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Physical Environment for Design Teaching: The Sustainable Influence of Space Factors in Interior Design on Students' Design Creativity

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Abstract:
Although the influence of the physical environment on creativity has been examined many times, the actual effect of space factors on users' creative performance has been controversial. This study examined the changes in 25 interior design students after design activities and studying under five kinds of spaces using the methods of quasi-experiment and semi-structured Interviews. The study used a mixed method. For the quantitative part, the Consensual Assessment Technique (CAT) is a tool for measuring design creativity in this study. For the qualitative part, semi-structured interviews were used in this study. The study noted that space factors primarily influenced participants' feasibility and originality, partially reflecting social and interpersonal relationships. Some of them, which have more significant effects in the short period, show the opposite results in the long term. The space has an appropriate mix of private and open areas and clear functional partitions, which is far more conducive to the long-term cultivation of creativity than the free-stretching super-order space. In the short term (one week), a more open and flexible layout is conducive to creative development, while in the long term (four weeks), the layout with clear activity boundaries and functional partitions is more conducive to design creativity development. Moreover, we found that some space factors became apparent only when interacting with time. This effect is sustainable and subtle, overlooked in many previous studies.

Keywords: creativity, space factors, interior design, physical environment.

设计教学的物理环境：室内设计中空间因素对学生设计创造力的可持续影响

摘要：
尽管物理环境对创造力的影响已被多次检验，但空间因素对用户创作表现的实际影响一直存在争议。本研究采用准实验和半结构化访谈的方法，考察了 25 名室内设计专业学生在设计活动后在五种空间下学习的变化。该研究采用混合方法。对于定量部分，共识评估技术（猫）是本研究中衡量设计创造力的工具。对于

定性部分，本研究使用了半结构化访谈。该研究指出，空间因素主要影响参与者的可行性和独创性，部分反映了社会和人际关系。其中一些在短期内具有更显着的效果，而在长期内则表现出相反的结果。空间的私密与开放区域搭配得当，功能分区清晰，远比自由伸展的超秩序空间更有利于创造力的长期培养。短期内（一周）更开放灵活的布局有利于创意发展，而长期（四周）活动边界和功能分区清晰的布局更有利于设计创意发展。此外，我们发现一些空间因素只有在与时间相互作用时才会变得明显。这种影响是可持续的和微妙的，在以前的许多研究中都被忽视了。

关键词：创意、空间因素、室内设计、物理环境。

1. Introduction

Students' divergent thinking and high cognition respond to their creativity (Scott et al., 2004). Cultivating creativity is also vital and emphasized in design education (Krathwohl, 2002). Despite this, the study has focused on the relationship between teaching methods, creative personality, and creativity, with relatively little study of the physical environment and some controversy. For example, in disciplines related to design, conventional classrooms will be gradually replaced by design studios and become mainstream teaching venues (Meinel et al., 2017; Casakin & Wodehouse, 2021). Although this type of teaching space facilitates the exchange of information and feedback, resulting in higher productivity, scholars are not unanimous on whether it supports the development of students' creativity (Vischer, 2008). Some studies point out that openness in the space determines users' creativity and that the formation of a coherent and holistic spatial layout is necessary to foster creativity (Hua et al., 2010). However, the study by Coradi et al. (2015) gives the opposite answer: private and secluded personal spaces, which avoid the interpenetration of creativity and the creative expression of each person, are not the same.

Creativity is the creation from various thinking abilities and characteristics, influenced by differences in individual factors (Hosseini, 2009). However, it is not a fixed individual talent and is influenced by specific external circumstances that can lead to its repression or development (Sternberg, 2004). A growing body of research on creativity development has shown that certain factors in the physical environment significantly impact creativity (McCoy & Evans, 2002). Compared to individual factors, such as intelligence, divergent thinking, imagination, and cognitive style, humans are more likely to enhance individual creativity by changing environmental factors (Amabile & Gryskiewicz, 1983). This is attributable to the fact that human interaction with the environment is not only physical but also psychological, which leads to subtle changes in the environment that may affect the processes of perception, recall, analysis, transformation of creativity, and likewise, the fluidity of the creative task process (Shafayi & Madani, 2010; Kasof, 1997).

Notwithstanding, the physical environment has not received enough attention in design education compared to some research on the interpersonal environment (Thoring et al., 2017). Even though such influence of the physical environment on creativity is not as significant as the individual personality, this is subliminal and sustainable for the long-term development of creativity (Dul et al., 2011; Oksanen & Ståhle, 2013). Indeed, Amabile et al. (1996), Woodman et al. (1993) also demonstrated that the combination of spatial factors and individual characteristics is more conducive to the sustainable development of creativity.

Therefore, this study focused on the influence of space factors in the physical environment on the participants' creativity, which was explored through a pre-test and two post-tests of the students' creativity to determine what factors played a crucial part. In four weeks, we replaced the original studio with five distinctive spaces where the students were instructed to do their design scheme and course activities within.

The following are the main objectives of the study:

1. To explore the space factors suitable for fostering students' creativity;

2. To identify the main dimensions or criteria for the influence of space factors on creativity;

3. To determine how space factors affect student creativity in the long term.

2. Literature Review

2.1. Space Factors and Creativity

The environment that can influence designers can be divided into interpersonal and physical environments. Physical environment factors include spatial perception and visual and auditory stimulation (Zhu, 2020). Interpersonal environment factors include brainstorming, SCAMPER, six hats, lateral thinking, and analogies. Space is defined as a generalization of a place or area for human activity in the physical environment (Galewska-Kustra, 2016). Space in this study refers to interior design involving artificially constructed indoor spaces (Casakin & Kreitler, 2008). Space factors, such as decoration, privacy and openness, furniture, view, and illumination, are the physical factors in the interior.

Earlier studies stressed that physical factors such as objects, sounds, and smells in space could influence people's creative performance, but not too markedly (Amabile, 1983; Friedman et al., 1978). For example,

an experimental study of children's creativity by Ward (1969) found that children's creativity scores did not differ between an empty room and a richly decorated room, but children who were highly creative thought more fluidly in a room that was more visually stimulating. In addition, Amabile's (1982, 1989) studies have illustrated that the effect of the physical environment on human creativity and cognitive abilities is variable.

With the development in environmental psychology, the interaction of tangible and intangible factors in space is gradually recognized, and the intangible influence affects work efficiency and product quality (Oksanen & Ståhle, 2013). Initially, scholars have focused on work efficiency, cognitive styles, and social interaction and collaboration (Wilson, 1984), noticing that space-optimized offices can indirectly stimulate creativity, resulting in a cohesive organizational culture (Haner, 2005; Kallio et al., 2015). Subsequently, it was gradually evident that there are more complex cognitions and interactions between people and space, including emotional perceptions, environmental associations, behavioral composition, and dependency styles in different spaces (Auburn & Barnes, 2006; Gustafson, 2001). These can stimulate teamwork and the development of individual creativity (Kowaltowski et al., 2010).

2.2. Space Factors for Promote Creativity

Gradually, research outcomes on the physical environment and creativity have evolved from business management to architecture and interior design. In terms of decorative materials, McCoy and Evans (2002) answer: color, walls, visual complexity, and decorative materials in an interior space all influence the designer's divergent thinking, with the user's design creativity scoring highest in interiors that mimic natural decorative materials. In contrast, Landry's (2012) study found that private space, the lighting (number of windows), and comfortable furniture were the top three factors influencing creativity, while color and material did not influence designers' creativity. Shaw (2010), Thoring et al. (2017) explain that the physical environment can influence personal creativity because it underpins the visual stimuli through which creative activity essentially takes place.

For visual stimulation, many studies have found that clever spatial structures can inspire designers and that most of the elements that inspire designers are related to nature. Dul and Ceylan (2011), based on 12 physical factors and nine social factors in an indoor environment, invented an instrument to measure the factors that affect creativity. It was found that the room plants, the overall tone of the space, and the window view of nature are all closely related to the users' creativity (Steidle & Werth, 2013).

Other scholars have delved into the impact of the intensity of lighting in interior spaces on designers' creativity. For example, Steidle and Werth (2013) found, through two controlled experiments, that designers' paintings were more innovative and atypical features in a dark room than in a bright room, and not only that, they were more fluid and took less time to think in the dark (Coradi et al., 2015).

In terms of spatial layout, flexible spaces without fixed functions allow for more office openness, which helps employees be more relaxed and focused and facilitates the exchange of ideas between team members and the generation of new and innovative ideas (Kristensen, 2004). The openness of the space is an essential criterion for the office space to foster creativity (Dul & Ceylan, 2011). Nevertheless, a case study of a media company concluded that openness in office space was not positively correlated with employee creativity. On the contrary, employees on the first floor were compartmentalized, and their private space was relatively closed, which facilitated their concentration and thus showed higher levels of creativity at work (Sailer, 2011). Thoring et al. (2017) interviewed eight experts in design education, architecture, psychology, and ergonomics to discover that the placement and shape of the furniture that invades too much public space can stifle designers' inspiration. Two experts in architecture said that buildings with interiors higher than 10 meters tend to transmit sound and sightlines to distant locations, which can easily stimulate the imagination and creativity of users (Thoring et al., 2017).

There is no relatively uniform conclusion on how the elements of interior space (light, sound, furniture) influence creativity. Perhaps, space is complex, and the interaction of multiple factors is the primary way to influence creativity. The study of a single factor does not represent the reality of the impact of space on users' creativity. Therefore, this type of research has been somewhat controversial.

2.3. Design Creativity Definition

Creative thinking is the bridge between art and science, while the design is in the middle of it, which includes aesthetic attraction and scientific innovation (Root-Bernstein, 2017). Within the field of design, creativity is one of the criteria to measure the designer's ability and plays an essential role in the whole design process; on top of that, behind the excellent scheme are the designer's novel and original ideas (Chiu & Shu, 2012; Crilly & Moroşanu, 2019; Toh & Miller, 2015).

Due to the cross-disciplinary nature of the design discipline, design creativity includes the novelty of artistic aesthetic appeal and functional and technical inventions (Han, 2020). Scholars have a vague definition of design creativity, which mainly includes artistic creativity (aesthetic appeal: form, material, space, profile, color) (Ishiguro & Okada, 2020), functional creativity (solving a specific problem and useful function) (Cropley & Kaufman, 2012), and

technical creativity (inventing multiple solutions and measuring the optimal solution among them) (Shah & Vargas-Hernandez, 2003).

Currently, industrial design, engineering design, architecture, graphic design, and apparel design are the main disciplines of design creativity research. Among them, except for engineering design, which tends to be a technically innovative study, the other disciplines tend to be defined as the pursuit of a balance between art and function (Wu et al., 2019). For example, in Watters's (2017) study, the criteria for assessing creativity in architecture were divided into novelty, usefulness, and appropriateness. Dissimilar to this, Casakin and Georgiev (2021) divided the test dimensions of creativity into usability, originality, and feasibility. In graphic design, Jeffries et al. (2018) examine the relationship between creativity and aesthetics, and the tests are more artistically inspired. In industrial design, Bonnardel and Didier (2020) emphasize ideas and constraints. In interior design, Allen (2010) argues that the evaluation of the interior designer's creativity should not only focus on the aesthetic user response (surprise, novelty, satisfaction) but also be consistent with functional rationality.

Therefore, based on the above research results, the design creativity in this study also includes artistic and functional dimensions. Moreover, since the knowledge system of environmental art major includes interior and landscape designs, students are not capable of technological innovation, so technical creativity is not measured as the content of the two experiments.

2.4. Measurement of Design Creativity

In this study, the design creativity was assessed with the product as the sole guidance. Students create design schemes in different spaces, and their creativity is evaluated based only on the quality of the design schemes. This assessment is derived from the product perspective in the four-P method (Guilford, 1950). In his study of the deep structure of creativity, Sternberg (2018) proposed the "implicit theory of creativity," which considers creativity as "a perception of the concept, structure, and development of creativity that is formed by the general public (experts and laymen) in the context of everyday life and work. It is a concept of creativity, its structure, and development, held in some form in the minds of individuals. The field experts' assessment of creativity in the field represents the authority of the field (Sternberg, 2018). On its roots, Amabile invented the Consensual Assessment Technique (CAT) and standardized the assessment process (Friedman et al., 1978; Amabile, 1996, 1999). The CAT is a subjective scoring of creativity by field experts. The scoring is flexible but revolves around novelty, originality, appropriateness, and usefulness. The CAT is scored on a 7-point or 5-point Richter scale. Moreover, the consistency of grading among the judges determines its reliability. Many studies have shown that experts (persons with a Ph.D. degree/elite/top practitioners) have much higher consistency for creativity scores than the standard (Hennessey et al., 2010).

Some classic generic creativity testing instruments have limitations in the design field. Although the classic Torrance Tests of Creative Thinking (TTCT) is well established in testing creativity, it does not fit well with the design. TTCT prefers the psychology of creative thinking and the individual's creative potential, which are not meant to substitute for the creative performance and creative product. Assessments such as the Alpha Biographical Inventory (ABI) and Design Rating Survey (DRS) are based on the subject's past achievements, experiences, and positions related to creativity, which cannot be measured multiple times over a short period to analyze it for changes.

In contrast, CAT, which is product-oriented and based on implicit theory, assesses creativity as a property in the product rather than the designer's creative thinking and creative potential (Dollinger et al., 2004). Moreover, that avoids an academic controversy on whether the designer's divergent thinking and associative ability can replace creativity. Therefore, CAT is also an instrument for measuring creativity in this study.

3. Methods

3.1. Experiment Design

Five groups of distinctive indoor spaces were used as the study site, and time was used as the independent variable to observe the changes in students' creativity within each space. The 25 interior majors were divided into five groups (5 per group) based on their pre-text CAT scores, where the average creativity scores of each group were almost equal (Table 5).

First, five groups of students completed the course tasks and the program design in different spaces, and we administered the CAT test to them again in the interim (after one week) and at the finish (after four weeks), and then performed Repeated Measured analysis on the three scores. Second, the effect of different spaces on different dimensions (novelty/originality/appropriately/usefully) within creativity was further analyzed using ANOVA (multivariate analysis). Finally, Pairwise Comparisons were conducted to obtain the differences in the effects of the five spaces on creativity.

Moreover, space influences creativity not only by formal differences but also by tangible or intangible factors (Supaporn Vithayathawornwong et al., 2003). Examples include decorative style/complexity, lighting/sunlight, view, openness, and privacy (Sicotte et al., 2019; McCoy & Evans, 2002; García-García et al., 2019). At the four-week experiment end, a

questionnaire was distributed to the participants to collect their responses on perceptions of the five factors within the space (Figure 1). After the experiment, we arranged a semi-structured interview with one student in each space. The primary purpose of the interview was to excavate the students' perceptions of the space they used to be in and what factors in the space were more fluid in conceiving the design.

3.2. Participants

There were 25 participants, all first-year interior design students at the university, 12 males and 13 females aged 18-20.

As participants, first-year students can avoid the differences in fundamental creativity caused by the significant differences in professional literacy among samples. According to related studies, creativity is strongly related to the proficiency of professional skills in the field and the career duration (Amabile & Mueller, 2008). As experience and knowledge accumulate, practitioners' judgment of what creative ideas are more suitable to be turned into creative products will become more and more mature (Hong & Milgram, 2010), which corresponds to the Feasibility in the CAT test dimension.

It is limited to interior design because students in this major are more sensitive to space factors related to interior design, such as space division, layout, decoration strategy, materials, and lighting. This is beneficial for the interviews to explore the influence of space factors on their creativity.

3.3. Measurement Materials and Procedure

Although there are many internal criteria for measuring creativity, such as aesthetic attraction and technological execution (Wojtczuk & Bonnardel, 2012), many studies on CAT by Amabile et al. found that more evaluation dimensions of CAT are more intrusive to the rater's judgment of the creativity (Jeffries et al., 2018). Therefore, the study defined the dimensions of CAT as novelty, originality, and feasibility to ensure the two most fundamental indicators of design creativity: innovation and practice. Fluency, neatness, and organization that appear in some studies are not considered.

The jury consisted of three experts, a professor of art and design, a professor of architecture, and an interior designer who has been practicing for 15 years. They passed the consistency test and met the CAT judges' criteria (Amabile, 1982, 1996). Experts, quasi-experts, and front-line elite practitioners can gain keen insight into the quality of products, especially professors and academics with Ph.D. degrees in the field, who have a voice in industry standards (Hennessey, 1994; Baer et al., 2014).

Table 1. Consistency of judges in CAT dimensions

CAT Dimensions	Definition	Inter-Raters Consistency
Novelty	The content and form of the scheme are unique, functionally reflecting a characteristic or skillful solution, and aesthetically attractive.	0.845
Originality	There is no plagiarism, or there is little trace of borrowing and imitation of existing works. The form and content of the scheme reflect the independent thinking of the author to some extent.	0.883
Feasibility	The degree to which the conception and innovation of the scheme meet the basic design specifications and the ease of realization of the scheme idea under realistic conditions.	0.864
Overall Creativity	The sum of the above dimensions	0.864

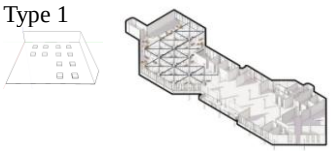
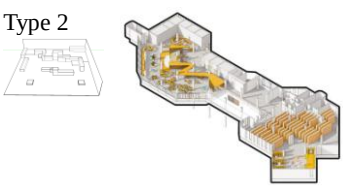
In order to identify how the five spaces influenced the students' creativity, the authors conducted semi-structured interviews with students in each space and quantitative analysis of the collected CAT index. The collected voices were transcribed into text (key content) to be coded and analyzed (Appendix 1).

After the pilot study, we found that the influence of space factors on students is divided into two stages roughly: the creative conception stage of design and the design deepening stage. We analyzed the four stages of creative design: collection of information, incubation, creative insight, and evaluation, as proposed by Csikszentmihalyi (Csikszentmihalyi & Sawyer, 2014).

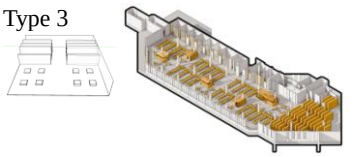
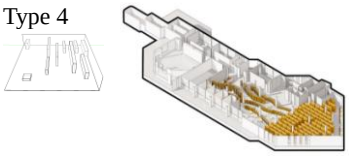
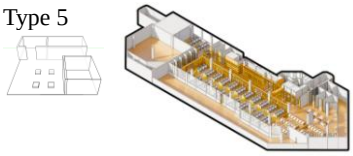
3.4. Experimental Site

The experimental site is the Bao Zhaolong Library in Shanghai, which has six floors, five of which are the main research areas. The foundation plan of each floor is almost the same, but the differences are in layout, decoration, furniture, and lighting. The most characteristic part of each floor was chosen to be the main activity area for the students during the experiment.

Table 2. Five space types in the experimental site

Space Type	Axonometric Drawing	Main Experimental Area (Field Photo)
Type 1		
Type 2		

Continuation of Table 2

Type 3		
Type 4		
Type 5		

In addition, drawing on the Pilot study, we found that decoration, view, illumination, sunlight, privacy, openness, furniture are space factors that appear more frequently. Illumination and sunlight, in most applications, appear together. In interior design, these two elements can be unified as lighting, so the questionnaire synthesizes these two factors into one (Appendix 2).

4. Result and Data Analysis

4.1. Participants' Creativity Change

A bar chart (Figure 1) shows that the initial index in CAT for each group of students did not differ much due to the grouping based on the pro-text results. However, in the test one week later, the creativity index of the T2 group became the highest (M = 8.80, SD = 1.30), while the T1 group showed a decline (M = 6.40, SD = 1.52). Additionally, compared to pro-text (M = 7.12, SD = 1.20), T5 showed the least significant increase in CAT index (M = 7.40, SD = 1.67), T3 (M = 8.00, SD = 0.71), and T4 (M = 8.20, SD = 0.45) also exhibited a relatively moderate increase, and individual differences within the T4 and T3 groups were relatively minimal.

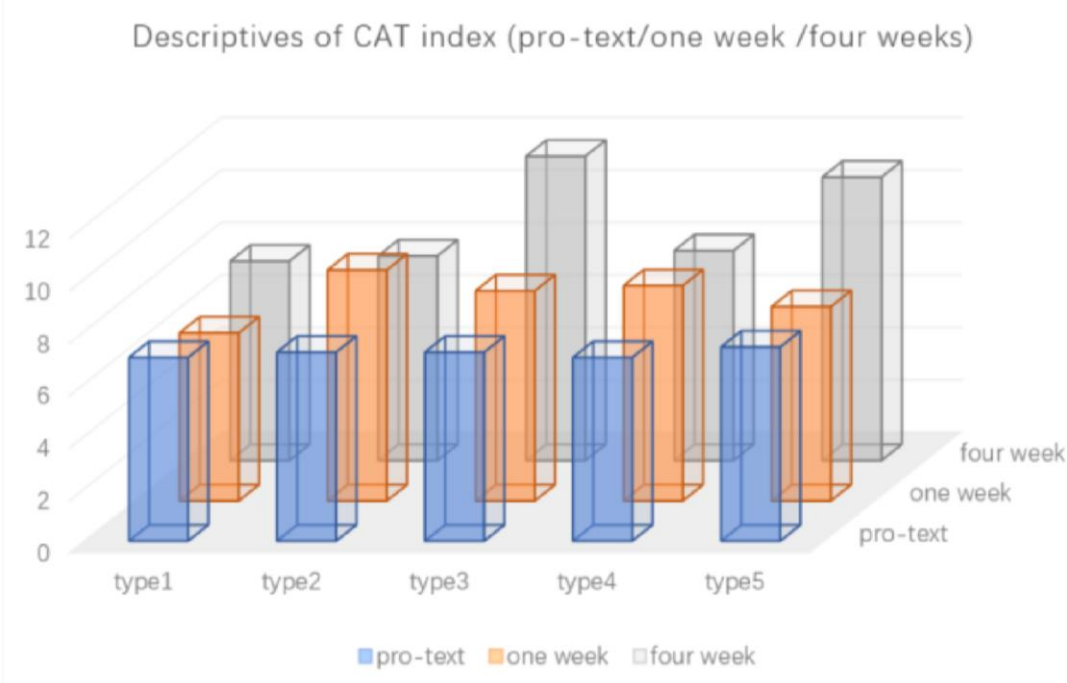


Figure 1. Descriptive CAT index

After four weeks, the differences between the groups became greater, with T3 and T5 widening. The T3 group had the highest mean score with M = 11.60 and SD=1.95, followed by T5 with M = 10.80 and SD = 1.30. It is noteworthy that T2, which had the highest score in the first week, decreased after four weeks. T4 showed almost no change from the last score (M = 8.10, SD = 1.58). The T1 (M = 7.60, SD = 1.14) group increased at the end.

In the ANOVA between the groups (Table 6), there was no statistical difference in the first week (F = 2.276, P > 0.05), and this difference was revealed in the fourth week (F = 8.92, P < 0.01) (Table 3).

Table 3. ANOVA between the CAT index and space (between the groups)

		Sum of Squares	*Df*	Mean Square	*F*	*Sig.*
Pro-text	Between Groups	.240	4	.060	.035	.997
	Within Groups	34.400	20	1.720		
	Total	34.640	24			
One week	Between Groups	16.560	4	4.140	2.760	.056
	Within Groups	30.000	20	1.500		
	Total	46.560	24			
Four weeks	Between Groups	71.360	4	17.840	8.920	.000***
	Within Groups	40.000	20	2.000		
	Total	111.360	24			

Notes: * p < .05, ** p < .01, *** p < .001

Table 4. Tests of within-subjects effects on time and space

	Source	Type III Sum of Squares	*df*	Mean Square	*F*	*Sig.*	Partial Eta Squared
Time	Greenhouse-Geisser	52.020	`	52.020	30.244	.000***	.602
	Lower-bound	2.407	1	2.407	3.967	.060	.166
Time * Space	Greenhouse-Geisser	33.080	4	8.270	4.808	.007**	.490
	Lower-bound	22.627	4	5.657	9.324	.000***	.651
Error (time)	Greenhouse-Geisser	34.400	20	1.720			
	Lower-bound	12.133	20	.607			

Notes: * p < .05, ** p < .01, *** p < .001

According to Tests of Within-Subjects Effects (Table 4), the interaction between space and time (F = 9.324, p < 0.001) was much higher than the independent effect of time (F = 3.967, p > 0.05), and, for the four-week results only, this effect increased with the accumulation of time. This supports the statements of some scholars, such as Amabile and Cropley. They have suggested that the development of creativity is a long-term process. The construction, selection, and deepening of ideas requires divergent thinking in conjunction with convergent thinking and is supported by a domain-relevant skill (Cropley, 2006; Dollinger et al., 2004). The Wallas Art of Thought mode also suggests that creativity is formed in stages, where external stimuli act at different stages of creativity formation (Wallas, 2016). In experimental designs, most studies did not consider temporal effects. As Steidle and Werth's (2013) lighting effects on creativity, they only considered the results of a single test with participants in different luminance environments and did not include a time variable to observe its long-term effects.

4.2. The Variation of CAT Dimension

After one week, the effect of space on overall creativity was not significant (F = 2.76, p > 0.05). However, from the change of each dimension of CAT, we found that the impact on originality was the most significant (F = 4.38, p < 0.05). After four weeks, feasibility was most significantly affected (F = 5.83, p < 0.01), followed by originality (F = 5.44, p < 0.01), while novelty remained little changed (F = 1.84, p > 0.05) (Table 5).

Table 5. ANOVA of the correlation between CAT dimensions and space

		Novelty	Originality	Feasibility	Overall Creativity
Pre-text	Mean Square	.060	.060	.160	.060
	F	.176	.231	.333	.035
	Sig	.948	.918	.852	.997
One week	Mean Square	.260	1.840	.160	4.140
	F	.722	4.381	.320	2.760

Continuation of Table 5

	Sig	.587	.010*	.861	.056
Four weeks	Mean Square	1.140	1.960	3.500	17.840
	F	1.839	5.444	5.833	8.920
	Sig	.0161	.004*	.003**	.000***

Notes: * p < .05, ** p < .01, *** p < .001

In Table 5, after one week, the effect of space on overall creativity was not significant ($F = 2.76$, $p > 0.05$). However, from the change of each dimension of CAT, we found that the impact on originality was the most significant ($F = 4.38$, $p < 0.05$). After four weeks, feasibility was most significantly affected ($F = 5.83$, $p<0.01$), followed by originality ($F = 5.44$, $p < 0.01$), while novelty remained little changed ($F = 1.84$, $p > 0.05$).

In hindsight, among the three dimensions, feasibility has the most significant impact. Feasibility can be interpreted as the ability to select and transform imaginative ideas into suitable programs, which requires domain-relevant skill as a foundation. This ability is inseparable from long-term practical experience. What is more, the interaction effect of time and space further confirms this conclusion (Table 5), i.e., feasibility is more significant with time ($p < 0.001$, $\eta^2 = 0.436$)

In Table 6, originality is more significant with space and time ($p < 0.01$, $\eta^2 = 0.150$). It can be inferred that the long-lasting effect of spatial form on creativity mainly acted on originality. Feasibility was more correlated with students' learning time and only secondly under the influence of space. In contrast, novelty was hardly affected ($F = 1.839$, $p > 0.05$). In other words, the experts recognized the non-copying or non-imitating character of the design scheme, but the innovativeness and aesthetic value were not influenced. In terms of the formation process of creative product, perhaps the difference in space influence is concentrated in the creative insight and evaluation stages of creative development.

Table 6. The impact of time and space on feasibility

	Source	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	***Sig.***	**Partial Eta Squared**
Time	Greenhouse-Geisser	9.787	1.870	5.234	15.453	.000***	.436
	Lower-bound	9.787	1.000	9.787	15.453	.001**	.436
Time * Space	Greenhouse-Geisser	8.880	7.480	1.187	3.505	.005**	.412
	Lower-bound	8.880	4.000	2.220	3.505	.025*	.412
Error (time)	Greenhouse-Geisser	12.667	37.398	.339			
	Lower-bound	12.667	20.000	.633			

Notes: * p < .05, ** p < .01, *** p < .001

Table 7. The impact of time and space on originality

	Source	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	***Sig.***	**Partial Eta Squared**
Time	Greenhouse-Geisser	2.427	1.824	1.330	3.534	.043*	.150
	Lower-bound	2.427	1.000	2.427	3.534	.075	.150
Time * Space	Greenhouse-Geisser	9.173	7.296	1.257	3.340	.007**	.400
	Lower-bound	9.173	4.000	2.293	3.340	.030*	.400
Error (time)	Greenhouse-Geisser	13.733	36.479	.376			
	Lower-bound	13.733	20.000	.687			

Notes: * p < .05, ** p < .01, *** p < .001

Based on this, it can be determined that the five spaces mainly influenced the students' independent thinking and originality, enhancing their creativity.

4.3. The Differences in the Influence of Five Spaces on Creativity

From the analysis results of Pairwise Comparisons, only T1 and T3 ($p < 0.01$) and T3 and T5 ($p < 0.05$) differed from each other. When comparing the differences in spatial form, T1 lacks the semi-open space formed by the wall and bookshelf enclosed by T3. Compared to T3, the opening of the T1 space is more uncomplicated and straightforward.

T5 is too absolute in the division of space compared to T3. Since T3 is a space formed by dividing with bookshelves and furniture, T5 is a space formed by a partition with a combination of wood and glass, so the space boundary of T5 is much clearer, but this is not the same as privacy. In privacy, in addition to the spatial isolation, the distance between people should be considered, and this distance, in T5, is magnified.

Table 8. The impact of time and space on originality

Space (I)	Space (J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Type 1	Type 2	1.200	.592	.056	-.034	2.434
	Type 3	1.933*	.592	.004**	.699	3.168
	Type 4	1.200	.592	.056	-.034	2.434
	Type 5	.467	.592	.440	-.768	1.701
Type 2	Type 3	.733	.592	.230	-.501	1.968
	Type 4	.000	.592	1.000	-1.234	1.234
	Type 5	-.733	.592	.230	-1.968	.501
Type 3	Type 4	-.733	.592	.230	-1.968	.501
	Type 5	-1.467*	.592	.022*	-2.701	-.232
Type 4	Type 5	-.733	.592	.230	-1.968	.501

Notes: * p < .05, ** p < .01, *** p < .001

4.4. Results of Questionnaires and Interviews

Among the long-term (four weeks) effects, privacy (M = 3.40, SD = 0.374) was more important than openness (M = 3.00, SD = 0.490). Although participants in the T5 group consistently complained about the openness of the space they were in, the content of the interviews and the final CAT index showed that T5 participants benefited from the privacy of the space. In the short term (one week), the influence of openness was more significant than that of privacy. For example, in the first week, the openness of the space was significantly higher in the T2 and T4 groups, with higher CAT scores than in the other groups (Figure 2).

Functional zoning is a crucial factor that participants mentioned but did not realize. Especially in terms of long-term effects, the clearer the demarcation between rest and work areas, the more conducive to creativity. For example, the T1 group, which also has a high degree of openness, has no clear working area, so participants are in a more restless state for a long time, which hinders the continuous development of creativity. Except for one person, almost all of the participants in the TI group said that a sense of restlessness persisted and became more pronounced the closer they got to the deadline. Besides, a few participants in the T2 and T4 groups also reported this problem, but their response to it was more moderate. Since T3 can meet open and private spaces and has clear functional partitioning, the T3 group scored the highest under the long-term effect.

The view was at a higher perceived level in all five spaces (M = 2.84 SD = 0.654), with T1 and T3 having a larger field of view in all five spaces, especially the T3 group, which scored much higher than the other groups (M = 3.80, SD = 0.654) due to the continuous windows to provide a vast scenery of the outdoors. Similarly, participants at T2, T3, and T5, described how plants outside the window and a distant landscape helped them relax and open their minds, which is consistent with the findings of Hicks et al. (2020). In addition, T1 and T2 participants indicated that the view of the room also influenced their creativity, the more open the view, the easier it was to empty the brain, and more inspiration followed.

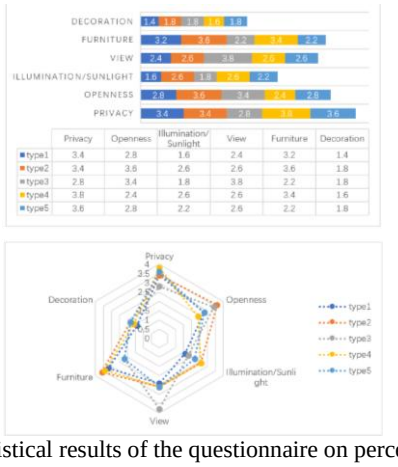


Figure 2. Statistical results of the questionnaire on perceptual space factors

Furniture was also the factor that appeared more frequently in the interviews (M = 2.92, SD = 0.672), where the form of the bookshelf, the way the table and chairs were combined, the shape of the table, and the comfort of the chairs were the main elements involved. At the same time, T2 and T4 participants always use the word "bookshelf" when it comes to the privacy of the space. We found that the essence of Furniture is still the issue of privacy and openness. For example, after brainstorming, participants prefer to rest, think, and further organize their thoughts in the area composed of bookshelves. The space enclosed by irregularly shaped bookshelves gave the participants in T4 a section with both openness and privacy, which led to a somewhat more significant influence in T4 than in T2.

Regarding illumination, only some participants considered its influences effective (M = 2.16, SD = 0.456). Interestingly, sunlight was mentioned when referring to view, the broader space outside the windows of T1 and T3, which is accompanied by strong sunlight shining into the room during the midday hours. Attitudes differed among participants, with some seeing no impact and others thinking it was a distraction. For example, a participant in the T5 group said that some seats occasionally experienced light pollution, but when she moved away from them, it did not affect her.

The influence of decoration on participants' creativity was minimal (M = 1.68, SD = 179). At least in these five spaces, there were no decisive factors affecting creativity. Several interviewees indicated that the wood materials, warm colors, and minimalist decorative style were conducive to the creative expression of their design solutions. The library's relatively uniform decoration and mild style do not distract the users' attention from the realistic interior space, so the students do not feel strongly about decoration.

5. Conclusion

From the perspective of the physical environment, this study examines the influence of five types of space (different space layouts) and seven space factors on the creativity of interior design students. After categorizing and summarizing the contents of the interviews, we find that the essence behind some space factors is interpersonal and social relations. The essence of keywords such as "relaxed," "calm," "isolated," "communication," and "restlessness," which appear in the interviews, is inseparable from the influence of human interaction on the psychological aspects. Perhaps it is not appropriate to divide the environmental influences on creativity into physical and social factors in an absolute sense. The space in the physical environment carries an interpersonal and social atmosphere to a large extent, changing the state of interaction between the users of the space and giving them a change of heart, thus suppressing or stimulating the users' creativity. Some space factors act directly on mental or visual intuitions, such as view, illumination, and decoration. These feelings directly influenced the students' mental condition, thus affecting their recall, cognition, analysis, and creativity. Certainly, most of the spatial elements contain the joint action of both aspects; they are more likely to be noticed by the users and have a more significant development or suppression of creativity than the single-acting factors, which supports Amabile's (1983, 1996) findings.

Although privacy is a crucial factor, its effect is different for various forms of space composition. As T5 is an example, the feeling of privacy is clear and dry in a space divided by partitions and walls. T2 and T4 belong to the hyperspace of the private experience, that is, through the material, furniture, and horizontal height difference, the formation of dislocation, merging, and superposition of space feeling occur (Gong, 2009). Such spaces as T2 and T4, on the other hand, belong to the privacy experience of hyperspace, the feeling of dislocation, merging, and superposition of spaces formed by means of materials, furniture, and horizontal height difference. While this increases the aesthetic appeal and enjoyment of the space, it also detracts from the participants' feelings of privacy. Combined with the post-test CAT index changes, the long-term impact of this spatial form on creativity is not significant enough. In contrast, T3 has complete separation by partitions and walls and flexible division by materials and furnishings.

The notable point is that the concealment and weakening of boundaries do not affect the area's functionality; it ensures continuity and openness in the space, thus enhancing the participants' creativity. This is reflected in T2 and T3. Thus, to a certain extent, the ingenious functional partitioning reinforces privacy or openness. However, the experimental results show that the long-term effect of such interior spaces, which dissolve spatial partitions and enhance spatial dialogue through boundary concealment or weakening, does not apply to the long-term cultivation of creativity.

In general, due to the short duration of the previous studies, the stimulus satiation and boundary effects caused by time variables were ignored, which led to their conclusions being limited. However, from the perspective of the physical environment, this study found that spatial openness and interactivity were not the main factors in developing design creativity, which is different from previous research conclusions. Design creativity is the embodiment of the joint action of many aspects. The space has an appropriate mix of private and open areas and clear functional partitions, which is far more conducive to the long-term cultivation of creativity than the free-stretching super-order space. The content of the interviews suggests that it is only complementary to the exploration of creative ideas.

However, it is sustainable and subliminal, which will facilitate the development of creativity in design education in the long term and lead to better application of interior design in the teaching environment.

6. Limitations and Further Study

This study has some limitations. First, we chose an actual indoor space (library) without a specially built experimental site, so many variables could not be effectively controlled. We could only ensure the relative consistency of the underlying planes. Second, participants in each group were not tested for open-mindedness and personality, which, in some studies, have shown to impact the development of creativity (Zhu et al., 2019). Third, to achieve the actual design outcomes, we did not imply or instruct participants on scheme creativity, but, according to relevant findings, intrinsic and extrinsic motivations also influence creativity to some extent (Kaufman & Sternberg, 2010; Carmen et al., 2019).

Therefore, in the near future, the researchers plan to build a closed laboratory to strictly control variables, quantify specific details such as space form, boundary, plane layout, and lighting, and further explore the impact of subtle changes in each element on creativity. This will facilitate a deep understanding of the relationship between space factors and creativity and guide the better application of interior design to teaching environments.

Appendix 1

Interview Questions-Guiding Direction- Purpose-Pilot study

Interview questions — Students in Five Types of Space	Further Guided Content	Main Purpose of Question	Pilot study preliminary Evaluation of Questions
1. How did this space affect your programming process compared to your previous studio? 2. Do you think this space will help you in some way to deepen the creativity or ideas of your scheme?	1. What are the specific influencing factors 2. Positive and negative effects 3. At which design stage was it influenced? 4. What is the way of influence?	To explore what factors in space influence students' creativity	This is effective for understanding participants' perception of the influence of the space where they are located

Appendix 2

The questionnaire on students' perceptions

Name: **Space:**

Assess the influence of the following factors of the space on the creative design.

	Rate your answer				
	Low	Medium low	Medium	High	Very high
Decoration					
View					
Illumination/Sunlight					
Privacy					
Openness					
Furniture					

What other factors were helpful to your creative design? Please elaborate.	

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