



Article

University Library Space Renovation Based on the User Learning Experience in Two Wuhan Universities

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Abstract: University library spaces play an important role in the learning experience of students. However, the traditional designs for these learning spaces no longer meet the needs of users, and researchers have been turning their attention to university library space renovation. By combining existing theories and practices, this study determined a framework of six university library space renovation design principles and subsequently conducted a survey to examine university library space user learning experience in two university libraries in Wuhan, China. Data analysis was conducted using SPSS. From the questionnaire-based survey results, this study determined seven design elements that affect the learning experience of university library users. The results of binary logistic regression showed that two elements, indoor physical space comfort and indoor acoustic environment comfort, have positive effects on the frequency and length of visits to the library. Key spatial elements that can promote library space users' learning experience were also identified, thus providing data that can reliably inform future design strategies for the space renovation of university libraries.



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Keywords: university library; user experience; space renovation

1. Introduction

The spatial renovation of university libraries has become a focus of construction worldwide since the beginning of the 21st century. Library space renovation refers to the overturning of the traditional space layout; this entails the rebuilding of the indoor and outdoor spaces and virtual spaces of libraries to meet users' material and spiritual needs and make the space concordant with technological development, people's cultural demands, and the transformation of the philosophy behind running libraries [1].

The user experience (UX) is the design practice of building research tools and services from a user-centered perspective. The motivation for implementing UX approaches in libraries is to actively focus on the individual needs of users, allowing libraries to design and deliver relevant services in a more targeted manner [2]. The library UX is focused on the behavioral experience of learning activities. Currently, the user learning experience in libraries is rapidly evolving toward "human interaction in service use," which is considered an important factor in the value and development of contemporary university libraries [3].

The motivation for library space renovation stems from three main reasons. First, higher educational objectives have recently changed from cultivating purely professional talents to comprehensive and innovative talents; with this change, the simple storage and one-way transmission of knowledge in libraries no longer fits the mission of contemporary universities. Second, along with the development of constructivist learning theory in the pedagogy field, today's higher education institutions have started emphasizing collaborative and social learning more than ever before. Third, the development of information technology has revolutionized readers' information-seeking habits, making it important

to provide relevant device technology and Internet support in the learning environment to improve users' learning efficiency and learning experience [4]. Furthermore, students' learning styles and demands related to the library space have also changed.

For the last two decades, there has also been much research conducted on the assessment of library space reengineering, bringing together many post-occupancy evaluations and studies involving anthropological approaches that have become a core component of the library space renovation process. The assessment of library spaces focuses on UX and is conducted based on activity types, learning preferences, space type needs, and social needs. One of the earliest space value assessments was conducted at Northeastern University in the United States. Additionally, the Tools for the Evaluation of Academic Library Spaces (TEALS) project at Deakin University in Australia made seven recommendations for space renovation. Another such assessment was conducted at the University of North Carolina at Greensboro; this evaluation project offered a progressive puzzle approach to assessing a space while renovating. There has also been such an assessment at Sheffield Hallam University, which proposed ten elements of spatial renovation based on user surveys [5].

After more than 20 years of development, the layout of the library space of universities worldwide has changed significantly. The aforementioned inventory-based approaches to space assessment have provided directional guidance for space renovation and new constructions at colleges and universities. However, the focus of many of these assessments varies, with some focusing on which space elements attract students to the library and others focusing on space utilization. Nonetheless, these two variables do not fully overlap with the student learning experience. From an architectural design perspective, the need remains to explore the specific space design elements that influence students' learning experience.

First, this study was established on the basis of a literature review to summarize and sort out the elements of spatial renovation design in university libraries, and on this basis a research framework was conducted (Figure 1). Then we used an empirical questionnaire-based survey with samples from two university libraries in Wuhan to collect feedback on and evaluate library space performance from the perspective of the user learning experience (including four levels: physical environment, interior decoration, service facilities, and different types of space perception). It explored how architectural design can enhance and facilitate users' learning experience in libraries, as well as identified which spatial elements impact the learning experience and which affect users' frequency and length of visits to the library. Evidence-based strategies are provided to guide future university library space renovation endeavors.

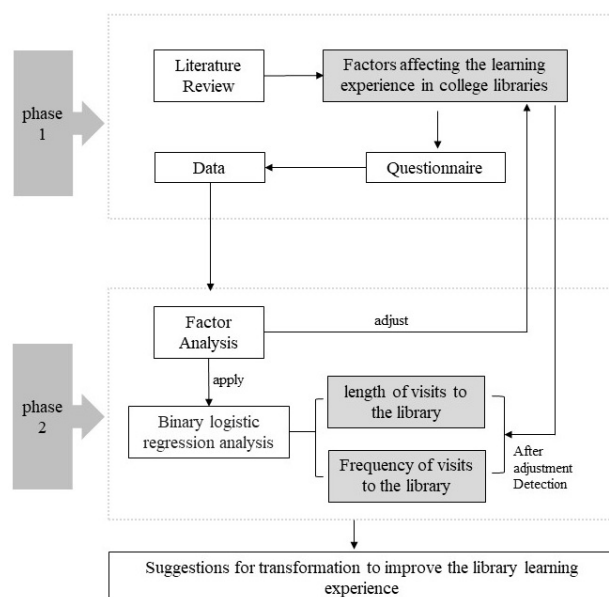


Figure 1. Research framework.

2. Principles of Library Space Renovation

Currently, university libraries, as academic resource centers in universities, are undergoing a new phase of spatial transformation. Such transformation is related to the expansion of the library's role in the campus ecological network [6]. Nowadays, users come to the library not only for learning activities but also for socializing, recreation, and other uses. Accordingly, Jamieson [7] stated that the space layout, decoration, home comfort, and interior aesthetics are important elements of the learning environment and should match the user's needs. Zeivots and Schuck's [4] study showed that students agreed that the physical spaces of learning environments should work together with the related virtual spaces and technological devices to support their learning activities. Moreover, Lam et al. [8], in a study on post-use evaluation of learning spaces, found that the interior design of learning spaces is an important factor that affects students' learning experience and effectiveness. The spatial contradictions between individual and collaborative learning can be better resolved by having a diverse and flexible mix of furniture in the learning space [9]. By exploring different elements of the spatial design characteristics of the user learning experience, we have listed and organized the descriptions of various studies on the design principles that can influence the contemporary user learning space experience (Tables 1 and 2).

Table 1. Spatial design features of learning spaces that affect user experience based on available literature.

Space Design Features	Sources
Sound; lighting (natural, artificial light); ventilation; temperature	[5,10–15]
Storage; power and outlet configurations; network and Wi-Fi quality; electronic equipment configurations such as printers, copiers, etc.; food availability; open hours; directional signage	[4,5,16–19]
Diversity of space types; individual study spaces; group discussion rooms	[5,20]
Decorative sophistication; colors; indoor greenery	[8,21–23]
Diversity of furniture types; home comfort; furniture flexibility	[24–26]
The geographically centralized location of the library	[27]

Table 2. Checklist for assessing the university library space user experience.

Primary Assessment Element	Secondary Assessment Element
a. Physical space environment	Interior acoustic environment Interior lighting status (natural/artificial lighting) Interior ventilation status Interior temperature status
b. Supporting facilities and services	Storage space Amount of power supply and outlet configuration Quality of the network and Wi-Fi signal in the building Configuration of electronic equipment such as printers and copiers Light refreshment supply Library opening hours Guiding signs
c. Space availability	Supply of tables and chairs for study and reading rooms Supply of individual study rooms Supply of group seminar rooms Supply of open, collaborative spaces Supply of leisure study spaces Supply of diversified learning spaces
d. Interior decoration	Interior decoration refinement Interior decoration color aesthetics Interior greenery configuration
e. Furniture type and comfort	Diversification of furniture types Furniture comfort Furniture flexibility
f. Space layout accessibility	Nearby residence Library cafeteria

3. Methods

3.1. Research Case Selection

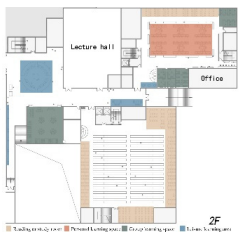
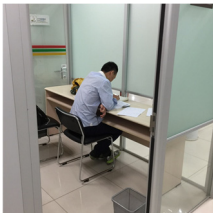
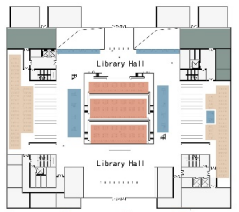
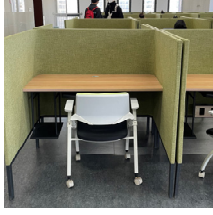
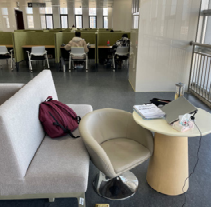
The participant universities were Wuhan University (WHU) and Wuhan University of Technology Nanhu Campus (WUT), both in Wuhan. These two universities were conveniently selected because, first, they are both located in Wuhan, and the study authors are from Huazhong University of Science and Technology in Wuhan. Thus, the research sites were near the researchers' location, which facilitated the research process. Second, both libraries were completed or renovated after the 2010s and are comparable in scale. WHU's library completed its latest spatial reengineering in 2011 and has a floor area of 35,548 m²; WUT's library completed its latest reengineering in 2016 and officially opened in 2018 with a floor area of 48,800 m² (Table 3).

Table 3. Basic information about the libraries of the two universities.

School Name	Basic Information			
	Site	Total Floor Area	Completion Date	Date of Expansion/Construction
Wuhan University	Core area of the campus teaching area	35,548	1981	2014
Wuhan University of Technology	West of the teaching	48,800	2016	/

Third, both cases are representative of the current space reengineering of university libraries in China. WHU, as one of the earliest university libraries in China to build a learning sharing space, can be considered a “wind vane” of space reengineering, albeit without resulting in any overall directional change in space reengineering. As a newly built library, WUT represents the latest domestic design trends for university libraries. The types of internal learning spaces in these libraries can be divided into the reading, individual learning, group learning, and leisure learning spaces (as shown in Table 4). We aimed to analyze the difference in users' learning experiences in university library spaces. The study was approved by the ethics committee of the Tongji Medical College of Huazhong University of Science and Technology (2022-S052), Wuhan, China. Written informed consent was obtained from the participants prior to completing the questionnaire, and oral consent was obtained for the web-based questionnaire.

Table 4. Distribution of learning space types in the two universities.

School Name	Partial Learning Space Distribution	Type of Learning Space			
		Reading or Study	Personal	Group	Leisure
Wuhan University					
Wuhan University of Technology					

3.2. Questionnaire Design

This was a comparative study using a quantitative method. The questionnaires were distributed in both online and offline formats. First, the researchers used social networks (WeChat group and QQ group) to disseminate the questionnaire forms made by Wen Juanxing software. Second, the researchers distributed information in the libraries, contacting library patrons and asking whether they would like to voluntarily complete the online questionnaire. The questionnaires were distributed from May to July 2022.

In the first part of the survey (shown as Appendix A), users were asked to provide personal information about their sex, year of college, and major. The second part of the survey comprised a questionnaire with a scale for user satisfaction with the spatial design characteristics of the university library (responded on a five-point Likert scale ranging from 1–5 with 1, *strongly unaffected*; 2, *somewhat unaffected*; 3, *neither affected nor unaffected*; 4, *somewhat affected*; 5, *strongly affected*), which in turn contained 25 design elements. These elements and dimensions were summarized based on a review of the literature on university library space design principles, studies related to learning spaces, and the research by Freeman et al. [26], Gayton [28], and Holder and Lange [29]. The final set of evaluation factors was extracted by combining the ideas of “users’ needs for diverse learning spaces” proposed in the aforementioned literature.

4. Results

4.1. Descriptive Statistics

For data analysis of the questionnaire data, SPSS version 26.0 was used. In total, 438 questionnaires were distributed and 435 were collected. After eliminating three repeated and four invalid responses, 428 valid responses were finally used for analysis, including 211 from WHU and 217 from WUT. The effective recovery rate of the questionnaires was 97%.

Through a reliability analysis of the university library space user experience questionnaire, the Cronbach’s alpha value was 0.950 (Table 5), indicating excellent reliability. After conducting rounds of discussions with experts in the field, we deleted some items based on these discussions; then, we checked whether the Cronbach’s alpha value of the scale changed after the deletion. This process informed the decision-making regarding which items to delete. Finally, three items were deleted (Table 6). The remaining 39 items were subject to subsequent factor analysis.

Table 5. Reliability statistics for the university library space user experience questionnaire.

Cronbach’s Alpha	Cronbach’s Alpha Based on Standardized Items	Number of Items
0.950	0.954	42

Table 6. Results for deleted items of the university library space user experience questionnaire.

Item-Total Statistics				
	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Cronbach’s Alpha If Item Deleted
Question 7.3. Library adjacent to dormitory and cafeteria	163.46	546.305	0.354	0.950
Question 12.4. Personal study space is visible from the outside line of sight	164.00	543.909	0.381	0.950
Question 13.4. Group study space is visible from the outside line of sight	163.93	543.267	0.379	0.950

Descriptive statistics of the sample are shown in Table 7. In total, 54.2% were men, and 45.8% were women, with a relatively even gender ratio of users in the study sample. Regarding educational level distribution, 46.5% of the total library users in WHU and WUT are undergraduates, and 51.7% are master's and doctoral students. In general, the users are mainly undergraduate students. Regarding majors, the highest percentages appeared for science, engineering, agriculture, and medicine.

Table 7. Descriptive statistics for all participants ($n = 428$, Wuhan, China, 2021–2022).

Variable	Option	Frequency	Percent
Gender	Male	232	54.2
	Female	196	45.8
Degree	Undergraduate	199	46.5
	Master's	186	43.5
	Doctorate	35	8.2
	Faculty and Researchers	7	1.6
	Other	1	0.2
Major	Philosophy, economics, law	49	11.4
	Pedagogy, literature, history	84	19.6
	Science, engineering, agriculture, medicine	246	57.5
	Military science, management science, science of art	49	11.4

As shown in Table 8, regarding the frequency of visits to the library, users who come to the library every week accounted for 46.0%, followed by users who come every month (24.5%). Regarding the distribution of length of visits to the library, the number of users who spent more than three hours each time they went to the library was the highest, accounting for 46.0%, followed by the number of students who came within 1–3 h, accounting for 36.0%. Regarding purposes for visiting the library (as shown in Table 9), users who come to the library for studying alone accounted for the highest proportion, at 40.5%.

Table 8. Descriptive statistics of frequency and length of visits to the library.

Variable	Option	Frequency	Percent
Frequency of visits to the library	Daily	31	7.2
	Weekly	197	46.0
	Monthly	105	24.5
	Quarterly	32	7.5
	Hardly	60	14.0
	Others	3	0.7
Length of visits to the library	Less than 30 min	46	10.7
	30–60 min	31	7.2
	1–3 h	154	36.0
	More than 3 h	197	46.0

Table 9. Descriptive statistics of the purpose for visiting the library.

Variable	Option	Frequency	Percent	Percentage of Cases
The purpose of visiting the library	Study alone	364	40.5%	85.0%
	Complete group work	106	11.8%	24.8%
	Borrow and return books	187	20.8%	43.7%
	Endorsement, speech practice	40	4.4%	9.3%
	Use electronic resources in the library	114	12.7%	26.6%
	Communication, interaction, and other social activities	58	6.5%	13.6%
	Entertainment (watching movies, listening to music, playing games, etc.)	18	2.0%	4.2%
	Others	12	1.3%	2.8%
	Total	899	100.0%	210.0%

4.2. Factor Analysis of the Questionnaire and Data Analysis of Survey Responses

Factor analysis was performed to reduce the large amount of data collected from the questionnaires into smaller, manageable sets of components (potentially clustered factor groups) for analysis and discussion. Factors were extracted using principal component analysis with Varimax rotation and Kaiser–Meyer–Olkin (KMO) normalization methods using the SPSS FACTOR program. The results showed a KMO value of 0.938—indicating the achievement of excellent metrics—and a very low correlation significance level (p -value) of 0.000 (i.e., <0.05) in Bartlett’s spherical test (Table 10). This validates that factor analysis can be used to analyze scale data with sufficient evidence for further statistical analysis. That is, the scales are suitable for factor analysis.

Table 10. Results of the Kaiser–Meyer–Olkin and Bartlett’s Test.

KMO and Bartlett’s Test		
Kaiser–Meyer–Olkin measure of sampling adequacy		0.938
Bartlett’s test of sphericity	Approximate chi-square value	10,996.908
	Degree of freedom (df)	741
	Significance level (p -value)	0.000

As listed in Table 11, seven potential clustered factors were generated after factor extraction and rotation. The percentage of total variance explained was 65.608%; as shown in Figure 2, the seven-dimension model represented the variables of the entire questionnaire appropriately.

Table 11. Exploratory factor analysis results for the university library space user experience questionnaire: total variance results.

Component	Initial Eigenvalues			Total Variance Explained			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	14.771	37.875	37.875	14.771	37.875	37.875	5.963	15.289	15.289
2	3.348	8.584	46.459	3.348	8.584	46.459	4.708	12.073	27.362
3	2.340	5.999	52.457	2.340	5.999	52.457	3.840	9.846	37.207
4	1.474	3.779	56.236	1.474	3.779	56.236	3.221	8.260	45.468
5	1.346	3.451	59.687	1.346	3.451	59.687	2.756	7.065	52.533
6	1.222	3.134	62.821	1.222	3.134	62.821	2.609	6.691	59.224
7	1.087	2.788	65.608	1.087	2.788	65.608	2.490	6.385	65.608

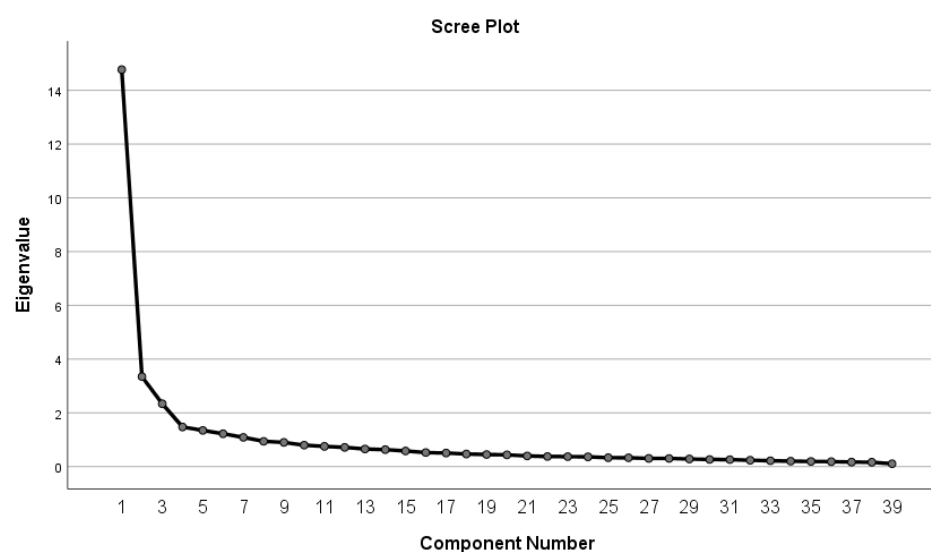


Figure 2. Scree Plot.

The results of the component matrix after rotation by factor analysis are shown in Table 12. These results were analyzed in combination with discussions with experts; specifically, we examined the changes in the cumulative explanatory variance of the remaining items after removing a specific item, then we decided whether to remove that item. We removed item by item several times until the extracted elements and the text items contained in the elements were more consistent with the theoretical architecture. Through this process, the original 39 items were reduced to 28 items. Based on the total variance explained, the original six factors as Table 2 (physical space environment; supporting facilities and services; space availability; interior decoration; Furniture type and comfort; Space layout accessibility) were reclassified into seven categories. The results of naming the seven first-level elements are shown in Table 13, including (E1) physical environment self-control; (E2) physical environment comfort; (E3) interior space aesthetics; (E4) interior acoustic environment comfort; (E5) interior space use comfort; (E6) interior space use flexibility; (E7) complete guidance and equipment.

Table 12. Exploratory factor analysis for the university library space user experience questionnaire: rotated component matrix.

Rotated Component Matrix							
	Component						
	1	2	3	4	5	6	7
Q13.1	0.854						
Q12.1	0.833						
Q12.2	0.778						
Q13.2	0.764						
Q14.1	0.654						
Q14.2	0.527						
Q11.1	0.523						
Q14.3	0.517						
Q7.7		0.701					
Q7.3		0.659					
Q8.2		0.656					
Q10.3		0.622					
Q8.4		0.621					
Q8.3		0.568					
Q10.1		0.547					
Q7.5		0.520					
Q10.2		0.518					
Q7.1							
Q9.3			0.812				
Q9.2			0.745				
Q8.5			0.731				
Q9.1			0.707				
Q8.1			0.509				
Q11.4							
Q12.3				0.660			
Q13.3				0.553			
Q11.3				0.530			
Q11.2				0.515			
Q14.4							
Q7.6					0.707		
Q7.4					0.596		
Q7.2					0.561		
Q10.7							
Q13.5						0.753	
Q13.4						0.721	
Q11.5						0.561	
Q10.5							0.775
Q10.6							0.697
Q10.4							

Table 13. Spatial factors that influence the university library space user experience.

Primary Assessment Element	Secondary Assessment Element
Physical environment self-control	Adjustable light level Adjustable temperature level Casual and comfortable furniture Furniture is lightweight, flexible, and movable Sight lines Space provides opportunities for social interaction
Physical environment comfort	Good learning atmosphere Library has continuous and long opening hours Sufficient artificial lighting in the library Sufficient power outlets in the library Temperature inside the library is suitable (warm in winter and cool in summer) Library has good ventilation Adequate storage space in the library Adequate supply of tables and chairs Good quality Wi-Fi signal in the building
Interior space aesthetics	Interior greenery is properly arranged Beautiful overall interior coloring Beautiful view outside the window Overall interior decoration is exquisite Ample natural light inside the building
Interior acoustic environment comfort	Acoustic environment is sufficiently private Low background noise
Interior space use comfort	Various types of learning spaces Abundant service facilities
Interior space use flexibility	Layout of the space can be flexibly changed Perceive the learning behavior of others
Complete guidance and equipment	Computer workstations in the pavilion Clear signage in the pavilion

4.3. Binary Logistic Regression Analysis

4.3.1. Frequency of Visits to the Library

Using binary logistic regression, the seven factors obtained were used to explore the variables influencing students' frequency and length of visits to the library. First, the independent variables were the seven factors that affect the university library user learning experience, and the dependent variable was the frequency of visits to the library. Results showed (Figure 3) that the total percentage of daily and weekly library users was 53.2%. Therefore, we dichotomized the frequency of coming to the library by daily and weekly visits ($F1 = \text{daily} + \text{weekly}$ vs. $F0 = \text{monthly} + \text{quarterly} + \text{basically not going} + \text{other}$). The Hosmer and Lemeshow test results are shown in Table 14; the model showed a good fit to the data ($p = 0.096, >0.05$).

Table 14. Hosmer and Lemeshow test results.

Hosmer and Lemeshow Test			
Step	Chi-Square	df	Sig.
1	13.491	8	0.096

The results of the binary logistic regression analysis for the frequency of visits to the library are shown in Table 15. Specifically, the p -values for physical environment comfort (E2; $p = 0.001, <0.05$) and indoor acoustic comfort (E4; $p = 0.037, <0.05$) were significant and positively correlated with the frequency of visits to the library. The p -value of interior

space aesthetics (E3; $p = 0.001$, <0.05) was also significant and negatively correlated with the frequency of visits to the library.

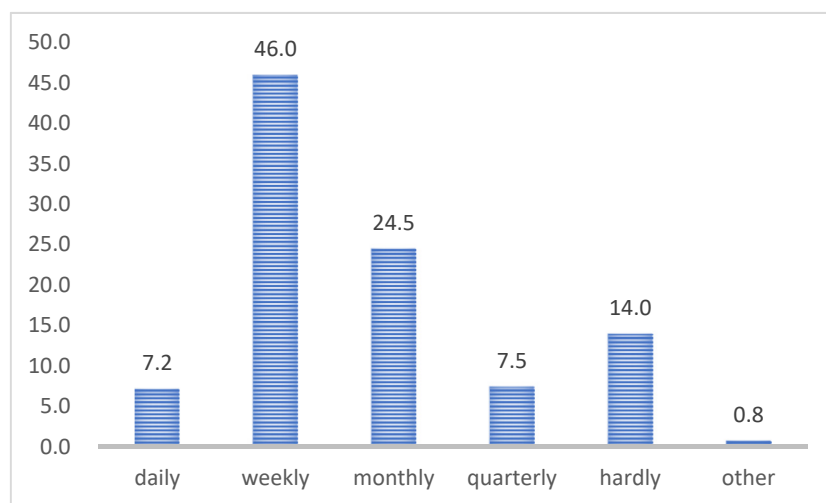


Figure 3. Visits' frequency of sample distribution.

Table 15. Results of logistic regression analysis for frequency of visits to the library.

	B	S.E.	Wald	df	Sig.	Exp (B)	95% CI for Exp (B)	
							Lower	Upper
E1	−0.230	0.242	0.900	1	0.343	0.795	0.494	1.278
E2	0.779	0.226	11.868	1	0.001	2.179	1.399	3.393
E3	−0.520	0.164	10.093	1	0.001	0.594	0.431	0.819
E4	0.445	0.213	4.363	1	0.037	1.560	1.028	2.368
E5	−0.012	0.146	0.007	1	0.932	0.988	0.743	1.314
E6	−0.115	0.152	0.571	1	0.450	0.891	0.662	1.201
E7	0.020	0.116	0.029	1	0.864	1.020	0.813	1.280
Constant	−1.795	0.790	5.163	1	0.023	0.166		

Note. E1: physical environment self-control; E2: physical environment comfort; E3: interior space aesthetics; E4: interior acoustic environment comfort; E5: interior space use comfort; E6: interior space use flexibility; E7: complete guidance and equipment.

4.3.2. Binary Logistic Regression Analysis of Length of Visits to the Library

Here, the independent variables are the seven factors that affect university library user learning experience, and the dependent variable is the length of visits to the library. The total time spent in the library for each study session was used to measure the length of visits to the library. According to the results (Figure 4), 82.0% of the students spent more than one hour in the library, so we chose one hour as the cutoff value and treated the length of visit to the library as a dichotomous variable (T1 = more than one hour/time vs. T0 = less than one hour/time; the latter was used as the reference group). The Hosmer and Lemeshow results are shown in Table 16 and indicate that the model fits the data well ($p = 0.747$, >0.05).

Table 16. Hosmer and Lemeshow test results.

Hosmer and Lemeshow Test			
Step	Chi-Square	df	Sig.
1	5.096	8	0.747

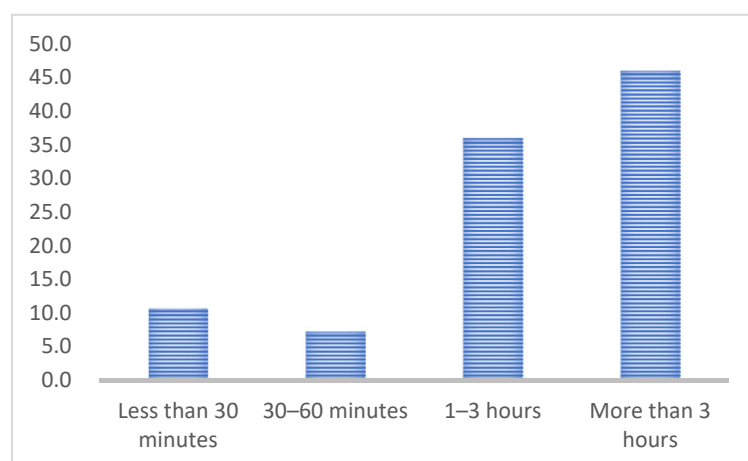


Figure 4. Visits' length of sample distribution.

The results of the binary logistic regression analysis of the length of time visiting the library are shown in Table 17. The p -values of physical environment comfort (E2; $p = 0.032$, <0.050) and indoor acoustic comfort (E4; $p = 0.001$, <0.050) were significant and positively correlated with the length of visit to the library. The p -value of interior space aesthetics (E3; $p = 0.003$, <0.05) was significant and negatively correlated with the length of visit to the library.

Table 17. Results of logistic regression analysis of length of visit to the library.

	B	S.E.	Wald	df	Sig.	Exp (B)	95% CI for Exp (B)	
							Lower	Upper
E1	0.174	0.339	0.263	1	0.608	1.190	0.612	2.314
E2	0.613	0.286	4.595	1	0.032	1.846	1.054	3.233
E3	−0.702	0.237	8.777	1	0.003	0.496	0.312	0.789
E4	0.993	0.291	11.667	1	0.001	2.700	1.527	4.773
E5	0.093	0.185	0.250	1	0.617	1.097	0.763	1.576
E6	−0.395	0.232	2.897	1	0.089	0.674	0.427	1.062
E7	−0.295	0.179	2.714	1	0.099	0.745	0.525	1.058
Constant	−1.244	0.818	2.314	1	0.128	0.288		

Note. E1: physical environment self-control; E2: physical environment comfort; E3: interior space aesthetics; E4: interior acoustic environment comfort; E5: interior space use comfort; E6: interior space use flexibility; E7: complete guidance and equipment.

5. Discussion

5.1. Major Findings

5.1.1. Seven Spatial Factors Affecting User Experience

This study conducted a factor analysis based on a questionnaire scale to obtain seven spatial factors that affect students' learning experience in the library: (E1) physical environment self-control; (E2) physical environment comfort; (E3) interior space aesthetics; (E4) interior acoustic environment comfort; (E5) interior space use comfort; (E6) interior space use flexibility; and (E7) complete guidance and equipment. The contribution of these spatial factors is shown in Figure 5. A binary logistic regression analysis was then performed to relate each of these seven factors to users' frequency and length of visit to the library to further explore the spatial factors that enhance these two variables.

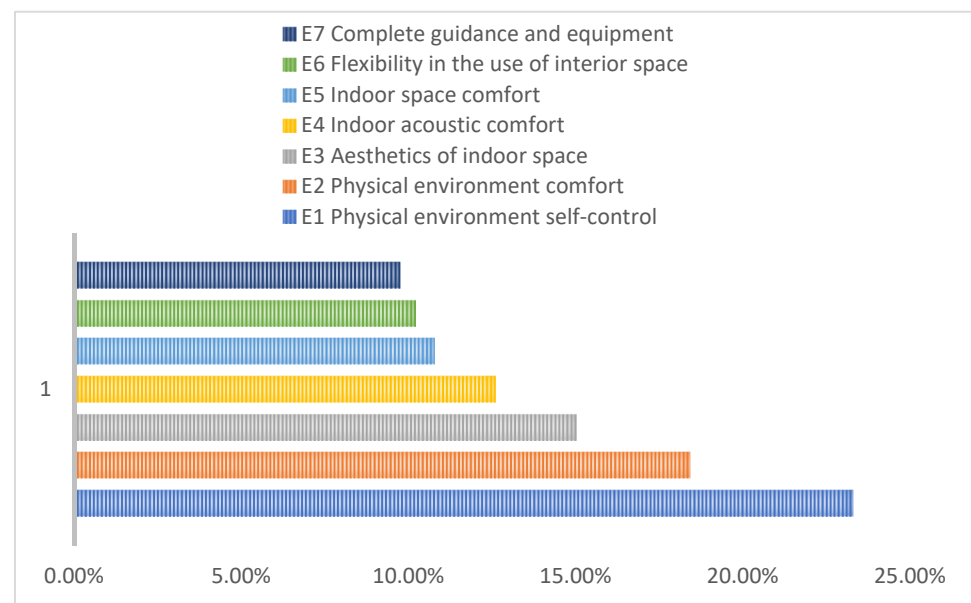


Figure 5. Contribution of spatial factors.

- **E1: Physical environment self-control**

In one empirical study, Beckers et al. [30] found users strongly needed personal control over noise, temperature, and room illumination in the learning space. Another study showed that differences in the quantity and quality of light can have different effects on the comfort level of the learning environment [31]. Hence, a room with natural lighting, due to its uncontrollability, makes it more urgent for users to have personal control and the ability to adjust artificial light sources.

Temperatures above the comfort zone (25 °C) can significantly negatively impact learners' learning performance [15], and changes in outdoor temperatures during different seasons require learners to have the autonomy to adjust artificial temperatures according to their needs in order to arrive at a comfortable temperature zone for learning.

Flexible and movable furniture can be used to meet the changing needs of users' learning or social activities and enhance the user's sense of domain over the learning space, thus creating an overall atmosphere of comfort [9]. The lightness and mobility of the furniture also promote flexibility in the use of the space, allowing learners to quickly and autonomously modify the layout of the learning space to meet the needs of different learning activities and improve their space use experience.

- **E2: Physical environment comfort**

For users, a learning space that provides continuous and prolonged open services enhances their learning experience [5]. When natural lighting is insufficient, adequate artificial lighting can be used to meet the learners' lighting needs. By contrast, when the natural lighting is adequate, it provides a comfortable lighting environment. An appropriate number of power outlets can also extend the length of time learners spend using electronic devices and enhance their space learning experience. Good ventilation in the room can improve air quality, which is positive for learners' health and concentration [13]. Providing sufficient storage space enables learners to have a place where they can store their belongings, which improves the orderliness of the learning space and facilitates the learning experience. An adequate supply of tables and chairs can increase the number of learners coming to the library and provide learners with the freedom to use the tables and chairs at their will. The 21st century learning environment is closely linked to wireless broadband (Wi-Fi) networks and mobile communication devices [18]. Accordingly, a library with high-quality Wi-Fi provides flexibility and choice for learners to engage in different learning activities.

- E3: Aesthetics of indoor space

The indoor greenery arrangement can have a soothing effect on the spirits of space users [23]. Different colors have different effects on the psychological perception of learners, and appropriate interior coloring can promote learners' positive learning emotions [32]. A beautiful view through a window near a study seat can also have a positive impact on students' physiological and psychological states. Furthermore, a well-designed interior creates a relaxed and comfortable learning environment and improves the learning experience for learners. Again, adequate natural lighting ensures that learners have a comfortable light environment.

- E4: Indoor acoustic comfort

Background noise can weaken learners' concentration [11]. A quiet acoustic environment can thus reduce the external environment's interference in the learning process of library users. Furthermore, having access to an acoustic environment that provides privacy to its users can motivate the engagement in different learning activities, such as group discussions; this is because, in such environments, users need not worry about the sound from their learning activities disturbing other learners.

- E5: Indoor space comfort

Providing learners with various study spaces in the library enables meeting different needs and increasing their frequency of visits. Furthermore, a comprehensive range of services and facilities associated with the library provides learners with a better library learning experience [4].

- E6: Flexibility in the use of interior space

Library space design is gradually moving toward the trend of being "rearrangeable" [27]. In other words, the space layout should be flexible and changeable to meet the needs of learners. Users can also perceive that the learning behavior of others promotes learning at the individual level.

- E7: Complete guidance and equipment

With the development of Internet technology, library users have started to increase their demands for computers, scanners, printers, and copiers [33]. Well-equipped facilities can improve the quality of library services and support more learning activities for students. A clear guidance system in the library can also improve the legibility and accessibility of the space and improve the learners' perceptions of space use.

5.1.2. Influence of Spatial Factors on Frequency of Visits and Length of Time in the Library

Our findings show that, first, physical environment comfort (E2) and interior acoustic environment comfort (E4) promote the frequency of student visits to the library. This result reaffirms that enhancing the physical elements of the learning environment, such as light and appropriate background sound, can enhance the space's attraction for students [5].

Second, physical and indoor acoustic comfort can encourage students to spend longer periods in the library to study or engage in other activities. As with the results of frequency of visits, the lighting [12], temperature [15], and ventilation [13] of the space may also encourage users to spend more time in the library once they visit it. Meeting the needs of students in the library for adequate power outlets and good Wi-Fi signal [34] can extend the length of time users study in the library. Furthermore, we confirm Harrop and Turpin's [5] study of student demand for open hours: if the library has longer and continuous opening hours, it may be able to meet the needs of a wider range of users for longer periods. Less background noise can also improve the concentration of users in the library.

Our findings also showed that the aesthetics of the interior space negatively affect the frequency and length of visits to the library. These results are inconsistent with the findings of prior studies, which have shown that elaborate interior decoration [35,36] and beautiful overall colors [32] positively affect learners. The reasons for this may be because first,

sophisticated decoration may attract more learners to the library, and excessive numbers of people create noise and other distractions that can affect individual learning experience [37]. Second, the two Chinese university libraries included in this study did not use a diverse range of colors, implying that learners may lack experience in the relationship between color and the learning experience. Third, the artificial lighting in Chinese libraries tends to be continuous and sufficient. Natural light that is too direct may cause glare and disrupt the learning experience. Fourth, indoor greenery may attract insects and emit odors, affecting students' learning experience. Fifth, the changing landscape outside the window may interfere with the learning state of indoor users.

5.2. Strengths and Limitations

One of the strengths of this study is that it was conducted in two representative university libraries in Wuhan. Our findings support some conclusions from previous literature that physical space comfort can attract learners to the library [12] and indoor acoustic comfort can promote a better learning experience [10]. Furthermore, space layout accessibility and longer hours of operation can encourage more frequent visits to the library. These findings enrich the literature by providing suggestions as to what should be prioritized in library space reengineering endeavors.

We also adopted the user learning experience as a new entry point for assessing the value of library learning spaces. Using this approach, this study quantitatively demonstrates that the Internet and electronic devices play an important role in users' learning experience in the 21st century, as well as that the location of the library on the campus can influence the frequency of visits to the library.

This research also has some limitations. First, the questionnaires were primarily administered to university students, so the opinions and comments of faculty and librarians were not collected. Second, the study was limited to the main libraries of two universities, so further research is needed to investigate more related settings. These future studies will allow us to have a more accurate assessment of the impact of variables related to library space on the user learning experience.

6. Conclusions

Through empirical research, we have appropriate evidence to identify the elements of university library space transformation that impact the user learning experience (Figure 6). This quantitative study determined seven first-level design elements of university library spaces that may influence user learning experience. Results showed that physical environment comfort (E2) and interior acoustic environment comfort (E4) of university libraries were positively correlated with the frequency and length of visits to the library. Therefore, in the process of space reengineering for university libraries, the following two suggestions are made: (1) improve the comfort of the physical space and (2) improve the indoor acoustic environment of the library.

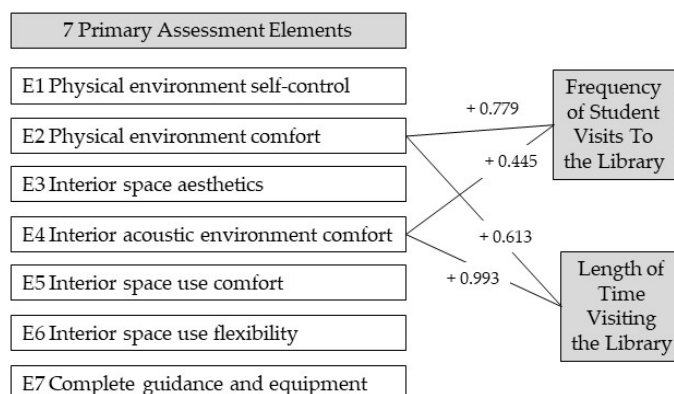


Figure 6. Empirical research conclusion.

Author Contributions: Conceptualization, L.P. and W.W.; first draft framework construction work: Y.G.; methodology, W.W. and L.P.; software, R.J.; validation, L.P. and R.J.; formal analysis, L.P. and W.W.; investigation, W.W.; data curation, W.W., L.P. and R.J.; writing—original draft preparation, W.W., L.P. and R.J.; writing—review and editing, L.P. and R.J.; visualization, R.J.; supervision, L.P. and R.J.; project administration, L.P. All authors have read and agreed to the published version of the manuscript and contributed equally to this work.

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Institutional Review Board Statement: The study was approved by the ethics committee of the Tongji Medical College of Huazhong University of Science and Technology (2022-S052), Wuhan, China.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

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

Appendix A

University library space user experience questionnaire:

Hello, we are the research group of “Research on the value of university library space based on user experience”. The purpose of this questionnaire is to understand your needs and satisfaction with the library learning space from the perspective of user experience and provide reference for optimizing the space design of university libraries. We make a solemn commitment to you and hope you can fill this questionnaire out with confidence!

This survey is anonymous. The questionnaire information you will fill in will be used for academic research purposes only and will be kept strictly confidential.

[single-choice question] Question 1. Your gender is:

- ☐ Male
- ☐ Female

[single-choice question] Question 2. You are a:

- ☐ Undergraduate student
- ☐ Postgraduate student
- ☐ Doctoral candidate
- ☐ Faculty and researcher

[single-choice question] Question 3. Subject of your major:

- ☐ Law, philosophy, and economics
- ☐ Pedagogy, literature, and history
- ☐ Science, engineering, agriculture, and medicine
- ☐ Military science, management science, and art science

[single-choice question] Question 4. On average, how often have you been going to the library in this semester:

- ☐ Every day
- ☐ Weekly
- ☐ Monthly
- ☐ Quarterly
- ☐ Basically not going
- ☐ Others

Please specify: . . .

[single-choice question] Question 5. On average, the time you spend in the library in each visit is about:

- ☐ Less than 30 min
- ☐ 30 min to 1 h
- ☐ 1–3 h

☐ More than 3 h

☐ Others

Please specify: . . .

[multiple-choice question] Question 6. Your main purpose for going to the library is to/for:

☐ Study alone

☐ Complete group work

☐ Borrow and return books

☐ Endorsement, speech practice

☐ Use electronic resources in the library for learning

☐ Communication, interaction, and other social activities

☐ Entertainment (watching movies, listening to music, playing games, etc.)

☐ Others

Please specify: . . . Your opinion about the extent to which the following elements contribute to your learning experience is:

Evaluation Dimension	Evaluation Factor	Your Comments				
		1	2	3	4	5
		Strongly Unaffected	Somewhat Unaffected	Neither Affected or Unaffected	Somewhat Affected	Strongly Affected
Question 7. the elements influence your learning experience is	7.1. High physical environment comfort (lighting, illumination, ventilation, room temperature, etc.)					
	7.2. Highly refined interior decoration (decorative materials, color matching, greenery arrangement, etc.)					
	7.3. Library adjacent to dormitory and canteen					
	7.4. The library is open continuously and for long hours					
	7.5. High number of service facilities (storage space, Internet/power supply, printers, copiers, etc.)					
	7.6. Sufficient supply of tables and chairs					
	7.7. Diversified learning space types (individual, group, casual learning areas, etc.)					
	7.8. Good learning atmosphere					
Question 8. Physical environment	8.1. There is sufficient natural lighting in the pavilion					
	8.2. Adequate artificial lighting in the pavilion					
	8.3. Good ventilation in the pavilion					
	8.4. The temperature inside the pavilion is suitable (warm in winter and cool in summer)					
	8.5. There is a beautiful view outside the window					

Evaluation Dimension	Evaluation Factor	Your Comments				
		1	2	3	4	5
		Strongly Unaffected	Somewhat Unaffected	Neither Affected or Unaffected	Somewhat Affected	Strongly Affected
Question 9. Interior decoration	9.1. The overall interior decoration is exquisite					
	9.2. Beautiful overall interior coloring					
	9.3. Interior greenery is properly arranged					
Question 10. Service facility availability	10.1. There is sufficient storage space in the pavilion					
	10.2. Good Wi-Fi signal quality in the pavilion					
	10.3. There is a sufficient number of power outlets in the pavilion					
	10.4. Electronic equipment, such as for printing and copying, are available					
	10.5. There are computer workstations in the pavilion					
	10.6 Clear signage in the pavilion					
	10.7. Drinks and light snacks are available in the pavilion					
Question 11. Study in the reading room or study room of the library	11.1. The learning space is open and transparent					
	11.2. Low background noise					
	11.3. The furniture is comfortable and ergonomic					
	11.4. The tables and chairs provide some visual shading					
	11.5. I can perceive the learning behavior of others					
Question 12. Study in the library's personal study space (personal study bin, personal study room, etc.)	12.1. Adjustable light level					
	12.2. Adjustable temperature level					
	12.3. The acoustic environment is private enough					
	12.4. Personal study space is visible from the outside line of sight					
Question 13. Study in the library's group study spaces (collaborative group discussion rooms, small seminar rooms, etc.)	13.1. Adjustable light level					
	13.2. Adjustable temperature level					
	13.3. The acoustic environment is sufficiently private					
	13.4. Group study space is visible from the outside line of sight					
	13.5. Space layout can be changed flexibly					
	13.6. The furniture is light and flexible and can be moved					

Evaluation Dimension	Evaluation Factor	Your Comments				
		1	2	3	4	5
		Strongly Unaffected	Somewhat Unaffected	Neither Affected or Unaffected	Somewhat Affected	Strongly Affected
Question 14. Study in the library's relaxed study area (lobby, atrium, cafe, etc.)	14.1. The furniture is casual and comfortable					
	14.2. The furniture is lightweight, flexible, and movable					
	14.3. Space provides opportunities for social interaction					
	14.4. The space provides an atmosphere of mental relaxation					

Question 15. Your overall satisfaction with the space of the library on the main campus of Huazhong University of Science and Technology is:

- ☐ Very dissatisfied
☐ Somewhat dissatisfied
☐ Neither satisfied nor dissatisfied
☐ Somewhat satisfied
☐ Very satisfied

References

- Liu, J. On the spatial reengineering of libraries. *Libr. World.* **2017**, *5*, 45–49.
- Massis, B. The user experience (UX) in libraries. *Inf. Learn. Sci.* **2018**, *119*, 241–244. [CrossRef]
- Liddle, D. Best value—The impact on libraries: Practical steps in demonstrating best value. *Libr. Manag.* **1999**, *20*, 206–214. [CrossRef]
- Zeivots, S.; Schuck, S. Needs and expectations of a new learning space: Research students' perspectives. *Australas. J. Educ. Technol.* **2018**, *34*, 27–40. [CrossRef]
- Harrop, D.; Turpin, B. A study exploring learners' informal learning space behaviors, attitudes, and preferences. *New Rev. Acad. Librariansh.* **2013**, *19*, 58–77. [CrossRef]
- Thorpe, A.; Lukes, R.; Bever, D.J.; He, Y. The impact of the academic library on student success: Connecting the dots. *Libr. Acad.* **2016**, *16*, 373–392. [CrossRef]
- Jamieson, P. Designing more effective on-campus teaching and learning spaces: A role for academic developers. *Int. J. Acad. Dev.* **2003**, *8*, 119–133. [CrossRef]
- Lam, E.W.M.; Chan, D.W.M.; Wong, I. The architecture of built pedagogy for active learning—A case study of a university campus in Hong Kong. *Buildings* **2019**, *9*, 230. [CrossRef]
- Thaler, M.; Burke-Vigeland, M.; Hickson, K.; Broz, D.; Anderson, A.; Barber, C. Why Do Students Really Go to the Library? 2014. Available online: <http://www.gensler.com/design-thinking/research/future-of-the-academic-library> (accessed on 17 March 2014).
- Gifford, R. *Environmental Psychology: Principles and Practice*, 5th ed.; Optimal Books: Colville, WA, USA, 2014.
- Venetjoki, N.; Kaarlela-Tuomaala, A.; Keskinen, E.; Hongisto, V. The effect of speech and speech intelligibility on task performance. *Ergonomics* **2006**, *49*, 1068–1091. [CrossRef]
- Samani, A.S. The impact of indoor lighting on students' learning performance in learning environments: A knowledge internalization perspective. *Int. J. Bus. Soc. Sci.* **2012**, *3*, 127–136.
- Daisey, J.M.; Angell, W.J.; Apte, M.G. Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information. *Indoor Air* **2003**, *13*, 53–64. [CrossRef]
- Mendell, M.J.; Heath, G.A. Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air* **2005**, *15*, 27–52. [CrossRef] [PubMed]
- Seppänen, O.; Fisk, W.J.; Faulkner, D. Cost Benefit Analysis of the Night-Time Ventilative Cooling in Office Building. In Proceedings of the 7th International Conference on Healthy Buildings, National University of Singapore, Singapore, 7–11 December 2013.
- Riddle, M.D.; Souter, K. Designing informal learning spaces using student perspectives. *J. Learn. Spaces* **2012**, *1*, 1–6.
- Lam, P.; Fox, B.; Ho, E. *Informal Learning Space Study Report—1/F, Esther Lee Building; Working Paper 5*; Centre for Learning Enhancement and Research, The Chinese University of Hong Kong: Hong Kong, China, 2009.

18. Fisher, K.; Newton, C. Transforming the twenty-first-century campus to enhance the net-generation student learning experience: Using evidence-based design to determine what works and why in virtual/physical teaching spaces. *High. Educ. Res. Dev.* **2014**, *33*, 903–920. [\[CrossRef\]](#)
19. Ramu, V.; Taib, N.; Massoomah, H.M. Informal academic learning space preferences of tertiary education learners. *J. Facil. Manag.* **2021**. *ahead-of-print*.
20. Burn, K.; Cunningham, M.; Waller, L.; Walton, E.; Walton, G. Capturing the student user experience (UX) in York and Loughborough University Library buildings. *Perform. Meas. Metrics* **2016**, *17*, 175–187. [\[CrossRef\]](#)
21. Earthman, G.; Lemasters, L. Review of Research on the Relationship between School Buildings, Student Achievement, and Student Behavior. In Proceedings of the International Annual Meeting of the Council of Educational Facilities Planners, Tarpon Springs, FL, USA, 8 October 1996.
22. Shandrow, K.L. How the Color of Your Office Impacts Productivity (Infographic). Entrepreneur Asia Pacific 9 March 2015. Available online: <https://www.entrepreneur.com/article/243749> (accessed on 3 October 2019).
23. Bringslimark, T.; Hartig, T.; Patil, G. The psychological benefits of indoor plants: A critical review of the experimental literature. *J. Environ. Psychol.* **2009**, *29*, 422–433. [\[CrossRef\]](#)
24. Andrews, C.; Wright, S.E.; Raskin, H. Library learning spaces: Investigating libraries and investing in student feedback. *J. Libr. Adm.* **2016**, *56*, 647–672. [\[CrossRef\]](#)
25. Mairaj, M.I.; Naseer, M.M. Library services and user satisfaction in developing countries: A case study. *Health Inf. Libr. J.* **2013**, *30*, 318–326. [\[CrossRef\]](#)
26. Freeman, G.T. The Library as Place: Changes in Learning Patterns, Collections, Technology, and Use. In *Library as Place: Rethinking Roles, Rethinking Space*, 1st ed.; Council on Library and Information Resources: Washington, DC, USA, 2005; pp. 1–9. Available online: <http://www.clir.org/pubs/abstract/pub129abst.html> (accessed on 5 December 2021).
27. Foster, N.F.; Gibbons, S. (Eds.) *Studying Students: The Undergraduate Research Project at the University of Rochester*; Association of College and Research Libraries: Chicago, IL, USA, 2007.
28. Gayton, J.T. Academic libraries: “Social” or “Communal?”. The nature and future of academic libraries. *J. Acad. Librariansh.* **2008**, *34*, 60–66. [\[CrossRef\]](#)
29. Holder, S.; Lange, J. Looking and listening: A mixed-methods study of space use and user satisfaction. *Evid. Based Libr. Inf. Pract.* **2014**, *9*, 4–27. [\[CrossRef\]](#)
30. Beckers, R.; van der Voordt, T.; Dewulf, G. Why do they study there? Diary research into students’ learning space choices in higher education. *High. Educ. Res. Dev.* **2016**, *35*, 142–157. [\[CrossRef\]](#)
31. Mott, M.S.; Robinson, D.H.; Walden, A.; Burnette, J.; Rutherford, A.S. Illuminating the effects of dynamic lighting on student learning. *SAGE Open* **2012**, *2*, 1–9. [\[CrossRef\]](#)
32. Hawkins, H. The Environment for Learning. In *Guide for Planning Educational Facilities*; Moore, D.P., Ed.; Council of Educational Facility Planners: Columbus, OH, USA, 1991; pp. 141–155.
33. Gibbons, S. Why Do Students Want to Be in the Library If They Aren’t Using the Books? In Upstate New York Science Librarians Conference. 2010. Available online: <https://surface.syr.edu/nyscilib/40/> (accessed on 15 February 2022).
34. DeFrain, E.; Hong, M. Interiors, affect, and use: How does an academic library’s learning commons support students’ needs? *Evid. Based Libr. Inf. Pract.* **2020**, *15*, 42–68. [\[CrossRef\]](#)
35. Lippincott, J.K. Linking the information commons to learning. In *Learning Spaces*; EDUCAUSE: Washington, DC, USA, 2006; Available online: <https://www.educause.edu/research-and-publications/books/learning-spaces/chapter-7-linking-information-commons-learning> (accessed on 2 November 2021).
36. Taylor, S.S. Effects of studio space on teaching and learning: Preliminary findings from two case studies. *Innov. High. Educ.* **2009**, *33*, 217–228. [\[CrossRef\]](#)
37. Mehrabian, A. Individual differences in stimulus screening and arousability. *J. Pers.* **1977**, *45*, 237–250. [\[CrossRef\]](#)