior architecture and design programs, specifically focusing on compulsory courses from three public universities. This chapter sets the stage for the subsequent findings and discussions presented in Chapter 4.

CHAPTER IV

Findings and Evaluation

In Chapter Four, the findings derived from the statistical analysis process sample are presented. In section 4.1, findings from the analysis of the student sample are presented. This section encompasses a range of analysis tools and tests that were employed to achieve the research objectives. The data collection process involved administering both paper and online surveys to students in Interior Architecture and Interior Design programs at Jordanian universities, including UJ, YU, and GJU. The official approval of universities was obtained, and efforts were made to ensure participants' anonymity and voluntary participation. A total of 98 completed responses were collected over a two-month period. The surveyed sample is detailed, and student's personal information, such as age and education level, is provided. Statistical tools such as SPSS were used for data analysis, including descriptive analysis, chart graphs, independent samples T-test, ANOVA, cross tabs, and Total Unduplicated Reach and Frequency Analysis (TURF).

In Section 4.2, the findings related to the academic sample are outlined. Due to the small sample size, descriptive statistics and charts were predominantly used for analysis. The data collection process for academics was conducted during visits to architecture departments, resulting in 11 valid responses. The surveyed academic sample is described, including their personal information such as age and education level. The presentation of findings utilizes pie charts and tables to visualize and summarize the collected data.

Overall, these findings serve as a comprehensive insight into the awareness, perceptions, and experiences of both students and academics in the field of Interior Architecture and Interior Design at Jordanian universities. The utilization of various statistical analysis methods aids in uncovering patterns and trends within the collected data, contributing to a well-rounded understanding of the research questions.

4.1 Students sample findings:

4.1.1 Introduction:

This section provides findings gathered by statistical analysis process for student's sample, a variety of analysis tools and tests were applied to gather findings that guided the researcher to achieve the objectives of the study.

4.1.2 Data collection:

The researcher made use of both paper and online survey to gather responses from targeted population, students in Interior Architecture programs in Jordanian universities that are: UJ, YU and GJU were targeted to gather their responses. The researcher contacted official public relationships in these universities to gain official approvals for contacting targeted students. The link of online survey was shared by the universities to the specified departments students, and to increase responding ratio the researcher made several visits to student's classes in the targeted universities, instructions related to the study purposes were provided for students, students were informed that their participation is voluntary, and to keep their identity anonymous, confidently of data was ensured for students. A set of paper questionnaires were handed for students, the researcher gave time for students to fill the questionnaires and return it back. All collected paper questionnaires were coded into online from of data.

For two months data collection was conducted, during this period a total of 98 completed responses were collected, all responses were valid due to careful contact by the researcher to target students by explaining the purposes of the study to them and ensuring their voluntary participation. The data collection process involved using Google Forms online and paper questionnaires, which were subsequently coded into an SPSS data file for statistical analysis.

4.1.3 Surveyed sample:

Below Table 6 gives statistics for surveyed sample from targeted universities, in total 98 students were surveyed: n= 54 [55.1%] were from YU, n= 31 [31.6%] were from UJ and n= 13 [13.3%] were from GJU. Out of a total of 283 students who were approached, 98 students agreed to participate in the survey. Additionally, out of 15 academics who were approached, 11 of them agreed to take part in the survey.

Table 6: Surveyed sample from targeted universities (n= 98).

University	Reponses count	% of the sample
YU	54	55.1%
UJ	31	31.6%
GJU	13	13.3%
Total	*98*	*100%*

4.1.4 Students' personal information:

Counts and percentages were presented in Table 7 to display students' personal information. Regarding age of respondents, more than half of the surveyed students n= 66 [67.3%] were at the age 18 – 24 years, n= 25 [25.5%] were at the age 25 – 30 years and n= 7 [7.1%] were at the age over 30 years. Meanwhile, for students' current levels of education: n= 70 [71.4%] were at Bachelor level and n= 28 [28.6%] were at Master level, none of the surveyed students were at Ph.D. level. Figure (28) for the pie chart showing the age results of the students surveyed and Figure (29) for the pie chart showing the results for the current educational level of the students surveyed.

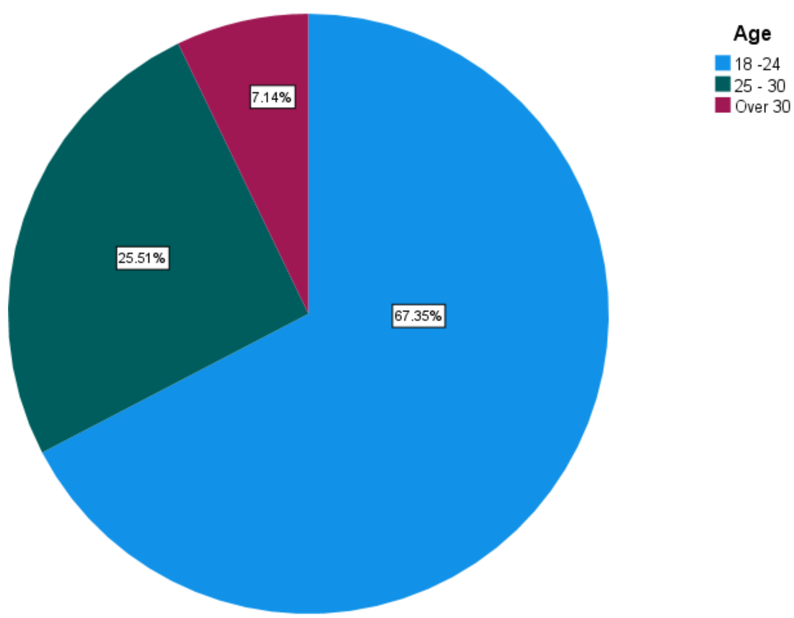

Figure 22: Pie chart presenting age results of surveyed students.

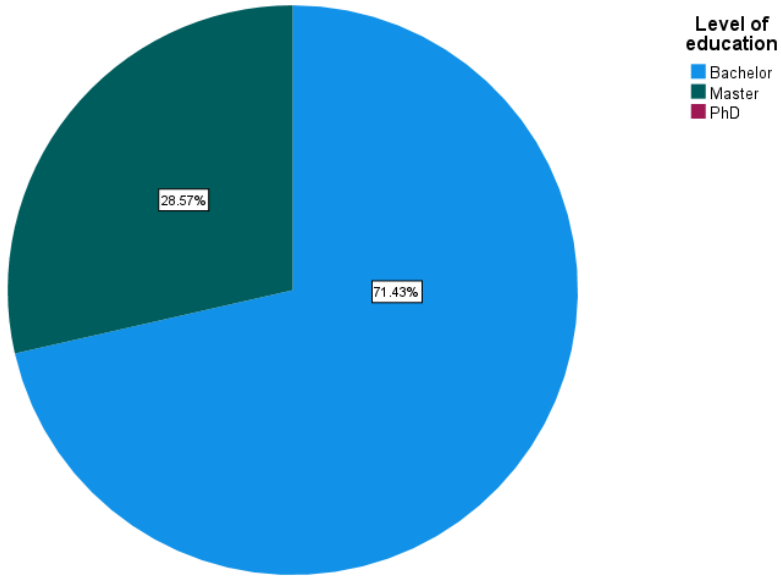

Figure 23: Pie chart presenting current education level results of surveyed students.

Table 7: Students' personal information (n= 98).

	Count	**%**
Age		
18 – 24 years	66	67.3%
25 – 30 years	25	25.5%
Over 30 years	7	7.1%
Current level of education		
Bachelor	70	71.4%
Master	28	28.6%
PhD	--	--

4.1.5 Findings:

This section presents the findings of the study. Various information was collected about the level of knowledge of biomimicry in interior architecture education in Jordan. The findings collected by the study were as follows:

Q.4 Level knowledge of Biomimicry concept among surveyed students:

Results displayed in Table 8 show modest levels of relevance among surveyed students with the Biomimicry concept, among the total sample, 60 students reported that they had heard about the concept in comparison to 38 students who didn't hear about the concept. Such findings entail the need for more efforts by academics in Jordanian universities to direct academic learning toward the Biomimicry concept among their students.

Comparisons were conducted according to university, age and level of education to gain more understanding for extent of relevance of the concept among students. According to university, in YU: 37 students have heard about the concept in compare to 17 who didn't hear before, UJ: 17 students have heard before about the concept in compare to 14 who didn't hear before, and for GJU: 6 students have heard before about the concept in compare to 7 who didn't hear before.

According to the current level of education: for bachelor level: 44 students have heard before in comparison to 26 haven't heard before, and for master level: 16 students have heard before in compare to 12 students who didn't hear before. Figures 30 and 31 introduced bar charts displaying reported results.

Table 8: Results of relevance of Biomimicry concept among surveyed students (n= 98).

	Total sample [n=98]	University			Level of education	
		YU [n=54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n=70]	Maste [n=28]
No	38	17	14	7	26	12
Yes	60	37	17	6	44	16
Total	98	54	31	13	70	28

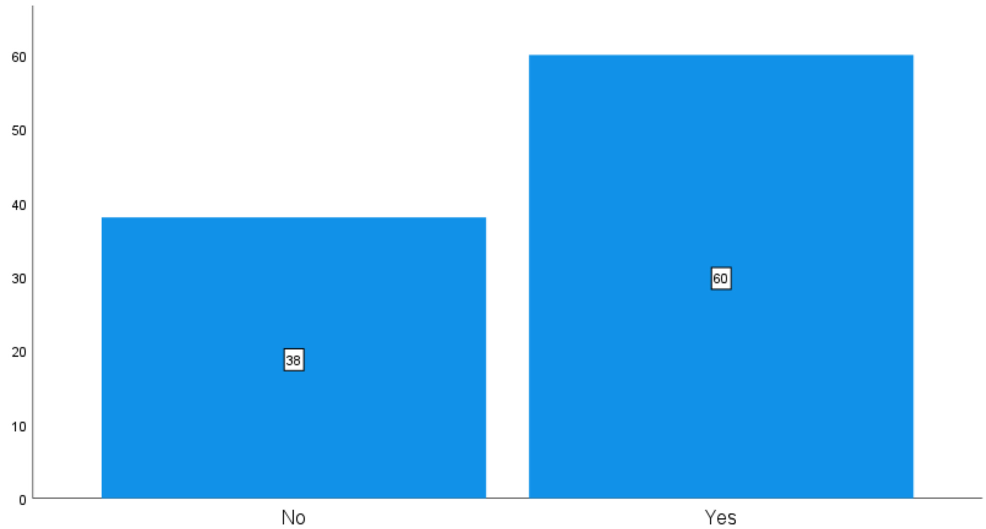

Figure 24: Bar chart presenting relevance of Biomimicry concept among surveyed students – total sample.

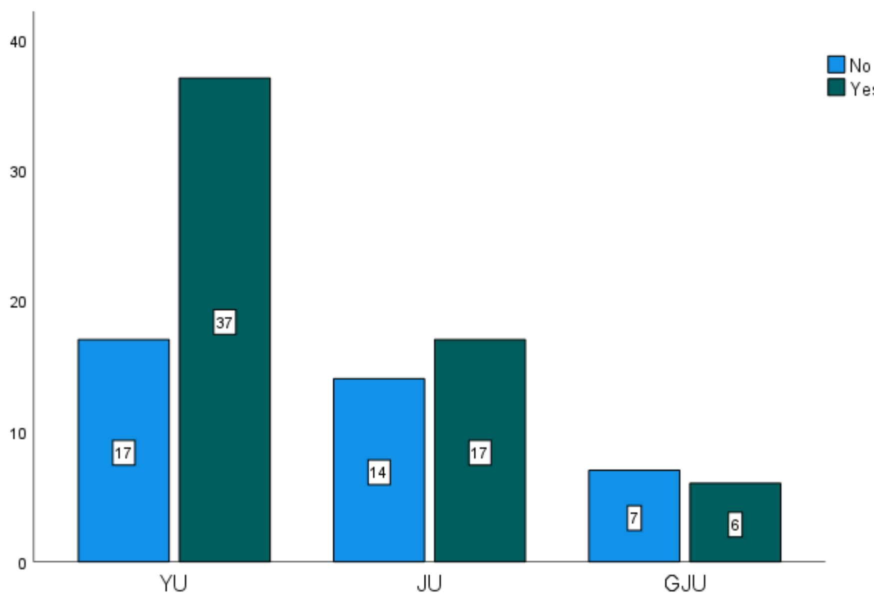

Figure 25: Bar chart presenting relevance of Biomimicry concept among surveyed students – according to studying university

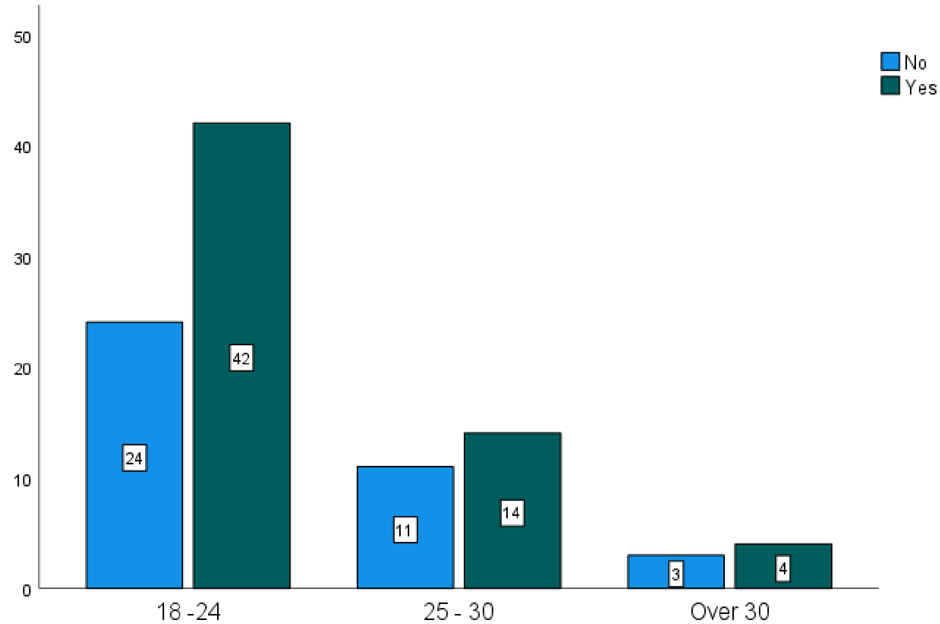

Figure 26: Bar chart presenting relevance of Biomimicry concept among surveyed students – according to age.

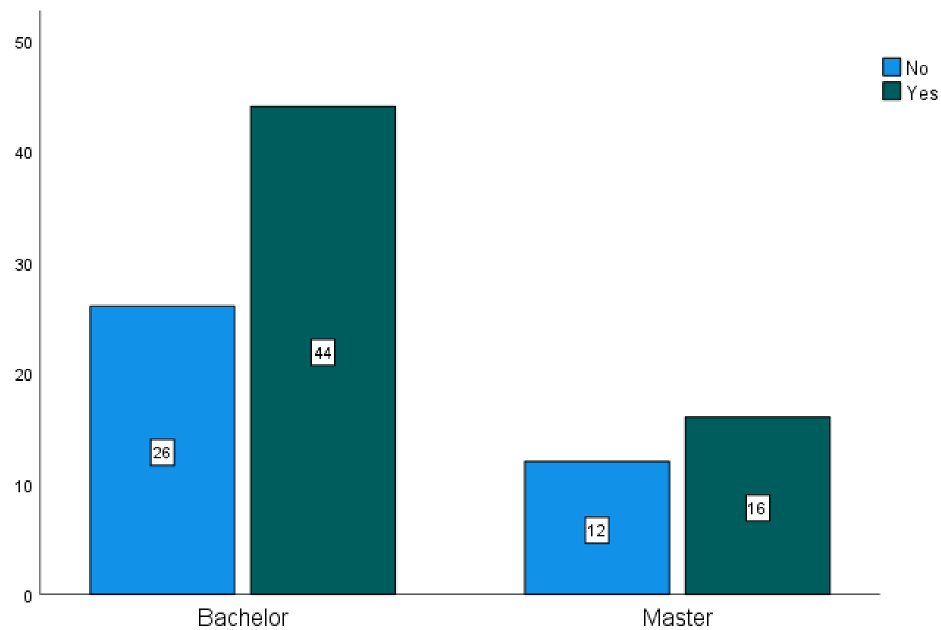

Figure 27: Bar chart presenting relevance of Biomimicry concept among surveyed students – according to current education level.

Q.5 Context for relevance of Biomimicry concept among surveyed students:

Students who reported that they have heard before about Biomimicry concept [n= 60] were asked to report the context that they hear from about the concept. Among the total sample of 60 students who were familiar with the concept: n= 26 reported from outside reading or research and through online resources or media, n= 17 reported in class lectures, n= 10 reported from design professionals or practitioners or colleagues in the field of interior architecture, n= 5 reported In-class projects or assignments and n= 2 reported from biomimicry-related events or workshops. Comparisons according to personal information (according to educational level and university) reported nearly same results, most selected context of relevance was from outside reading or research and through online resources or media showing the need for more efforts by academic in the field to raise the awareness among students toward Biomimicry concept.

Table 9: Results of context of relevance of Biomimicry concept among surveyed students (n= 60).

Context	Total sample heard before [n= 60]	*University*			*Level of education*	
		YU [n= 37]	UJ [n= 17]	GJU [n= 6]	Bachelor [n= 44]	Master [n= 16]
In class lectures	17	12	4	1	14	3
In-class projects or assignments	5	3	1	1	5	0
From outside reading or research and through online resources or media	26	15	7	4	15	11
From biomimicry-related events or workshops	2	0	2	0	2	0
From design professionals or practitioners or colleagues in the field of interior architecture	10	7	3	0	8	2
Total	*60*	*37*	*17*	*6*	*44*	*16*

Q.6 Extent of familiarity with Biomimicry concept in interior architecture among surveyed students:

To determine extent of familiarity with Biomimicry concept in interior architecture among surveyed students, we used Likert scale of 3-points that takes 1 for least familiarity level which is Unfamiliar, 2 for being familiar and 3 for being very familiar, hence, highest score was assigned for highest familiarity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward being familiar with the concept. Table 10 gives results for this question.

Reported results showed most of the students surveyed had more familiarity with the Biomimicry concept in interior architecture, which is close to earlier results in the relevance of the Biomimicry concept section. Overall, the sample scored a mean value of 1.86, exceeding 1.5 in the middle of the scale, showing positive assessments by the students toward the concept; however, such familiarity is not very high. STD. The coefficient was 0.66, showing homogeneity in assessments as assessments can be seen as clustering around their mean values. Further, companions were made in terms of personal information (according to educational level and university) to determine who was more familiar with the concept.

For differences in familiarity levels according to the university, ANOVA test scored [F= 7.869] which was significant at 0.05 level having [P < 0.001] showing significant differences in familiarity levels between universities, posttest Scheffe that provided multiple companions reported that source of significant differences was YU having the highest mean value [2.07], hence we can conclude that YU students have the highest facility in compare to students in UJ or GJU. On the other hand, non-significant differences were seen according to age and according to level of education as ANOVA test for age was non-significant [F= 0.416, P= 0.661], and T-Test for level of education was also non-significant [T= -0.338, P= 0.736]. Provided bar charts displaying the familiarity with the concept of biomimicry in interior architecture among the students surveyed according to their personal information.

Table 10: Extent of familiarity with Biomimicry concept in interior architecture among students (n= 98).

**Difference is significant at 0.05 level.*
- F donates ANOVA test.
- T donates Independent Samples T-Test.

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n= 54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n=70]	Master [n=28]
Mean [STD.]	1.86 [0.66]	2.07 [0.64]	1.65 [0.61]	1.46 [0.52]	1.84 [0.65]	1.89 [0.69]
Significant differences	//	F= 7.869* [P < 0.001] **YU***			T= -0.338 [P= 0.736]	

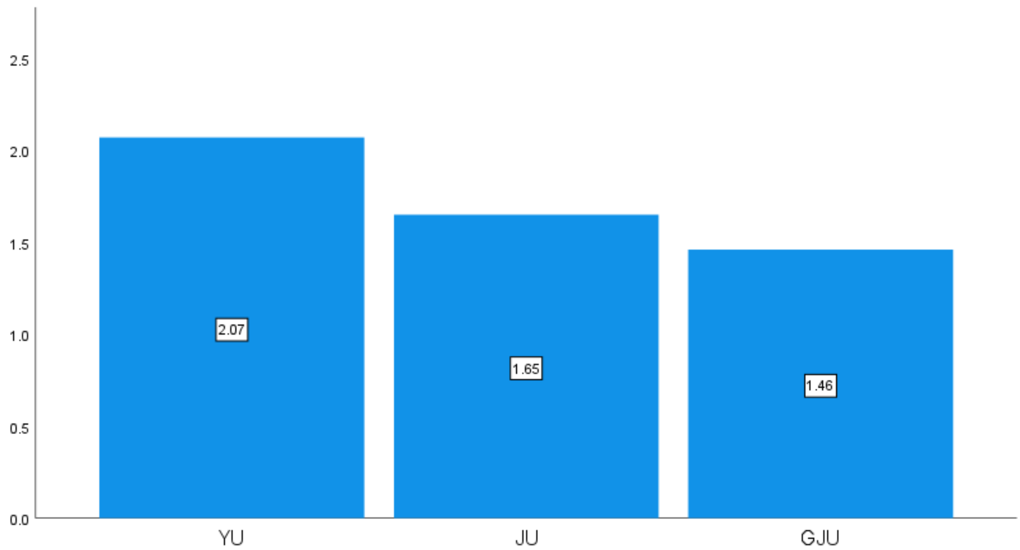

Figure 28: Bar chart presenting extent of familiarity with Biomimicry concept in interior architecture among surveyed students – according to university.

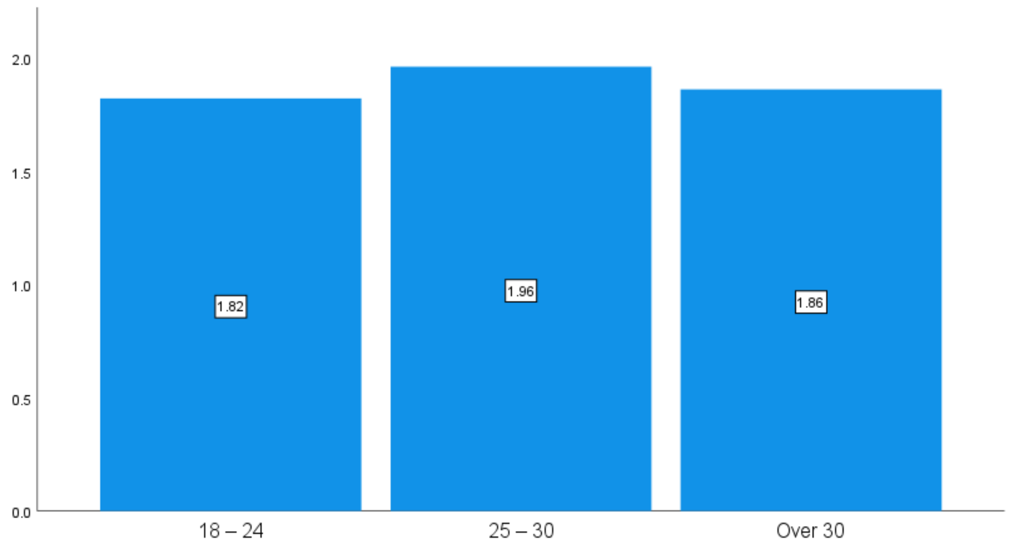

Figure 29: Bar chart presenting extent of familiarity with Biomimicry concept in interior architecture among surveyed students – according to age.

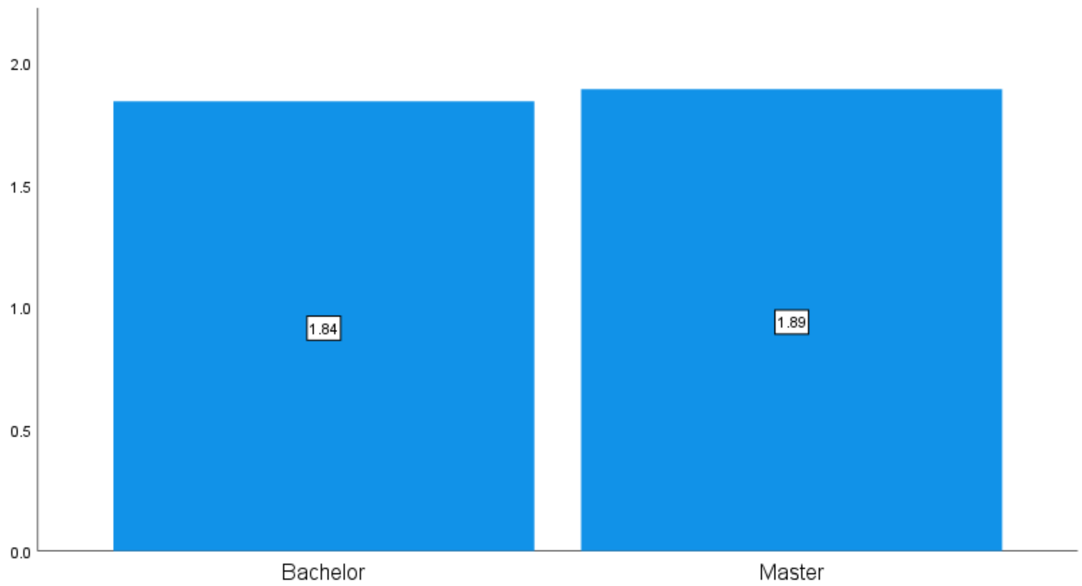

Figure 30: Bar chart presenting extent of familiarity with Biomimicry concept in interior architecture among surveyed students – according to current level of education.

Q.7 Perceptions of surveyed students toward usefulness of Biomimicry concept in interior architecture:

To determine levels of student's perceptions toward usefulness of Biomimicry concept in interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward usefulness of the concept. Table 11 presents results for this question.

Reported results showed that all the students surveyed had a high level of perception toward the usefulness of biomimicry in interior architecture. Overall sample scored a mean value of 2.43 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the students toward usefulness of the concept. STD. coefficient was 0.89 showing homogeneity in assessments as assessments can be seen as clustering around its mean values. Further, companions were made in term of personal information to determine who had the higher level of perceptions toward usefulness of the concept. Neither of conducted companions were significant, showing an indicator of high levels of perceptions toward usefulness of the Biomimicry concept in interior architecture among surveyed students in all three surveyed universities, and regardless their age or current education level. Provided bar charts displaying levels of perceptions about the usefulness of biomimicry in interior architecture among the students surveyed according to their personal information.

Table 11: Perceptions of students toward the usefulness of Biomimicry concept in interior architecture (n= 98).

**Difference is significant at 0.05 level.*

- *F donates ANOVA test.*
- *T donates Independent Samples T-Test.*

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n= 54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n=70]	Master [n=28]
Mean [STD.]	2.43 [0.89]	2.52 [0.84]	2.39 [0.92]	2.15 [0.99]	2.46 [0.86]	2.36 [0.95]
Significant differences	//	F= 0.938 [P= 0.395]			T= 0.503 [P= 0.616]	

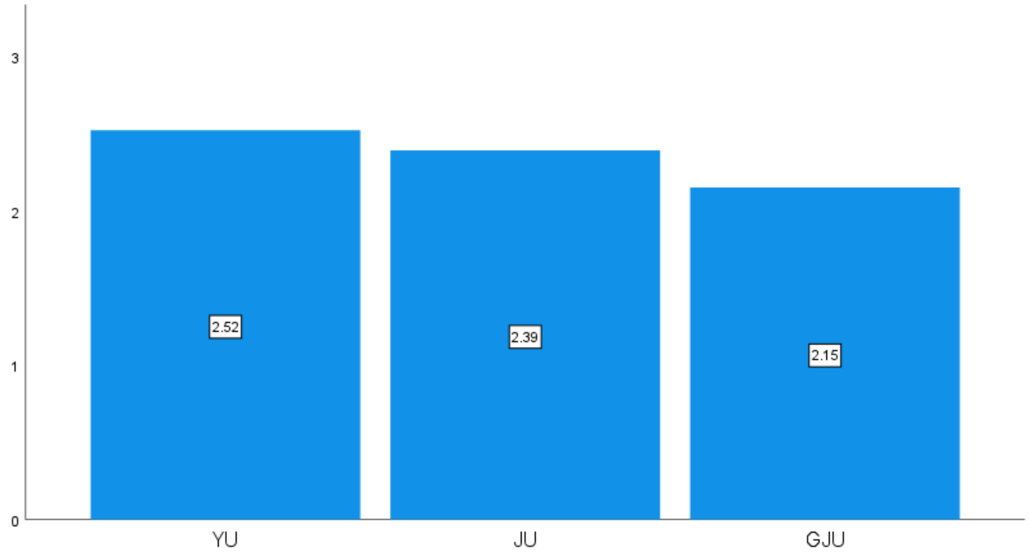

Figure 31: Bar chart presenting Perceptions of surveyed students toward usefulness of Biomimicry concept in interior architecture – according to university.

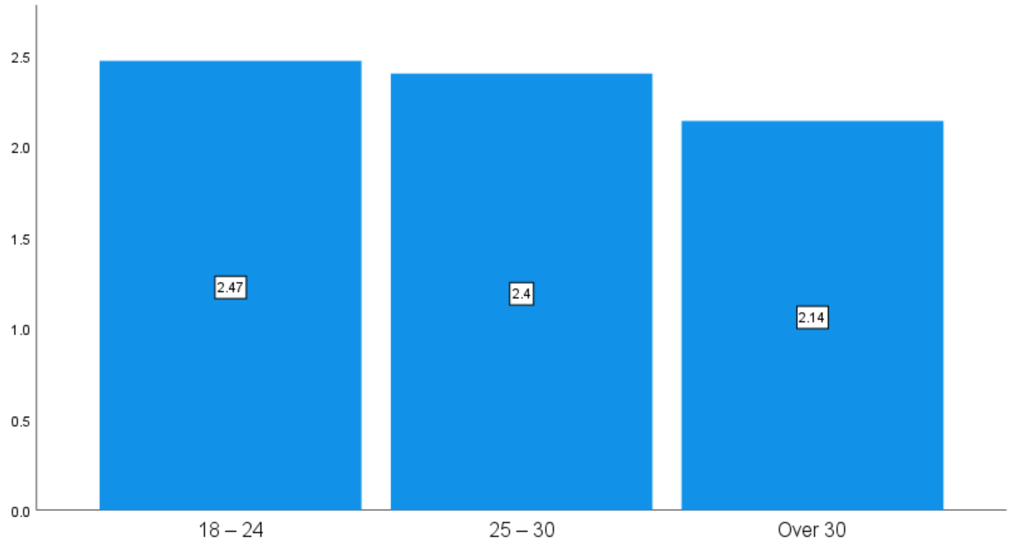

Figure 32: Bar chart presenting Perceptions of surveyed students toward usefulness of Biomimicry concept in interior architecture – according to age.

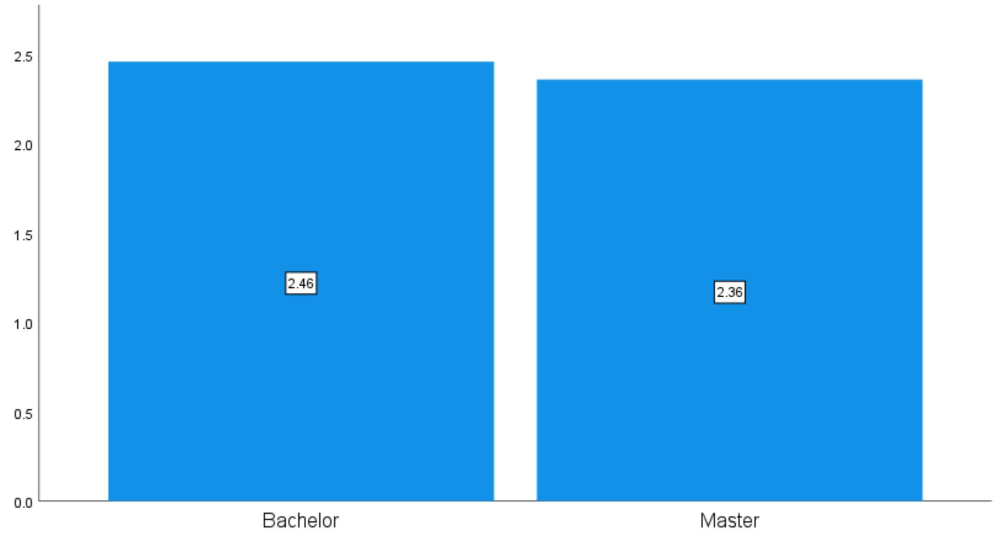

Figure 33: Bar chart presenting Perceptions of surveyed students toward usefulness of Biomimicry concept in interior architecture – according to current level of education.

Q.8 Experiencing practical example of Biomimicry in interior architecture:

Results collected in Table 12 showed that more than half of the surveyed students didn't experience any practical example of Biomimicry in interior architecture, as n= 64 reported no and n= 34 reported yes, evidently show that academic of interior architecture in Jordanian universities could provide more efforts for integrating practical examples for their students. Moreover, companions among students in term of personal information, reported that those who didn't experience a practical example exceeded the counts of those who experienced a practical example. Follow the bar charts provided for visualized results of companions.

Table 12: Experiencing practical example of Biomimicry in interior architecture (n= 98).

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n= 54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n=70]	Master [n=28]
No	64	30	23	11	46	18
Yes	34	24	8	2	24	10
Total	*98*	*54*	*31*	*13*	*70*	*28*

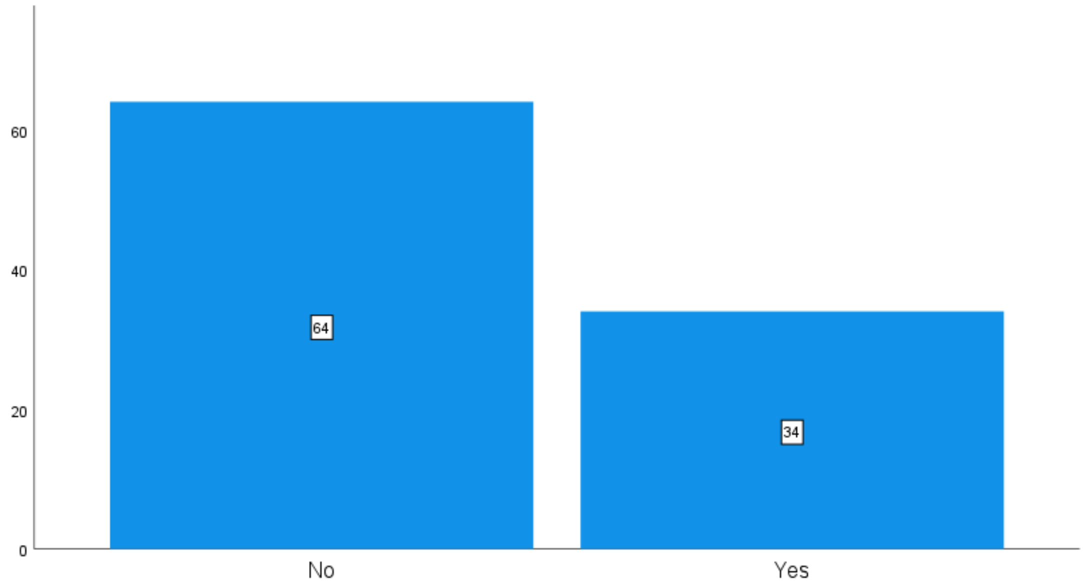

Figure 34: Bar chart presenting Experiencing practical example of Biomimicry in interior architecture among surveyed students – total sample.

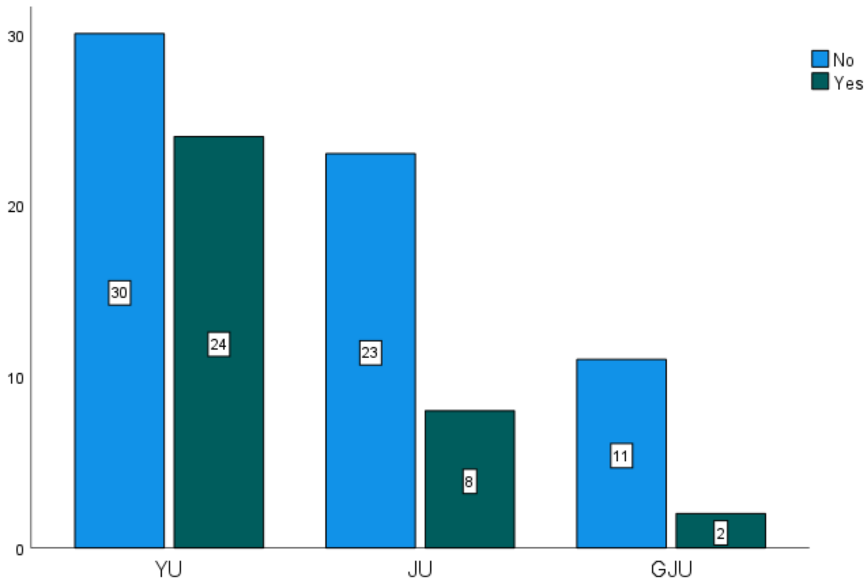

Figure 35: Bar chart presenting Experiencing practical example of Biomimicry in interior architecture among surveyed students – according to studying university.

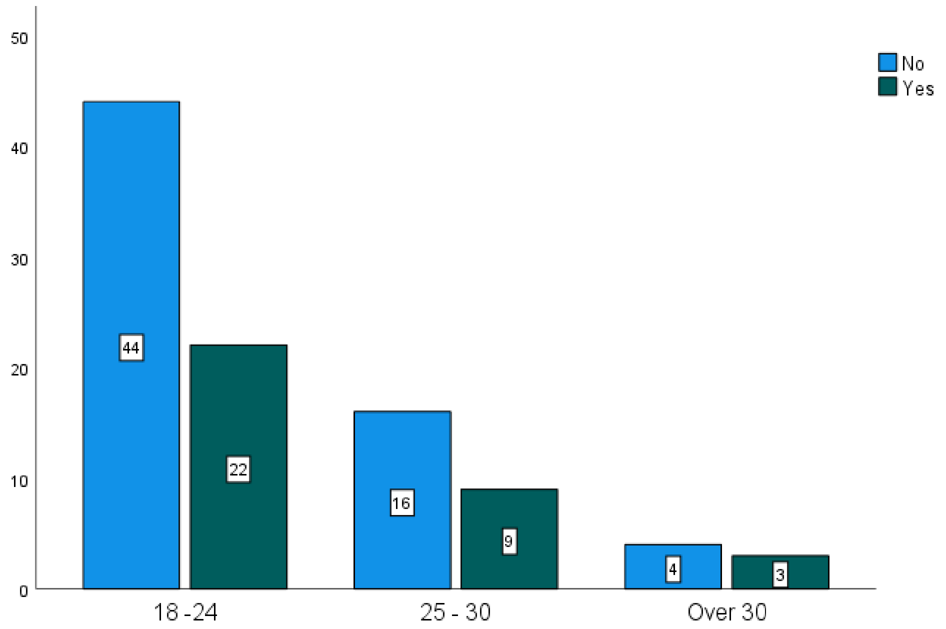

Figure 36: Bar chart presenting Experiencing practical example of Biomimicry in interior architecture among surveyed students – according to age.

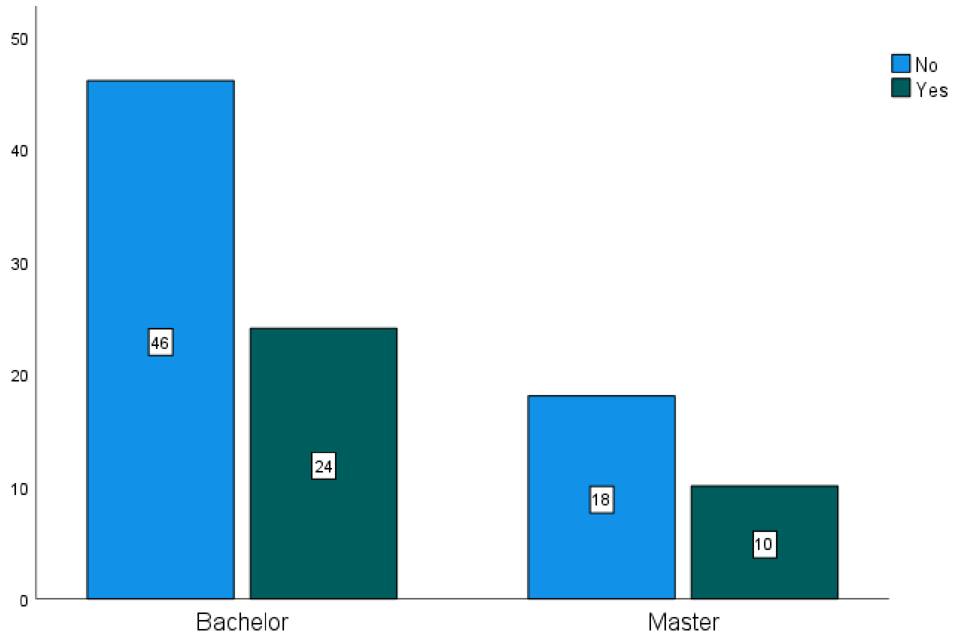

Figure 37: Bar chart presenting Experiencing practical example of Biomimicry in interior architecture among surveyed students – according to current education level.

Q.9 Applying the concept of Biomimicry in interior architecture project or design courses:

Results collected in Table 13 showed that majority of the surveyed students didn't apply the concept of Biomimicry in interior architecture, as n= 74 reported no and n= 24 reported yes, evidently show that academic of interior architecture in Jordanian universities could provide more efforts for integrating Biomimicry in interior architecture projects or design courses. Moreover, companions among students in term of personal information, reported that those who didn't apply the concept of Biomimicry in interior architecture exceeded the counts of those who had applied the concept of Biomimicry in interior architecture. Follow the bar charts provided for visualized results of companions.

Table 13: Applying the concept of Biomimicry in interior architecture project or design courses. (n= 98).

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n=54]	UJ [n=31]	GJU [n=13]	Bachelor [n=70]	Master [n=28]
No	74	37	25	12	53	21
Yes	24	17	6	1	17	7
Total	*98*	*54*	*31*	*13*	*70*	*28*

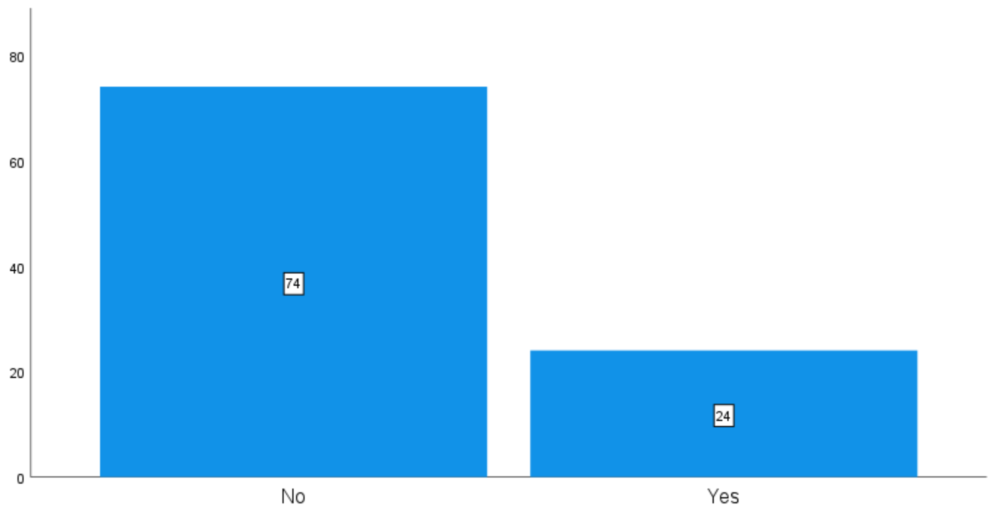

Figure 38: Bar chart presenting Applying the concept of Biomimicry in interior architecture project or design courses among surveyed students – total sample.

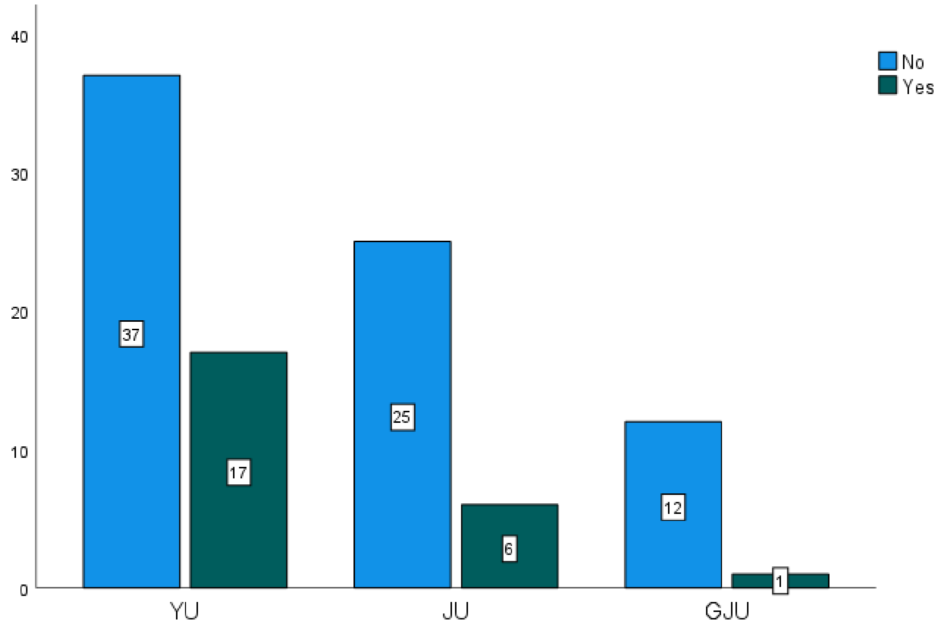

Figure 39: Bar chart presenting Applying the concept of Biomimicry in interior architecture project or design courses among surveyed students – according to studying university.

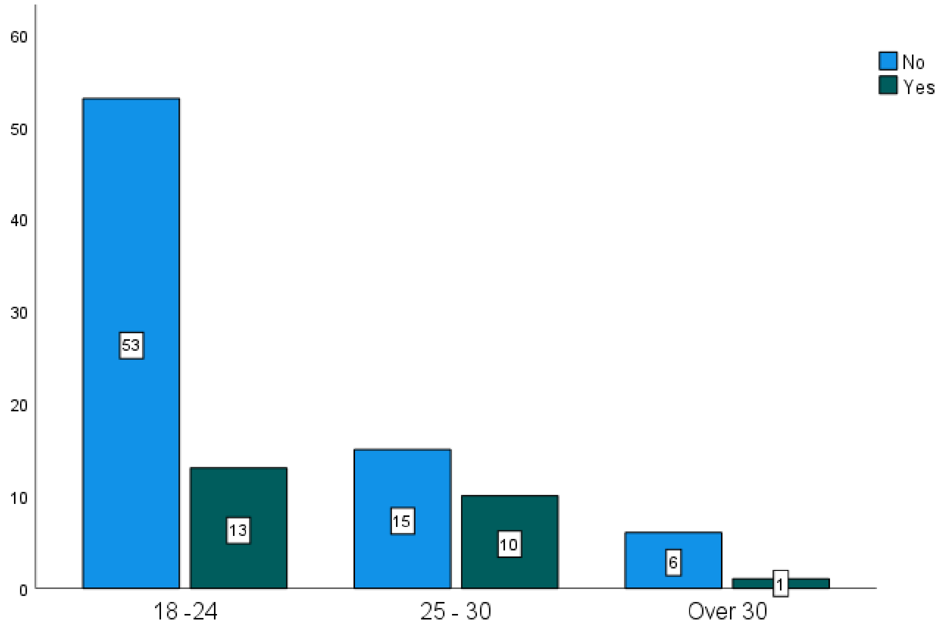

Figure 40: Bar chart presenting Applying the concept of Biomimicry in interior architecture project or design courses among surveyed students – according to age.

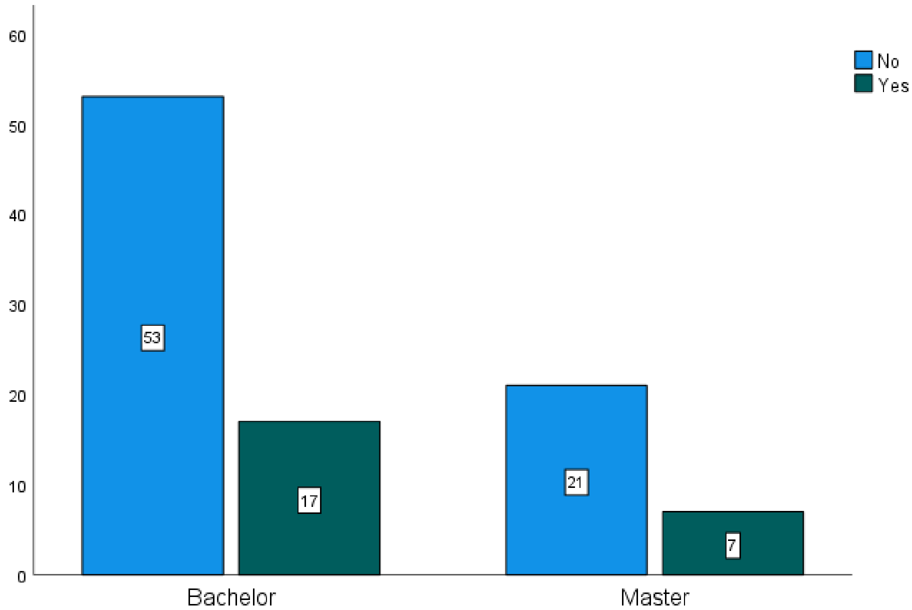

Figure 41: Bar chart presenting Applying the concept of Biomimicry in interior architecture project or design courses among surveyed students – according to current education level.

Q.10 Perceptions of surveyed students toward the relationship between biomimicry and the field of interior architecture:

To determine levels of student's perceptions toward the relationship between biomimicry and the field of interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward the relationship between biomimicry and the field of interior architecture. Table 14 presents results for this question.

Reported results showed that surveyed students have high level of perceptions toward the relationship between biomimicry and the field of interior architecture. Overall sample scored a mean value of 2.35 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the students toward the relationship between biomimicry and the field of interior architecture. STD. coefficient was 0.93 showing homogeneity in assessments as assessments can be seen as clustering around its mean values. Further, companions were made in term of personal information to determine who had the higher level of perceptions toward the relationship between biomimicry and the field of interior architecture. Neither of conducted companions were significant, showing an indicator of high levels of perceptions toward the relationship between biomimicry and the field of interior architecture among surveyed students in all three surveyed universities, and regardless their age or current education level. See provided bar charts displaying levels of perceptions toward the relationship between biomimicry and the field of interior architecture among surveyed students according to their personal information.

Table 14: The relationship between biomimicry and the field of interior architecture (n= 98).

**Difference is significant at 0.05 level.*
- F donates ANOVA test.
- T donates Independent Samples T-Test

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n= 54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n= 70]	Master [n= 28]
Mean [STD.]	2.35 [0.93]	2.43 [0.90]	2.39 [0.92]	1.92 [1.04]	2.27 [0.96]	2.54 [0.84]
Significant differences	//	F= 1.587 [P= 0.210]			T= -1.273 [P= 0.206]	

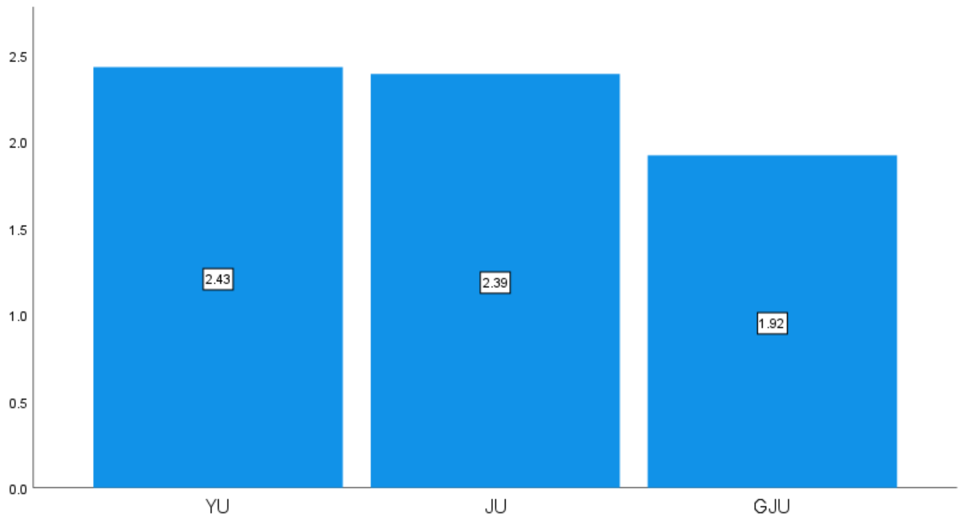

Figure 42: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and the field of interior architecture – according to university.

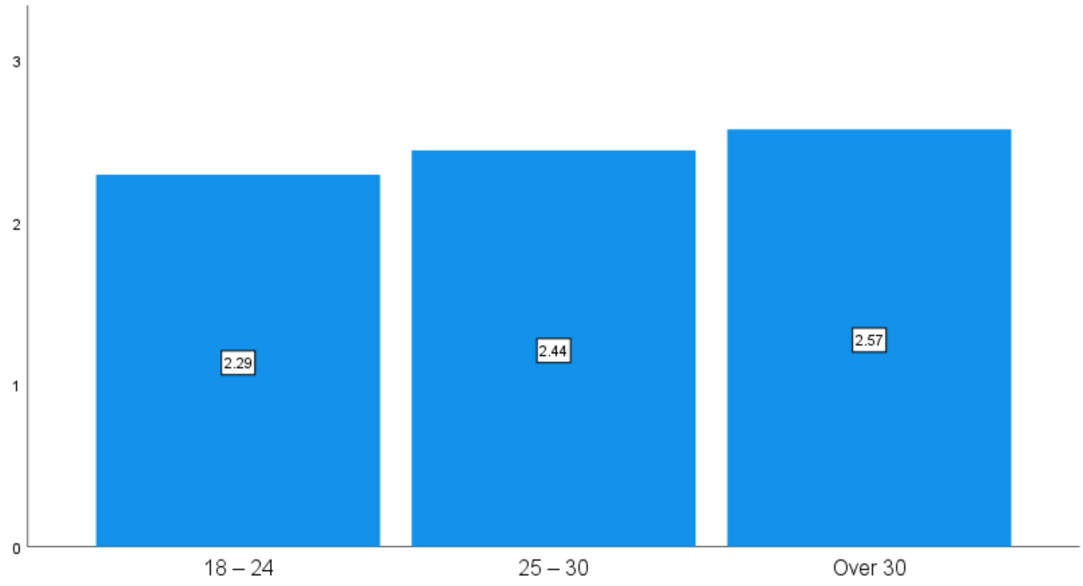

Figure 43: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and the field of interior architecture – according to age.

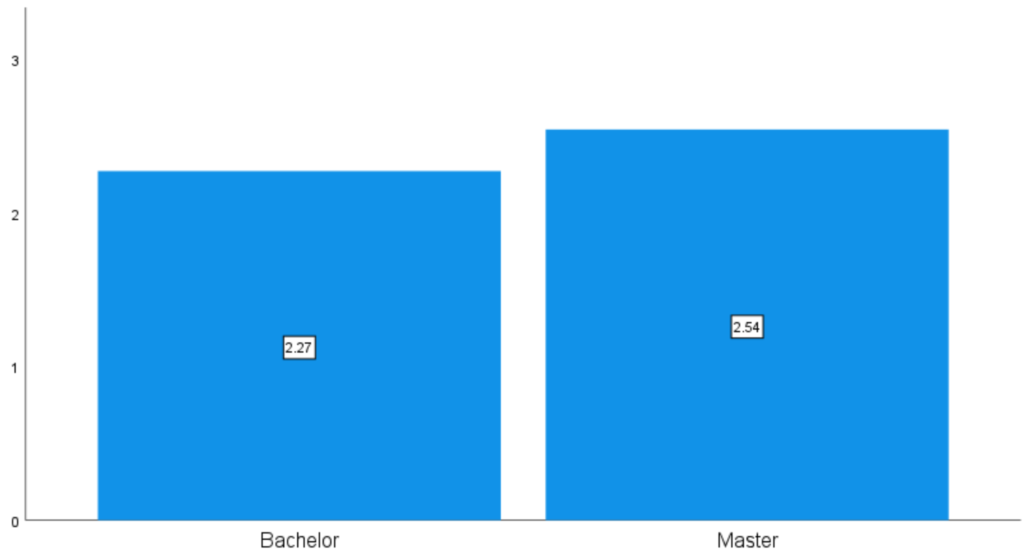

Figure 44: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and the field of interior architecture – according to current level of education.

Q.11 Perceptions of surveyed students toward the relationship between biomimicry and sustainability in interior architecture:

To determine levels of student's perceptions toward the relationship between biomimicry and sustainability in interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward the relationship between biomimicry and the field of interior architecture. Table 15 presents results for this question.

Reported results showed that all the students surveyed had a high level of perceptions toward the relationship between biomimicry and sustainability in interior architecture. Overall sample scored a mean value of 2.32 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the students toward the relationship between biomimicry and sustainability in interior architecture. STD. coefficient was 0.93 showing homogeneity in assessments as assessments can be seen as clustering around its mean values. Further, companions were made in term of personal information to determine who had the higher level of perceptions toward the relationship between biomimicry and sustainability in interior architecture. Neither of conducted companions were significant, showing an indicator of high levels of perceptions toward the relationship between biomimicry and sustainability in interior architecture among surveyed students in all three surveyed universities, and regardless their age or current education level. See provided bar charts displaying levels of perceptions toward the relationship between biomimicry and sustainability in interior architecture among surveyed students according to their personal information.

Table 15: The relationship between biomimicry and sustainability in interior architecture (n= 98).

**Difference is significant at 0.05 level.*
- *F donates ANOVA test.*
- *T donates Independent Samples T-Test.*

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n=54]	UJ [n= 31]	GJU [n=13]	Bachelor [n= 70]	Master [n= 28]
Mean [STD.]	2.32 [0.93]	2.39 [0.90]	2.23 [0.96]	2.23 [1.01]	2.36 [0.92]	2.21 [0.96]
Significant differences	//	F= 0.364 [P= 0.696]			T= 0.688 [P= 0.493]	

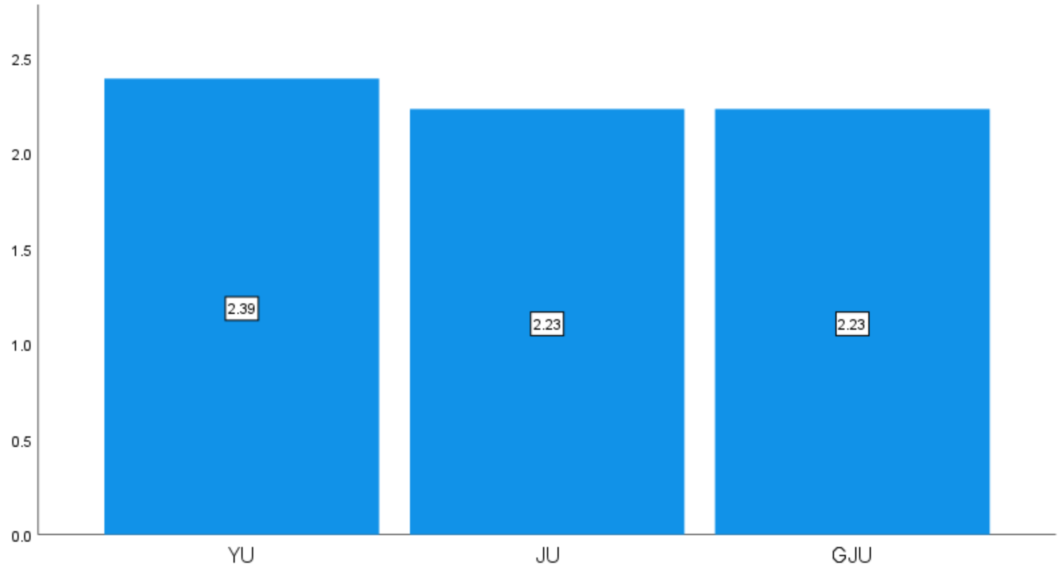

Figure 45: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and sustainability in interior architecture – according to university.

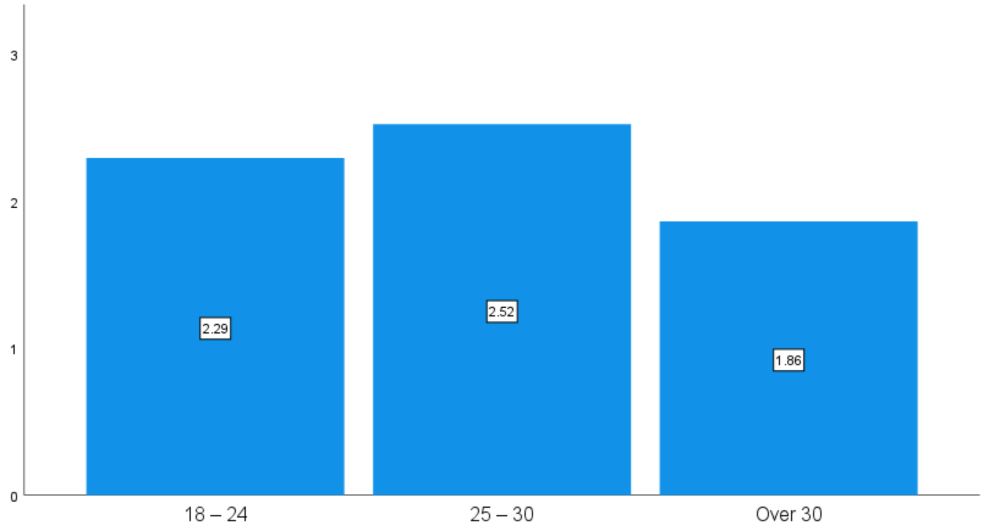

Figure 46: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and sustainability in interior architecture – according to age.

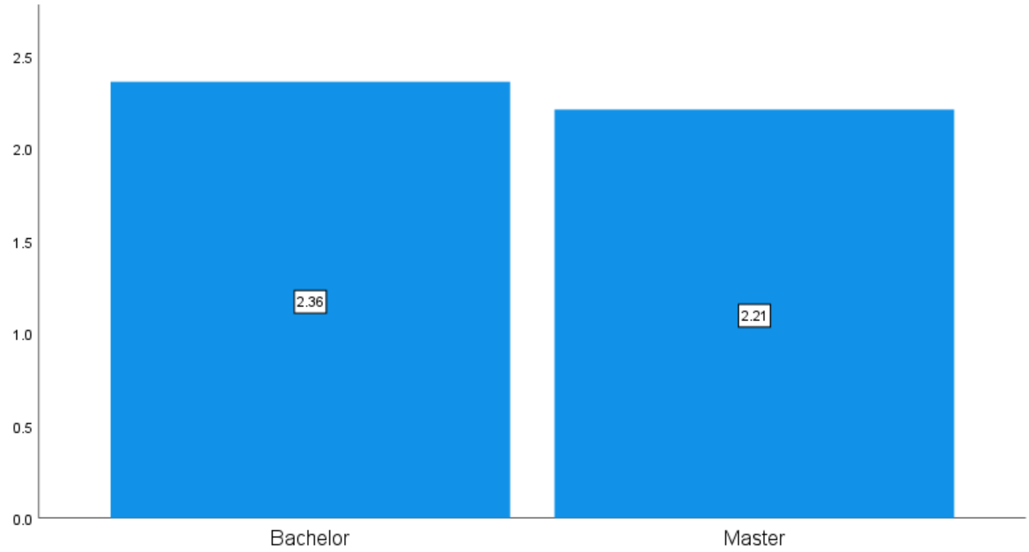

Figure 47: Bar chart presenting Perceptions of surveyed students toward the relationship between biomimicry and sustainability in interior architecture – according to current level of education.

Q.12 Perceptions of surveyed students toward the important role of biomimicry in interior architecture for interior architecture education:

To determine levels of student's perceptions toward the important role of biomimicry in interior architecture for interior architecture education, Likert scale of 3-points was used, this scale takes 1 for least necessity level which is not necessary, 2 for maybe and 3 for necessary, hence, highest score was assigned for highest necessity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward the important role of biomimicry in interior architecture for interior architecture education. Table 16 presents results for this question.

Reported results showed that surveyed students have high level of perceptions toward the important role and necessity of biomimicry in interior architecture for interior architecture education. Overall sample scored a mean value of 2.26 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the students toward the necessity of biomimicry in interior architecture for interior architecture education. STD. coefficient was 0.94 showing homogeneity in assessments as assessments can be seen as clustering around its mean values. Further, companions were made in term of personal information to determine who had the higher level of perceptions toward the necessity of biomimicry in interior architecture for interior architecture education. Neither of conducted companions were significant, showing an indicator of high levels of perceptions toward the necessity of biomimicry in interior architecture for interior architecture education among surveyed students in all three surveyed universities, and regardless their age or current education level. See provided bar charts displaying levels of perceptions toward the necessity of biomimicry in interior architecture for interior architecture education among surveyed students according to their personal information.

Table 16: The necessity of biomimicry in interior architecture for interior architecture education (n= 98).

**Difference is significant at 0.05 level.*
- F donates ANOVA test.
- T donates Independent Samples T-Test.

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n=54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n= 70]	Master [n= 28]
Mean [STD.]	2.26 [0.94]	2.24 [0.95]	2.35 [0.91]	2.08 [1.04]	2.26 [0.94]	2.25 [0.97]
Significant differences	//	F= 0.405 [P= 0.668]			T= 0.034 [P= 0.973]	

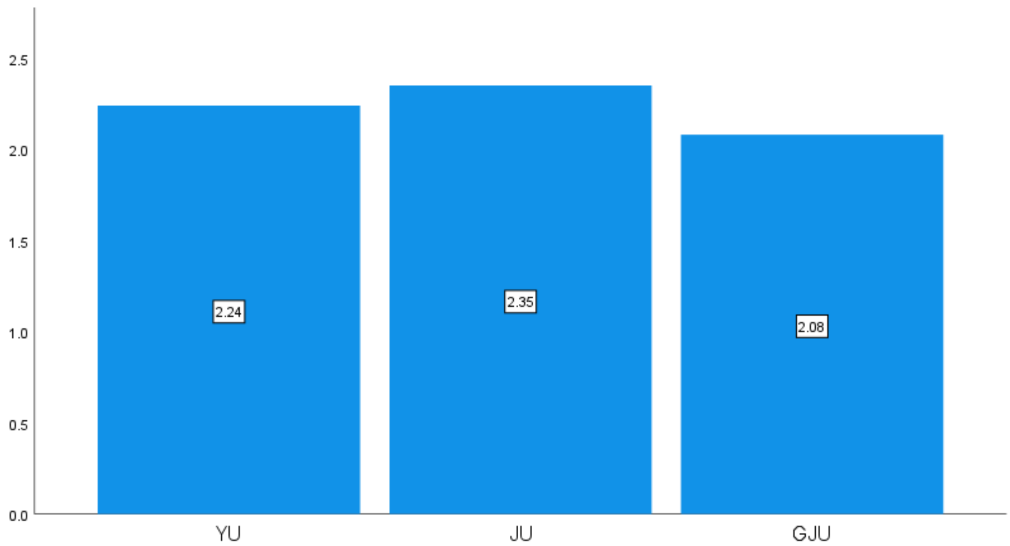

Figure 48: Bar chart presenting Perceptions of surveyed students toward the necessity of biomimicry in interior architecture for interior architecture education – according to university.

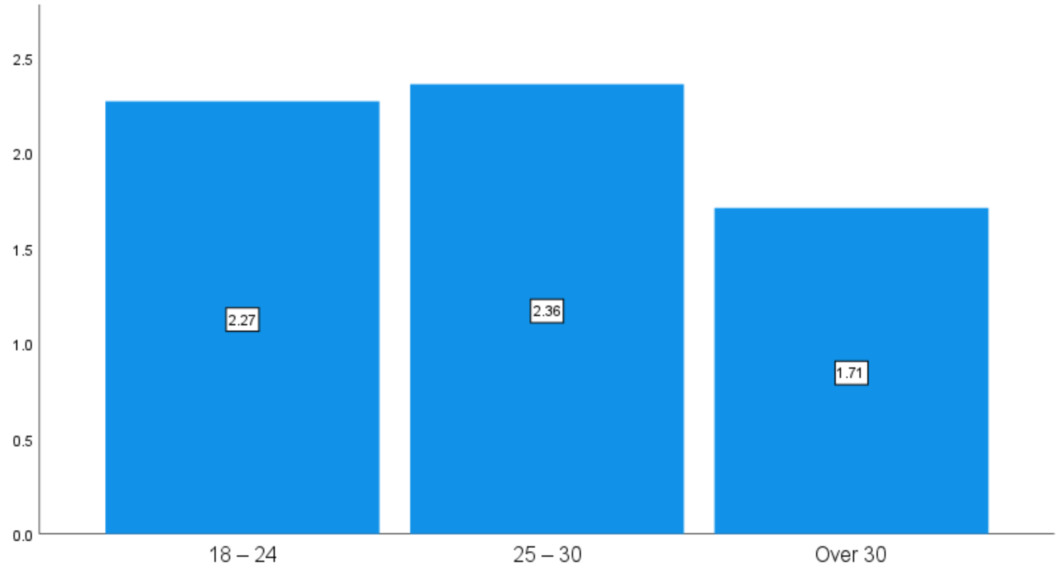

Figure 49: Bar chart presenting Perceptions of surveyed students toward the necessity of biomimicry in interior architecture for interior architecture education – according to age.

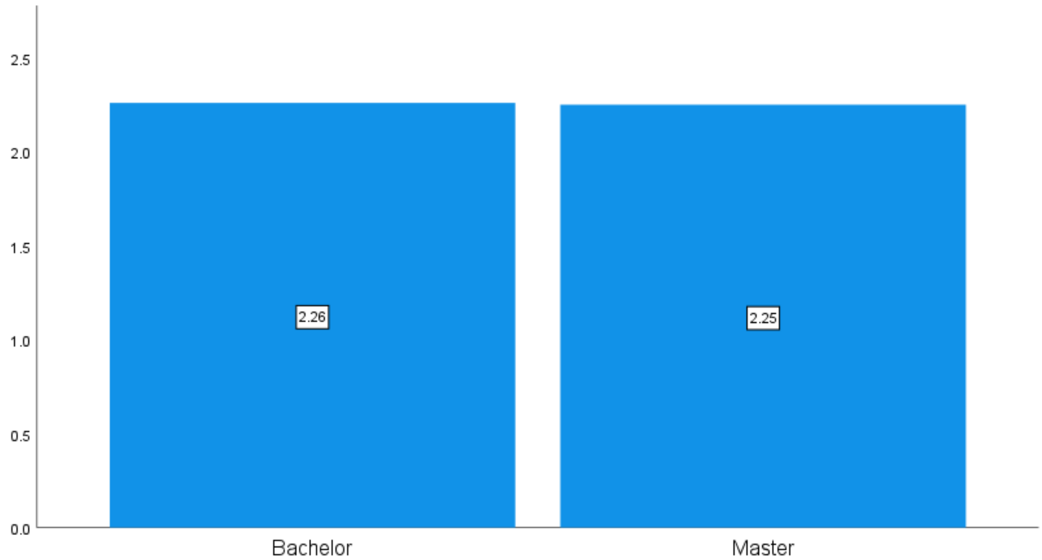

Figure 50: Bar chart presenting Perceptions of surveyed students toward the necessity of biomimicry in interior architecture for interior architecture education – according to current level of education.

Q.13 Perceptions of surveyed students toward the role of biomimicry in interior architecture sustainability and in improving the design of interior spaces:

Five suggested contributions were proposed in the survey, and multiple screening was allowed for all students surveyed, results collected in Table 17 showed that most frequent selected contribution by the students was Material Selection scoring counts [72], then in 2nd order the contribution related to Energy Efficiency scoring counts [66], and in 3rd selection the contribution relate to Indoor Air Quality was scoring count [40], then the contribution related to Human-cantered Design [n= 23] and least frequent selected contribution was Circular Economy [n= 11].

Table 17: Biomimicry contribution to sustainability in interior architecture and to improving the design of interior spaces.

Contribution	**N**	**%**
Energy Efficiency	66	31.1%
Material Selection	72	34.0%
Indoor Air Quality	40	18.9%
Circular Economy	11	5.2%
Human-cantered Design	23	10.8%
Total	*212*	*100%*

As multi-select was allowed for students, and to determine which contributions were most frequent combined together, TURF analysis was applied and results were provided in Table 18. Results reported that most frequent selected contribution was Material Selection, and the combination of Material Selection, Energy Efficiency was most frequent selected among the combined perceptions, and the most frequent three contribution combined were Material Selection, Energy Efficiency, Human-cantered Design.

Table 18: Results of TURF, Biomimicry contribution to sustainability in interior architecture and to improving the design of interior spaces.

Contribution	**Reach**	**% of Responses**
Material Selection	72	34.0
Material Selection, Energy Efficiency	86	65.1
Material Selection, Energy Efficiency, Human-cantered Design	95	75.9

Q.14 Reasons for Biomimicry is not used in interior Architecture in Jordanian Universities:

Three possible reasons were provided, and results displayed in Table 19 reported that all three proposed reasons scored to close frequencies, highest selection 34.7% was for Academics Lack of knowledge about Biomimicry, 2nd reason was General lack of information on Biomimicry in Interior Architecture (examples/research) 34.1% and 3rd reason was Lack of Instruction on How to Use it in Interior Architecture Education 31.2%. Percentages were found using SPSS statistical analysis software.

Table 19: Reasons for not used biomimicry in the interior architecture of Jordanian universities.

Reason	**N**	**%**
Academics Lack of knowledge about Biomimicry	60	34.7%
General lack of information on Biomimicry in Interior Architecture (examples/research)	59	34.1%
Lack of Instruction on How to Use it in Interior Architecture Education	54	31.2%
Total	*173*	*100%*

Q.15 Suggestions for better integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities:

Seven suggestions were provided and surveyed students were asked to select which suggestion they believe can lead to better integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities, results were provided in Table 20. Highest selected suggestion was Incorporate more biomimicry-focused lectures and discussions into existing classes by 30.7% among all selected suggestions. Percentages were found using SPSS statistical analysis software.

Table 20: Suggestions for integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities.

Suggestion	**N**	**%**
Incorporate more biomimicry-focused lectures and discussions into existing classes	50	30.7%
Offer standalone biomimicry courses or workshops	25	15.3%
Encourage students to incorporate biomimicry into their class projects or assignments	46	28.2%
Collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom	16	9.8%

Provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry	6	3.7%
Encourage faculty members to integrate biomimicry into their own research or design work	12	7.4%
Encourage interdisciplinary collaboration between architecture, biology, and other related fields	8	4.9%
Total	*163*	*100%*

Further, below Table 21 gives results of TURF analysis for combined suggestions for better integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities.

Table 21: Results of TURF, Suggestions for integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities.

Suggestion	**Reach**	**% of Cases**
Incorporate more biomimicry-focused lectures and discussions into existing classes, encourage students to incorporate biomimicry into their class projects or assignments, collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom	80	81.6%
Incorporate more biomimicry-focused lectures and discussions into existing classes, offer standalone biomimicry courses or workshops, encourage students to incorporate biomimicry into their class projects or assignments	75	76.5%
Incorporate more biomimicry-focused lectures and discussions into existing classes, encourage students to incorporate biomimicry into their class projects or assignments, encourage faculty members to integrate biomimicry into their own research or design work	75	76.5%
Incorporate more biomimicry-focused lectures and discussions into existing classes, encourage students to incorporate biomimicry into their class projects or assignments,	73	74.5%

provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry		
Incorporate more biomimicry-focused lectures and discussions into existing classes, offer standalone biomimicry courses or workshops, collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom	73	74.5%

Q.16 Perceptions of surveyed students toward the necessity to add biomimicry as a Compulsory course in interior architecture education:

To determine levels of student's perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education, Likert scale of 3-points was used, this scale takes 1 for least necessity level which is not necessary, 2 for maybe and 3 for necessary, hence, highest score was assigned for highest necessity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed students toward the necessity to add biomimicry as a compulsory course in interior architecture education. Table 22 presents results for this question.

Reported results showed that all surveyed students have a high level of perception toward the necessity to add biomimicry as a compulsory course in interior architecture education. Overall sample scored a mean value of 2.24 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the students toward the necessity to add biomimicry as a compulsory course in interior architecture education. STD. coefficient was 0.96 showing homogeneity in assessments as assessments can be seen as clustering around its mean values. Further, companions were made in term of personal information to determine who had the higher level of perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education. Neither of conducted companions were significant, showing an indicator of high levels of perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education among surveyed students in all three surveyed universities, and regardless their age or current education level. See provided bar charts displaying levels of perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education among surveyed students according to their personal information.

Table 22: The necessity to add biomimicry as a compulsory course in interior architecture education (n= 98).

**Difference is significant at 0.05 level.*
- F donates ANOVA test.
- T donates Independent Samples T-Test.

Results	Total sample [n= 98]	*University*			*Level of education*	
		YU [n= 54]	UJ [n= 31]	GJU [n= 13]	Bachelor [n= 70]	Master [n= 28]
Mean [STD.]	2.24 [0.96]	2.09 [1.00]	2.48 [0.89]	2.31 [0.95]	2.21 [0.98]	2.32 [0.94]
Significant differences	//	F= 1.678 [P= 0.192]			T= -0.495 [P= 0.622]	

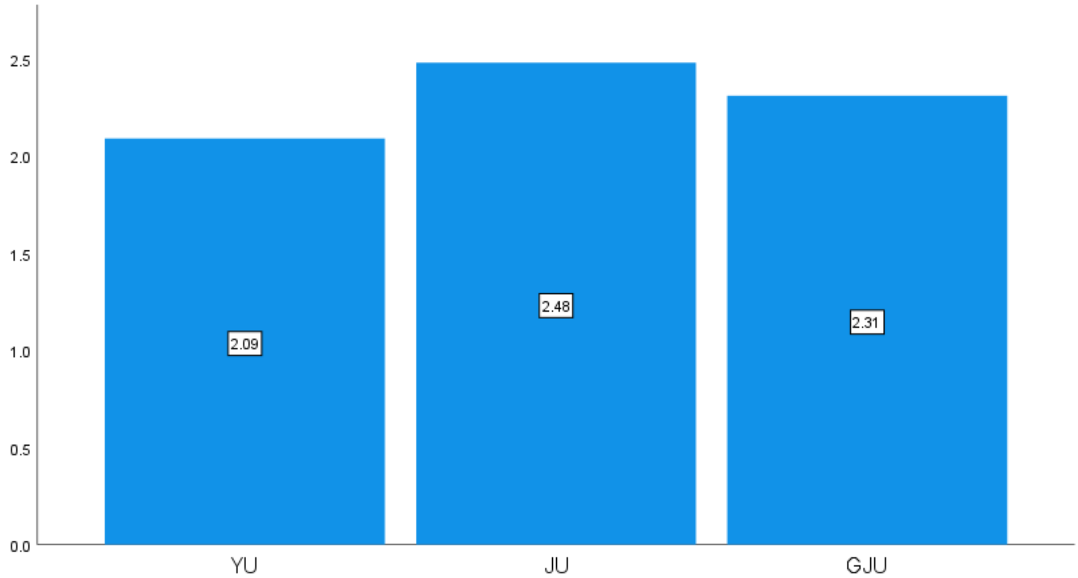

Figure 51: Bar chart presenting Perceptions of surveyed students toward the necessity to add biomimicry as a compulsory course in interior architecture education – according to university.

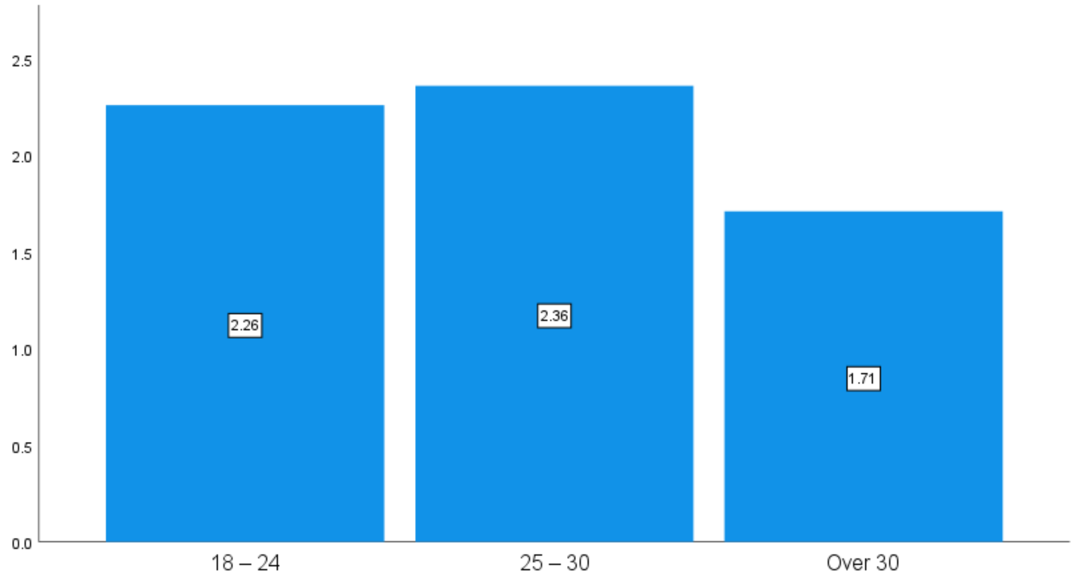

Figure 52: Bar chart presenting Perceptions of surveyed students toward the necessity to add biomimicry as a compulsory course in interior architecture education – according to age.

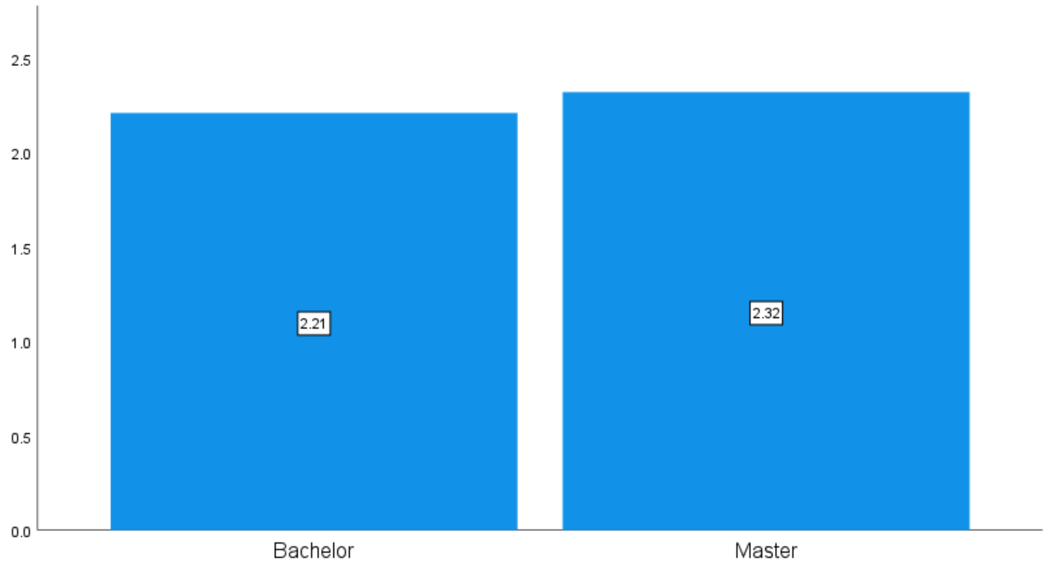

Figure 53: Bar chart presenting Perceptions of surveyed students toward the necessity to add biomimicry as a compulsory course in interior architecture education – according to current level of education.

4.2 Academics sample findings:

4.2.1 Introduction:

Results for academic's sample were displayed in this section, statistical analysis relied on descriptive statistics and charts, due to small sample size that when categorized into subsets based on personal information, applying mean comparisons tests even the non-parametric one [such as Mann-Whitney U-test alternative of the Independent Samples T-Test and Kruskal-Wallis Test the alternative of ANOVA test] that handle small sample sizes would provide non-reliable and biased results.

4.2.2 Data collection:

During visits to architecture departments to collect responses from students, the researcher also visited academic staff in these departments and asked them for participation in the study by answering the survey directed to them, the researcher was able to collect 11 complete responses that were valid for analysis.

4.2.3 Surveyed academic sample:

In total 11 academics were surveyed in the sample, among them, n= 4 [36.4%] were from YU, n= 3 [27.3%] were from UJ, and n= 4 [36.4%] were from GJU, showing that the sample included academics from the three targeted universities. Out of 15 academics who were approached, 11 of them agreed to take part in the survey.

Table 23: Surveyed academic sample from targeted universities (n= 11).

University	Reponses count	% of the sample
YU	4	36.4%
UJ	3	27.3%
GJU	4	36.4%
Total	*11*	*100%*

4.2.4 Academics' personal information:

Counts and percentages were presented in Table 24, in regrade of current level of education of academic's, n= 4 [36.4%] hold master, n= 4 [36.4%] hold PhD and n= 3 [27.3%] hold above PhD. Figures 60 and 61 introduced the Pie charts displaying reported results.

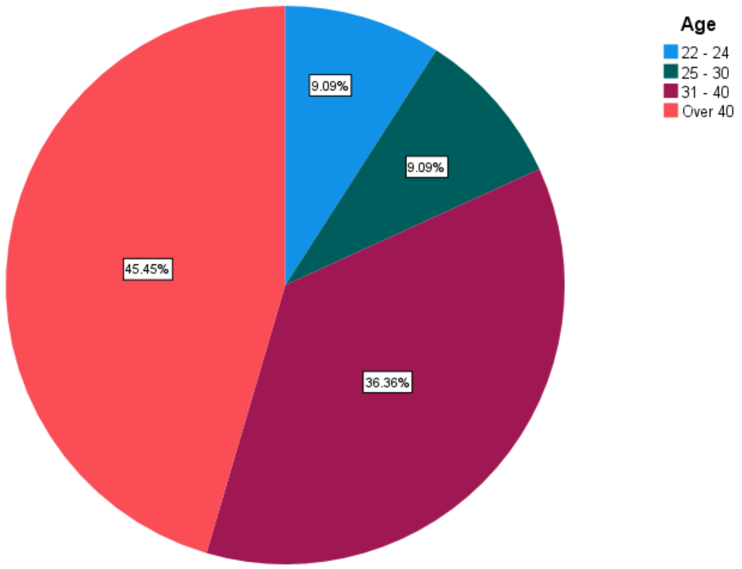

Figure 54: Pie chart presenting age results of surveyed academics.

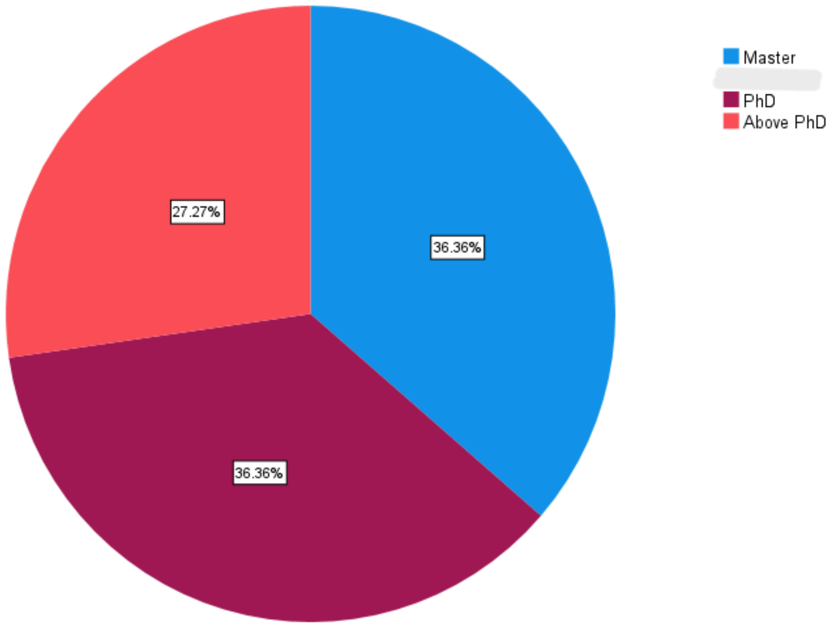

Figure 55: Pie chart presenting current education level results of surveyed academics.

Table 24: Academics' personal information (n= 11).

	Count	**%**
Age		
22 – 24	1	9.1%
25 – 30	1	9.1%
31 - 40	4	36.4%
Over 40	5	45.5%

Current level of education		
Master	4	36.4%
Bachelor	--	--
PhD	4	36.4%
Above PhD	3	27.3%

4.2.5 Findings from the point view of academics:

Results from the point view of academics were presented in this section:

Q.4 Level knowledge of Biomimicry concept among surveyed academics:

Gathered results in Table 25 demonstrated high levels of relevance among surveyed academics in relation to biomimicry concept, among the surveyed 11 academics: 9 reported that they have hear before about the concept, and 2 reported that they didn't hear before about the concept.

Table 25: Results of relevance of Biomimicry concept among surveyed academics (n= 11).

	Total sample [n= 11]
No	2
Yes	9
Total	*11*

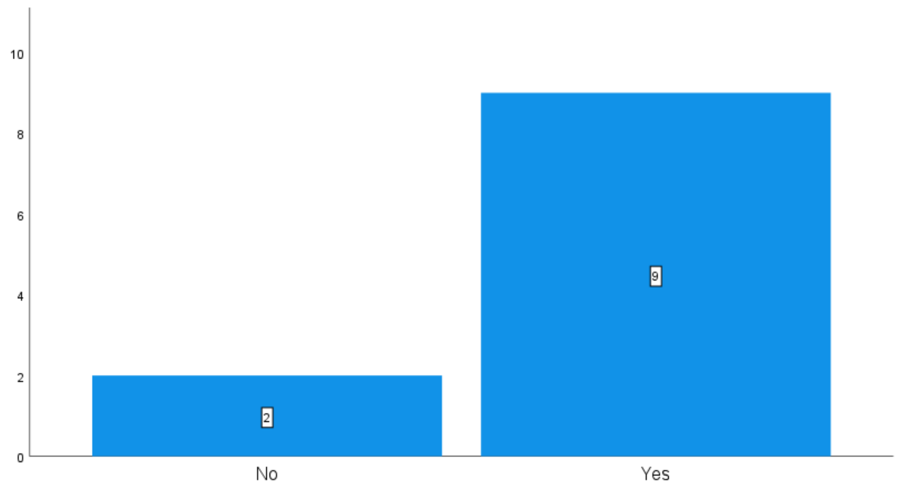

Figure 56: Bar chart presenting relevance of Biomimicry concept among surveyed academics.

Q.5 Context for relevance of Biomimicry concept among surveyed academics:

For academics who reported their relevance with Biomimicry concept, n= 6 reported that that the context they hear from was from outside reading or research and through online resources or media, n= 2 reported from biomimicry-related events or workshops and n= 1 reported another context.

Table 26: Results of context of relevance of Biomimicry concept among surveyed academics (n= 9).

Context	Total sample heard before [n= 9]
From outside reading or research and through online resources or media	6
From biomimicry-related events or workshops	2
From design professionals or practitioners or colleagues in the field of interior architecture	--
Other	1
Total	*9*

Q.6 Extent of familiarity with Biomimicry concept in interior architecture among surveyed academics:

To determine extent of familiarity with Biomimicry concept in interior architecture among surveyed academics, we used Likert scale of 3-points that takes 1 for least familiarity level which is Unfamiliar, 2 for being familiar and 3 for being very familiar, hence, highest score was assigned for highest familiarity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward being familiar with the concept. Table 27 gives results for this question.

Reported results showed that surveyed academics have high level of familiarity with Biomimicry concept in interior architecture, scored mean value was 2.27 close to 3 highest familiarity level showing positive assessments by the academics toward the concept. STD.

coefficient was 0.47 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 27: The extent of familiarity with Biomimicry concept in interior architecture. (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.27 [0.47]

Q.7 Perceptions of surveyed academics toward usefulness of Biomimicry concept in interior architecture:

To determine levels of academics' perceptions toward usefulness of Biomimicry concept in interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward usefulness of the concept. Table 28 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward usefulness of Biomimicry concept in interior architecture. Recorded mean value was 2.91 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward usefulness of the concept. STD. coefficient was 0.30 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 28: The usefulness of Biomimicry concept in interior architecture (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.91 [0.30]

Q.8 Experiencing practical example of Biomimicry in interior architecture by academics:

Results collected in Table 29 showed that about half of the surveyed academics have experienced a practical example of Biomimicry in interior architecture, as n= 5 reported yes and n= 6 reported no.

Table 29: Practical example experiment of Biomimicry in interior architecture (n= 11).

	Total sample [n= 11]
No	6
Yes	5
Total	*11*

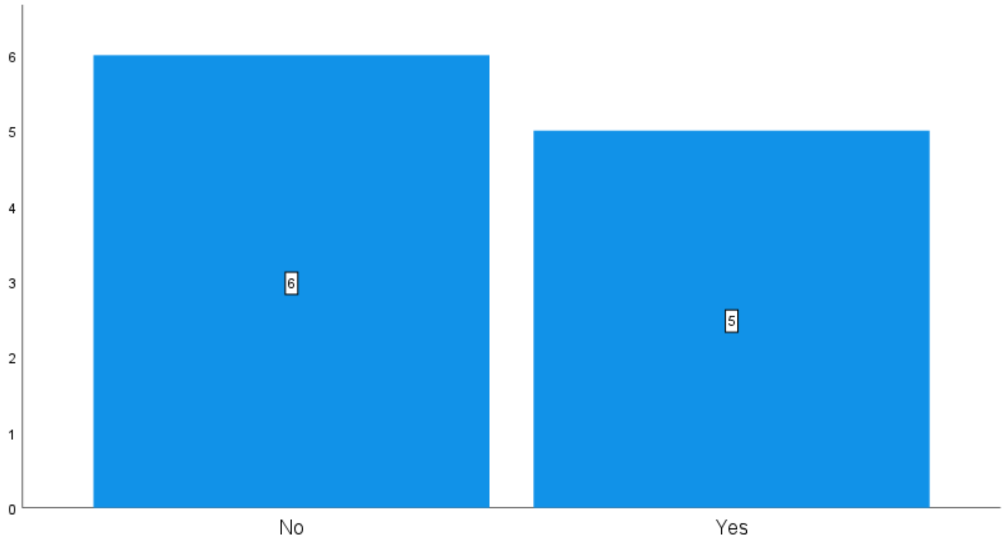

Figure 57: Bar graph presenting levels of Experiencing practical example of Biomimicry in interior architecture among surveyed academics (n= 11).

Q.9 Integrating the principle of Biomimicry into teaching of interior architecture:

To determine levels of academics' integration the principle of Biomimicry into teaching of interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for occasionally and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward integration the principle of Biomimicry into teaching of interior architecture. Table 30 presents results for this question.

Reported results showed that surveyed academics have high level of integration the principle of Biomimicry into teaching of interior architecture. Recorded mean value was 2.00

exceeding 1.5 middle of the scale. STD. coefficient was 0.63 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 30: Integrating the principle of Biomimicry into teaching of interior architecture by academics (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.0 0.63]

Q.10 Increase interest by students toward biomimicry in interior architecture in recent years:

Gathered results in Table 31 demonstrated that most of surveyed academics n= 9 provided agreement toward the increase interest by students toward biomimicry in interior architecture in recent years showing a good indicator about such interior architecture students.

Table 31: Increase interest by students toward biomimicry in interior architecture in recent years (n= 11).

	Total sample [n= 11]
No	2
Yes	9
Total	*11*

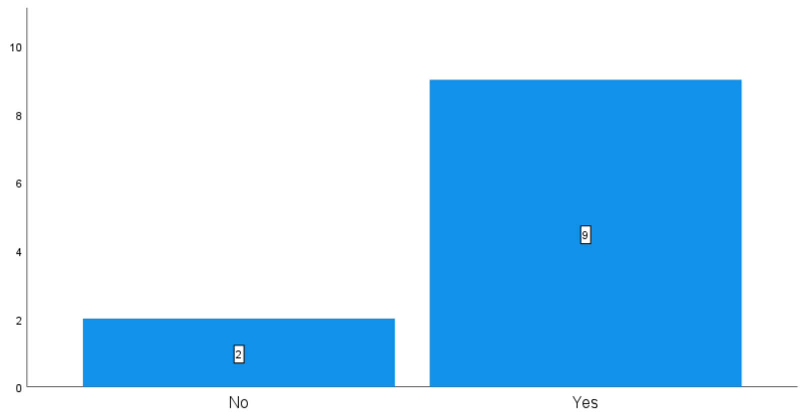

Figure 58: Bar graph presenting increase interest by students toward biomimicry in interior architecture in recent years as reported by surveyed academics (n= 11).

Q.11 Perceptions of surveyed academics toward the relationship between biomimicry and the field of interior architecture:

To determine levels of academic's perceptions toward the relationship between biomimicry and the field of interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward the relationship between biomimicry and the field of interior architecture. Table 32 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward the relationship between biomimicry and the field of interior architecture, recorded mean value was 2.91 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward the relationship between biomimicry and the field of interior architecture. STD. coefficient was 0.30 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 32: The relationship between biomimicry and the field of interior architecture (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.91 [0.30]

Q.12 Perceptions of surveyed academics toward the relationship between biomimicry and sustainability in interior architecture:

To determine levels of academic's perceptions toward the relationship between biomimicry and sustainability in interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward the relationship between biomimicry and sustainability interior architecture. Table 33 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward the relationship between biomimicry and sustainability in interior architecture. Mean value recorded 2.82 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward the relationship between biomimicry and sustainability in interior architecture. STD. coefficient was 0.40 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 33: The relationship between biomimicry and sustainability in interior architecture (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.82 [0.40]

Q.13 Perceptions of surveyed academics toward the necessity of biomimicry in interior architecture for interior architecture education:

To determine levels of academic's perceptions toward the necessity of biomimicry in interior architecture for interior architecture education, Likert scale of 3-points was used, this scale takes 1 for least necessity level which is not necessary, 2 for maybe and 3 for necessary, hence, highest score was assigned for highest necessity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward the necessity of biomimicry in interior architecture for interior architecture education. Table 34 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward the necessity of biomimicry in interior architecture for interior architecture education, recorded mean value was 2.73 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward the necessity of biomimicry in interior architecture for interior architecture education. STD. coefficient was 0.47 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 34: Results of the necessity of biomimicry in interior architecture for interior architecture education (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.73 [0.47]

Q.14 Availability of enough resources and support for students who are interested in learning more about biomimicry in interior architecture as perceived by surveyed academics:

To determine levels of academic's perceptions toward availability of enough resources and support for students who are interested in learning more about biomimicry in interior architecture, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward availability of enough resources and support for students who are interested in learning more about biomimicry in interior architecture. Table 35 presents results for this question.

Reported results showed that surveyed academics have average level of perceptions toward availability of enough resources and support for students who are interested in learning more about biomimicry in interior architecture, recorded mean value was 1.64 exceeding 1.5 middle of the scale. STD. coefficient was 0.92 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 35: Availability of resources and support for students in learning about biomimicry in interior architecture, by academics (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.64 [0.92]

Q.15 Academics perceptions toward extent of university facilities and providing adequate support for biomimicry research and projects:

Gathered findings in Table 36 reported that majority of surveyed academic n= 10 perceive that their universities don't facilities nor providing adequate support for biomimicry research and projects, showing the need for such universities to provide more support in this vin.

Table 36: Extent of university facilities and providing adequate support for biomimicry research and projects (n= 11).

	Total sample [n= 11]
No	10
Yes	1
Total	*11*

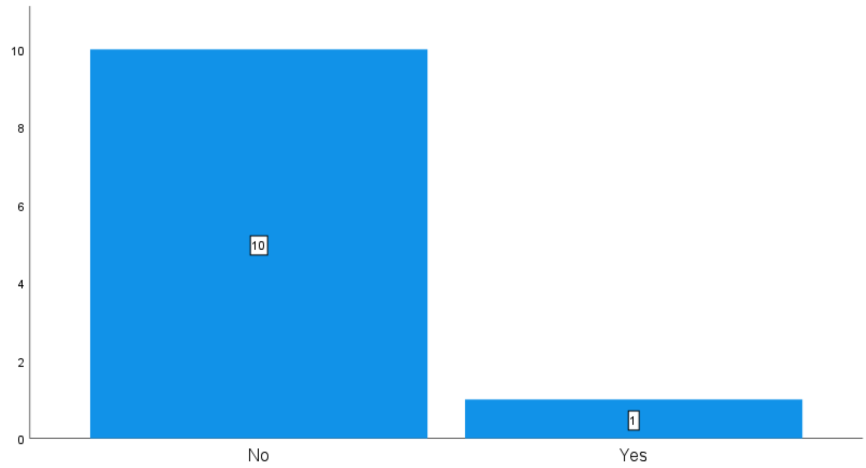

Figure 59: Bar graph presenting academics perceptions toward extent of university facilities and providing adequate support for biomimicry research and projects (n= 11).

Q.16 Reasons for Biomimicry is not used in interior Architecture in Jordanian Universities as reported by academics:

Results in Table 37 reported that main reasons that academics believe for not using Biomimicry in interior Architecture in Jordanian Universities as: General lack of information on Biomimicry in Interior Architecture (examples/research) n= 5, and Lack of Instruction on How to Use it in Interior Architecture Education n= 5 and Academics Lack of knowledge about Biomimicry n= 1.

Table 37: Reasons for Biomimicry is not used in interior Architecture in Jordanian Universities by academics.

Reason	N	%
Academics Lack of knowledge about Biomimicry	1	9.1%
General lack of information on Biomimicry in Interior Architecture (examples/research)	5	45.5%
Lack of Instruction on How to Use it in Interior Architecture Education	5	45.5%
Total	*11*	*100%*

Q.17 Suggestions for better integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities as reported by academics:

Based on results gathered in Table 38, top suggestions were as follows: Incorporate more biomimicry-focused lectures and discussions into existing classes n= 10, and Offer standalone biomimicry courses or workshops n= 10, Encourage students to incorporate biomimicry into their class projects or assignments n= 8 and Encourage faculty members to integrate biomimicry into their own research or design work n= 8 and Provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry n =7. Percentages were found using SPSS statistical analysis software.

Table 38: Integration of biomimicry into the curriculum of interior architecture programs in Jordanian Universities by academics.

Suggestion	N	%
Incorporate more biomimicry-focused lectures and discussions into existing classes	10	20.0%
Offer standalone biomimicry courses or workshops	10	20.0%
Encourage students to incorporate biomimicry into their class projects or assignments	8	16.0%
Collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom	4	8.0%
Provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry	7	14.0%
Encourage faculty members to integrate biomimicry into their own research or design work	8	16.0%

Encourage interdisciplinary collaboration between architecture, biology field	3	6.0%
Total	*50*	*100%*

Q.18 Perceptions of surveyed academics toward contribution of biomimicry to sustainability in interior architecture and to improving the design of interior spaces:

Among the proposed contributions for biomimicry in sustainability of interior architecture and to improving the design of interior spaces, both Energy Efficiency and Material Selection were selected by all surveyed academic, meanwhile, Circular Economy was selected by n= 9 academic and Indoor Air Quality was the least selected by n= 7 academics. Percentages were found using SPSS statistical analysis software.

Table 39: Biomimicry contribution to sustainability in interior architecture and to improving the design of interior spaces.

Contribution	**N**	**%**
Energy Efficiency	11	28.9%
Material Selection	11	28.9%
Indoor Air Quality	7	18.4%
Circular Economy	9	23.7%
Human-cantered Design	--	--
Total	*38*	*100%*

Q.19 Level knowledge of Analogical reasoning among surveyed academics:

Gathered results in Table 40 demonstrated high levels of relevance among surveyed academics regarding analogical reasoning, among the surveyed 11 academics: 8 reported that they have hear before about the concept, and 3 reported that they didn't hear before about the concept.

Table 40: Results of relevance of Analogical reasoning among surveyed academics (n= 11).

	Total sample [n= 11]
No	3
Yes	8
Total	*11*

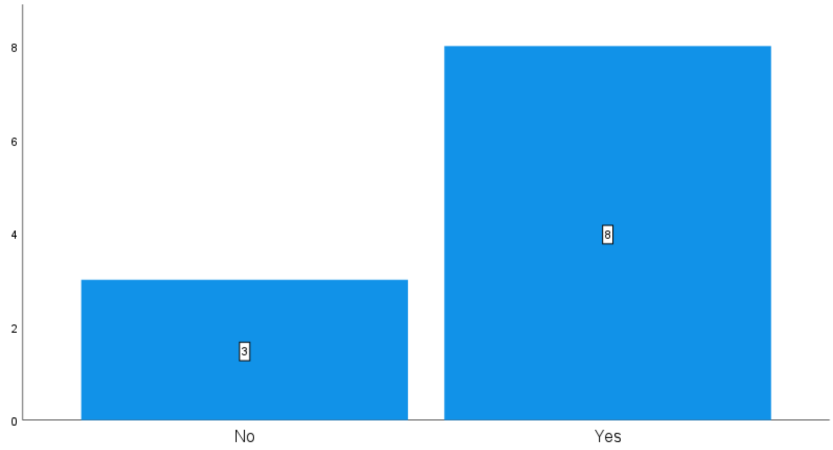

Figure 60: Bar chart presenting relevance of Analogical reasoning among surveyed academics.

Q.20 Context for relevance of analogical reasoning among surveyed academics:

For academics who reported their relevance with analogical reasoning, all of them reported that the context for relevance with this concept is from outside reading or research and through online resources or media.

Table 41: Results of context of relevance of analogical reasoning among surveyed academics (n= 8).

Context	Total sample heard before [n= 8]
From outside reading or research and through online resources or media	8
From biomimicry-related events or workshops	--
From design professionals or practitioners or colleagues in the field of interior architecture	--
Other	--
Total	*8*

Q.21 Prior instruction or education on analogical reasoning in relation to biomimicry by academics:

Fathered findings in Table 42 showed very low practicing for analogical reasoning in relation to biomimicry by academics, as only one academic provided agreement toward the proposed question.

Table 42: Results of education or previous education analogical reasoning in relation to biomimicry by academics (n= 11).

	Total sample [n= 11]
No	10
Yes	1
Total	*11*

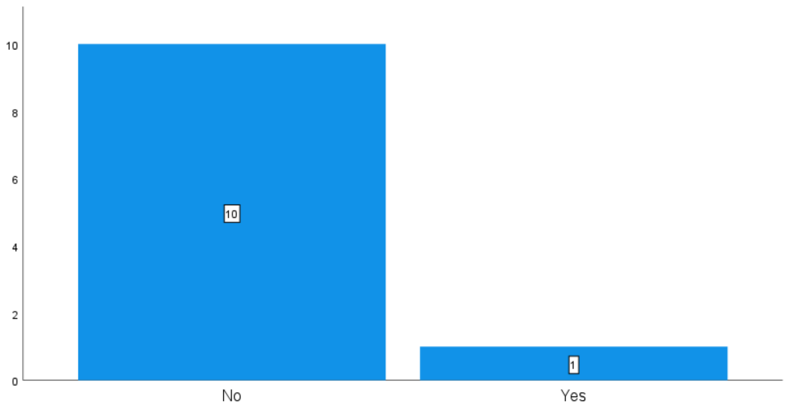

Figure 61: Bar graph presenting Prior instruction or education on analogical reasoning in relation to biomimicry by academics (n= 11).

Q.22 Perceptions of surveyed academics toward the role of analogical reasoning in overcoming any challenges or barriers in the application of biomimicry:

To determine levels of academic's perceptions toward the role of analogical reasoning in overcoming any challenges or barriers in the application of biomimicry, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward the role of analogical reasoning in overcoming any challenges or barriers in the application of biomimicry. Table 43 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward the role of analogical reasoning in overcoming any challenges or barriers in the application of biomimicry, recorded mean value was 2.55 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward the role of analogical reasoning in overcoming any challenges or barriers in the application of biomimicry. STD. coefficient was 0.52 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 43: The role of analogical reasoning in overcoming any challenges in the application of biomimicry (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.55 [0.52]

Q.23 Academics perceptions of faculty expertise in analogical reasoning for biomimicry support:

To determine levels of academic's perceptions toward levels of knowledge and expertise of faculty members have in analogical reasoning to support students in their biomimicry, Likert scale of 3-points was used, this scale takes 1 for least agreement level which is no, 2 for maybe and 3 for yes, hence, highest score was assigned for highest agreement level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward levels of knowledge and expertise of faculty members have in analogical reasoning to support students in their biomimicry. Table 44 presents results for this question.

Reported results showed that surveyed academics believe that levels of knowledge and expertise of faculty members have in analogical reasoning to support students in their biomimicry is at moderate level, recorded mean value was 1.73 exceeding 1.5 middle of the scale. STD. coefficient was 0.47 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 44: Levels of knowledge and expertise of academics have in analogical reasoning in biomimicry (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	1.73 [0.47]

Q.24 Perceptions of surveyed academics toward the necessity to add biomimicry as a compulsory course in interior architecture education:

To determine levels of academic's perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education, Likert scale of 3-points was used, this scale takes 1 for least necessity level which is not necessary, 2 for maybe and 3 for necessary, hence, highest score was assigned for highest necessity level. Mean value for this question ranges between 1 to 3, hence having a mean value exceeding [1.5] middle of the scale shows positive assessments by surveyed academics toward the necessity to add biomimicry as a compulsory course in interior architecture education. Table 45 presents results for this question.

Reported results showed that surveyed academics have very high level of perceptions toward the necessity to add biomimicry as a compulsory course in interior architecture education. Recorded mean value was 2.64 exceeding 1.5 middle of the scale and close to 3 showing positive assessments by the academics toward the necessity to add biomimicry as a compulsory course in interior architecture education. STD. coefficient was 0.50 showing homogeneity in assessments as assessments can be seen as clustering around its mean values.

Table 45: The necessity to add biomimicry as a compulsory course in interior architecture education (n= 11).

Results	Total sample [n= 11]
Mean [STD.]	2.64 [0.50]

The findings encompass several key observations, including the limited awareness of biomimicry among both academics and students, the scarcity of biomimicry-related resources and research within the field of interior architecture, and the underutilization of biomimicry as an educational tool in interior design and architecture programs across Jordanian universities. In conclusion, these outcomes underscore the necessity of integrating biomimicry education into interior architecture design curricula in Jordanian universities and beyond. This integration is essential for addressing complex environmental challenges and promoting sustainable design practices on a global scale. The data also reveals that students hold positive perceptions regarding the connection between biomimicry and interior architecture, suggesting a willingness to embrace biomimicry concepts in their education. The findings collectively emphasize the urgent need for increased awareness, educational resources, and support related to biomimicry within the field of interior architecture at Jordanian universities. To effectively incorporate biomimicry into interior architecture programs, students advocate for a multifaceted approach, including more lectures, student projects, and collaboration with professionals.

Furthermore, a TURF analysis highlights that Material Selection and Energy Efficiency were the most frequently combined perceptions among students, underscoring their significance in biomimicry's contributions. Additionally, Circular Economy was identified as a significant contribution of biomimicry by nine out of eleven academics. These results indicate a positive assessment by academics regarding the role of analogical reasoning in addressing challenges and barriers in the application of biomimicry. Overall, the study suggests that universities should enhance their support for biomimicry-related activities and initiatives.

CHAPTER V
CONCLUSION

In conclusion, this study has delved into the realm of biomimicry as a potential educational tool within the domain of interior architecture in Jordanian universities. By exploring the educational methodologies and approaches used to teach biomimicry, the study aimed to evaluate the level of knowledge among interior architecture students and academics in Jordan regarding this concept. The significance of biomimicry in fostering creative problem-solving abilities, enhancing sustainability awareness, and promoting innovative thinking has been underscored throughout this research.

The study shed light on the existing gap in the integration of biomimicry principles within interior architecture education. By examining the awareness levels among students and academics, it became evident that more efforts are needed to promote the concept of biomimicry and its potential application in sustainable design practices. The lack of recognition and underutilization of biomimicry in interior architecture curricula is a challenge that needs to be addressed to bridge the educational gap.

Through a comprehensive methodology encompassing both qualitative and quantitative approaches, the study obtained valuable insights from students and academics. The survey results indicated a varying level of familiarity with the biomimicry concept among students from different universities, age groups, and educational levels. Similarly, academics exhibited a higher level of awareness, emphasizing the relevance of biomimicry in interior architecture education.

The qualitative research seeks to uncover the causes behind the gap in assimilating biomimicry concepts into the design process. Noteworthy hurdles have surfaced, notably the Challenge of Scaling Transfer. This issue stems from designers having restricted influence over design factors right at the inception. However, despite this constraint, the indirect method holds significant potential for transformation, contingent upon robust interdisciplinary collaboration. Another significant challenge is the Knowledge Gap, wherein designers who maintain control over initial objectives may encounter difficulties if they lack profound comprehension or struggle to effectively translate biological insights. This study underscores the importance of analogical thinking in biomimicry and its profound impact on education and innovation, highlighting a knowledge gap between students and academics in this field. It emphasizes that analogical reasoning in biomimicry education involves three core processes: recalling relevant knowledge, assessing its suitability, and applying it, in line with abstracted design principles and the nature technology summary. Furthermore, pedagogical methods such as iterative feedback loops and the integration of hand drawing assist students in comprehending and effectively applying analogical reasoning. Implementing biomimicry's analogical reasoning in education not only enhances learning engagement but also equips students with valuable tools for contributing to sustainable solutions and fostering a deeper appreciation for nature and scientific engagement. Ultimately, the study emphasizes the urgent need for a better understanding of the impacts and significance of effective analogical reasoning in biomimicry design and education.

Biomimicry, a comprehensive methodology, is understood in three dimensions:

- Biomimicry as Model and Guide: Nature serves as inspiration and a benchmark, assessing human innovations' effectiveness.
- Design Spiral: Biomimicry practice follows a cyclic process guiding problem-solving and design with Biomimicry principles.
- Nine Principles of Life: A framework to understand and replicate nature's strategies.

Technological advancement and diverse strategies positively influence sustainable attributes in interior architecture. Contrary to the notion that biomimicry merely inspires forms and structures, it improves indoor quality through daylighting, thermal comfort, energy efficiency, durability, and productivity. These factors significantly shape future building design.

The findings highlighted the importance of incorporating biomimicry as an essential component of interior architecture education. It is important to acknowledge the limitations of this study, including the sample size and the focus on specific universities in Jordan. However, these limitations provide opportunities for future research to expand the scope and explore biomimicry integration in broader educational contexts.

In summary, biomimicry holds remarkable potential as a revolutionary educational approach in interior architecture. By drawing insights from nature's design solutions, both students and academics can reshape their design perspectives. In a world confronted with intricate environmental issues, integrating biomimicry into interior architecture education can be instrumental in nurturing a new generation of designers.

This study strongly advocates for biomimicry's integration as a fundamental pillar of interior architecture education. It encourages further exploration and implementation of this concept in curricula across Jordanian universities and beyond. The journey of biomimicry in interior architecture education is continuous, marked by challenges and opportunities. This research serves as a foundational step, contributing essential knowledge and awareness needed for the growth and advancement of biomimicry education in Jordan and the global design community.

The findings indicated that more than half of the students surveyed had not encountered any real-life applications of biomimicry in interior architecture within Jordanian universities. Consequently, it is imperative to introduce biomimicry instruction into the curriculum for interior architecture design. Jordanian universities offering interior architecture programs should put in additional effort to incorporate practical biomimicry examples for their students. Embracing this approach would enable students to fully tap into the benefits of biomimicry, ultimately fostering the development of environmentally conscious and innovative interior designs.

Recommendations:

Despite the study's limitations concerning sample size and university focus, it lays a critical foundation for future investigations into integrating biomimicry across diverse educational settings. It strongly advocates for structured educational methods that empower students to leverage biomimicry, fostering the creation of environmentally conscious and innovative interior spaces. In the context of interior architecture education, several practical recommendations emerge:

- Launch each semester with a biomimicry design workshop, igniting students' enthusiasm for nature-inspired design solutions and equipping them with tools like Life's Principles to inspire sustainable ideas.
- Integrate Life's Principles into discussions, visually and textually connecting natural patterns to design principles, guiding students in developing and evaluating sustainable solutions.
- Promote hand drawing to enhance the translation of biomimicry concepts and help students internalize scientific concepts from primary research sources.
- Employ conceptual systems-mapping exercises to assist students in tackling complex challenges by drawing parallels with existing ecosystems, while explaining the taxonomy function bridge that supports analogical reasoning in biomimicry design thinking, thereby enhancing their problem-solving skills.

These recommendations present practical strategies for enriching biomimicry education, nurturing a generation of designers equipped with the skills and mindset required to address intricate challenges through sustainable and nature-inspired solutions.

Future Research:

Suggestions for future research based on the results of the thesis for global insights, compare biomimicry integration and awareness in Jordanian interior architecture programs with those in other countries.

Develop and assess biomimicry-focused courses in interior architecture to improve students' understanding and application of biomimicry principles.

Enhance interior architecture faculty's biomimicry knowledge through training programs to better support biomimicry education.

Analyse real-world biomimicry applications in interior architecture projects, understanding challenges and successes.

Investigate how integrating biomimicry in student design projects enhances creativity and sustainability awareness.

Evaluate the effectiveness of biomimicry awareness campaigns among interior architecture students and academics.

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Appendices

Appendix A

The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities

Survey form for Students of the Department of Interior Architecture.

Dear Participant,

This survey is part of a master thesis titled "The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities." The data collected through this survey will be used to explore the possibility of using biomimicry as an educational course in interior architecture in Jordanian universities. And to research on the methods used in a biomimicry approach in the education of interior architecture. And to biomimicry inclusion in interior Architecture education in Jordan and examining the awareness of students and academicians. And to find the reasons why biomimicry is not used in interior architecture at Jordanian universities. And to explore the experiments that can be used as an educational approach in interior architecture courses. By filling in the following scale, you agree to participate in this study.

Please note that your participation in the study is voluntary. The data collected during this study will be used for academic research purposes only and may be presented at national/international academic meetings and publications. Your identity will not be revealed in any case to third parties and pseudonyms will be used in all observational and interview data. You may quit participating in this study at any time by contacting us. If you opt out of the study, your data will be deleted from our database and will not be included in any further steps of the study. In case you have any questions or concerns, please contact us using the information below.

Deya Aldeen Hakamat Alrefai Dr. Elnaz Farjami

Department of Interior Architecture, Near East East University

Tel: +905488442018 / +962790795951

E-mail: 20214613@std.neu.edu.tr.

Department of Architecture, Near University

E-mail: Elnaz.farjami@neu.edu.tr.

We hope you will take all questions into full consideration. It will not take you more than 10-15 minutes to complete the survey. Please answer each question as well as you can.

Thank you in advance,

1- Age:

☐ 18 - 24

☐ 25 - 30

☐ Over 30

2- What is your current level of education?

☐ Bachelor

☐ Master

☐ PhD

3- Where do you studying?

☐ UJ ☐ YU ☐ GJU

4- Have you Heard of the concept of Biomimicry?

☐ Yes

☐ No

5- If yes, Where and in what context did you hear about the concept of biomimicry?

☐ In-class lectures.

☐ In-class projects or assignments.

☐ From outside reading or research & through online resources or media.

☐ From biomimicry-related events or workshops.

☐ From design professionals or practitioners or colleagues in the field of interior architecture.

☐ I haven't heard about it.

6- To what extent are you familiar with the concept of biomimicry in interior architecture?

☐ Very familiar

☐ Familiar

☐ Not familiar

7- Do you think the concept of biomimicry can be useful in interior architecture?

☐ Yes

☐ No

☐ Maybe

8- Have you come across any examples of biomimicry in interior architecture in practice?

☐ Yes

☐ No

9- Have you applied the concept of Biomimicry to your interior architecture projects or Design Courses?

☐ Yes

☐ No

10- Do you think there is a relationship between biomimicry and the field of interior architecture?

☐ Yes

☐ No

☐ Maybe

11- Do you think there is a relationship between biomimicry and sustainability in interior architecture education?

☐ Yes

☐ No

☐ Maybe

12- Do you think that the concept of biomimicry in interior architecture is necessary for interior architecture education?

☐ Necessary

☐ Not Necessary

☐ Maybe

13- How can biomimicry contribute to sustainability in interior architecture and to improving the design of interior spaces?

☐ Energy Efficiency.

Inspired by the way that nature regulates temperature and light, biomimicry can inform the design of more energy-efficient buildings with less dependence on artificial lighting and heating/cooling systems.

☐ Material Selection.

Biomimetic design can lead to the selection of more sustainable materials, such as recycled or biodegradable materials or materials with low embodied energy.

☐ Indoor Air Quality.

By mimicking natural ventilation systems and incorporating plants and other elements of nature into interior spaces, biomimicry can improve indoor air quality and enhance occupant health and well-being.

☐ Circular Economy.

By taking cues from nature's cyclical processes, biomimetic design can promote the principles of a circular economy, where waste is minimized and resources are conserved and reused.

☐ Human-cantered Design:

Biomimicry can also inform the design of interior spaces that are more attuned to human needs and behaviors, creating spaces that are more comfortable, productive, and fulfilling for occupants.

14- What do you think are the reasons that Biomimicry is not used in interior Architecture in Jordanian Universities? (You may mark more than one.)

☐ Academics Lack of knowledge about Biomimicry.

☐ General lack of information on Biomimicry in Interior Architecture (examples/research).

☐ Lack of Instruction on How to Use it in Interior Architecture Education.

15- How could biomimicry be better integrated into the curriculum of interior architecture programs in Jordanian Universities? (You may mark more than one.)

☐ Incorporate more biomimicry-focused lectures and discussions into existing classes.

☐ Offer standalone biomimicry courses or workshops.

☐ Encourage students to incorporate biomimicry into their class projects or assignments.

☐ Collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom.

☐ Provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry.

☐ Encourage faculty members to integrate biomimicry into their own research or design work.

☐ Encourage interdisciplinary collaboration between architecture, biology, and other related fields.

16- Do you think adding biomimicry as an elective course in interior architecture education is necessary?

☐ Necessary

☐ Not Necessary

☐ Maybe

Appendix B

The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities

Survey form for Academics of the Department of Interior Architecture and the Department of Biological Sciences.

Dear Participant,

This survey is part of a master thesis titled “The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities.” The data collected through this survey will be used to explore the possibility of using biomimicry as an educational course in interior architecture in Jordanian universities. And to research the methods used in a biomimicry approach in interior architecture education. And to biomimicry inclusion in interior Architecture education in Jordan and examining the awareness of students and academicians. And to find out why biomimicry is not used in interior architecture at Jordanian universities. And to explore the experiments that can be used as an educational approach in interior architecture courses. You agree to participate in this study by filling in the following scale.

Please note that your participation in the study is voluntary. The data collected during this study will be used for academic research purposes only and may be presented at national/international academic meetings and publications. Your identity will not be revealed in any case to third parties, and pseudonyms will be used in all observational and interview data. You may quit participating in this study at any time by contacting us. If you opt out of the study, your data will be deleted from our database and will not be included in any further study steps. If you have any questions or concerns, please get in touch with us using the information below.

Deya Aldeen Hakamat Alrefai Dr. Elnaz Farjami

Department of Interior Architecture, Near East University

Department of Architecture, Near East University

Tel: +905488442018 / +962790795951

E-mail: Elnaz.farjami@neu.edu.tr.

E-mail: 20214613@std.neu.edu.tr.

We hope you will take all questions into full consideration. It will not take more than 10-15 minutes to complete the survey. Please answer each question as well as you can.

Many thanks for considering my request.

1- Age:

☐ 22 - 24

☐ 25 – 30

☐ 31- 40

☐ Over 40

2- What is your current level of education?

☐ Master

☐ Assistant

☐ PhD

☐ above PhD

3- Where do you teach?

☐ UJ ☐ YU ☐ GJU

4- Have you heard about the concept of Biomimicry?

☐ Yes

☐ No

5- If yes, Where and in what context did you hear about biomimicry?

☐ From outside reading or research & through online resources or media.

☐ From biomimicry-related events or workshops.

☐ From design professionals or practitioners or colleagues in the field of interior architecture.

☐ I haven't heard about it.

6- To what extent are you familiar with the concept of biomimicry in interior architecture?

☐ Very familiar

☐ Familiar

☐ Not familiar

7- Do you think the concept of biomimicry can be useful in interior architecture?

☐ Yes

☐ No

☐ Maybe

8- Have you come across any examples of biomimicry in interior architecture in practice?

☐ Yes

☐ No

9- Have you integrated the principles of biomimicry into your teaching of interior architecture?

☐ Yes

☐ No

☐ Occasionally

10- Have you noticed an increased student interest in biomimicry in interior architecture in recent years?

☐ Yes

☐ No

11- Do you think there is a relationship between biomimicry and the field of interior architecture?

☐ Yes

☐ No

☐ Maybe

12- Is there a relationship between biomimicry and sustainability in interior architecture education?

☐ Yes

☐ No

☐ Maybe

13- Do you think the concept of biomimicry in interior architecture is necessary for interior architecture education?

☐ Necessary

☐ Not Necessary

☐ Maybe

14- Do you think there are enough resources and support available for students interested in learning more about biomimicry in interior architecture?

☐ Yes

☐ No

☐ Maybe

15- Do the university facilities adequately support biomimetic research and projects?

☐ Yes

☐ No

16- What do you think are why Biomimicry is not used in interior Architecture in Jordanian Universities? (You may mark more than one.)

☐ Academics Lack of knowledge about Biomimicry.

☐ General lack of information on Biomimicry in Interior Architecture (examples/research).

☐ Lack of Instruction on How to Use it in Interior Architecture Education.

17- How could biomimicry be better integrated into the curriculum of interior architecture programs in Jordanian Universities? (You may mark more than one.)

☐ Incorporate more biomimicry-focused lectures and discussions into existing classes.

☐ Offer standalone biomimicry courses or workshops.

☐ Encourage students to incorporate biomimicry into their class projects or assignments.

☐ Collaborate with design professionals or experts in the field to bring real-world biomimicry applications into the classroom.

☐ Provide access to additional resources or tools (e.g., books, websites, software) related to biomimicry.

☐ Encourage faculty members to integrate biomimicry into their own research or design work.

☐ Encourage interdisciplinary collaboration between architecture, biology, and other related fields.

18- How can biomimicry contribute to sustainability in interior architecture and improve interior design? (You may mark more than one.)

☐ Energy Efficiency.

Inspired by how nature regulates temperature and light, biomimicry can inform the design of more energy-efficient buildings with less dependence on artificial lighting and heating/cooling systems.

☐ Material Selection.

Biomimetic design can lead to selecting more sustainable materials, such as recycled or biodegradable materials or materials with low embodied energy.

☐ Indoor Air Quality.

By mimicking natural ventilation systems and incorporating plants and other elements of nature into interior spaces, biomimicry can improve indoor air quality and enhance occupant health and well-being.

☐ Circular Economy.

By taking cues from nature's cyclical processes, biomimetic design can promote the principles of a circular economy, where waste is minimized, and resources are conserved and reused.

☐ Human-cantered Design:

Biomimicry can also inform the design of interior spaces more attuned to human needs and behaviors, creating more comfortable, productive, and fulfilling spaces for occupants.

19- Have you heard about Analogical Reasoning?

☐ Yes

☐ No

20- If yes, Where and in what context did you hear about analogical reasoning?

☐ From outside reading or research & through online resources or media.

☐ From educational methods-related events or workshops.

☐ From practitioners or colleagues in the field of interior architecture.

21- Have you had any instruction or education on analogical reasoning in relation to biomimicry?

☐ Yes

☐ No

22- Do you think analogical reasoning can help overcome any challenges or barriers in applying biomimicry?

☐ Yes

☐ No

☐ Maybe

23- Do you think the faculty members have enough knowledge and expertise in analogical reasoning to support students in their biomimicry studies?

☐ Yes

☐ No

☐ Maybe

24- Do you think it is necessary to add biomimicry as an elective course in interior architecture education?

☐ Necessary

☐ Not Necessary

☐ Maybe

APPENDIX C

Official approvals from the University of Jordan to conduct questionnaires with academics and students of interior architecture and interior design.

YARMOUK UNIVERSITY
Office of the President

جامعة اليرموك
دائرة رئاسة الجامعة

Reference: .... الرقم : ....

Date: ....24 May 2023.......... التاريخ : .... هـ

الموافق : .... م

Dear Dr. Çiğdem ÇAĞNAN

In response to your letter dated 17th April, about permitting your student (Deya Aldeen Hakamat Alrefai, ID 20214613) to carry out a survey among students and faculty members at Yarmouk University. We confirm that the above mentioned student was given the permition to distribute his questionnaire and collect the data he needed for his research and that he accomplished his task at YU.

Please do not hesitate to contact us in case you want any further information.

Dr. Samer M. Samarah
Full Professor of Data Science - Data Mining
Vice President for Research, Development and Accreditation.
Yarmouk University, Irbid-Jordan
Cell: (+962) 775683294
Office: (+962) 2 7211111 Ext. 2108
Email: samers@yu.edu.jo, vice.PL@yu.edu.jo

تلفون : ٧٢١١١١١ – ٢ – ٩٦٢ فاكس : ٧٢٧٤٧٢٥ –٢– ٩٦٢ اربد – الأردن
www.yu.edu.jo P.O. Box 566, Irbid, Jordan P: +962 2 7211111 F: +962 2 7274725 E-mail: yarmouk@yu.edu.jo, president@yu.edu.jo

الجامعة الأردنية

THE UNIVERSITY OF JORDAN

رئاسة الجامعة

University Administration

Ref: 1/2023/1376
Date: 22/5/2023

Dr. Çigdem Cağnan
Vice Dean, School of Architecture
Near East University
North Cyprus
Email: cigdem.cagnan@neu.edu.tr

Dear Dr. Cağnan,

This letter serves to certify that **Mr. Deya Aldeen Hakamat Alrefai**, a Master student of Interior Architecture at Near East University in north Cyprus (student no. 20214613), has distributed a questionair that is part of his MA thesis entitled "the Use of Biomimicry in Interior Architecture Education: Case Study; in Jordanian Universities" among academics and students of Visual Arts Department in the School of Arts and Design at the University of Jordan, Jordan.

Sincerely,

Vice President for Humanities Faculties
Professor Salameh Naimat

نسخة:
- كلية الفنون والتصميم.
- دائرة العلاقات الدولية، شعبة التعاون الدولي والمراسلات الخارجية.

R.S

هاتف: ٥٣٥٥٠٠٠ (٦- ٩٦٢) فرعي: ٢١١٢١ فاكس: ٥٣٥٥٥١١ (٦-٩٦٢) فرعي- ٢١٠٣٥ عمان ١١٩٤٢ الأردن
Tel.: (962-6) 5355000 Ext.: 21121 Fax: (962-6) 5355511 Ext: 21035 AMMAN 11942 JORDAN
E-mail: admin@ju.edu.jo
http://www.ju.edu.jo

GJU
الجامعة الألمانية الأردنية
German Jordanian University

كليـة هندسـة العمـارة والبيئـة المبنيـة
School of Architecture & Built Environment

الرقم: 361/23/5/10
Ref:

التاريخ: 14.6.2023 الموافق:
Date:

To whom it may concern,

Referring to the explanations of President of the German Jordan University Prof. Alaa Alddin Al Halhouli on the letter received from Near East University regarding facilitating the distribution of the questionnarie for the master's student, Deya Aldeen Hakamat Alrefai ID(20214613), amongst students and academics in Department of Architecture and Interior Architecture at School of Architecture and Built Environment.

We would like to inform you that the questionnaire was distributed to students and academics at Department of Architecture and Interior Architecture at School of Architecture and Built Environment at German Jordan University, and the data was collected appropriately.

Very Sincerely,

Dr. Omaimah Ali

14/6/2023

Dean, School of Archeticture and Build Environment

كلية هندسة العمارة والبيئة المبنية
School of Architecture and Built Environment

هاتف: ٤٢٩٤٣٠٠ ٦ ٩٦٢+ فاكس: ٤٦١٨٧٥٤ ٦ ٩٦٢+ ص.ب: ٣٥٢٤٧ عمان ١١١٨٠ الأردن
Tel. +962 6 4294300 Fax. +962 6 4618754 P.O.Box. 35247 Amman 11180 info@gju.edu.jo www.gju.edu.jo

April 17, 2023

Department of Architecture
Faculty of Architecture
Near East University
North Cyprus

To whom it may concern

I am writing to formally indicate our awareness of the research questionnaire survey by DEYA ALDEEN HAKAMAT MOHD ALREFAI - 20214613, a student at NEU- department of Architecture. We are aware that the mentioned student intends to conduct his/her research by administering a questionnaire survey among your university students and academicians.

As Vice Dean of the Department of Architecture, I am responsible for the graduate student's committee. I kindly request your instant permission to conduct his/her research at your organization.

Please do not hesitate to ask for further information and contact my email: cigdem.cagnan@neu.edu.tr

Sincerely,

Assist. Prof. Dr. ÇİĞDEM ÇAĞNAN
Vice Dean
Architecture Department/ NEU

The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities

Yazar Deya Alrefai

Gönderim Tarihi: 27-Eyl-2023 09:42PM (UTC+0300)
Gönderim Numarası: 2178743786
Dosya adı: Thesis,_Deya_Aldeen_Alrefai_27-9-2023.docx (9.25M)
Kelime sayısı: 32949
Karakter sayısı: 203998

The Use of Biomimicry in Interior Architecture Education: Case Study; Jordanian Universities

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