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Online Learning Space Environment in Colleges and Universities Based on Learning Effectiveness

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ABSTRACT

In recent years, online teaching has gradually become the mainstream learning method for college students. As a result, research on the factors influencing online learning behavior has gained attention. The physical environment is one of the important factors affecting behavior, and studying online learning spaces is key to exploring the factors that influence online learning effectiveness. Empirical analysis is a research method that verifies hypotheses using actual data. This paper combines statistical methods with interview and survey data to investigate the impact of various environmental factors, such as thermal conditions, air quality, and furniture, on online learning effectiveness. Additionally, it incorporates findings from surveys of learning spaces on campus and empirical analysis results to assess the demand for online learning environments. Based on this comprehensive analysis, the paper proposes targeted optimization strategies for online spaces aimed at enhancing learning effectiveness.

Keywords: Online learning space, Learning engagement, Human factors engineering, Spatial strategies

INTRODUCTION

With the rapid development of information technology, society has entered the "Internet Plus" era, where the integration of the education sector and the internet has revealed significant market potential and commercial prospects. The online learning model has rapidly evolved, becoming an important method of study for university students, altering their learning behaviors and environments, and allowing them to engage in coursework in relatively independent spaces. The structure of time allocation for learning has also undergone significant changes. Although there has been research exploring online learning behaviors, studies on how environmental factors influence students' online learning remain relatively scarce. Therefore, this study aims to analyze the spatial aspects of online teaching for university students from the perspective of human factors research. It seeks to understand the spatial factors affecting students' online learning through surveys and to establish corresponding evaluation tools through data analysis, in order to enhance the efficiency and user experience of online teaching spaces. This

research expands upon the methods of spatial design within environmental psychology through empirical analysis, providing guidance for the design of online learning spaces and helping universities formulate more effective online learning strategies to improve educational quality.

RESEARCH THEORIES AND MODELS

Environmental Psychology Theory

Environmental psychology is the comprehensive science that studies the relationship between human behavior and experience and both artificial and natural environments (Paul A. Bell). It emphasizes the importance of examining the environment-behavior relationship as a whole, as there is a genuine interaction between the two: the environment encompasses and influences behavior, while behavior also alters the environment. Statistical analysis is a commonly used method in the field of environmental psychology. Therefore, this study employs statistical knowledge to investigate spatial factors.

Indoor Environmental Quality

Indoor Environmental Quality (IEQ) refers to the various environmental conditions and characteristics within living or working spaces that directly affect people's health, comfort, and work efficiency. It primarily includes aspects such as air quality, lighting, temperature, humidity, noise, and spatial layout. The different aspects of the indoor environment are interconnected and collectively influence individuals' physical and mental health as well as work performance. Improving indoor environmental quality is a crucial way to enhance the quality of life and work.

Learning Engagement Theory

In the 1980s, Mosher et al. (1985) pointed out that student engagement includes not only the investment of time and effort but also the attitudes and emotions of the learners. At the same time, there is a significant relationship between student engagement and outcomes such as academic performance and social behavior. Jimerson (2003) reviewed 45 research reports on student engagement and identified dimensions for measuring engagement, including emotional, behavioral, and cognitive aspects. Behavioral engagement refers to the level of student participation in the classroom, such as attendance and completion of assignments. Emotional engagement involves students' feelings towards school, including their attachment to teachers and peers. Cognitive engagement pertains to the depth of understanding and thought that students apply to the learning content.

The Impact of Environment on Learning Engagement

Zhang Lin et al. (2023) found that environmental factors are important influences on student engagement. Tawarah et al. (2022) indicated that students' motivation and the availability of facilities can affect the achievement of course objectives. Hollister et al. (2022) discovered that when

students lack interaction with peers and teachers, it reduces the appeal of learning. Akpen et al. (2024) showed that the digital devices used may have restrictive effects, making it difficult for students to maintain engagement levels comparable to those in face-to-face learning environments. Wang Yashuang et al. (2023) found in their research that physical environmental factors have an indirect impact on online learning engagement.

RESEARCH METHODS AND TOOLS

This study uses a questionnaire for investigation. A scale is a tool used to measure specific variables or characteristics. Established scales are usually validated through practical application, providing significant reference value. Due to the lack of authoritative scales in existing research on online learning environments, this study constructs a research questionnaire through interviews and spatial scales.

Environmental Quality Satisfaction Measurement Tools

This study uses spatial environment satisfaction to measure users' feelings about online learning spaces. According to research by Schaufeli et al. (2002), learning activities share similarities with work activities in terms of role composition, allowing the MBI tool developed by Maslach et al. (1981) to retain its research value by substituting "learning" for "work." Therefore, this study references established work space satisfaction scales for its research.

CBE Questionnaire for Occupant Survey

This questionnaire is sourced from the Center for the Built Environment (CBE) at the University of California, Berkeley, and is widely used in empirical research on office spaces. The sample for the questionnaire is drawn from data on 351 different types of office buildings surveyed by CBE since 2000. This questionnaire provides a framework (such as lighting environment, acoustic environment, and air quality) for assessing spatial factors' satisfaction and serves as a reliable survey tool for this study.

Composite Scales

Newsham et al. (2009) developed this scale in their research on the impact of environmental satisfaction on job satisfaction, testing and expanding it based on the COPE (Cost-effective Open-Plan Environments) research model. The scale aims to explore the significant effects of satisfaction with environmental factors such as lighting, privacy, and furniture on job satisfaction. Most of the anticipated bivariate correlations in the study were significant and consistent in direction, indicating that overall environmental satisfaction is an important factor influencing job satisfaction. This suggests that the scale can serve as a reliable reference tool for the investigation in this study.

Learning Engagement Measurement Tools

Online Student Engagement Scale

The Online Student Engagement Scale (Dixson et al., 2015) is designed to measure student engagement in online learning environments. This scale

not only focuses on student behaviours but also encompasses multiple dimensions such as emotions, skills, and performance, providing a comprehensive tool for assessing student engagement.

QUESTIONNAIRE DESIGN

Based on the review of previous literature, coding of interview texts, and the online learning engagement scale, the research dimensions for the subsequent questionnaire were defined. Grounded in the literature review and interview analysis, and referencing professional scales, this study has established the necessary measurement scale. Below is the overall structure of the scale and the indicators for each research variable.

Demographic Variable Information

The basic information section primarily investigates two aspects. First, it collects demographic information about the participants, including gender and highest educational attainment. Second, it examines learners' online learning behaviors, including preferences for learning environments and online learning equipment.

Table 1: Demographic variable information table.

Dimensions	Questionnaire Items
Demographic information	Gender/Education level, etc.
Learning Behavior	Learning environment/Learning equipment, etc.

Online Learning Space Satisfaction Section

Based on the CBE Questionnaire for Occupant Survey, the Composite scales, and interview analysis, the satisfaction section for online learning spaces is divided into three dimensions: environmental quality, spatial layout, and furniture and equipment.

Table 2: Online learning space satisfaction table.

Dimensions	Questionnaire Items
Environmental Quality	Thermal Environmental Quality/Air Quality/Lighting Environmental Quality
Spatial Layout	Size of Storage Area/Size of Learning Area/ Interactivity with Others
Furniture and Equipment	Online Learning Equipment/Furniture in Online Learning Space/Decoration in Online Learning Space

Online Learning Engagement Scale Section

Use the OSE Learning Engagement Scale to investigate students' online learning engagement, exploring four dimensions: skill engagement, emotional engagement, interactive engagement, and performance engagement.

Table 3: Online student engagement scale.

IEQ Dimensions	Questionnaire Items
Skills	Study regularly/Stay up on reading, etc.
Emotion	Put forth effort/Find ways to make materials relevant/Apply to my life, etc.
Participation	Have fun in online chats/Participate actively in forums, etc.
Performance	Do well on tests/Get good grades

In the questionnaire, each section uses a 5-point Likert scale, with levels ranging from 1 to 5, representing five levels of psychological feelings. A higher value indicates a greater degree. Generally, a score of 3.0 is defined as the average intensity value; higher scores indicate that respondents' actual learning experiences are more aligned with the situations described in the questionnaire.

QUESTIONNAIRE DATA ANALYSIS

After pre-questionnaire testing and expert review, a total of 120 questionnaires were collected in the formal survey. After excluding 9 invalid questionnaires and those from respondents who had not participated in online learning, 111 valid questionnaires remained, resulting in a valid response rate of 92.5%.

Reliability Analysis

The reliability coefficients for each item in the scale exceed 0.9, with an overall reliability coefficient of 0.949, which is less than 0.950. This indicates that the questionnaire has high internal consistency, and each item can measure the same indicator from different dimensions. This proves the reliability of the questionnaire results, allowing for further in-depth analysis.

Validity Analysis

Conduct KMO and Bartlett's tests on the overall scale. A KMO value between 0.7 and 0.9 indicates that the research data is suitable for extracting information. A value less than 0.01 in Bartlett's test indicates that the current analysis results are significant. When the significance P-value is less than 0.05 and the KMO value is greater than 0.6, it suggests that the data meets the requirements for factor analysis.

Table 4: Online learning space satisfaction table.

KMO& Bartlett's Test		
	KMO	0.897
Bartlett's Test	p	<0.01

Based on the rotated factor loading matrix, items with rotated factor coefficients greater than 0.5 are selected. Items on the same vertical axis are

considered to be in the same dimension, indicating that the factor dimensions align with the research's predefined dimensions.

DESCRIPTIVE STATISTICAL ANALYSIS

Demographic Variable Statistics

In the demographic variable statistics of the participant group, there are 50 males, accounting for 45%, and 61 females, accounting for 55%. All participants are college students, with undergraduates making up the majority at 62.2% of the total. Graduate students account for 30.6%, while those at the doctoral level or above make up 7.2%. Additionally, over 80% of participants reported engaging in discussions during classes, while those who have not participated in discussions comprise only 14.4%.

Learning Preference Statistics

Online Learning Space

The highest frequency of online learning occurs in dormitories, with a response rate of 29.1%, followed by home at 24.5%. The frequency for learning pods is the lowest, at only 1.8%. Interviews indicate that most students prefer spaces with a certain level of privacy and seclusion to meet the acoustic needs for online discussions. However, the usage frequency of learning pods that meet these needs is the lowest, indicating a need for further on-site research to understand more.

Table 5: Online learning space satisfaction table.

Learning Space	Response		Penetration Rate(%)
	n	Response Rate(%)	
Library	55	19.5	49.5
Café/Bookstore	19	6.7	17.1
Learning pod	5	1.8	4.5
Dormitory	82	29.1	73.9
Study area/Classroom	52	18.4	46.8
Home	69	24.5	62.2
Total	282	100	254.1

Learning Devices

Among these, the proportion of computer users is the highest, while the proportion of smartphone users is the lowest. Additionally, feedback on online learning using other types of devices is very limited, so they will not be included in the study. Based on interviews, most students prefer to use computers as their primary device for online learning, while also using tablets and smartphones as supplementary learning tools.

Table 6: Online learning space satisfaction table.

Learning Devices	Response		Penetration rate(%)
	n	Response rate(%)	
Computer	101	50.8	91
Tablet	58	29.1	52.3
Smartphone	40	20.1	35
Total	199	100	179.3

DIFFERENTIAL STATISTICAL ANALYSIS

Differences in Spatial Perception Based on Varying Learning Duration

In terms of spatial perception, the P-values for all dimensions are greater than 0.05, indicating no significant differences. However, the samples with online learning durations of 0–1 hour reported the lowest satisfaction with the online learning space, suggesting that the learning environment may have a significant impact on this group's learning duration. Additionally, the overall satisfaction with spatial layout is lower than the other two dimensions, indicating that when optimizing online learning spaces, greater emphasis should be placed on designing the layout of the learning environment.

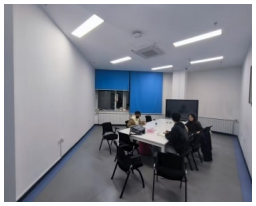
Table 7: Online learning space satisfaction table.

	Learning Duration(h)	$M+SD$	F	P
Environmental Quality	0–1	3.434±0.867	2.557	0.059
	2–3	3.595±0.699		
	3–4	4.000±0.625		
	>4	3.696±0.754		
Spatial Layout	0–1	3.395±0.842	0.227	0.877
	2–3	3.370±0.903		
	3–4	3.288±0.916		
	>4	3.583±0.684		
Furniture and Equipment	0–1	3.569±0.909	0.505	0.680
	2–3	3.692±0.829		
	3–4	3.852±0.625		
	>4	3.703±0.590		

ONLINE LEARNING SPACE SURVEY AND STRATEGIES

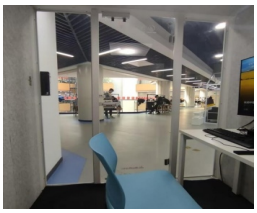
This study conducted an offline survey based on the public online learning spaces mentioned in the questionnaires and interviews. The spaces surveyed include the study area in the Zhengxin Building at Harbin Institute of Technology, seminar rooms, and library study pods. Observations were recorded over one day for each learning space, documenting student learning behaviors. Finally, optimization strategies for the functionality and overall spatial layout design of each type of space were developed based on the questionnaire data.

Table 8: Online learning space strategies.

Photos of Learning Space	Space Name	Space Factor Analysis	Optimization Strategies
	Study area	**Frequency of Use:** 52 people in the sample reported having used it; **Vacancy Rate:** Remains fully occupied throughout the day; **Thermal comfort:** With poor insulation and average comfort; **Lighting:** Good lighting, but there is glare; **Storage Space:** There are many lockers, but there are still many books placed on the seats; **Furniture:** Each set of tables and chairs can accommodate 4–6 people, but on average, three people use each table.And the furniture has a single function	1. Establish this type of space in underutilized public areas of the school, such as corridors 2. Install curtains, air conditioning, or fans to reduce direct sunlight and lower indoor temperatures 3. Install space dividers to reduce glare 4. Use smaller-sized tables and chairs, with modular tables that meet multifunctional needs to improve usage efficiency 5. Increase the number of lockers to meet storage needs 6. Increase the number of power outlets
	Discussion Space	**Frequency of Use:** 52 people in the sample reported having used it; **Vacancy Rate:** Advance reservation is required, and demand exceeds supply, but the number of users at one time rarely exceeds four; **Thermal comfort:** Indoor temperature can be adjusted, providing a high level of comfort; **Lighting:** Comfortable artificial lighting environment; **Furniture:** Fully equipped with screens, outlets, etc., and with partitions to minimize external disturbances	1. Design seminar spaces in tiered segments of varying sizes to enhance usage efficiency 2. Increase the availability of such spaces or provide alternative spaces to meet students' needs

Continued

Table 8: Continued

Photos of Learning Space	Space Name	Space Factor Analysis	Optimization Strategies
	Learning Pod	**Frequency of Use:** people have used it in the sample; **Vacancy Rate:** Remains fully occupied throughout the day; Difficult to make a reservation; **Thermal comfort:** Indoor temperature can be adjusted, providing a high level of comfort; **Lighting:** Comfortable artificial lighting environment; Space functionality: Single-purpose, designed for use by one person only **Furniture:** Fully equipped with screens, outlets, etc., However, the partitions are transparent, providing no visual privacy	1. Increase the number of study pods on campus; 2. Add curtains or blinds to enhance privacy 3. Regular maintenance to ensure the safety and hygiene of the space 4. Design a modular study pod that accommodates multiple users

CONCLUSION

Online learning has become one of the mainstream methods of education in universities, and research on online learning spaces significantly impacts the effectiveness of online learning. This study proposes the following optimization strategies for online learning spaces from three perspectives: environmental quality, spatial layout, and furniture and equipment: Optimize the environmental quality of online learning spaces to ensure good sound, light, thermal conditions, and air quality; Ensure the rationality of the learning space layout by setting appropriate sizes for storage and work areas, providing suitable space for student interactions; Arrange suitable online learning equipment and reasonable space decoration, and enhance the maintenance and management of the space.

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