Fronteiras: Journal of Social, Technological and Environmental Science
http://periodicos.unievangelica.edu.br/fronteiras/
ISSN 2238-8869

Article

A Study on Biophilic *Design* as a Sustainable Technique in University Environments

Patrícia Martins de Oliveira Pagano[1], Luciana Cristina Soto Herek[2], Flávia Aparecida Reitz Cardoso[3], Juliana de Castro Prado Friedrich[4], Alba Regina Azevedo Arana[5], Rute Grossi-Milani[6]

[1] Doutoranda. Universidade do Oeste Paulista. ORCID: 0000-0002-8146-4354. E-mail: arq.patriciamartins@gmail.com
[2] Doutora. Instituto Cesumar de Ciência, Tecnologia e Inovação. Universidade Cesumar. ORCID: 0000-0001-9677-4139. E-mail: luciana.rezende@unicesumar.edu.br
[3] Doutora. Universidade Tecnológica Federal do Paraná. ORCID: 0000-0002-0432-9191. E-mail: reitz@utfpr.edu.br
[4] Doutoranda. Universidade Cesumar. ORCID: 0009-0002-5568-9047. E-mail: jujcp@hotmail.com
[5] Doutora. Universidade do Oeste Paulista. ORCID: 0000-0001-8995-4449. E-mail: alba@unoeste.br
[6] Doutora. Instituto Cesumar de Ciência, Tecnologia e Inovação. Universidade Cesumar. ORCID: 0000-0003-2918-1266. E-mail: rute.milani@unicesumar.edu.br

RESUMO
A biofilia se destaca como um aliado nos projetos construtivos ao promover a conexão entre pessoas e o ambiente natural, criando espaços que oferecem conforto, bem-estar e felicidade aos usuários. Este estudo teve como objetivo analisar a percepção de estudantes universitários em relação aos atributos do *design* biofílico e às técnicas sustentáveis empregadas no ambiente construído de uma universidade privada na região Sul do Brasil. Trata-se de um estudo de caso exploratório com abordagem mista. A amostra foi composta por 67 alunos de diversas áreas - saúde, exatas e humanas - que responderam a um questionário via Google Forms, utilizando a metodologia de bola de neve virtual. O questionário incluiu questões sobre as emoções positivas percebidas em relação aos elementos construtivos, aspectos sociodemográficos e a percepção do ambiente construído. Verificou-se que os ambientes naturais geraram o maior número de emoções positivas, especialmente em locais com paisagens, materiais naturais e áreas ao ar livre, destacando-se encantamento e relaxamento. Nos ambientes com elementos construtivos, os atributos mais valorizados foram a iluminação natural, a diversidade de funções, os elementos construtivos inovadores e a estrutura das salas de aula, nesta ordem. Além disso, os elementos de design biofílico mais relevantes para o desenvolvimento de emoções positivas foram a iluminação natural, as vistas para paisagens e os espaços ao ar livre. Observou-se também que as emoções positivas associadas ao ambiente universitário estavam vinculadas a características sustentáveis, como energia eólica, materiais recicláveis, materiais naturais e reaproveitamento da água. Constatou-se que um ambiente universitário com atributos do *design* biofílico voltados para a sustentabilidade pode induzir emoções positivas na comunidade acadêmica.
Palavras-chave: bem-estar; sustentabilidade; espaço construído.

ABSTRACT
Biophilia stands out as an ally in construction projects by promoting the connection between people and the natural environment, creating spaces that offer comfort, well-being, and happiness to users. This study aimed to analyze the perception of university students regarding the attributes of biophilic design and the sustainable techniques employed in the built environment of a private university in the southern region of Brazil. This is an exploratory case study with a mixed-methods approach. The sample consisted of 67 students from various fields - health, exact sciences, and humanities - who used the virtual snowball sampling methodology to answer a questionnaire via Google Forms. The questionnaire included questions about the positive emotions perceived in relation to the built elements, sociodemographic aspects, and the perception of the built environment. It was found that natural environments generated the highest number of positive emotions, especially in locations with landscapes, natural materials, and outdoor areas, with delight and relaxation standing out. In environments with built elements, the most valued attributes were natural lighting, diversity of functions, innovative construction elements, and classroom structure, in that order. Additionally, the most relevant biophilic design

Submissão: 12/10/2024 Aceite: 25/04/2025 Publicação: 05/06/2025

v.14, n.2, 2025 • p. 110-129. • DOI http://dx.doi.org/10.21664/2238-8869.2025v14i2p.110-129

elements for the development of positive emotions were natural lighting, views of landscapes, and outdoor spaces. It was also observed that the positive emotions associated with the university environment were linked to sustainable characteristics, such as wind energy, recyclable materials, natural materials, and water reuse. It was concluded that a university environment with biophilic design attributes focused on sustainability can induce positive emotions in the academic community.
Keywords: well-being; sustainability; built environment.

Introduction

The everyday life of the urban environment directly interferes with quality of life due to fast-paced routines, excessive noise, and the lack of adequate green spaces. This urban scenario, characterized by the constant expansion of the built environment, often does not take into account the integration between the occupied space and the health of the individuals who will use it. Lopes (2012) highlights that human health and well-being are directly affected by the quality of the environments in which people live. When these environments are worked on together, they can promote a healthier and more beneficial environment. This imbalance is worsened by a hectic life and stressful work routines, marked by pressure and rush, as pointed out by Facey et al. (2015). Rapid urbanization, when carried out without proper planning and adequate public policies, becomes a significant challenge to sustainability. On one hand, there is the excessive and unsustainable use of natural resources, such as water and energy, and the generation of solid, liquid, and gaseous waste. On the other hand, problems arise related to public health, education, and the supply of water and sewage. These issues are particularly accentuated in less developed countries, where urbanization happens in a spontaneous and disorganized manner (Silva & Santos, 2015).

In this context, public policies often fail to keep up with the rapid growth of cities, resulting in disordered and unplanned densification (Ribeiro et al., 2019). The lack of sanitation, security, infrastructure, health, and proper education is a reflection of this gap, which leads to a deterioration in the quality of urban life. According to Reis et al. (2012), this lack of planning and resources results in negative social and environmental impacts, arising from a disorganized process of industrialization and urbanization. Flowers et al. (2017) introduce the concept of "Nature Deficit Disorder," which reflects a growing disconnection with nature, shown by the fact that only 10% of young people have contact with nature, in contrast to 40% of young adults. The National Human Activity Pattern Survey (Klepeis et al., 2001) corroborates this disconnection, revealing that people spend almost 90% of their time inside built environments.

In this scenario, Frederick Law (1822–1903) argues that nature has the power to relieve the mind from fatigue and bring tranquility and renewal to the individual. Hartig and Kahn (2016) support this view, showing that contact with natural environments or with materials that refer to nature is associated with improved quality of life and physical and mental health. Ulrich (2012) observed that natural environments reduce stress and enhance attention, indicating that natural features can increase autonomy and control of the nervous system. Therefore, the integration of nature into built environments, through biophilic design, emerges as a solution to meet the human need for connection with the natural environment. Heerwagen and Lloftness (2012) emphasize

that biophilic design is crucial not only to create healthier environments and improve living conditions, but also to stimulate cognitive capacity, concentration, and productivity.

The concept of biophilic design, derived from biophilia, reinforces the idea that humans need a connection with nature, even in built environments (Yin & Spengler, 2019). However, biophilic design must be integrated into the planning and execution processes of architectural projects, encompassing everything from interior and façade design to landscaping (Calabrese & Kellert, 2015). Beatley and Newman (2013) highlight that the implementation of biophilia should take place from the micro scale, in the design of the building, to the macro scale, in the analysis of the site and region, incorporating natural elements into the city. Heerwagen and Lloftness (2012) also affirm that spaces that apply biophilic design are more valued both by people and by the real estate market, attracting more visitors and generating greater investment interest. Design elements such as skylights, windows with views of natural landscapes, indoor gardens, and tree-lined sidewalks make staying in these environments more pleasant.

Jones (2013) observes that, when applied to specific environments such as schools and academic institutions, biophilic design offers benefits that go beyond aesthetic appeal. It can promote environmental education and pro-environmental behavior, reduce mental fatigue, improve academic performance, and enhance skills to perform tasks. The pursuit of more sustainable architecture aims to offer health, well-being, quality of life, and to mitigate environmental impacts. The more architecture is able to evoke emotions and positive feelings, the greater the benefit for emotional development (Okamoto, 2002). The connection between people and place can awaken a sense of belonging, and architecture should encourage experiences in both built and natural spaces.

In this context, the thematic axis of this investigation focuses on the application of biophilic design in university environments. Many of these places are still inadequate and do not use architecture in favor of the educational practices developed. The objective of this study was to analyze the perception of university students regarding the attributes of biophilic design and sustainable techniques applied to the built environment of a private university in the southern region of Brazil. The attributes of the university environment were characterized based on biophilic principles and sustainable techniques, and the perceptions and emotions awakened in students by experiencing environments that incorporate these attributes were investigated. Finally, the study proposes ways to integrate restorative environments with biophilic design.

Materials and Methods

This exploratory study was conducted in a university environment and is classified as a case study that employed both qualitative and quantitative approaches.

Study Area

The research was conducted at a private Higher Education Institution (HEI) located in Maringá, Paraná, in southern Brazil. Founded in 1947, Maringá has an estimated population of 410,000 inhabitants, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2022). The city is an important hub in the macroeconomic region, encompassing 25 municipalities with over one million inhabitants (Maringá, 2016). The local economy is diversified, including agriculture, livestock, commerce, the agro-industrial and textile sectors, as well as education and healthcare. These characteristics make it the third-largest city in Paraná and the fifth-largest in the southern region of Brazil (Maringá, 2016). Maringá has a high Human Development Index (HDI) of 0.841, which is higher than both the state and national averages, and it preserves 17 native forest groves totaling 217.8 hectares, providing 25.47 m² of green area per inhabitant (Vidigal Filho & Vidigal, 2016).

The city has eight higher education institutions (HEIs), offering programs in various fields of knowledge, and has established itself as an educational hub, according to data from the Maringá Development Company (Codem) and IBGE. Approximately 10% of the population is composed of higher education students (Maringá, 2016).

Among these institutions, one was selected for the study. Founded in 1987, the institution began its activities on a plot of land that previously served as a landfill, which had been deactivated for around 10 years and was donated by the city government as an incentive to the founders. The neighborhood, which had previously been undervalued and sparsely populated, was quickly transformed by the arrival of the institution. The former landfill site was rehabilitated to house the first private higher education institution in Maringá.

Today, the institution occupies an area of 100,000 m² and includes 15 buildings, 92 laboratories, 250 classrooms, as well as physical therapy, nutrition, dentistry, psychology, and veterinary clinics, a university radio and TV station, and a large sports complex. The university campus is frequented not only by students and staff but also by members of the community who use the on-site clinics. Due to the diversity of users and their varying perceptions, it was necessary to define a specific sample in order to obtain more precise data.

Participants

The study sample consisted of 67 participants, students from the academic community of both genders, including courses from the health, exact, and human sciences fields. The selection of participants considered their use of the built environment on the HEI campus and their continued presence on-site. Individuals who did not express interest in participating or who did not sign the Informed Consent Form (ICF) were excluded. The project was approved by the Research Ethics Committee (CAAE No.: 51001421.8.0000.5539), in accordance with the ethical principles established by Resolution No. 466/2012.

Instruments

Questionnaire on Positive Emotions Perceived in Relation to Constructive Elements

To assess the emotions elicited in students by the university environment, a questionnaire developed by Detanico et al. (2019) was used. This questionnaire includes eight closed-ended questions and three photographs of each biophilic attribute, with the aim of identifying the intensity of positive emotions perceived by users when viewing the images. A 7-point Likert scale is used, where 1 represents the lowest and 7 the highest intensity of emotion in relation to the biophilic attribute. In addition, there is one question that allows participants to rank the relevance of the attributes from 1 to 8, according to their perception. Detanico et al. (2019) reported a Cronbach's alpha coefficient of 0.86, indicating good internal consistency.

The biophilic design attributes addressed included: natural materials (wood, stone, brick finishes, vegetation); outdoor spaces (sports court, outdoor gym, knowledge square); landscape views (views from classrooms and cafeteria); innovative constructive elements (glass skin, wind energy, photovoltaic panels); natural lighting (study and work areas); classroom structure (chairs, walls, blackboards); diversity (activities and functions on campus); and landscaping. The emotions evaluated were the 15 proposed by Detanico et al. (2019): friendliness, kindness, respect, admiration, joy, fun, surprise, stimulation, courage, pride, trust, inspiration, enchantment, relaxation, and satisfaction.

Sociodemographic and Perception of the Built Environment Questionnaire

To analyze students' perceptions of the university environment, a structured questionnaire with nine closed-ended questions was developed. The first six questions collected general information about the students (age, gender, family income, enrolled program, year of study, and time of attendance). The final three questions aimed to understand students' environmental perceptions, addressing feelings evoked by the institution's physical environment, objects that trigger these emotions, and natural elements that contribute to sustainability.

Data Collection Procedures

Data collection began using the virtual snowball sampling method, with the questionnaire link being shared via the social media platforms WhatsApp and Instagram, accompanied by a request for participants to forward it to other university peers. The data collection took place between June and November 2021. The questionnaire was created using the Google Forms tool and included: (1) a presentation of the project and the Informed Consent Form (ICF); (2) the questionnaire on positive emotions perceived in relation to constructive elements; and (3) the sociodemographic and built environment perception questionnaire.

The purpose of the data collection was to assess individuals' perceptions of the physical and visual attributes of space, the emotions and engagement prompted by the built environment, and the need to apply biophilic design techniques and practices to improve quality of life, well-being, and sustainability. Each space

and students' engagement with sustainable development were taken into consideration. The data collection was conducted during the pandemic, which may have affected students' willingness to respond to the questionnaires.

Data Analysis

The data obtained were entered into spreadsheets using Microsoft Excel 365 Personal and statistically analyzed with the aid of the software Statistica Single User, version 13.2. Descriptive measures such as mean and standard deviation were calculated for quantitative variables. Student's t-test was used to compare quantitative variables between the groups of students enrolled or not enrolled in Architecture and Urbanism, adopting a significance level of 5% ($p < 0.05$).

For qualitative variables, the most frequently mentioned words by participants were entered into Excel spreadsheets to organize the responses. Nonsensical answers and participants who did not complete the questions were disregarded. A word cloud was created online using the website wordart.com.

Results and Discussion

Characterization of the Biophilic and Sustainable Attributes of the University Built Environment

To examine the perceptions and emotions elicited in students through their experience in the university environment, a building with appropriate characteristics for the study was selected. The chosen location was the campus of Cesumar University (UniCesumar) in Maringá, Paraná, in southern Brazil. The selected site features biophilic attributes, such as open areas and natural landscapes, and covers approximately 100,000 m², distributed across 15 blocks that include classrooms, a library, laboratories, clinics, administrative offices (with a building characterized as sustainable construction), a museum, auditoriums, cafeterias, and a restaurant (Figure 1).

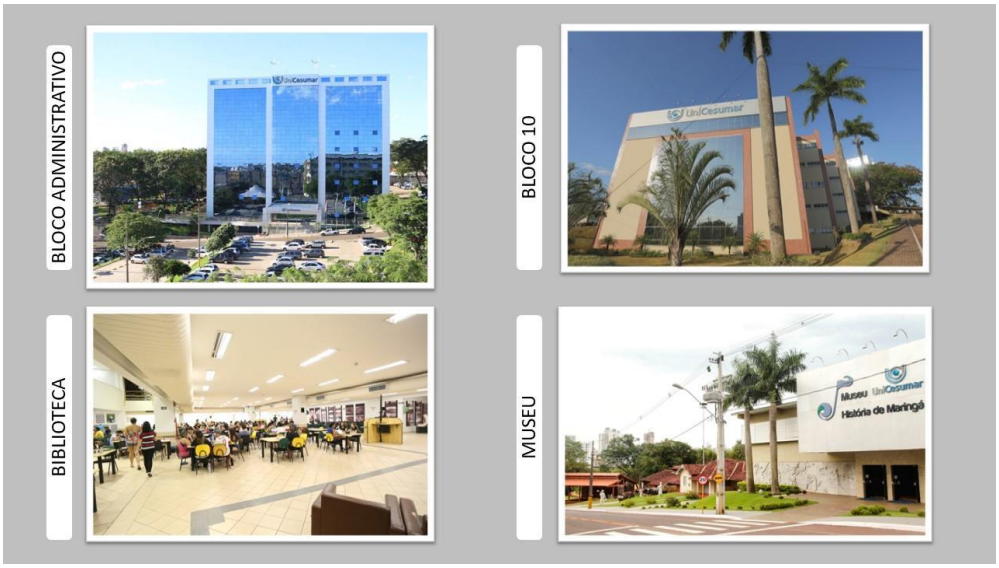

Figure 1: Campus Unicesumar photographs – Maringá. Source: the authors, 2024.

The building also stands out for its multiple possible uses, including an indoor and outdoor multisport court (for tennis and beach tennis), a gym, an outdoor fitness area (known as ATI), and a heated swimming pool. In addition, the campus features the *Inspira Space*, an environment located in Block 7, designed to provide inspiring experiences for students and faculty. This space includes a coffee area, games, and meeting tables, enabling professors to interact and share experiences with their peers. It is also worth highlighting the classrooms based on the *design thinking* concept, with specific furniture and decoration aimed at fostering students' professional practice. Several biophilic design attributes can also be identified throughout the university's built environment, such as a plaza with a reflecting pool, classrooms with views of the landscape, grassy areas, and integration between open spaces and constructed environments (Figure 2).

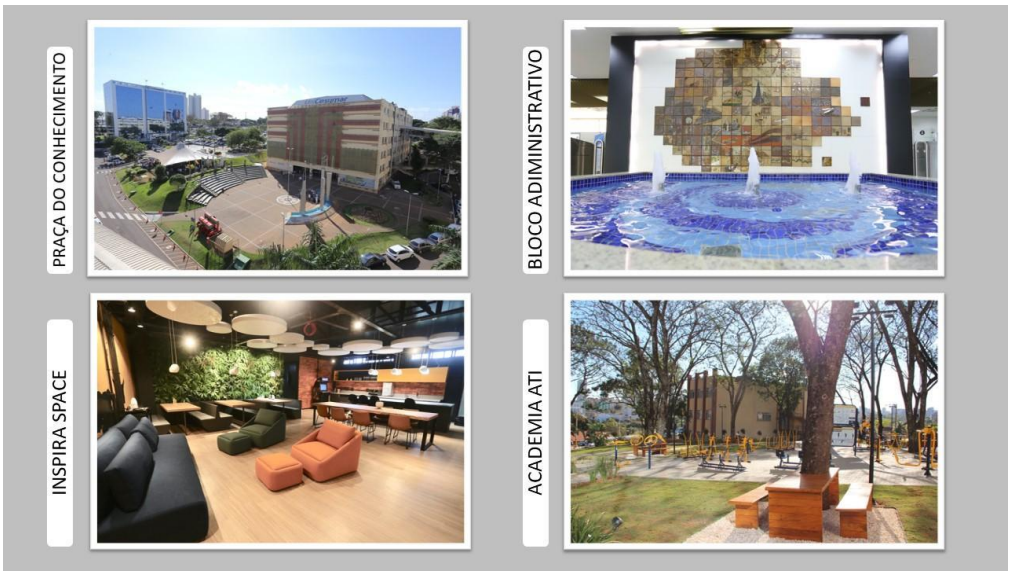

Figure 2: Photographs of the biophilic attributes at Unicesumar– Maringá. Source: the authors, 2024.

Positive Emotions Perceived in Relation to the University Environment and the Application of Biophilic Design Attributes

Within the university campus, there is a high circulation of people, including students, visitors, staff, and community members who seek the services offered by the specialized clinics. Considering that each group has distinct objectives and perceptions of the spaces, this study focused specifically on students. A total of 67 students were evaluated, with ages ranging from 17 to 56 years and an average age of 24.12 ± 6.88 years. Among them, 58.2% (n = 39) were between 21 and 30 years old. The majority of respondents were female (65.7%, n = 44), and 43.3% (n = 29) had a monthly income between 4 and 9 minimum wages. A significant number of participants were enrolled in the Architecture and Urbanism program (41.8%, n = 28), with 61.2% (n = 41) attending classes in the morning and 26.9% (n = 18) being in their second year of study.

To evaluate the emotions elicited in students through their experience of the university environment and the application of biophilic design attributes, a questionnaire focused on positive emotions perceived in relation to constructive elements was used. This instrument employs a scale from 1 to 7, where 1 represents the lowest and 7 the highest intensity of emotional perception. The analysis aimed to interpret the results both in general terms and from the perspective of students in Architecture and Urbanism, who are assumed to have a heightened sensitivity to the subject.

Table 1 presents the distribution of emotions associated with attributes of spaces featuring natural environments, differentiating between students of Architecture and Urbanism and those from other programs. The data provide a detailed view of the emotions evoked by various environmental aspects, such as natural materials, open air, landscape, and landscaping.

Natural Materials

- Positive sensations such as tranquility, relaxation, and enchantment showed similar averages between the groups, with no statistically significant differences ($p > 0.05$). This suggests that, regardless of the academic program, natural materials in the university environment provide a consistent level of emotional well-being for students. The selection of these emotions was based on previous studies regarding the impact of natural elements on restorative experiences in built environments (e.g., Kaplan, 1995; Ulrich et al., 1991).

- Respect and sympathy: again, the differences between the groups are not significant, indicating a uniform perception of the attributes of

respect and sympathy elicited by natural materials.

- Joy and pride: although the averages are similar, it was noted that Architecture and Urbanism students reported a slight decrease in joy and pride compared to students from other programs. However, these differences are not statistically significant.

Outdoors

- *Satisfaction, stimulation, relaxation, inspiration, and joy:* The average scores for these emotions are consistent across groups, with no significant differences ($p > 0.05$). This indicates that the experience of being outdoors on campus has a uniformly positive effect on students' satisfaction, stimulation, relaxation, inspiration, and joy.

- *Fascination and sympathy:* the scores are similar between the groups, indicating a uniform perception of the attributes of enchantment and sympathy provided by the outdoor spaces.

Landscapes

- **Relaxation, satisfaction, and fascination**: these attributes are evaluated similarly by all students, with average scores showing no statistically significant differences. The presence of a natural landscape appears to have an equally positive impact in terms of relaxation, satisfaction, and fascination.

- **Admiration and stimulation**: in this case, students from the Architecture and Urbanism program reported a higher average level of stimulation compared to students from other programs. However, the difference is not statistically significant ($p > 0.05$).

Landscaping

- **Joy and fascination**: the data show that the emotion of joy was slightly higher among students from other programs compared to those in Architecture and Urbanism, although the difference is not

statistically significant ($p > 0.05$). Fascination was also evaluated similarly between the groups.

- **Relaxation, satisfaction, and inspiration**: the emotions associated with these attributes did not show significant differences between the groups.

Table 1: Distribution of variables related to spaces with natural environments, evaluated according to the participants' academic programs

Variáveis	Geral (n = 56)	Arquitetura Urbanismo (n = 25)	Outros cursos (n = 31)	p*
Materiais naturais				
Tranquilidade	5,9 ± 1,5	5,9 ± 1,4	5,8 ± 1,6	0,7731
Relaxamento	5,9 ± 1,6	5,8 ± 1,7	5,9 ± 1,5	0,6749
Encantamento	5,9 ± 1,6	5,8 ± 1,9	6,0 ± 1,4	0,7048
Respeito	5,7 ± 1,7	5,5 ± 1,9	5,8 ± 1,6	0,5249
Simpatia	5,7 ± 1,6	5,5 ± 1,8	5,7 ± 1,5	0,5995
Alegria	5,6 ± 1,5	5,6 ± 1,6	5,7 ± 1,4	0,8745
Orgulho	5,3 ± 1,8	5,1 ± 2,2	5,5 ± 1,6	0,4879
Ar livre				
Satisfação	5,7 ± 1,8	5,6 ± 1,8	5,7 ± 1,8	0,7581
Estímulo	5,7 ± 1,7	5,7 ± 1,8	5,8 ± 1,6	0,7825
Relaxamento	5,7 ± 1,7	5,6 ± 1,9	5,8 ± 1,7	0,7717
Inspiração	5,7 ± 1,7	5,6 ± 1,7	5,7 ± 1,8	0,9564
Alegria	5,7 ± 1,6	5,7 ± 1,7	5,7 ± 1,6	0,9929
Encantamento	5,6 ± 1,7	5,5 ± 1,8	5,6 ± 1,7	0,8080
Simpatia	5,6 ± 1,7	5,6 ± 1,7	5,6 ± 1,7	0,9198
Respeito	5,3 ± 1,8	5,1 ± 1,9	5,5 ± 1,7	0,3660
Paisagem				
Relaxamento	6,1 ± 1,5	6,1 ± 1,6	6,1 ± 1,5	0,8105
Satisfação	6,0 ± 1,5	6,0 ± 1,7	6,1 ± 1,4	0,8401
Encantamento	6,0 ± 1,5	6,0 ± 1,6	6,0 ± 1,5	0,9900
Admiração	5,3 ± 2,0	5,3 ± 2,3	5,3 ± 1,9	0,9499
Estímulo	5,1 ± 2,1	6,0 ± 1,8	5,9 ± 1,7	0,7920
Paisagismo				
Alegria	5,8 ± 1,7	5,6 ± 1,9	6,0 ± 1,5	0,3785
Encantamento	5,8 ± 1,7	5,9 ± 1,7	5,8 ± 1,7	0,8823
Relaxamento	5,7 ± 1,8	5,5 ± 1,9	5,9 ± 1,7	0,4480
Satisfação	5,7 ± 1,8	5,5 ± 2,0	5,8 ± 1,6	0,5619
Inspiração	5,7 ± 1,9	5,8 ± 2,0	5,7 ± 1,8	0,9026
Simpatia	5,6 ± 1,8	5,5 ± 2,0	5,7 ± 1,7	0,7330
Orgulho	5,5 ± 1,9	5,4 ± 2,0	5,6 ± 1,8	0,5422
Respeito	5,5 ± 1,8	5,2 ± 2,0	5,6 ± 1,7	0,3500

*Teste *t* não significativo considerando nível de significância de 5%. Fonte: Os autores, 2024.

The results indicate that biophilic design, when applied to built environments, has the potential to consistently generate positive emotions among students from different academic programs. The presence of natural elements contributes to a general increase in well-being, relaxation, and fascination, demonstrating the effectiveness of these practices in creating a more pleasant and healthier environment.

However, subtle differences were observed between students of Architecture and Urbanism and those from other academic programs. For example, Architecture and Urbanism students reported slightly lower levels

of emotions such as joy, inspiration, and courage, which may reflect a heightened sensitivity or different expectations regarding elements of the built environment.

These differences may be associated with the students' familiarity with design and biophilia concepts, which can influence their perceptions and emotional responses. A greater degree of critical sensitivity and a more detailed view of the built environment may lead to a less intense perception of certain emotions compared to other groups.

Moreover, the results support existing literature on the importance of integrating nature into built environments to promote mental health and well-being (Kellert, 2016; Cooper & Browning, 2015). The analysis highlights the importance of biophilic attributes in promoting a university environment that supports not only academic performance but also students' health and emotional well-being.

Table 2 provides a detailed overview of the positive emotions evoked by different biophilic design attributes and constructive elements, segmented between Architecture and Urbanism students and those from other programs.

Although this analysis contributes to understanding how the university environment influences students' emotions, it is important to acknowledge that factors such as cultural context, personal experiences, and socioeconomic conditions may also exert a significant influence on individual perceptions and emotional responses, potentially even outweighing the influence of academic background.

Innovative Constructive Elements

- **Surprise**: This attribute shows the highest average among those analyzed (5.3 ± 2.0), although the difference between the groups (Architecture and Urbanism vs. other programs) is not significant ($p = 0.6194$). This suggests that innovation in constructive elements has a broadly positive impact in terms of eliciting surprise, with little variation across different student groups.
- **Fascination**: Similar to surprise, fascination also presents comparable averages between the groups, with an overall mean of 5.1 ± 2.1 and no significant differences ($p = 0.6084$).

Classroom Structure

- **Confidence and joy**: The data indicate that the classroom structure elicits relatively low levels of confidence and joy, with averages of 4.4 ± 2.1 for confidence and 4.3 ± 2.1 for joy. The analysis shows that Architecture and Urbanism students have statistically lower averages for joy ($p = 0.0489$) and inspiration ($p = 0.0105$), as well as courage ($p = 0.0442$), compared to students from other programs. This result may

be attributed to the conventional design of classrooms, which may not incorporate biophilic elements that stimulate positive emotions.

- **Stimulation and kindness**: The averages are somewhat higher but still show no significant differences between the groups (stimulation p = 0.1491 and kindness p = 0.0766). This indicates that, although the classroom structure may positively influence these emotions, the difference is not sufficient to be considered significant.
- **Inspiration and courage**: The emotions of inspiration and courage are notably lower among Architecture and Urbanism students, with statistically significant differences (inspiration p = 0.0105 and courage p = 0.0442), which may reflect a lower perception of positive attributes in the classroom structure.

Table 2: Distribution of biophilic design attributes and elicited positive emotions, evaluated according to participants' academic programs

Variáveis	Geral (n = 56)			Arquitetura Urbanismo (n = 25)			Outros cursos (n = 31)			p
Elementos construtivos inovadores										
Surpresa	5,3	±	2,0	5,1	±	2,2	5,4	±	1,9	0,6194
Encantamento	5,1	±	2,1	5,0	±	2,3	5,2	±	1,9	0,6084
Estrutura das salas de aula										
Confiança	4,4	±	2,1	3,9	±	2,2	4,9	±	1,9	0,0510
Alegria	4,3	±	2,1	3,7	±	2,2	4,7	±	1,9	0,0489*
Estímulo	4,1	±	2,1	3,6	±	2,2	4,4	±	2,0	0,1491
Gentileza	4,0	±	2,1	3,5	±	2,2	4,4	±	2,1	0,0766
Inspiração	4,0	±	2,2	3,2	±	2,2	4,6	±	2,0	0,0105*
Simpatia	3,9	±	2,1	3,5	±	2,2	4,3	±	2,0	0,1351
Coragem	3,9	±	2,1	3,3	±	2,1	4,4	±	2,0	0,0442*
Surpresa	3,4	±	2,1	2,8	±	2,2	3,8	±	2,0	0,0693
Diversidade das funções no campus										
Admiração	5,7	±	1,7	5,6	±	1,8	5,7	±	1,7	0,7337
Estímulo	5,7	±	1,8	5,4	±	1,8	5,8	±	1,7	0,3734
Alegria	5,5	±	1,7	5,3	±	1,7	5,7	±	1,8	0,3922
Satisfação	5,5	±	1,8	5,4	±	1,8	5,5	±	1,8	0,6852
Relaxamento	5,4	±	1,9	5,3	±	2,0	5,5	±	1,8	0,5905
Diversão	5,2	±	1,9	5,1	±	1,9	5,2	±	2,0	0,7990
Luz natural										
Estímulo	5,8	±	1,7	5,9	±	1,7	5,8	±	1,7	0,7041
Satisfação	5,7	±	1,8	6,0	±	1,6	5,5	±	1,9	0,3034
Inspiração	5,7	±	1,8	5,8	±	1,8	5,6	±	1,7	0,6568
Presença	5,6	±	1,8	5,4	±	2,1	5,7	±	1,7	0,5162
Alegria	5,5	±	1,8	5,5	±	1,8	5,6	±	1,8	0,8867

Non-significant t-test considering a significance level of 5%. Source: Authors, 2024.

Diversity of functions on campus

- **Admiration and stimulation**: The emotions of admiration and stimulation have relatively high averages (Admiration 5.7 ± 1.7 and Stimulation 5.7 ± 1.8), with no significant differences between groups (Admiration p = 0.7337 and Stimulation p = 0.3734). This demonstrates that the diversity of campus functions is well received by all students and consistently promotes these emotions. **Joy, satisfaction, and relaxation**: The averages for these emotions are also high and similar across groups (Joy 5.5 ± 1.7 and Satisfaction 5.5 ± 1.8). The differences are not significant, indicating a uniform perception of the benefits provided by the diversity of functions on campus.

Natural Light

- **Stimulation and satisfaction:** Natural light has a positive impact on the emotions of stimulation and satisfaction, with averages of 5.8 ± 1.7 for stimulation and 5.7 ± 1.8 for satisfaction. Although the differences between groups are not significant (Stimulation p = 0.7041 and Satisfaction p = 0.3034), these attributes are well rated by all students.
- **Inspiration and presence:** Natural light also promotes inspiration (5.7 ± 1.8) and presence (5.6 ± 1.8), with averages indicating similarly positive effects across all groups (Inspiration p = 0.6568 and Presence p = 0.5162).
- **Joy:** The average score for joy is high (5.5 ± 1.8) and shows no significant differences between groups (p = 0.8867), suggesting that natural light contributes uniformly to students' emotional well-being.

It is understood that the health and well-being of an individual or the general population can be influenced by the cyclical interaction between the physical, social, and personal environments (Stokols, 1992; Hartmann, Marshall, & Goldenberg, 2015). In this regard, it is believed that physical environments featuring characteristics such as appropriate temperature, lighting, acoustics, and ergonomics are capable of providing pleasant and healthy experiences, as well as fostering a sense of well-being and reducing negative thoughts

(Benedicto et al., 2019; Elali, 2003).

For a better understanding of the emotions and feelings elicited by this person-environment interrelation, it is necessary to further explore the concept of restorative environments. This theory proposes that certain environments possess specific characteristics capable of reducing stress and restoring attentional capacity and mental fatigue caused by routine activities (Alves, 2011). These characteristics are directly linked to the presence of natural elements within the space, which are responsible for positive modifications in individuals' emotional and cognitive states (Berto, 2014). According to Heerwagen and Iloftness (2012), these emotional changes are explained by the biophilia theory, which demonstrates that humans have a biological need to connect with nature at physical, mental, and social levels. Thus, environments that facilitate distancing from everyday life promote moments of reflection, relaxation, and well-being—features that were also observed in the positive emotions related to students' interactions with the university campus (Carrus et al., 2017).

Incorporated into the concept of restorative environments are the stress reduction theory (Ulrich et al., 1991; Ulrich, 1983) and attention restoration theory (Kaplan, 1995; Kaplan & Berman, 2010). The stress reduction theory observes that daily interaction with unpleasant situations and environments leads to negative emotional responses. However, when exposed to environments featuring natural elements in their design, such spaces can facilitate recovery from fatigue, reduce stress, and increase positive emotional states (Berto, 2014). The attention restoration theory aims to understand the capacity of the person-environment interaction to restore attention and mental fatigue, with natural elements having a greater potential to trigger such restoration (Berman, Jonides, & Kaplan, 2008). For restoration to occur, the environment must contain four elements: escape, extent, fascination, and compatibility (Scopelliti, Carrus, & Bonaiuto, 2019).

Therefore, it is possible to observe that some of the positive emotions elicited in students' relationships with perceived biophilic design attributes on campus—such as relaxation, satisfaction, and joy—align with Ulrich's Stress Reduction Theory (1983). Similarly, emotions such as enchantment correspond to the concept of fascination proposed by Kaplan (1995), an essential factor for restoring mental fatigue. These relationships were also observed concerning constructive elements. However, it is important to emphasize that the biophilic design attributes present at the institution were not objectively assessed but rather considered based on students' perceptions. Previous studies indicate that different environments—natural or built—can influence varying rates of stress recovery (Berto, 2014; Von Lindern, Lymeus, & Hartig, 2022), with physiological measures indicating more effective recovery in contexts featuring direct presence of nature. Thus, although the institution offers good environmental comfort conditions, the absence of prominent natural elements—such as lush vegetation, water features, or animal biodiversity—limits the characterization of the space as a fully biophilic environment.

Moreover, San Juan, Subiza-Pérez, and Vozmediano (2017) demonstrated that certain conditions must be met for natural environments to promote recovery, including the environment's restorative value and the

provision of positive emotions, alongside the presence of natural elements, spatial depth (open spaces), and absence of threats. Furthermore, it has been shown that such restoration caused by interaction with natural elements does not necessarily require direct contact, as simply viewing photos or images of natural scenes can evoke positive emotions in participants (van den Berg, Joye, & Koole, 2016). Barnes et al. (2018) concluded that any green space, whether small or large, can positively reflect on individuals' mental health.

Regarding the classroom structure, the lowest scores were observed when compared to other attributes analyzed across all participants, with Architecture and Urbanism students presenting statistically lower averages for feelings of joy, inspiration, and courage. This result can be understood considering that, unlike other spaces analyzed, the classroom design employs a conventional layout without the use of biophilic design attributes. Therefore, considering that classrooms are places where students tend to concentrate and absorb information—making them prone to mental fatigue—this physical environment could also serve as a supportive setting to enhance students' overall well-being (Castilla et al., 2017). Accordingly, Bogerd et al. (2020) argue that introducing biophilic design elements into classrooms represents a promising intervention, as students reported increased attention following a lecture held in a classroom containing natural elements such as plant pots and green walls.

Once the positive emotions elicited by contact with biophilic design environments and constructive elements were presented, the importance and relevance of each attribute to the students were explored. From a general perspective, the attributes that showed significant preference and relevance indices were natural lighting, views of landscapes, and outdoor spaces. Attributes with lower relevance included institutional landscaping and innovative constructive elements. Nevertheless, no significant difference was found between the mean relevance rankings when comparing Architecture and Urbanism students and those from other programs ($p > 0.05$). However, the most relevant items for Architecture and Urbanism students were views of landscapes and natural lighting, whereas for students from other programs, the most relevant topics were outdoor space and natural lighting (Table 3).

Based on this premise, the study sought to identify which biophilic design elements held greater importance and relevance in developing positive emotions among students. It was found that environmental characteristics responsible for these emotions prominently include natural lighting, views of landscapes, and outdoor spaces. Regarding the positive emotions triggered by natural lighting, there is no indication of studies conducted with university students; however, research with elderly participants identified that environmental lighting has a significant and positive effect on emotional well-being (Peralta, Fernández-Caballero, & Latorre, 2021). Concerning the attribute of views of landscapes, it was observed that viewing green roofs through windows was responsible for stimulating changes in brainwave patterns commonly associated with positive emotions, motivation, and attention mechanisms in residents (Olszewska-Guizzo et al., 2018).

Table 3: Distribution of the ranking of relevance of the surveyed items — overall and according to participants' courses

Ordem de relevância	Geral (n = 67)			Arquitetura Urbanismo (n = 28)			Outros cursos (n = 39)			p*
Iluminação natural	49,8	±	22,5	51,6	±	26,1	48,4	±	19,5	0,6002
Vistas para paisagens	49,1	±	23,6	53,2	±	25,3	45,8	±	22,0	0,2476
Espaços ao ar livre	48,0	±	26,8	45,2	±	28,6	50,3	±	25,5	0,4820
Estrutura da sala de aula	45,2	±	27,6	43,2	±	30,5	46,8	±	25,3	0,6339
Revestimentos e materiais naturais	44,8	±	25,0	48,4	±	24,9	41,9	±	25,1	0,3409
Diversidade de funções no campus	43,8	±	21,5	46,8	±	23,4	41,3	±	20,0	0,3459
Paisagismo na instituição	42,7	±	22,6	45,6	±	25,5	40,3	±	20,1	0,3900
Elementos construtores inovadores	41,3	±	24,9	43,6	±	28,7	39,4	±	21,7	0,5315

*Non-significant t-test considering a significance level of 5%. Source: The authors, 2024.

Finally, the attribute of outdoor spaces is also related to the development of positive emotions, especially when associated with university students in urban squares (San Juan; Subiza-Pérez; Vozmediano, 2017), botanical gardens (Carrus et al., 2017), forests (Pasanen et al., 2017), and outdoor spaces on university campuses (Malekinezhad et al., 2020). Thus, it can be concluded that the university environment, through the application of certain biophilic design attributes, is capable of inducing positive emotions in its students, such as relaxation, delight, satisfaction, and joy. Moreover, it was observed that spaces with natural and constructive elements are complementary, as both types of spaces were considered important and relevant for the development of positive emotions.

Based on the data provided and the analyses presented, some correlations and trends can be observed:

Importance of Natural Elements

- **Natural materials:** The predominant emotions associated with natural materials are tranquility, relaxation, and delight. This indicates that students perceive these elements as positive and contributing to an emotionally pleasant experience.
- **Outdoor spaces:** This attribute stands out in multiple positive emotions, such as satisfaction, stimulation, relaxation, inspiration, and joy. This wide range of emotional responses reinforces the importance of outdoor spaces in promoting well-being.

Emotions Related to Landscape and Landscaping

- **Landscape:** The emotions associated with landscape, such as relaxation, satisfaction, and delight, show a strong connection with visual perception and positive emotional experience.

- **Landscaping:** Joy and delight are predominant, indicating that the presence of landscaping elements also contributes to emotional well-being.

Differences Between Courses

- Although no significant difference was found between Architecture and Urbanism students and those from other courses regarding biophilic design variables, some interesting trends emerged. For example, Architecture and Urbanism students tend to attribute lower value to certain emotions such as joy, inspiration, and courage in classrooms. This may be related to higher expectations or a more critical standard concerning the design of the environment.

Classroom Structure

- Emotions such as joy, inspiration, and courage have lower scores among Architecture and Urbanism students compared to those from other courses. This may reflect dissatisfaction with the classroom design or a heightened critical awareness of the educational space.

Relevance of Biophilic Design Attributes

- **Natural lighting:** It stands out as an important and relevant attribute, associated with positive emotions in various contexts.

- **Views of landscapes:** The ability to see natural landscapes is valued for its capacity to stimulate positive emotions and promote a sense of well-being.

- **Outdoor spaces:** This attribute is also highly relevant to students, reflecting the importance of external environments in promoting well-being.

Integration of natural and built elements

- The analysis indicates that both natural and built elements are important for the development of positive emotions. The combination of these elements within the university environment can

be crucial to promoting an enriching and pleasant educational experience.

Thus, the following correlations are observed:

- **Natural attributes and positive emotions:** Natural materials, outdoor spaces, and landscapes show a strong correlation with positive emotions such as relaxation, satisfaction, and delight.

- **Course differences:** Although no significant differences were found, students of Architecture and Urbanism tend to have more critical perceptions, potentially reflecting a mismatch between their expectations and the actual environment.

- **Importance of attributes:** Natural lighting, views of landscapes, and outdoor spaces are identified as particularly important attributes for the emotional well-being of students.

These observations highlight the importance of biophilic design and how it can be integrated to optimize the educational and emotional experience of students. Considering the lack of significant differences between courses, it is evident that the characteristics of biophilic design have a generally positive impact regardless of the students' academic background.

Environmental perception of the university built environment

After identifying the main emotions evoked by the university environment with the application of some biophilic design attributes, the study also sought to examine students' perceptions of these spaces. Through analysis of their responses, the most frequently used words were identified — the more frequently a word appeared in the students' discourse, the larger and more central it is shown in the word cloud.

When asked which objects within the space evoked positive emotions, the most common words referred to natural environments such as: trees, gardens, plants, outdoor areas, vegetation, nature, and greenery. The students' narratives also highlighted specific university spaces where biophilic design is applied, for example: "Inspira Space," chapel, plazas, Knowledge Plaza, classrooms, and cafeterias (Figure 3).

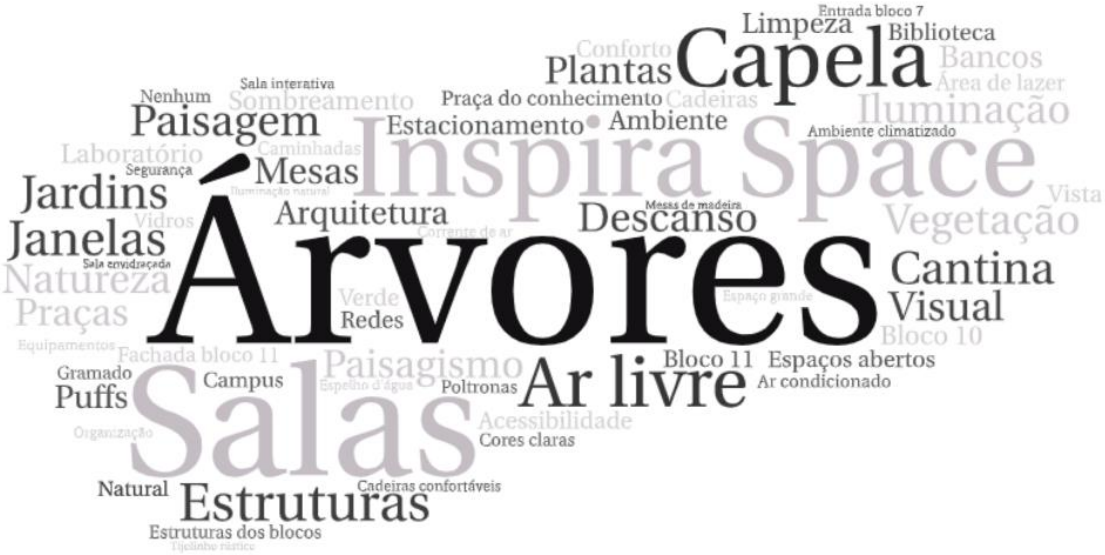

Figure 3: Word cloud based on the respondents' answers to the question: Which objects belonging to this space can evoke the mentioned emotions?
Source: The authors, 2024.

Natural environments, such as those mentioned by the students, are frequently associated with health-related factors as well as attributes that support environmental care, such as the reduction of noise, air pollution, and heat (Bowler et al., 2010; Hartig et al., 2014). This interrelation is important, as built and urbanized spaces can both enhance population quality of life and promote increased urban biodiversity, thereby minimizing environmental impacts (Stoltz and Schaffer, 2018).

Environmental perception can be considered one of the variables influencing individuals' pro-environmental behavior (Chierrito-Arruda et al., 2018). In this regard, the results of this study align with previously conducted research, as it is understood that a connection with nature can improve well-being and also foster sustainable behaviors. Although current studies do not explicitly correlate positive emotions with pro-environmental behaviors, it is suggested that emotions such as admiration, compassion, and gratitude are capable of promoting prosocial behaviors (Zelenski and Desrochers, 2021).

Furthermore, from the students' perspective, the study investigated which natural elements and materials on campus could contribute to sustainability. A specific set of words emerged that were linked to sustainable characteristics of the university environment, such as wind energy, recyclable materials, natural materials, and water reuse. A category of more generic words also appeared, including reduce, pollution, awareness, incentives, planning, and environment (Figure 4).

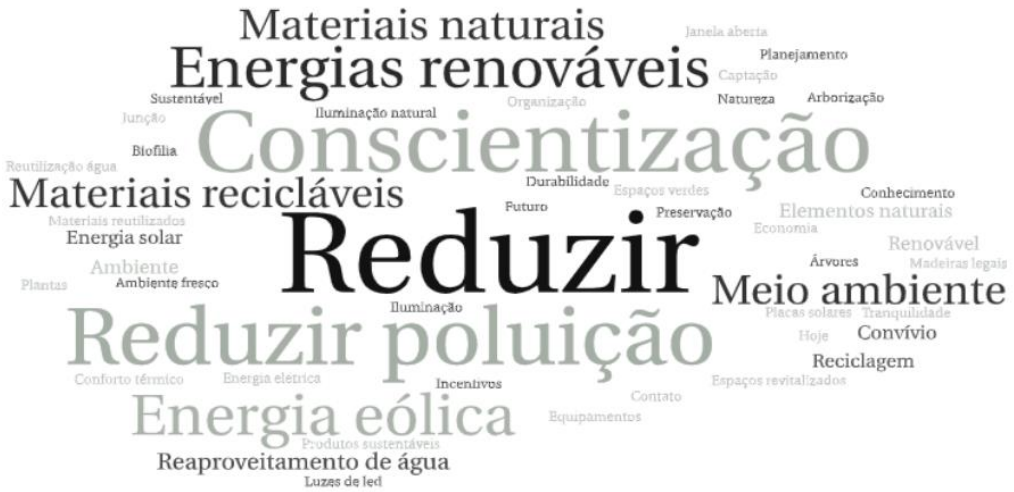

Figure 4: Word cloud based on respondents' answers to the question: "In your opinion, can the natural elements and materials at the university contribute to sustainability? Please justify." Source: The authors, 2024.

It is observed that emotions influence individual environmental protection behavior, as they can serve as a motivation for pro-environmental behavior (Lu et al., 2021). In this sense, it is hypothesized that the positive emotions elicited by interaction with university environments that incorporate some of the biophilic design attributes in this study may be capable of promoting pro-environmental behaviors and fostering innovation in higher education (Abdelaal, 2019). However, a Chinese study conducted with university students showed that students' environmental knowledge has a direct impact on their pro-environmental behavior, emphasizing that, in addition to the use of biophilic attributes, environmental education must also be prioritized in universities (Wang and Zhang, 2021).

Conclusion

This study aimed to analyze university students' perceptions of biophilic design attributes and sustainable techniques employed in the built environment of a private university in southern Brazil. The research was conducted in two main stages: characterization of the university environment based on biophilic principles and sustainable strategies, followed by the analysis of the emotions and perceptions elicited in students through their experience in this space.

It was found that interaction with spaces containing natural elements—such as landscapes, natural materials, wooded areas, and outdoor environments—generated higher scores for positive emotions. The most frequent emotions associated with these environments were relaxation, enchantment, satisfaction, and joy. In contrast, environments characterized predominantly by constructed elements—such as natural lighting, campus functional diversity, architectural innovation, and classroom structure—evoked emotions like stimulation, admiration, inspiration, and, in some cases, trust. These findings demonstrate that natural and built elements complement each other in promoting positive emotional experiences.

Positive emotions were strongly linked to environments with vegetation, trees, gardens, plants, and

direct contact with the outdoors. Students' narratives also highlighted specific campus spaces that incorporate biophilic attributes, such as the *Inspira Space*, chapel, social squares, knowledge square, classrooms, and cafeterias. From the students' perspective, sustainable features of the campus—such as the use of wind energy, recyclable and natural materials, renewable energy, and water reuse—also contribute to a positive perception of the university environment.

Although the study compared the responses of Architecture and Urbanism students with those from other disciplines, no statistically significant differences were found between the groups for most of the attributes evaluated. This suggests that the benefits of biophilic design are broadly shared among students, regardless of academic background, and that course segmentation may not be a determining factor in emotional perception of the environment.

One critical point identified was the low score of positive emotions associated with classrooms, indicating the need to rethink these spaces. The inclusion of natural elements, even indirectly (such as nature images, textures, and organic materials), can enhance emotional comfort, concentration, and student well-being during the learning process.

As a recommendation for future research, the use of more qualitative and sensitive tools, such as mental maps or in-depth interviews, is suggested to identify potential biases, better understand emotional bonds with space, and deepen the understanding of the emotions triggered by biophilic design and sustainable strategies in the university context.

Acknowledgments

This study was supported by the Research Productivity Programs of the Cesumar Institute of Science, Technology and Innovation (ICETI), the Araucária Foundation for the Support of Scientific and Technological Development of the State of Paraná (FA), and the National Council for Scientific and Technological Development (CNPq), under number 302078/2023-1.

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