sustainability

MDPI

Article

Classroom Indoor Environment Assessment through Architectural Analysis for the Design of Efficient Schools

Vicente López-Chao [1,*], Antonio Amado Lorenzo [1], Jose Luis Saorín [2], Jorge De La Torre-Cantero [2] and Dámari Melián-Díaz [2]

[1] Department of Architectural Graphics, Universidad de A Coruña, A Coruña 15008, Spain; antonio.amado@udc.es

[2] Department of Techniques and Projects in Engineering and Architecture, Universidad de La Laguna, San Cristóbal de La Laguna 38204, Spain; jlsaorin@ull.edu.es (J.L.S.); jcantero@ull.edu.es (J.D.L.T.-C.); dmeliand@ull.edu.es (D.M.-D.)

* Correspondence: v.lchao@udc.es

Received: 19 February 2020; Accepted: 3 March 2020; Published: 6 March 2020

check for updates

Abstract: Optimization of environmental performance is one of the standards to be achieved towards designing sustainable buildings. Many researchers are focusing on zero emission building; however, it is essential that the indoor environment favors the performance of the building purpose. Empirical research has demonstrated the influence of architectural space variables on student performance, but they have not focused on holistic studies that compare how space influences different academic performance, such as Mathematics and Arts. This manuscript explores, under self-reported data, the relationship between learning space and the mathematics and art performance in 583 primary school students in Galicia (Spain). For this, the Indoor Physical Environment Perception scale has been adapted and validated and conducted in 27 classrooms. The results of the Exploratory Factor Analysis have evidenced that the learning space is structured in three categories: Workspace comfort, natural environment and building comfort. Multiple linear regression analyses have supported previous research and bring new findings concerning that the indoor environment variables do not influence in the same way different activities of school architecture.

Keywords: acoustics; environmental quality; learning space; occupant comfort; sustainable architecture; sustainable building; visual comfort; thermal comfort; ventilation comfort

1. Introduction

The term sustainable building has generally been attributed to low levels of energy consumption. However, providing quality interior environments is another goal of the so-called green buildings. On the one hand, this fact is related to the Sick Building Syndrome (SBS) that has evidenced that poor quality environments harm the health of users. On the other hand, the design of buildings must guarantee the purpose for which they were built and for which that energy cost was assumed. This effect could be measured through user performance.

Regarding education, school architecture must ensure that students learn concepts and knowledge from different disciplines. Previous literature focus on the influence of learning physical environment factors in academic outcomes. Furthermore, educational buildings are designed to last for several years, and their state remains constant for a long time without rehabilitation or diagnosis of their influence on users. It implies that some facilities do not meet the minimum quality standards that are a requirement for the new constructions, such as the case of lighting. Also, ICT (Information a Communication

Technologies) implementation has promoted the use of blinds to improve the visibility of the laser projectors in classrooms.

This situation causes bad lighting conditions that can lead to poor school performance. Specifically, math performance is higher in students in classrooms with greater illumination [1]. Likewise, young children can differentiate lighting needs according to the activity performed [2], while visual comfort is a key element for arts activities, especially on drawing [3].

Schools are closed spaces that human beings occupy and in which they breathe for hours every day. Normally they do not have constant and automatic ventilation, which generates a lack of oxygen in the environment, and only schools with a mechanical supply and exhaust type of ventilation meet the recommended ventilation rate per student [4]. As well, low ventilation rates are associated with poor mathematics results [5,6], besides causing attention and concentration problems. These effects have shown to be more negative in tasks that require the use of spatial skills [7].

The thermal factor has also been correlated with academic performance, since thermal discomfort may lead to stress behaviors that influence learning [8]. Thermal alterations affect the problem-solving capacity and attention of students, which play a key role in mathematical skills competencies [9,10].

The acoustic environment correlates with attention levels in a classroom. Noise is an important factor of influence when identifying the words mentioned during classes and reducing reverberation values affect the levels of students' attention and performance [11]. Moreover, in order to solve noise problems, it is essential to understand and adapt the structure, organization and use of learning spaces in schools [12].

The environment in which students and teachers learn and teach are human-made. It is not the natural environment of a living being, and it is precisely the relationship with nature another concern in this area of research. Benfield, Rainbold, Bell and Donovan [13], studied the perceptions and behaviors of students in classrooms with landscape views. Similarly, van de Berg, Wesselius, Maas and Tanja-Dijkstra [14] conducted a controlled evaluation study on green walls as a restorative environment in the classroom. Both contributions provide a direct relationship between the inclusion of nature and performance in mathematics. Besides, views can influence the variance of reading vocabulary, language arts, and mathematics [15].

The classroom configuration has a close relationship with the teaching approach. The disposition of the space that will affect the interaction in the classroom and the choice of student seats also generates an impact on academic performance based on mathematics [16]. Besides, other studies focused on the influence of class size on the performance and behaviour of kindergarten [17–19], and satisfaction in secondary education [20]. Regarding arts, when elements, such as the aesthetics of the classroom and the furniture arrangement should allow greater interaction between students. Because it allows students to sit in a calm climate, leading to freely develop their creativity and improve their performance [21].

The literature focuses on one of the factors or dimensions mentioned above. However, some studies have developed holistic approaches to the impact of classroom spaces on learning [22–25]. The first empirical holistic model [24] included the learning space attachment factor, which were more significant than lighting for the development of mathematical performance.

Other elements of the classroom that may influence learning space attachment are the student seating location, due to issues, such as proximity to the teacher, accessibility to the halls or distance to the screen [26]. This choice of location in the classroom is influenced by the territoriality and personality of the individual [27,28]. Additionally, the learning space attachment has been associated with students' perception whose artworks were permanently exhibited [29]. This bond between students and their classroom is also related to their security and privacy feeling, which contribute to their comfort [30]. Likewise, the personalization of the space contributes to the creative development and aesthetic values of the students [31].

In a recent study, none of these factors are the answer when students were surveyed about their learning space preferences, but they mainly prefer learning spaces related to the end of their learning activities [32]. Other studies have focused on the vital relation between learning space and pedagogy [33,34], and in need to consider the perception of the student to obtain a more holistic knowledge [35]. So, it seems consistent that disciplines as different as Art and Mathematics, which respond to different teaching needs or methodologies, receive different influences from the same learning space.

Concerning the prediction of performance based on learning space, most researchers have measured mathematical performance through the Grade Point Average in different evaluation periods [24] or by national student performance evaluation programs [4]. While math outcome is considered to be accurately assessed, the evaluation of art performance is presented as a very complex task [36]. Although evidence has raised for isolated disciplines, little research has focused on how learning space factors influence the learning of different subjects [15,24,25].

In Spain, primary schools normally assign a classroom to each course group, except for Physical Education. So, students attend every subject in the same space, which seems not to be an efficient and sustainable use of the building in terms of learning. For that, this research aims to contribute to the explanation concerning how learning space influence art and mathematics performance in primary education, as well as to deepen the measurement of the learning space through the perception of the elementary school student and to investigate whether there are differences in the outcome prediction depending on the academic course.

Diagnostic studies create knowledge bases in order to support new, more efficient and sustainable classroom designs. Since it should be clarified how the learning space affects different subjects and high economic and sustainable costs must be prevented in school designs.

2. Materials and Methods

The main objective of this research is to explore the influence of learning space in mathematics and art performance in Primary Education schools in Galicia (Spain), and to explore learning space relationship with academic courses. For this, a quantitative research was designed, which relates the measurement of the perception of observable variables of the physical learning environment by students through a questionnaire with their performance in mathematics and arts.

First, the design of the questionnaire was adapted to the cognitive level of primary school students based on the *Indoor Physical Environment Perception* scale (iPEP scale) [25,37] (focused on university students), previously based on the holistic model of Barret, Davies, Zhang and Barret [38]. Next, public elementary schools are randomly chosen from the regions of A Coruña and Lugo (Galicia, Spain). Communication is established with the centers to request the possibility of conducting the questionnaires. Subsequently, the visits take place and the test data analyzed.

The psychometric properties of the instrument will be assessed through the corresponding reliability and validity analyzes to ensure that the use of the data. Then, the classrooms are described through the means and standard deviations of the variables of the scale to know in which values the data are grouped. Finally, a multiple linear regression analysis is applied to know if the space variables are predictors of mathematical performance and art education.

2.1. Sample

The sample consists of 583 Primary School (PS) students (307 boys and 276 girls), belonging to fourth, fifth and sixth grade of nine public centers. A total of 27 different classrooms in Lugo and A Coruña. The sample selection corresponds to a simple random sampling. Table 1 shows the distribution of attendants by course, center, and region.

The procedure to collect the information consisted of communicating with the centers obtained from the random selection process, of which four rejected the study proposal. The first contact was with the directors of the schools and later with the tutors of the course. The research was explained to the teaching staff, as well as the guidelines for solving the questionnaires.

Figure 1 shows the sample distribution by school and course. The fifth course of School 5 and the fourth course of School 6 stand out for a greater number of students, which is because they were centers with two small lines in both courses. Their classroom conditions were similar from a technical point of view (number and surface area of windows, orientation, sunshine, classroom size), so they have been presented together.

Table 1. Sample distribution by course, center, and region.

Region	Centre	Course			Total
		4th	5th	6th	
Lugo	**School 1**	24	19	14	**57**
	School 2	24	18	18	**60**
	School 3	23	24	17	**64**
	School 4	21	23	16	**60**
A Coruña	School 5	24	35	24	**83**
	School 6	32	20	24	**76**
	School 7	19	22	10	**51**
	School 8	21	22	20	**63**
	School 9	24	23	22	**69**
	Total	**212**	**206**	**165**	**583**

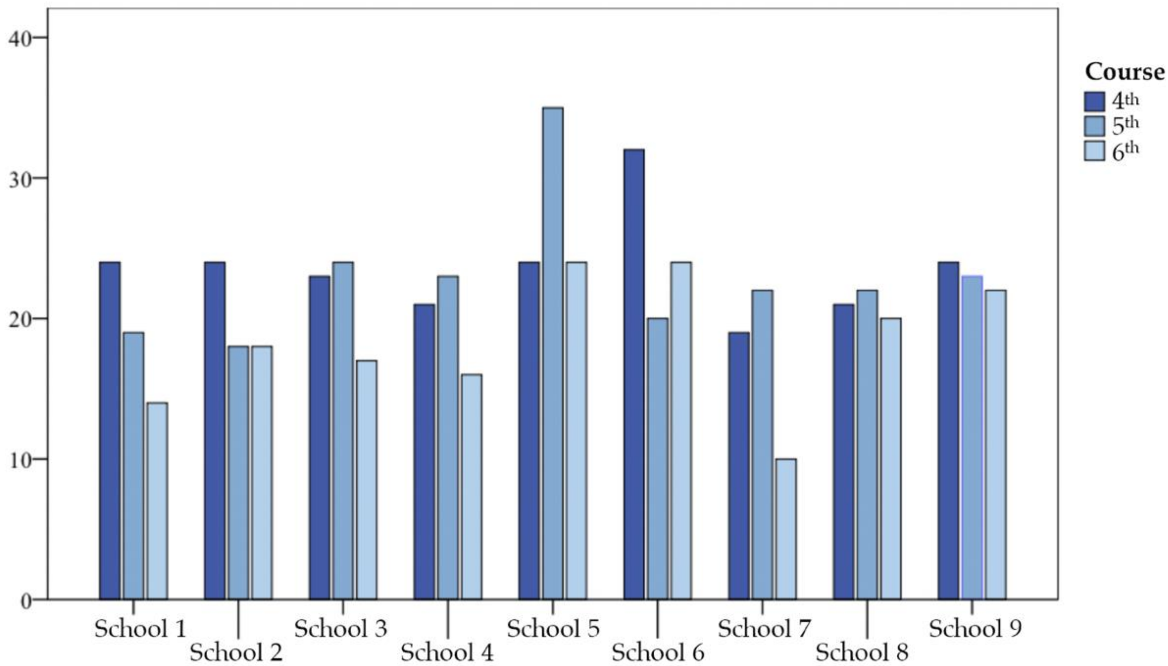

Figure 1. Student distribution by schools and courses.

2.2. Measurement Instrument

The instrument adapted is the *Indoor Physical Environment Perception* scale (iPEP scale), a 1–7 Likert scale. Students had to rate the degree of the learning space variables from 1 (low degree) to 7 (high degree). In the process of adaptation to the primary school context, the number of independent variables has been reduced to fourteen: Academic (the course), sex and age, and the physical learning space (11 variables); as well as two dependent variables: The GPA (Grade Point Average) obtained in the subjects of Mathematics and Arts. The statement of these items has been modified for students between the ages of 9 and 13. In addition, the variables School and Classroom were created in the database, based on the data obtained. The items related to the physical learning space are the following:

- Daylight quantity;
- Artificial light quantity;

- Number of times the classroom is ventilated;
- Thermal level comfort;
- Acoustic comfort;
- Room size;
- Chair comfort;
- Desk comfort;
- Connection with nature (i.e., landscapes);
- I appreciate the color of the walls;
- Learning space attachment.

3. Results

3.1. Descriptive Anaylses. Mean and Standard Deviations

Students' perception of the indoor environment of their classes ranges from values close to 4 and above 6 (see Table 2). Appreciation for the color of the walls is the worst valued (m = 3.84), followed by the chair comfort, the ventilation and the amount of natural light. While the best rated is the acoustic comfort, followed by classroom size, the learning space attachment and the connection with nature.

Table 2. iPEP descriptive values.

		Mean (1.00 to 7.00)	**Standard Deviation**
V1	Daylight quantity	4.95	1.469
V2	Artificial light quantity	5.18	1.618
V3	Number of times the classroom is ventilated	4.59	1.887
V4	Thermal level comfort	5.36	1.784
V5	Acoustic comfort	6.19	1.295
V6	Room size	5.82	1.313
V7	Chair comfort	4.84	1.858
V8	Desk comfort	5.17	1.739
V9	Connection with nature (i.e., landscapes)	5.43	1.804
V10	I appreciate the color of the walls	3.84	2.156
V11	Learning space attachment	5.71	1.543

Table 3 shows the descriptive analysis results in relation to the average grade of Mathematics (m_M = 7.48) and Arts (m_A = 8.24), since it has a different scale: 0–10.

Table 3. Descriptive values of mathematics and art education average grade.

Average Grade Subject	**Mean (0.00–10.00)**	**Standard Deviation**
Mathematics	7.48	1.684
Arts	8.24	1.648

Figure 2 corresponds to the analysis of the distribution of the learning space and academic variables through a boxplot diagram. In almost all cases of the iPEP variables, the lower limit is 1, while the upper limit is 7. However, the quartiles in the case of the acoustic variable are grouped in a much lower range than the rest of the variables, practically 100 per cent of the sample is located between values 5 and 7. The rest of the variables distribute the data in a range of values 1 and 7.

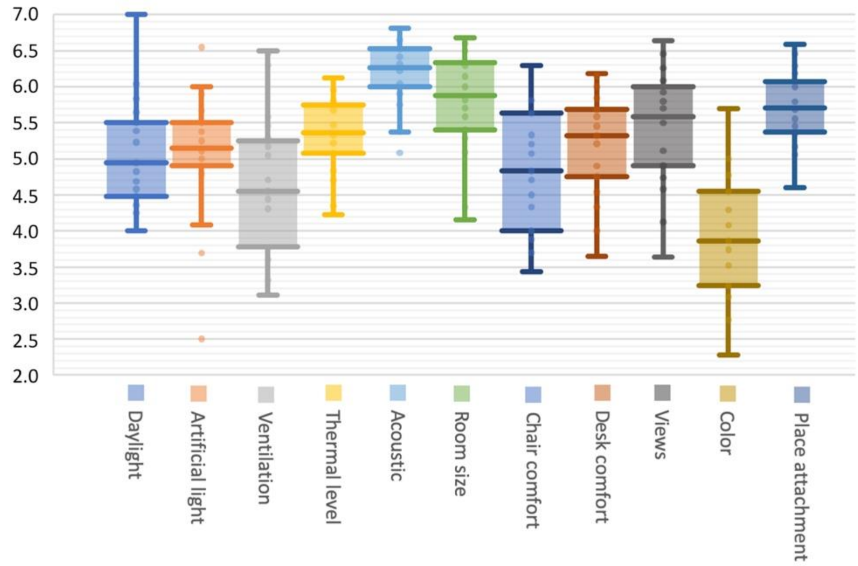

Figure 2. iPEP boxplot.

The variables Natural light, Room size, Chair comfort and Space appropriation are grouped into smaller ranges of values. While the color variable occupies a greater range between the values 2 and 6.

Subsequently, the mean variable values of the student perception of each classroom were made in order to obtain a global measurement. Figure 3 shows the dispersion of the iPEP variable mean values for each of the 27 classrooms, indicating the variability that exists in each of them.

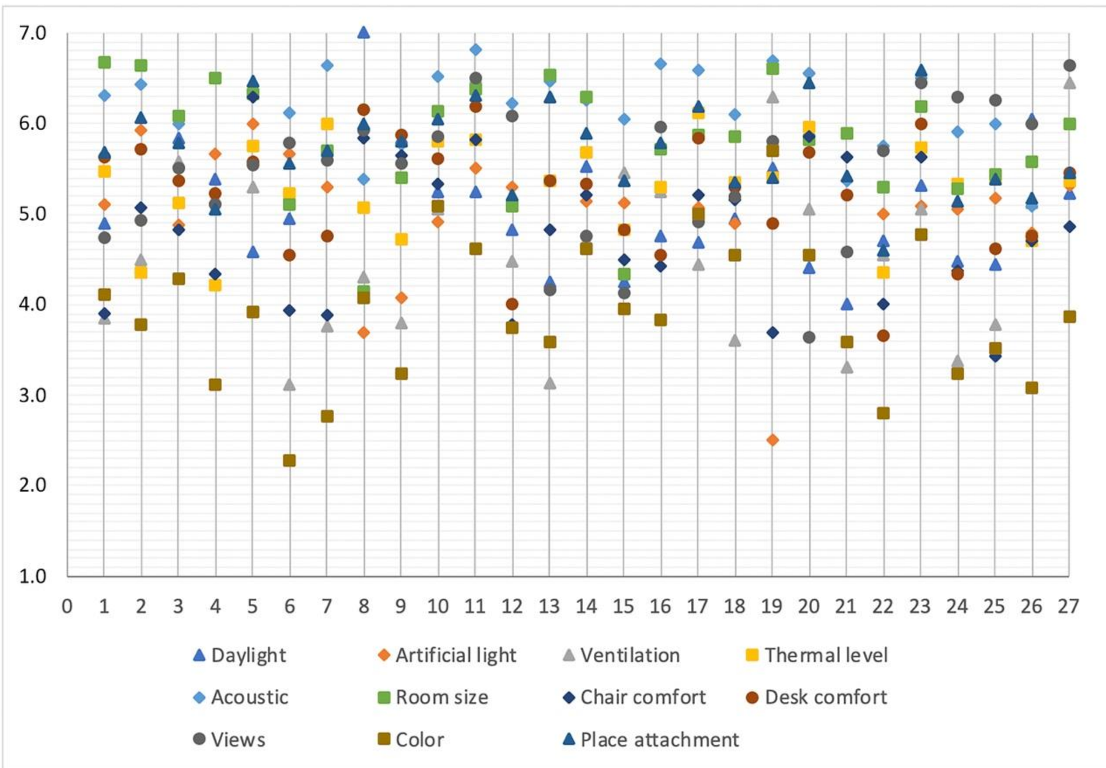

Figure 3. iPEP mean values by classroom.

Classrooms 10 and 23 have a higher concentration in the grouping of iPEP values, with values between 5–6.5; and 4.6–5.7, respectively. On the contrary, classrooms 6, 7, and 19 indicate values between 2.2 and 6.1; 2.7 and 6.6; and 2.5 and 6.7. Moreover, this figure allows us to analyze whether the sets of means are superior or inferior to the rest of classrooms. In this case, classrooms 18, 20, and 21 indicate a concentration in lower values, followed by 6 and 22. On the other hand, classrooms 5, 11, and 12 are grouped in the highest values, followed by 13 and 3.

3.2. iPEP Psychometric Roperties

The reliability of the tool has been calculated using Crombach's alpha to determine if it performs stable measurements, obtaining a result of 0.729, which indicates that the questionnaire is reliable. Subsequently, to verify the validity of the construct, the principal component method of Exploratory Factor Analysis has been applied, with varimax orthogonal rotation.

First, to verify that the factors are correlated with each other, Bartlett's Sphericity ($p < 0.001$) and the Kaiser-Meyer-Olkin test (KMO = 0.802) were calculated, in order to know the adequacy of the sample and if appropriate apply the factor analysis. The result indicates a high partial correlation coefficient, which indicates that it is possible to make a comparison between the magnitudes of correlation coefficients observed and those of partial correlation (Table 4).

Table 4. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test.

Kaiser–Meyer–OlkinMeasure of Sampling Adequacy		0.802
Bartlett's Test of Sphericity	Aprox. Chi-square	1093.778
	df	55
	Sig.	< 0.001

The Exploratory Factor Analysis (EFA) results in a structure of six factors that explains 50.70 per cent of the construct. The grouping of the variables (see Table 5) is grouped into the following factors:

- Workspace comfort: Describes chair and desk comfort (V7 and V8), place attachment (V11), the appreciation for the wall color (V10), as well as the thermal level (V4).
- Natural environment: Represents the amount of daylight (V1), the connection of the classroom with the outside (V9) and the frequency of natural ventilation (V3).
- Building comfort: It is described as the amount of artificial light (V2) and acoustic comfort (V5).

Table 5. Exploratory Factorial Analysis results.

Factor	Variables	Communalities	Total Variance Explained (%)
Workspace comfort	V8	0.816	24.39
	V7	0.806	
	V11	0.627	
	V10	0.610	
	V4	0.565	
	V6	0.473	
Natural environment	V1	0.748	38.53
	V3	0.695	
	V9	0.487	
Building environment	V2	0.729	50.70
	V5	0.699	

3.3. Multiple Linear Regression Analysis

The multiple linear regression analysis is applied to investigate to what extent the iPEP scale is able to predict the performance in Mathematics and Arts. Stepwise method has been conducted.

On the one hand, the prediction of mathematical performance displays a 6-variable model (V3, V6, V7, V11, V4 and V9) that explains 7.2 per cent of the dependent variable. In addition, the value of the Durbin-Watson statistic (1.758) indicates compliance with the assumption of the independence of the residuals (Table 6). On the other hand, the prediction of performance in Arts establishes a model of 2 variables (V6 and V9) that explains 3.7 per cent of the dependent variable. The Durbin-Watson statistic is 1.408, which complies the assumption of independence of the residuals.

Table 6. Multiple linear regression results.

Model	Adjusted R^2	Std. error	Sig. F	Durbin-Watson
Mathematics performance	0.072	1.622	0.022	1.758
Arts performance	0.037	1.617	0.002	1.408

Table 6 shows the Pearson correlations. In the first model (dependent variable = Mathematics grade), the independent variables V3, V6, V11 and V9 obtain positive values reveal a direct relationship. While the variables V7 and V4, indicate an inverse relationship with mathematical performance. In the second model, both variables (V6 and V9) indicate a direct relationship with arts performance.

The validity of the models depends on the verification of the assumptions, such as the non-existence of perfect multicollinearity. The collinearity diagnosis is made through the Variance Inflation Factor (VIF), whose values are close to 1, indicating that the assumption is met (see Table 7).

Table 7. Global regression model for model 1 and 2.

Model	Variable	Beta	t	Sig.	Tolerance	VIF
1	V3	0.123	2.844	0.005	0.859	1.164
	V6	0.102	2.268	0.024	0.786	1.273
	V7	−0.182	−3.298	0.001	0.522	1.917
	V11	0.269	3.973	< 0.001	0.348	2.871
	V4	−0.176	−3.437	0.001	0.606	1.650
	V9	0.098	2.298	0.022	0.868	1.153
2	V6	0.179	4.331	< 0.001	0.970	1.031
	V9	0.130	3.141	0.002	0.970	1.031

One of the premises sought to explore whether these influences could be related to the academic level. For this purpose, multiple linear regression analyzes have been conducted for each course (see Table 8).

Table 8. Multiple linear regression results.

Predictor Variable	Course	R^2	Std. Error	Sig.	Durbin-Watson
Mathematics performance	4^{th}	0.141	1.649	0.050	2.000
	5^{th}	0.096	1.601	0.012	1.475
	6^{th}	0.101	1452	< 0.001	1.290
Art performance	4th	0.135	1.543	0.026	1.739
	5^{th}	0.321	1.437	< 0.001	1.557
	6^{th}	0.101	1.404	0.037	1.893

Concerning mathematics performance of the fourth course, a model of four variables (V6, V4, V5 and V3) has been obtained that explain 14.1 per cent. In the fifth course, the percentage explained is 9.6 per cent for two variables (V7 and V1). In the sixth course, the V7 explains 10.1 per cent of the performance in mathematics. With regards to the performance in Arts in the fourth course, it is explained in 13.5 per cent by two variables (V6 and V4). In the fifth course, five variables explain 32.1 per cent (V9, V6, V2, V7 and V3). In the sixth course, this performance is explained in 10.1 per cent by two variables (V8 and V9).

Table 9 shows the standardized Beta coefficients that indicate whether the relationship of each variable in the model is direct or inverse towards mathematics performance. In the fourth course the V6, V5 and V3 have a direct relationship and the V4 an inverse relationship. In the fifth course V7 indicates an inverse relationship with the dependent variable and V1 a direct relationship. Moreover, in the sixth course the relation of V7 indicates a direct relation.

Table 9. Global regression model by course (predictor variable: Mathematics performance).

Course Model	Variable	Beta	t	Sig.	Tolerance	VIF
4th	V6	0.185	2.151	0.033	0.503	1.987
	V4	−0.377	−4.573	< 0.001	0.546	1.833
	V5	0.251	2.506	0.013	0.370	2.703
	V3	0.131	1.973	0.050	0.835	1.197
5th	V7	−0.346	−4.810	0.000	0.851	1.175
	V1	0.182	2.528	0.012	0.851	1.175
6th	V7	0.327	4.111	< 0.001	1.000	1.000

Table 10 shows the results regarding the multiple linear regression models regarding the art performance. In the fourth course both variables show a direct relationship with the dependent variable. In the fifth course, V9, V6 and V3 indicate a direct relationship and V2 and V7 an inverse relationship. In the sixth course, V8 indicates a direct relationship and V9 an inverse relationship.

Table 10. Global regression model by course (predictor variable: Art performance).

Course Model	Variable	Beta	t	Sig.	Tolerance	VIF
4th	V6	0.438	6.072	<0.001	0.717	1.395
	V9	0.162	2.245	0.026	0.717	1.395
5th	V9	0.165	2.013	0.045	0.496	2.018
	V6	0.287	4.479	<0.001	0.809	1.236
	V2	−0.509	−5.737	<0.001	0.420	2.380
	V7	−0.366	−5.020	<0.001	0.622	1.607
	V3	0.293	3.710	<0.001	0.533	1.878
6th	V8	0.305	3.820	<0.001	0.995	1.005
	V9	−0.168	−2.108	0.037	0.995	1.005

4. Discussion and Conclusions

The present research aimed to deepen the relationship between the physical learning space in Primary Education and the performance in Mathematics and Art, as well as at the academic course. Self-reported empirical data has confirmed the existence of direct and inverse relationships between variables of physical space and performance in mathematics and in art of Primary School students.

It has been shown that the adaptation of iPEP for the measurement of student perception of the variables of the physical learning space in Primary Education is valid and reliable. Likewise, the study has allowed us to investigate the factorial structure of the learning space construct, resulting in an organization in three factors: Workspace comfort, natural environment and building environment, which support previous results [25]. However, findings have evidenced that more question would be needed in order to improve the percentage of learning space measure in primary education level.

The distribution analysis of the learning space variables by classroom (Figure 3) has shown good levels of the indoor environment in the primary school classrooms in Galicia. In addition, this type of evaluation reports on the dispersion of responses, which have sometimes shown little variability. This has happened in the color, and acoustic variables, which may be related to their absence of significant relationships in the prediction analyzes. Therefore, it would be advisable to reconsider how to measure these variables.

The prediction analysis of mathematics performance has confirmed a direct relationship with ventilation, room size, views and place attachment; according to latest contributions of holistic approaches [24], and two inverse thermal level and chair comfort. These results support the inevitable fact of social impact in architectural spaces [33–35], and the need for their measurement through empirical and architectural analyses to understand how they work and to design more sustainable learning spaces in terms of usability. However, relations with art performance seem smaller, results that could be linked to the difficult measurement of Arts [36].

Chair comfort has evidenced an inverse relationship with mathematical performance, while it is the second variable that most explains the measurement of learning space according to the exploratory factor analysis. Despite being the second worst rated variable, the score is close to 5 on a 1–7 scale. However, anthropometry studies indicate that academic performance is reduced when furniture conditions are bad [39]. This provides evidence of an inverse relationship between a good condition of the furniture with a negative result in mathematical performance, pointing out that excess comfort could lead to a detrimental influence. A similar situation seems to happen in terms of the thermal comfort variable.

This research contributes to the literature on the existence of relationships between space and mathematical and art performance in Primary Education. In addition, an effective and easy-to-apply tool is published to diagnose situations related to the learning space in schools, in order to improve the educational purpose of the architectural space.

Concerning future lines of research, it is necessary to combine perception measurements with technical measures to estimate the best efficacy ranges of the different variables. Likewise, the influence in different areas within the study of mathematics and arts need to be studied.

Author Contributions: Conceptualization, V.L.-C. and A.A.L.; Formal analysis, V.L.-C.; Investigation, J.D.L.T.-C. and D.M.-D.; Methodology, V.L.-C., A.A.L., J.L.S. and J.D.L.T.-C.; Resources, J.D.L.T.-C.; Supervision, A.A.L., J.L.S. and J.D.L.T.-C.; Validation, V.L.-C. and J.L.S.; Visualization, D.M.-D.; Writing – original draft, V.L.-C.; Writing—review and editing, V.L.-C., A.A.L., J.L.S. and D.M.-D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Heschong Mahone Group. *Daylighting in Schools. An Investigation into the Relationship between Daylight and Human Performance*; Pacific Gas and Electric Company: San Francisco, CA, USA, 1999; pp. 1–31.
2. Vásquez, N.G.; Felippe, M.L.; Pereira, F.R.; Kuhnen, A. Luminous and visual preferences of young children in their classrooms: Curtain use, artificial lighting and window views. *Build. Environ.* **2019**, *152*, 59–73. [CrossRef]
3. Fernández, A.I. El trabajo por rincones en el aula de Educación Infantil. Ventajas del trabajo por rincones. Tipos de rincones. *Innovaciones y experiencias educativas* **2009**, *15*, 1–8.
4. Oluyemi, T.; Shaughnessy, R.; Turunen, M.; Putus, T.; Metsämuuronen, J.; Kurnitski, J.; Haverinen-Shaughnessy, U.; Oluyemi, T. Building characteristics, indoor environmental quality, and mathematics achievement in Finnish elementary schools. *Build. Environ.* **2016**, *104*, 114–121.
5. Bakó-Biró, Z.; Kochlar, N.; Clements-Croomel, D.; Awbi, H.; Williams, M. Ventilation Rates in Schools and Learning Performance. *Build. Environ* **2011**, *48*, 215–223. [CrossRef]
6. Haverinen-Shaughnessy, U.; Shaughnessy, R.; Cole, E.C.; Toyinbo, O.; Moschandreas, D.J. An assessment of indoor environmental quality in schools and its association with health and performance. *Build. Environ.* **2015**, *93*, 35–40. [CrossRef]
7. Bakó-Biró, Z.; Clements-Croome, D.; Kochhar, N.; Awbi, H.; Williams, M. Ventilation rates in schools and pupils' performance. *Build. Environ.* **2012**, *48*, 215–223. [CrossRef]
8. Amasuomo, T.T.; Amasuomo, J.O. Perceived Thermal Discomfort and Stress Behaviours Affecting Students' Learning in Lecture Theatres in the Humid Tropics. *Buildings* **2016**, *6*, 18. [CrossRef]

9. Huang, L.; Zhu, Y.; Ouyang, Q.; Cao, B. A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices. *Build. Environ.* **2012**, *49*, 304–309. [CrossRef]
10. Ison, M.S.; Greco, C.; Korzeniowski, C.; Morelato, G. Attentional Efficiency: A Comparative Study on Argentine Students Attending Schools from Different Socio-Cultural Contexts. *Elect. J. Res. Educ. Psychol.* **2015**, *13*, 343–368.
11. Castro-Martã-nez, J.A.; Roa, J.C.; Benítez, A.P.; González, S. Effects of classroom-acoustic change on the attention level of university students. *Interdisciplinaria: Revista de Psicología y Ciencias Afines* **2017**, *33*.
12. Longino, A. International Journal Of Environmental Research And Public Health. *Wilderness Environ. Med.* **2015**, *26*, 99. [CrossRef]
13. Benfield, J.A.; Rainbolt, G.N.; Bell, P.A.; Donovan, G. Classrooms With Nature Views. *Environ. Behav.* **2013**, *47*, 140–157. [CrossRef]
14. Berg, A.E.V.D.; Wesselius, J.E.; Maas, J.; Tanja-Dijkstra, K. Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study. *Environ. Behav.* **2016**, *49*, 791–813. [CrossRef]
15. Tanner, C.K. Effects of school design on student outcomes. *J. Educ. Adm.* **2009**, *47*, 381–399. [CrossRef]
16. Haghighi, M.M.; Jusan, M.B.M. The impact of classroom settings on students' seat-selection and academic performance. *Indoor Built Environ.* **2013**, *24*, 280–288. [CrossRef]
17. Fan, F.A. Class Size: Effects on Students' Academic Achievements and Some Remedial Measures. *Res. Educ.* **2012**, *87*, 95–98. [CrossRef]
18. Finn, J.D.; Pannozzo, G.M. Classroom Organization and Student Behavior in Kindergarten. *J. Educ. Res.* **2004**, *98*, 79–92. [CrossRef]
19. Milesi, C.; Gamoran, A. Effects of Class Size and Instruction on Kindergarten Achievement. *Educ. Evaluation Policy Anal.* **2006**, *28*, 287–313. [CrossRef]
20. Norazman, N.; Che-Ani, A.I.; Ja'Afar, N.H.; Khoiry, M.A. Standard compliance and suitability of classroom capacity in secondary school buildings. *J. Facil. Manag.* **2019**, *17*, 238–248. [CrossRef]
21. Kolb, A.Y.; Kolb, D.A. Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education. *Acad. Manag. Learn. Educ.* **2005**, *4*, 193–212. [CrossRef]
22. Shamaki, T.A. Influence of learning environment on students' academic achievement in mathematics: A case study of some selected secondary schools in Yobe State – Nigeria. *J. Educ. Practice* **2015**, *6*, 40–44.
23. Muñoz-Cantero, J.-M.; Mira, R.G.; Lopez-Chao, V. Influence of Physical Learning Environment in Student's Behavior and Social Relations. *Anthropologist* **2016**, *25*, 249–253.
24. Barrett, P.; Davies, F.; Zhang, Y.; Barrett, L. The Holistic Impact of Classroom Spaces on Learning in Specific Subjects. *Environ. Behav.* **2016**, *49*, 425–451. [CrossRef] [PubMed]
25. Lopez-Chao, V.; Amado, A.; Martín-Gutiérrez, J. Architectural Indoor Analysis: A Holistic Approach to Understand the Relation of Higher Education Classrooms and Academic Performance. *Sustainability* **2019**, *11*, 6558. [CrossRef]
26. Benedict, M.E.; Hoag, J. Seating Location in Large Lectures: Are Seating Preferences or Location Related to Course Performance? *J. Econ. Educ.* **2004**, *35*, 215–231. [CrossRef]
27. Marshall, P.D.; Losonczy-Marshall, M. Classroom Ecology: Relations between Seating Location, Performance, and Attendance. *Psychol. Rep.* **2010**, *107*, 567–577. [CrossRef]
28. Clément, G.; Bukley, A. Where Do You Sit in Class? A Study of Spatial Positioning During Two Courses of Different Duration. *J. Hum. Psychol.* **2017**, *1*, 1–7. [CrossRef]
29. Killeen, J.P.; Evans, G.W.; Danko, S. The Role Of Permanent Student Artwork In Students' Sense Of Ownership In An Elementary School. *Environ. Behav.* **2003**, *35*, 250–263. [CrossRef]
30. Alves, H.; Raposo, M. Conceptual Model of Student Satisfaction in Higher Education. *Total. Qual. Manag. Bus. Excel.* **2007**, *18*, 571–588. [CrossRef]
31. Pol, E. La apropiación del espacio. In Iniguez, L. & Pol, E. (coord.). In *Cognición, representación y apropiación del espacio*; Publicacions Universitat de Barcelona: Barcelona, Spain, 1996; pp. 45–62.
32. Beckers, R.; Van Der Voordt, T.; Dewulf, G. Learning space preferences of higher education students. *Build. Environ.* **2016**, *104*, 243–252. [CrossRef]
33. Daniels, H.; Leadbetter, J.; Warmington, P.; Edwards, A.; Martin, D.; Popova, A.; Apostolov, A.; Middleton, D.; Brown, S. Learning in and for multi-agency working. *Oxf. Rev. Educ.* **2007**, *33*, 521–538. [CrossRef]
34. Pérez, G.B.; Roig, A.E.; Costa, M.L. Diseño y validación de un instrumento para medir las dimensiones ambiental, pedagógica y digital del aula. *RMIE* **2019**, *24*, 1055–1075.

35. Daniels, H.; Tse, H.M.; Stables, A.; Cox, S. Design as a social practice: the experience of new-build schools. *Camb. J. Educ.* **2018**, *49*, 215–233. [CrossRef]
36. Stake, R.; Munson, A. Qualitative Assessment of Arts Education. *Arts Educ. Policy Rev.* **2008**, *109*, 13–22. [CrossRef]
37. López-Chao, V. El Impacto del Diseño del Espacio y otras Variables Socio-físicas en el Proceso de Enseñanza-Aprendizaje. Ph.D. Thesis, Universidade da Coruña, A Coruña, Spain, 17 January 2017.
38. Barrett, P.; Davies, F.; Zhang, Y.; Barrett, L. The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Build. Environ.* **2015**, *89*, 118–133. [CrossRef]
39. Castellucci, H.; Arezes, P.; Viviani, C. Mismatch between classroom furniture and anthropometric measures in Chilean schools. *Appl. Ergon.* **2010**, *41*, 563–568. [CrossRef]