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Purpose Adequacy as a Basis for Sustainable Building Design: A Post-Occupancy Evaluation of Higher Education Classrooms

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Abstract: Building design is one of the essential elements to consider for maximizing the sustainability of construction. Prior studies on energy and resource consumption and on indoor environmental quality indicators (IEQs) are increasingly frequent; however, attention has not been focused on design as supporting the function performed within architecture. Educational buildings have specific conditions related to teaching methodologies, including activating students and promoting participation and interaction in the classroom. This manuscript aims to explore whether the social dimension of physical space in educational settings can explain a student's academic outcome. For this, the Learning Environment and Social Interaction Scale was designed and validated and applied to 796 undergraduate students at the University of Coruña, and multiple linear regression analysis was applied to the academic results. The results display a structure comprising five factors; these include novelties such as the division of conventional IEQs into two groups: the workspace and the classroom environment. In addition, place attachment, the design of the classroom as a facilitator of social interaction, the learning value of social interaction, and the satisfaction of the IEQ demonstrated their influence on the academic result.

Keywords: architecture; building evaluation; functional adequacy; human-centered; IEQ; learning space; place attachment; social interaction; social participation; sustainable building

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1. Introduction

Indoor environment quality indicators have been recognized as main features of sustainable design. Therefore, research on their influence is increasingly abundant [1–3]. However, an evident sustainability factor—the suitability or usefulness of the environment for the use of the building—has not received the same attention. It seems logical that if the relationship between built space and its function is consistent, the energy and resources required will be more efficient.

Previous studies have focused on the technical measurement of learning spaces through indoor environment quality indicators, which include lighting, ventilation, thermal levels, connection with nature, acoustics, etc. [4–9]. The validity of this approach is proven and of great relevance to understand to what extent and how the indoor environment can influence the users of the space. The IEQ has become a key factor in the design and construction of buildings, since internal conditions can significantly influence the well-being, productivity, health and safety of people [10]. Therefore, in recent decades, different certifications have been designed, such as LEED (Leadership in Energy and Environment Design), the WELL Building Standard and Fitwel, for different types of buildings. However, these focus on low energy consumption or technical aspects of the building or on the health and comfort of the users. However, both the socio-psychological factors and those related to intended activities are significant in this field.

Since 1960, attempts have been made to study social interactions and the user's perception of the environment, an issue that emerged in the field of environmental psychology through post-occupancy evaluation (POE) studies [11]. Sustainable design is not only about reducing emissions and saving energy but also about providing the necessary comfort in the environment for the development of human activities [12,13]. For this reason, in POE studies, it is usual to include user characteristics, work processes, user satisfaction regarding the possibilities of interaction with their colleagues, and privacy and comfort [14].

Current studies have explored the effects of poor environments on cognitive functions, including social cognition [15]. Advances in this field confirm that subjective issues play an important role in user behavior, such as attitude, social customs, or perceived behavioral control, as well as intentionality [16]. Social values, cultural differences, and personality traits have also become factors to be valued among the scientific community [17–19]. However, there is still some uncertainty about the selection and use of appropriate contextual, social and personal variables; this could be addressed through the implementation of interdisciplinary frameworks [20]. In addition, recent studies have emphasized the need to consider the relationships and interactions between physical or technical variables and personal and social factors [9,21].

This manuscript deals with the learning space typology that considers social interactions as a means of learning. Regarding educational buildings, the literature has already identified that elements such as satisfaction or comfort, functionality, the possibilities of social interaction and place attachment are key for the development of learning [22]; this will be considered in this research as part of the social dimension of space.

1.1. Peer Effect and Active Methodologies in Higher Education

In recent decades, peer effect studies have provided contradictory results, including positive and negative influences [23,24] as well as large or small effects in similar contexts. Some investigations have focused on the characteristics of classmates. Booij, Leuven, and Oosterbeek [25] found that low-ability students perform better when in groups with peers of a similar skill level. Others have focused on group size, such as Brady, Insler, and Rahman [26], who identified different social influences depending on group size, showing negative effects at a broader company level and positive effects at a narrower company level.

The influences of social interactions and the peer effect have been analyzed in recent studies on educational buildings that include disruptive and attractive methodologies such as gamification [27,28]. In addition, classroom design can foster interaction and collaboration among peers, affecting teaching methodology and improving learning [29]. Specifically, flexible spaces are more appropriate for adapting to different teaching methodologies, including a better flow of interactions between users [30].

There is general agreement on the benefits of social relationships among classmates [31,32], since they provide companionship, affection, intimacy, assistance, improvement of self-esteem and emotional support, as a basis for the development of identity [33]. The results show that those students who participate in positive social interactions with other classmates are associated with greater academic motivation as well as a higher academic result [34,35].

1.2. Satisfaction and IEQ Perception

Comfort and satisfaction are social constructions that can influence the value of the indoor environment, not only over time, but also from one culture to another [36]. However, this satisfaction covers environmental aspects and social characteristics that can contribute to the mental harmony or instability of the users [37]. This indicator has been correlated with building characteristics, personal characteristics and variables related to the purpose of the space [38]. Under these premises, studies were carried out regarding buildings classified as "green", showing that the interior environments led to a positive perception that affected productivity [39,40]. In addition, some research has focused on how the social influence of friends and family affects the opinion and satisfaction of sustainable elements [41]. Non-physical and subjective aspects influence the way occupants perceive environmental comfort; therefore, psychological and social factors can positively affect users' perception of comfort [42]. For this reason, satisfaction as a variable that favors social relations is part of Kopec's theory of integration [43] on the relationship between human beings and space. The literature on buildings destined for education reiterates that the satisfaction of students with their environment is related to their academic results [44,45].

Studies on the comfort and satisfaction in school buildings have identified that a good quality environment positively affects the well-being, learning capacity and comfort of students [46]. It has been suggested that a better understanding of students' perceptions is necessary to understand their comfort level with the different variables of building design, such as temperature or lighting [47]. The effects of artificial light on the emotional state of adolescent students have also been explored, since inadequate lighting can be very harmful to the psyche of young people. Thus, ethical and healthy regulations regarding the optimization of lighting have been put forward [48]. Satisfaction regarding the indoor environment of schools, according to thermal comfort, air quality, and visual and acoustic comfort, has been addressed in recent studies, verifying that the discomfort of a specific element does not result in general discomfort; thus, individualized treatment of IEQs is necessary [49]. The literature has brought to light visual or aesthetic satisfaction, beyond the color of the classroom, as being influenced by images in primary education settings [50]. This is an unusual practice in university classrooms, but it is important to keep in mind the possible relationship with the place attachment. Other studies have shown that the level of satisfaction decreased when there were many people in the same room, which can be attributed to a lower degree of perceived control and greater necessary social interactions [51].

However, perceptions of comfort and satisfaction are usually incomplete or biased, which leads to failure when performing any type of intervention. Specifically, in educational buildings, the approach that involves students in POE provides researchers with contextualized information on which elements are most influential in overall comfort. This helps analyses to be carried out with greater precision, taking into account the factors that maximize solutions [13,52].

1.3. Place Attachment

In recent years, researchers have become more interested in the human dimension of sustainable design as it relates to health and well-being [53]. POE studies identified a series of outcomes related to the well-being of users, such as reduced absenteeism and stress, greater comfort and learning outcomes, and more positive attitudes [54,55]. However, among these human factors, place attachment and the relationships between people and their places have received little attention in the literature [56]. This fact is reflected in the multiple definitions of this construct in the literature before Scannell and Gifford [57] synthesized them and created an organizational framework with three main dimensions.

The first focuses on a personal and cultural dimension and is centered on who is becoming attached and how places are meaningful, both in individual and collective experience. The second brings a dimension that focuses on what a person is attached to, including physical and social characteristics, such as the natural environment that surrounds him or her or the opportunities for interaction with the rest of the users. The third, a psychological process dimension that focuses on how attachment includes certain behaviors, affective bonds and cognition, such as memories. Thus, in the case of students, their need to define their territory and their sense of belonging to it can be seen, for example, in the choice of seating area [58]. Affection is a key element in the process of creating a bond between the person and the place. Therefore, place attachment is more likely to occur in spaces with physical characteristics that support stress reduction, that evoke memories of people, and that facilitate the inclusion and interaction of other people [59,60]. It is also related to the personal or cultural circumstances of the users, which can lead to variations in the affective bonds with the different architectural contexts and even with the other users of the space [61].

Several studies have highlighted the value of place attachment concerning green or sustainable buildings and have tried to determine a connection between these feelings and pro-environmental behavior [62]. Thus, its consideration in educational buildings has the potential to support sustainable behavior, providing an incentive for green building practices [63]. Building design strategies focused on human attachment have also been found to improve community well-being, quality of life, and resilience [64]. They can also increase the amount of time spent in the building and the kinds of activity engaged in [65]. In this sense, Heerwagen and Zagreus [66] found an association between the feeling of place attachment and pride in the adoption of actions focused on sustainability. The results provided information on a series of psychosocial benefits, such as a more positive work experience, better communication between colleagues, and a strong connection with the environment and the company.

Regarding learning spaces, holistic studies on place attachment have shown that it has a greater value than other common IEQs, such as light, in the development of educational activities [67].

1.4. Objective

The objective of this research is to explore whether the social dimension of physical space in educational settings explains a student's academic results through a post-occupancy evaluation design.

2. Materials and Methods

The research was conducted using a quantitative approach that sought to understand the perception of students regarding their satisfaction with their indoor environment and its ability to foster learning interactions.

First, appointments were arranged with each dean or person in charge of infrastructure to visit centers to identify the learning space designs. Figure 1 shows selected classrooms and their diversity in layout design, lighting typology, furniture, information technology support, etc. Then, the professors who teach in these classrooms were identified, and they were contacted to determine their availability for applying the data collection instrument to their students. The purpose of the study and the average time of responding to the questionnaire were indicated. Consequently 21 of the 30 groups were able to establish a date to conduct the test.

The Learning Environment and Social Interaction scale (LESI) was provided in hard copy, and the students' answers were entered into a digital spreadsheet (educational Microsoft Excel 365).

The analysis of data consisted of a description of the sample, the reliability and validity, and prediction of the Grade Point Average (GPA) from IEQ satisfaction and learning interaction. First, the mean value and the standard deviation were defined to determine the empirical framework. Then, Cronbach's Alpha and Exploratory Factor Analysis were conducted to evidence the reliability and the construct validity of the data collection instrument. Finally, multiple linear regression was calculated to identify which items of the scale could predict academic performance and to what extent. The linear independence of predictor variables and the homoscedasticity of residuals were checked.

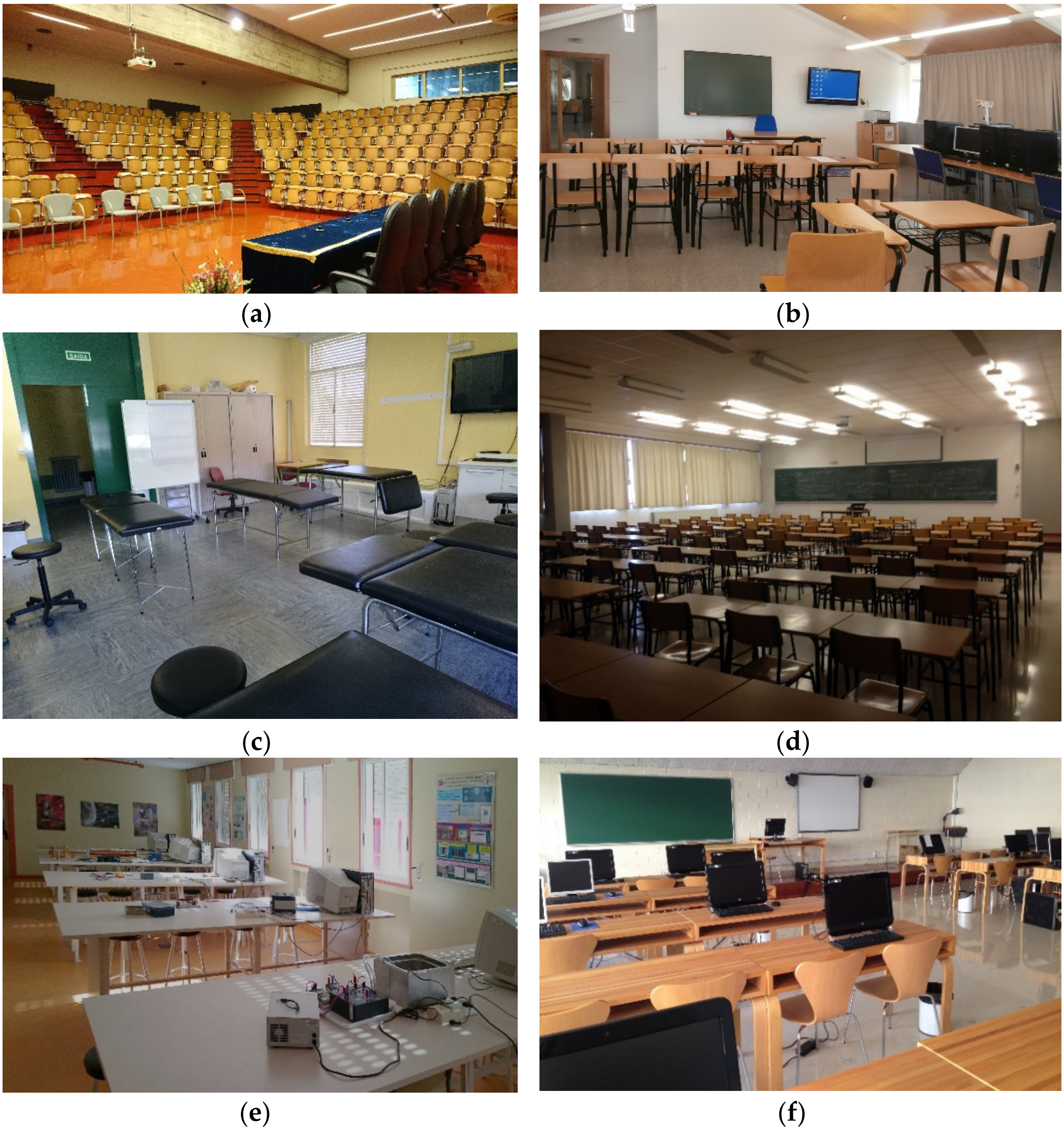

Figure 1. Pictures of some classrooms in the sample: (**a**) lecture hall; (**b**) practice room; (**c**) health practice room; (**d**) lecture room; (**e**) engineering practice room; (**f**) computer lab.

2.1. Sample

The sampling model is non-probabilistic by convenience and intentional, based on the representativeness of the areas of knowledge and the diversity of the space design. In other words, more and less illuminated rooms, more and less ventilated rooms, etc., were searched to obtain a sample with a wide range of possibilities in order to be able to relate the different levels of the predictor variables. The LESI scale was completed by 796 undergraduate students from 18 bachelor degree programs at Universidade da Coruña, who were reasonably balanced among arts and humanities, engineering and architecture, health science, science, and social and legal sciences. Table 1 shows the distribution of participants by bachelor degree program. The number of students in each degree program is proportional to participants in the study.

Table 1. Sample distribution by bachelor degree program.

Bachelor Degree	n	n (%)
Architecture	35	4.40
Biology	26	3.30
Chemistry	35	4.40
Civil engineering	61	7.70
Computer science	30	3.80
Early childhood education	80	10.10
Economics	62	7.80
Economy	16	2.00
Humanities	29	3.60
Industrial design and product development	8	1.00
Law	117	14.70
Mechanical engineering	12	1.50
Nursing	28	3.50
Occupational therapy	34	4.30
Podiatry	15	1.90
Primary education	81	10.20
Public works engineering	11	1.40
Social education	9	1.10
Sociology	22	2.80
Speech therapy	71	8.90
Technical architecture	14	1.80
Total	796	100.00

2.2. Data Collection Instrument

Learning Environment and Social Interaction (LESI) is a 1–7 Likert scale that is part of the Student Perception Questionnaire of Learning Space [68]. The instrument seeks to measure the collective perception of the environment by users regarding its power to favor learning interactions, the indoor environment quality satisfaction, and the importance of learning interaction in education. Students rated 18 independent variables from 1 (completely disagree) to 7 (completely agree). In addition, grade point average was requested at the beginning of the test template (Table 2).

Table 2. LESI scale items.

Item	Variable
The lecture classroom favors teacher–student interactions	V1
The lecture classroom favors interactions between students	V2
The practice classroom favors teacher–student interactions	V3
The practice classroom favors interactions between students	V4
Classroom design encourages participation	V5
Learning space attachment	V6
Lighting satisfaction degree	V7
Ventilation satisfaction degree	V8
Thermal level satisfaction degree	V9
Wall color satisfaction degree	V10
Acoustics satisfaction level	V11
Room layout satisfaction	V12
Furniture comfort satisfaction	V13
Connection with nature satisfaction	V14
Importance of professor–student interactions	V15
Importance of interactions with professors from other courses	V16
Importance of interactions between students	V17
Importance of interactions with students from other courses	V18

3. Results

3.1. Descriptive Analysis

Regarding the descriptive analyses (see Table 3), the LESI items could be grouped around four values:

- A value close to 3.40 was determined for the ventilation satisfaction degree (m = 3.32), the importance of interactions with professors from other courses (m = 3.43), the thermal level satisfaction (m = 3.45) and the furniture comfort satisfaction (m = 3.52).
- Values close to 4 represent the learning space attachment (m = 3.80), the connection with nature satisfaction (m = 3.84), the room layout satisfaction (m = 4.04), the acoustic satisfaction degree (m = 4.08), the importance of interactions with students from other courses (m = 4.14), the lecture classroom favors teacher–student interactions (m = 4.30) and the practice classroom favors teacher–student interactions (m = 4.31).
- A score of over 4.70 was determined for the wall color satisfaction (m = 4.62), the lighting satisfaction (m = 4.69), the lecture classroom favors interactions between students (m = 4.76), the practice classroom favors interactions between students (m = 4.82) and the classroom design encourages participation (m = 4.82).
- The best scored items received values close to 5.50, including the importance of interactions between students (m = 5.48) and the importance of professor–student interactions (m = 5.51).

Table 3. Descriptive results of LELI scale.

Variable	Min.	Max.	Mean	Std. Dev.
V1	1	7	4.30	1.716
V2	1	7	4.76	1.721
V3	1	7	4.31	1.793
V4	1	7	4.82	1.762
V5	1	7	4.82	1.844
V6	1	7	3.80	1.737
V7	1	7	4.69	2.576
V8	1	7	3.32	1.626
V9	1	7	3.45	1.713
V10	1	7	4.62	1.823
V11	1	7	4.08	1.665
V12	1	7	4.04	1.696
V13	1	7	3.52	1.715
V14	1	7	3.84	1.677
V15	1	7	5.51	1.488
V16	1	7	5.48	1.496
V17	1	7	4.14	1.790
V18	1	7	3.43	1.786

3.2. Reliability and Sample Adequacy

The sample for internal consistency analysis was 796. The Cronbach's Alpha index was used to check the level of reliability. Table 4 shows the results of Cronbach's α for the LESI scale, obtaining appropriate results (0.809).

Table 4. LESI internal consistency.

Cronbach's Alpha	Number of Items
0.809	18

3.3. Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was applied using the Principal Components method and Varimax rotation for the LESI scale. Previously, the Kaiser–Meyer–Olkin Sample Adequacy Measure (KMO = 0.767) was performed (see Table 5), which showed a high partial correlation coefficient. This result evidenced that the variance was not caused by underlying factors. Subsequently, the Bartlett's test of Sphericity was 4416.101 ($p_{153} < 0.001$), which demonstrated that there is no relationship between the test items.

Table 5. Kaiser–Meyer–Olkin (KMO) and Bartlett's test.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
	Approx. Chi-Square	df	Sig.
0.767	4416.101	153	<0.001

The analysis provides a structure of five factors that explain 60.158% of the total variance. During the process, coefficients lower than 0.3 were suppressed. Figure 2 shows a sedimentation graph of the factorial structure of five factors on the abscissa axis and the eigenvalues on the ordinate. The factors with high variances are located in the first five components, evidenced by a steep slope. After the fifth component, there is an evident change in slope, correlating with a weaker interpretation of the construct.

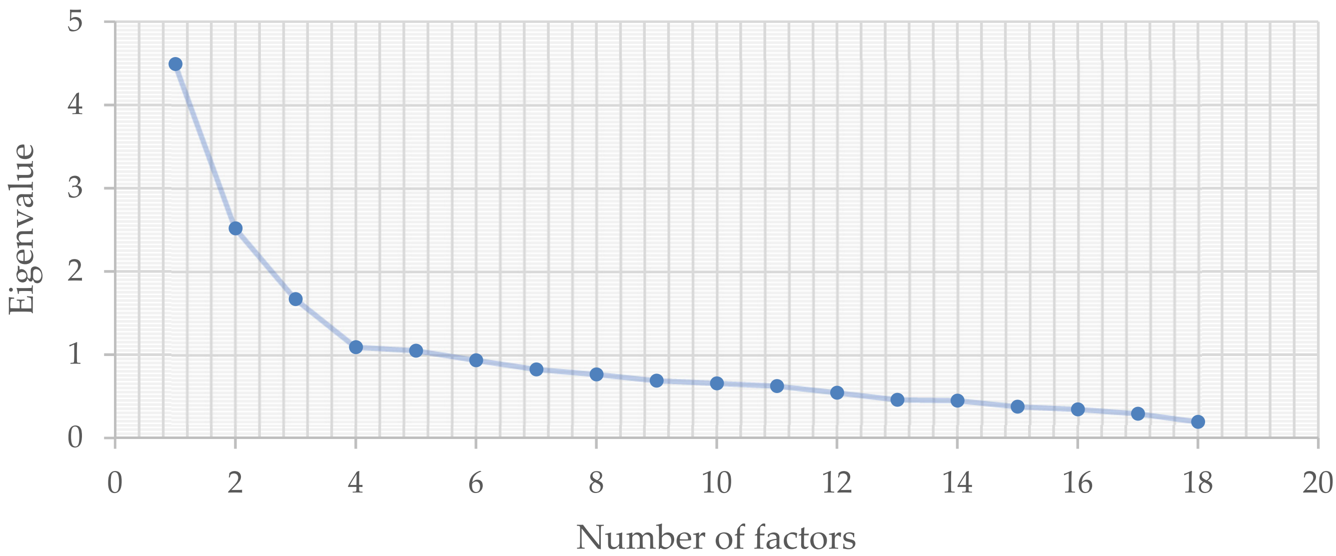

Figure 2. Sedimentation graph of the factor components.

The variables were grouped as follows (see Table 6):

- *Classroom design as a facilitator of social interactions*: This factor describes the extent to which the classroom design supports social interaction between students, both among those in the same classroom and different classrooms, as well as between students and professors in the same classroom and different classrooms.
- *Workspace design satisfaction*: This factor describes satisfaction in terms of organization, comfort of furniture, acoustic conditions, connection to the outside, and color of the classroom walls.
- *Learning value of social interaction*: This factor describes the extent to which students believe that social relationships with professors in other classrooms or between students in the same classroom and in different classrooms influence learning.
- *Classroom environmental satisfaction*: This factor is interpreted as satisfaction with regard to air renewal and thermal and light conditions.
- *Place attachment*: This factor describes the perception regarding the feeling of belonging to one's own space or a certain privacy within a broader social space, as well as the extent to which the relationship with the classroom professor influences learning.

Table 6. Exploratory Factor Analysis results.

Factor	Item	Communalities
1	The practice classroom favors interactions between students	0.818
	The practice classroom favors teacher–student interactions	0.808
	The lecture classroom favors interactions between students	0.799
	The lecture classroom favors teacher–student interactions	0.794
	Classroom design encourages participation	0.466
2	Room layout satisfaction	0.810
	Furniture comfort satisfaction	0.749
	Acoustics satisfaction level	0.636
	Connection with nature satisfaction	0.545
	Wall color satisfaction degree	0.435
3	Importance of interactions with students from other courses	0.841
	Importance of interactions with professors from other courses	0.828
	Importance of interactions between students	0.587
4	Lighting satisfaction degree	0.714
	Ventilation satisfaction degree	0.710
	Thermal level satisfaction degree	0.601
5	Learning space attachment	0.714
	Importance of professor–student interactions	0.553

3.4. Multiple Linear Regression Analysis

In order to verify the prediction assumption, a multiple linear regression analysis of the sample was applied using the Stepwise method. For this, the 18 LESI variables were included. As a result, a general model of seven variables was established (see Table 7): Learning space attachment (v5), Wall color satisfaction degree (v10), Importance of interactions with students from other courses (v18), Acoustics satisfaction level (v11), Ventilation satisfaction degree (v8), Importance of professor–student interactions (v15) and Practice classroom favors teacher–student interactions (v3). The model explains 7.6% of the academic outcome (GPA), establishing direct and inverse relationships. In addition, the Durbin-Watson statistic is 1.519, which fulfills the assumption of residual independence (Table 7).

Table 7. Multiple linear regression results: LESI variables on GPA.

Variables	Adjusted R^2	Std. Error	F	df1	df2	Sig.	Durbin-Watson
V5; V10; V18; V11; V8; V15; V3	0.076	0.97926	3.944	1	761	0.047	1.519

The Pearson correlations of the seven-variable model are provided in Table 7. Positive Beta values, indicating a direct relationship with the academic outcome variable, are associated with five variables: Learning space attachment (v5), Wall color satisfaction degree (v10), Acoustics satisfaction level (v11), Ventilation satisfaction degree (v8), Importance of professor–student interactions (v15). Negative Beta values, indicating an inverse relationship with the academic outcome, as provided by the remaining variables: Importance of interactions with students from other courses (v18) and Practice classroom favors teacher–student interactions (v3).

In addition, it must be verified that perfect multicollinearity does not exist, to validate the model; for this, the variance inflation test was applied. Table 8 provides the VIF values that are close to one, indicating no collinearity problems or correlation between the input variables. Furthermore, the tolerance values are also close to one, so the other independent variables do not explain any of them in particular.

Table 8. Standardized coefficients and collinearity statistics: LESI variables on GPA.

Variable	Beta	t	Sig.	Tolerance	VIF
(Constant)		23.356	<0.001		
V5	0.137	3.816	<0.001	0.931	1.075
V10	0.134	3.632	<0.001	0.880	1.137
V18	–0.118	–3.234	0.001	0.902	1.109
V11	0.134	3.512	<0.001	0.828	1.208
V8	0.131	3.566	<0.001	0.886	1.129
V15	0.107	2.843	0.005	0.855	1.169
V3	–0.072	–1.986	0.047	0.919	1.088

Another of the assumptions to be checked is linearity; Figure 3 displays the values that predict our estimation with respect to the values of the regression residuals. The result confirms the assumption of homoscedasticity, since the variance is practically homogeneous for the entire range of values. This figure also demonstrates compliance with the principle of linearity, since there is no non-linear pattern in the data cloud.

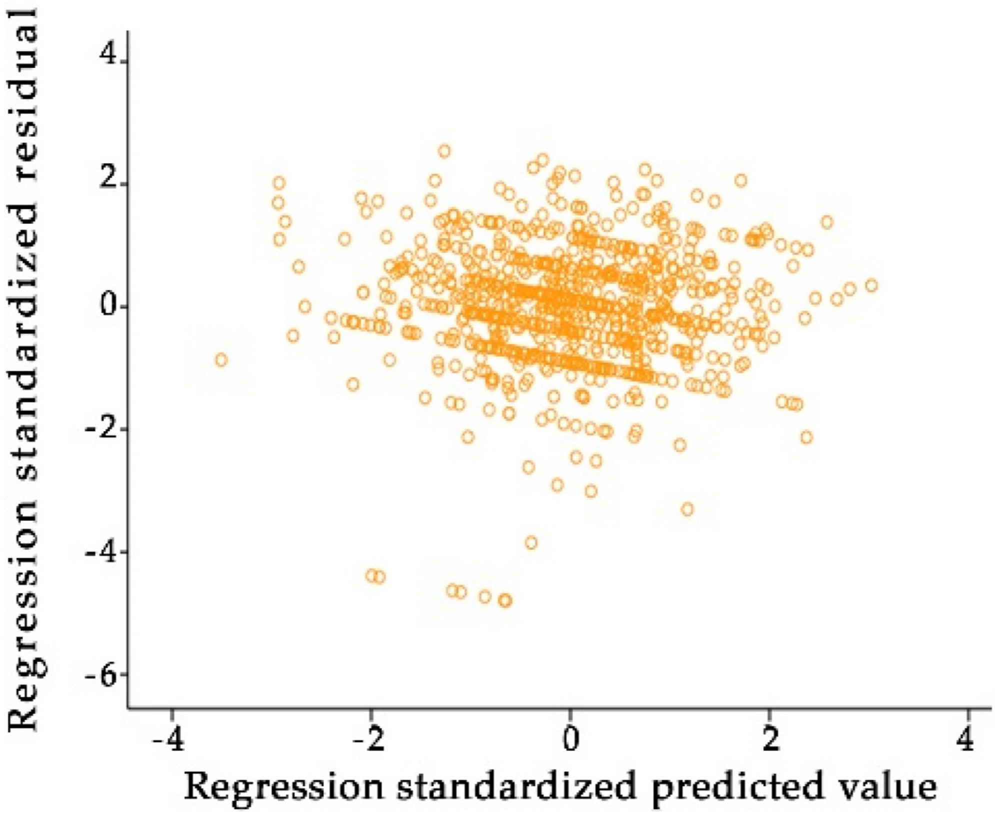

Figure 3. Cloud points of standardized predicted values vs. standardized residuals.

The last check requires that the distribution of the residuals follow a pattern close to normality. The P-P plot verifies compliance since, in general, the factors are close to or above the line (see Figure 4).

Once the validity of the model is verified, it is necessary to analyze the ANOVA results (see Table 9). This provides an F statistic value and an associated probability value, as well as sums of squares, degrees of freedom, and mean squares. A probability value less than 0.05 indicates that the model is consistent, thus allowing us to explain the relationship between the input and output variables.

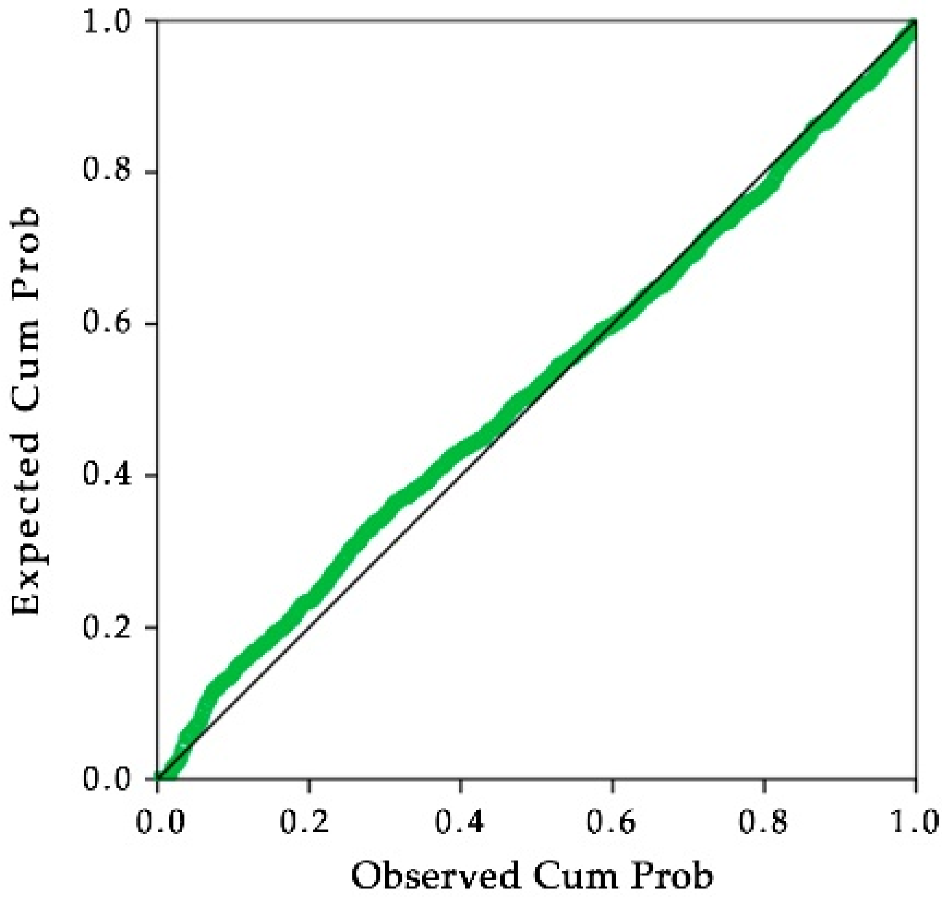

Figure 4. Normal P-P plot of Regression Standardized Residual. Dependent variable: GPA.

Table 9. ANOVA results.

Model	Sum of Squares	Difference	Mean Square	F	Sig.
Regression	67.056	7	9.579	9.990	<0.001
Residual	729.759	761	0.959		
Total	796.815	768			

Finally, Figure 5 shows the partial regression graphs of each variable in the model, where the line is the equation obtained from the linear regression analysis.

The multiple linear regression analysis performed on LESI demonstrated the existence of a relationship with academic outcome. The coefficient of determination was 0.076, while the mean square error was 0.9540.

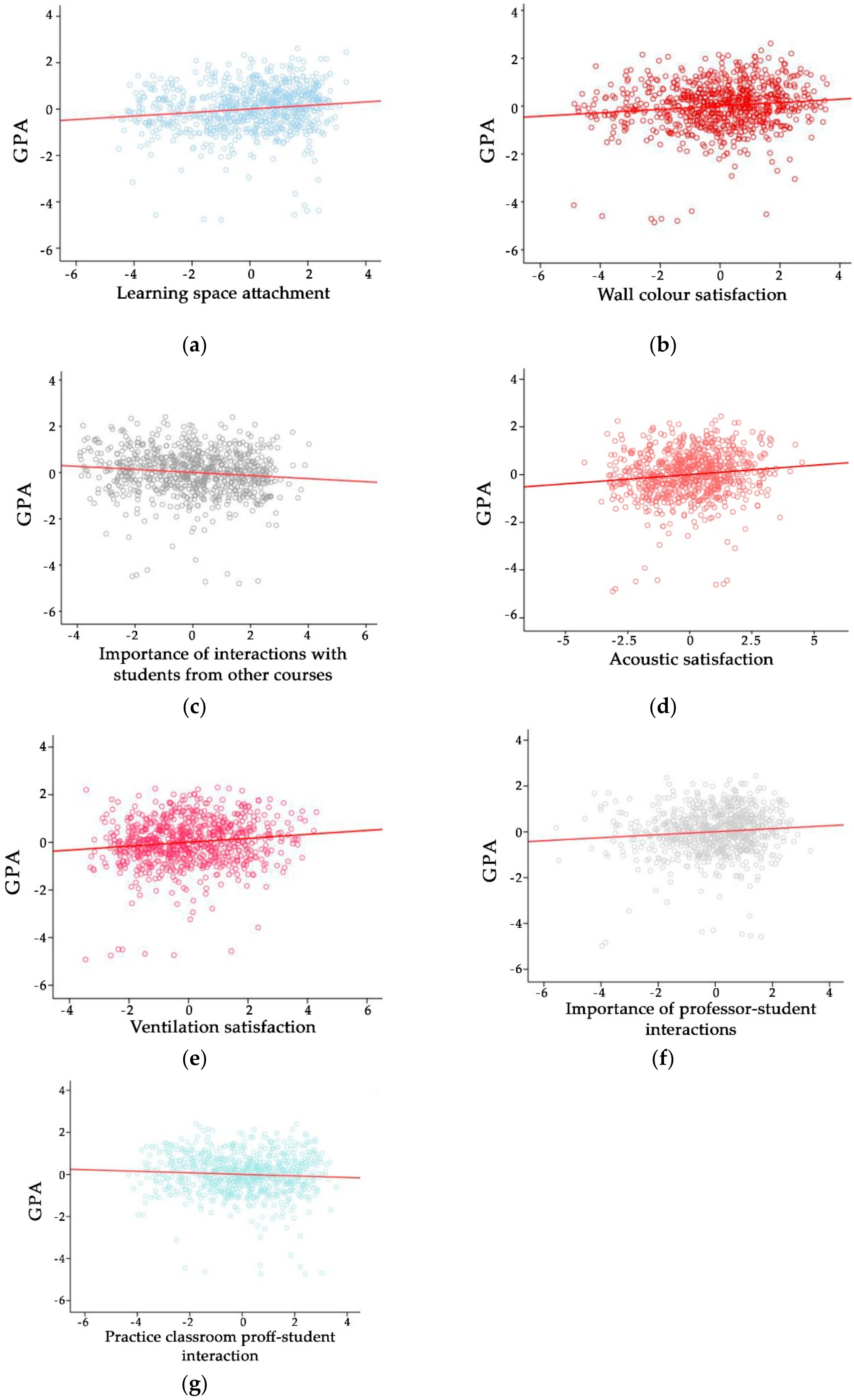

Figure 5. Partial regression graphs: LESI variables on GPA. (**a**) Learning space attachment; (**b**) Wall color satisfaction degree; (**c**) Importance of interactions with students from other courses; (**d**) Acoustics satisfaction level; (**e**) Ventilation satisfaction degree; (**f**) Importance of professor–student interactions; (**g**) Practice classroom favors teacher–student interactions.

4. Discussion and Conclusions

Sustainable building design is one of the priorities for the preservation of resources and energy. In recent decades, research based on post-occupation evaluation studies of indoor environment quality indicators have become more and more common. Factors such as geographic, cultural and climatological diversity have confirmed that it is not possible to develop a single model, but rather it is essential to disseminate research to diagnose reality. In addition, it is important to consider the functions, uses and habits in order to determine a sustainable design. In the case of educational buildings, in addition to IEQs, teaching methods should be taken into consideration. At present, several university models involve active teaching, which promotes the participation and interaction of students as a basis for learning. This research aimed to delve into three constructs—the peer effect, place attachment and IEQ satisfaction—and their relationship with academic outcomes.

For this, the Learning Environment and Social Interaction scale was designed and validated, which evidenced a structure of five factors: classroom design as a facilitator of social interactions, working design satisfaction, the learning value of social interaction, classroom environmental satisfaction and place attachment. Regarding the first factor, the literature shows that flexible designs allow teachers to promote greater learning and better adaptability to active methodologies, which also allows an improvement in the flow of social interactions between students [29,30]. The IEQ satisfaction has was divided into two factors: workspace design and classroom environmental satisfaction. The literature does not really show this separation, but there is agreement on the variables related to the activity performed in the space and those related to the environment [38,69]. Regarding the learning value of social interaction, positive relationships between classmates have shown benefits for academic performance and motivation [34,35]. Finally, place attachment has been confirmed as a factor in itself; as the basis of the link between the person and the place [60], it not only improves the well-being of the users of the building but also favors inclusion and interaction between people [57].

The regression results indicate that place attachment is the LESI variable that explains academic performance in the sample to the greatest extent. This contribution supports previous studies that demonstrated that place attachment had a higher value than other common IEQs, such as lighting, regarding the development of academic performance [67]. Regarding IEQ satisfaction, wall color, acoustics and ventilation also evidenced a direct relationship with the academic outcome, in line with evidence on satisfaction with the learning environment [44,45] and quality of environment [46].

Two variables of the learning value of social interaction showed an inverse and a direct relationship with the learning outcome: the importance of interactions with students from other courses and the importance of professor–student interactions. These findings indicate that greater interaction with the teacher may be related to a better understanding of the objectives or content of the subject and consequently of the academic outcome, while greater interaction with students from other courses leads to lower solvency of the course. Although it seems a consistent result, it is common for students to lean on peers from other courses, as they create bonds of friendship beyond academic assignments. However, this scenario would require a larger study to determine whether the support of outsiders is correlated with fewer interactions in the classroom itself. Previous research has verified the negative effects of a greater number of classmates and interactions and the positive effects of interactions in a smaller group [26], which could identified as the academic group within the classroom.

Finally, only one of the variables of classroom design as a facilitator of social interaction showed an inverse relationship with the academic outcome: the practice classroom favors teacher–student interactions. This result shows an apparent contradiction, in line with the literature [23,24]. Previously, it came to light that those students who assign higher value to teacher–student interactions obtain better GPAs, and those users who perceive that the classroom favors these interactions obtain worse results. The research does not allow for determination of the reason for this difference, but it seems logical that those who value interaction for their learning use it for academic purposes, also known as "learning interaction". Meanwhile, those who indicate that the design favors interaction would use it for social purposes.

This leads to the conclusion that the social dimension of the physical space contributes to the explanation of a student's academic result. In addition, the research contributes to the design and validation of LESI, the scale that those responsible for higher education centers can apply to diagnose their particular scenario and consequently manage the pertinent modifications.

This research focused on quantitative methods, due to its exploratory nature. A multi-method approach would be beneficial to complement the theory on learning space satisfaction and social interaction in higher education. Furthermore, more research is necessary both in higher education and at other educational levels, so that the high costs of building can be justified by substantial data on sustainable architecture in terms of purpose adequacy. Likewise, research on each factor, allowing an in-depth understanding of the particular complexity of each variable, is required.

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