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Smart classroom learning environment preferences of higher education teachers and students in China: An ecological perspective

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A R T I C L E I N F O

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A B S T R A C T

By evaluating learners' perceived preferences for the learning environment, we can understand the important characteristics and better improve the learning environment, ultimately to provide great potential for the optimization of teaching practice. Seeing that the current research pays less attention to teachers' and students' preferences for the space environment simultaneously, based on the survey of 1937 undergraduates and 107 teachers from a university in central China, this study aims to explore their preferences for smart learning environment. Based on the ecological theory and research results of the existing learning environment, this paper constructed an ecological model and a conceptual model of learning space preferences. An empirical study was conducted to explore the impact of sociodemographic variables on personal spatial preference. The results showed that teachers and students had a positive attitude towards the smart learning environment, and gender, age, grade, subject category and other variables had limited impact on spatial preference.

1. Introduction

Technology is considered to be a powerful driving force for educational reform and innovation. In 2017, EDUCAUSE Center for Analysis and Research identified the learning environment supported by technology as the strategic investment of colleges and universities [1,2]. Educational service industry institutions, including colleges and universities, can survive in this era of digital revolution only through certain transformation, and smart classrooms can become a bridge to the future [3]. Therefore, with the rapid development of intelligent technology, more and more universities begin to build smart classrooms to improve the learning environment. They believe that smart classrooms can play an important role in efficiently spreading knowledge [4], adapting to new learning paradigms and teaching methods [5,6], obtaining learning resources [7], improving teaching interaction [8,9] and collecting feedback data [10].

Smart classroom is a face-to-face physical classroom. It applies advanced educational technology to education and is committed to improving teachers' ability to promote students' learning and students' ability to participate in formal education, teaching and learning experience, which is far beyond the possibility of traditional classroom [11,12]. In previous relevant studies, scholars have

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also discussed the important technical features of different types of smart classrooms, which usually include interactive whiteboards or similar digital display interfaces (such as touch screens) [13,14], large projection displays [15], wireless display and shared screens [16], cameras and recording and broadcasting equipment, which support synchronous and asynchronous video transmission, Near Field Communication (NFC) system [11], Internet of things equipment (collect CO2, temperature, humidity, noise and other environmental data) [17]. In addition to various technologies and hardware devices, education management software is usually used to solve related problems in smart classrooms. For example, learning management system is used to provide personalized learning experience [10], which enables students to personalized control their own learning time, place, content and speed [18]. At the same time, specific software systems can also be developed to enrich the smart classroom. Yue proposed an "open smart classroom" synchronous distance learning system to solve the problems of remote software control, file upload and adding new remote classrooms (including mobile devices) to synchronous live courses [19]. Therefore, with the introduction of information and communication (ICT) technology, smart classroom has expanded from physical environment to network virtual environment.

It is imperative to reconstruct a resource rich higher education learning environment mediated by technology that meets the learning needs of students, conforms to modern learning methods, and is conducive to promoting the social interaction between students and teachers, because this space is related to students' well-being, learning process, learning motivation and academic achievement [20–22]. At present, the research on smart classroom in higher education mainly discusses the impact of smart classroom on students' achievement and learning performance [23–25]. However, there are few studies on the preferences of teachers and students in the learning environment of smart classroom. Learning environment preference refers to the attitude or liking of learners for many elements such as learning activities, learning resources, software and hardware equipment in the environment after having the learning experience in the environment. Fraser pointed out that researchers can understand the important characteristics of special learning environment by measuring and evaluating learners' perceived preference for learning environment, so as to better improve the learning environment and provide great potential for the optimization of teaching practice [26]. Li investigated the preferences of 462 pre-service teachers with one year's learning experience for the constructivist smart classroom environment, and explored the relationship between connectivity and other key learning environment characteristics [14]; Beckers investigated the learning space preferences of 697 students majoring in business administration, and analyzed the differences of students' personal background information [27]. Although a large number of experiments have been carried out on the new learning environment in higher education, the current research pays less attention to the analysis of teachers' and students' preference for the spatial environment. As the main battlefield of teachers' teaching, it is necessary to let teachers' voice participate in the research of learning environment.

Looking at the learning environment from the perspective of ecology, we can regard the learning environment of smart classroom as an ecosystem formed by the interaction between students, teachers and managers in a certain physical space as well as social space and ecological factors in resource space. In this ecosystem, each participant can adjust each other through dynamic feedback to achieve the most adaptive state. Barron defined learning ecology as "a set of situations found in physical or virtual spaces that provide learning opportunities, including the unique configuration of resources and interactions" [28]. Luckin constructed a learner-centered resource ecological model so that learners can make use of a wider range of resources to best support their learning needs in the learning environment [29]. Westberry discussed the knowledge construction of learners mediated by asynchronous online technology from the perspective of ecology. The research results highlighted the importance of establishing a resource rich learning environment for promoting social interaction and ability perception [30]. Yang and Yu integrated the overall elements of the learning environment from the perspective of ecology, thus building a ubiquitous learning ecosystem [31]. Johnson put forward the ecological framework of human learning and development in the interactive learning environment, where the interaction between and within the system provided more opportunities for human learning and growth [32]. Damsa understood the learner-constructed space from the perspective of ecology, so as to provide framing conditions for educational contexts and pedagogical arrangements [33]. Scholars are fully aware that learners are the starting point of ecology and that individual background, resources, technology, learning environment and other components of learning ecology have an important impact on learners to complete specific learning purposes [29,34]. However, the current learning situation is becoming more and more extensive and learning methods are diversified [35]. Higher education is facing a major challenge of providing learners with a continuous learning environment and learning opportunities through technology [36]. The demand of contemporary college students for the integration of multiple learning spaces is that they can not only sit in the physical environment and listen to lectures, but also use the intelligent terminal to query the relevant knowledge mentioned by teachers on the network anytime and anywhere, and participate in peer interaction and knowledge sharing in the social space according to the teaching/learning needs. We should further develop and optimize the learning environment [37].

In order to support the successful development of this rapidly expanding alternative classroom environment, based on the ecological theory and the research results of the existing learning environment, this paper constructed an ecological model of smart learning environment (physical space, resource space and social space) and a conceptual model of learning space preferences. An empirical study of large samples was conducted to deeply understand the spatial preferences of different groups through the difference analysis, so as to better tap the shortcomings and improvements of the current smart learning environment. Therefore, this study mainly starts from the following three research questions.

Q1. Whether the smart learning environment model can be constructed based on the ecological theory?

Q2. How to construct a conceptual model of learning space preferences from the perspective of physical space, resource space, social space and sociodemographic characteristics?

Q3. Whether teachers and students have different preferences for the smart learning environment?

2. Theoretical background

Smart classroom uses ICT technology to create a superior teaching environment [3]. Li identified four characteristics of smart classroom: first, smart classroom is a technology rich learning environment that fully combines physical and virtual space. Second, the smart classroom provides information and communication technology tools, learning resources and interactive support for a variety of teaching activities such as personalized learning, group learning, inquiry learning, collaborative learning and mobile learning. Third, the smart classroom can store, collect, calculate and analyze learners' data in order to make optimal teaching decisions. Fourth, the smart classroom is an open environment that brings learners to a real learning environment [38]. Palau and Mogas proposed three dimensions that must coexist in the smart classroom and smart learning environment: technology, environment and implementation process, which are interrelated [39]. Beckers discussed the learning space preference of college students from the physical and social dimensions [27]. Therefore, on the basis of previous studies, combined with the development status of smart classroom and the connotation of ecology, this paper will explore the learning environment of smart classroom from the three dimensions of physical space, resource space and social space.

2.1. Physical space

Many studies involve the physical aspects of the learning environment that may affect learning and teaching, whose attributes such as air quality [40], overall layout [41], space design [42], ICT facilities, environmental perception (location, temperature, humidity, CO2, light, etc.) [40] will affect students' perception of the learning environment. Therefore, the physical environment is an important factor to be considered in the design of smart classroom [43], because the elements in the physical space can support the presentation of resources and provide a place for the storage and management of various resources. As the carrier of message transfer, physical space also provides learning environment support for social space. Its constituent elements include infrastructure, teaching equipment and sensing equipment. The infrastructure mainly includes the spatial layout of physical environment [12], tables and chairs [3], ventilation and lighting, power supply and distribution [44] and other equipment. Teaching equipment is mainly used to realize the functions of teaching content presentation [45], communication and cooperation, knowledge transfer [4], such as smart display equipment, smart terminal, augmented reality (AR)/virtual reality (VR) equipment, audio and video equipment, etc. [11,19,46,47]. Sensing equipment is the main channel to obtain data in the smart learning environment. It senses, identifies and collects various data in the environment (CO2, temperature, humidity, noise and other environmental parameters) through various sensor [17,42,48,49].

2.2. Resource space

Resource space, a main place for learning activities can construct and share resources across time and space. In terms of information resources, relevant studies have shown that providing a variety of different information sources and formats can improve critical thinking [50,51]. Therefore, learning through the combination of multiple physical and digital resources determined by students or teachers is an important feature of smart learning environment [12]. Teachers and students can upload and share various educational resources, as well as download, use and evaluate these educational resources. With the help of data mining, analysis, guidance and optimization of elements in physical space, resource space can provide resources and data for social space user groups. At the same time, it also acts as a link of social relations, that is, taking resources as a link to form a community of people with the same or similar learning needs and interests, encourage cooperative learning. It should be noted that participating in cooperative learning can make participants share the responsibility of determining relevant learning contents more equally and build a large interconnected interpersonal network [12,52].

2.3. Social space

The teaching group in the social space uses the elements in the physical space to carry out teaching and learning activities, and is responsible for the production, consumption and decomposition of resources. Among them, the production of resources includes the production and innovation of resources to promote knowledge sharing and knowledge regeneration [52]. The consumption of resources refers to the absorption, transformation, evaluation and feedback of resources by teaching groups. The decomposition of resources is the processing and elimination of invalid or redundant resources in the resource space to reduce the repeated development of low-quality resources. Smart classrooms must allow various types of interaction and interconnection [10]. Social space represents the sum of all relationships in the teaching group. Systems such as e-learning space, teacher-student interaction platform, teaching management service and learning evaluation platform create an integrated, three-dimensional and virtual reality integrated communication and interaction environment for the user group, and provide public or personal on-demand services.

3. Conceptual model

3.1. Construction of ecological model

The term "ecology" has been associated to learning since the beginning of the new Millennium through the work of Brown, defining it as "an open, complex, adaptive system comprising elements that are dynamic and interdependent" and involving overlapping communities of interest in constant evolution and largely self-organized [53]. As a relatively new concept, it has received extensive attention in recent years [54]. The research on learning environment is receiving global attention because it may provide some technical ideas that are valuable for effective teaching activities [55]. Using ecological theory to study the smart learning environment, it also has the characteristics of a complete ecosystem. The ecological smart learning environment in this paper creates a smart, resource-saving, personalized and adaptive learning environment, so as to realize the sustainable development of educational ecology. This environment is a kind of learning space jointly constructed by learners, which is created through learners' practice, interaction, and activities, and provides convenience for teaching. In the process of jointly constructing a learning space, utilizing various resource ecosystems, whether intellectual, relational, or digital materials, has become an organic, iterative, and dynamic effort for learners [56]. Drawing on the ecological theory and the research results of the existing learning environment, and based on the above analysis of the ecological characteristics of the smart learning environment, this paper constructs the ecological model of the smart learning environment as shown in Fig. 1.

The outer ring of the model consists of the social ecosystem and the external environment supporting the smart learning environment. There is the input, output and exchange of material, energy and information between the two. Economic and ecological systems are interlinked complex adaptive systems [57,58], hence they co-evolve with one another, as changes in ecological systems affect those in economic systems, and vice versa. In particular, the main bodies of the economic system (individuals, institutions and governments) compete for resources by utilizing the services provided by the natural capital of the ecosystem to optimize their objectives - utility, profits, and social welfare [59]. For example, the material, energy and information in the social ecosystem are transformed into various teaching and learning needs of the participants in learning activities through the smart learning environment. Participants feedback the acquired knowledge, skills and innovation to the social ecosystem through learning activities, so as to contribute to the development of the ecosystem.

The middle ring of the model is composed of normative environment and design principles of smart learning environment, which are the guarantee to maintain the sustainable and benign development of smart learning environment. Normative environment undertakes the responsibility of maintaining the atmosphere and order of the learning environment, mainly including student behavior, learning norms and learning modes. The design principle of smart classroom aims to bridge the gap between students and teachers [45], help teachers teach more effectively and make the environment more conducive to teaching and learning. Therefore, the design principle is not only a mechanism to restrict the construction of learning environment, but also a measure to resist the interference of external environment, so as to promote the internal dynamic balance of smart learning environment.

The inner ring of the model includes physical space, resource space and social space, which is the core of the ecological model of smart learning environment. Moreover, it provides technical support for the smart learning environment and is the guarantee of its sustainable development, in which all spaces are interrelated and affect each other.

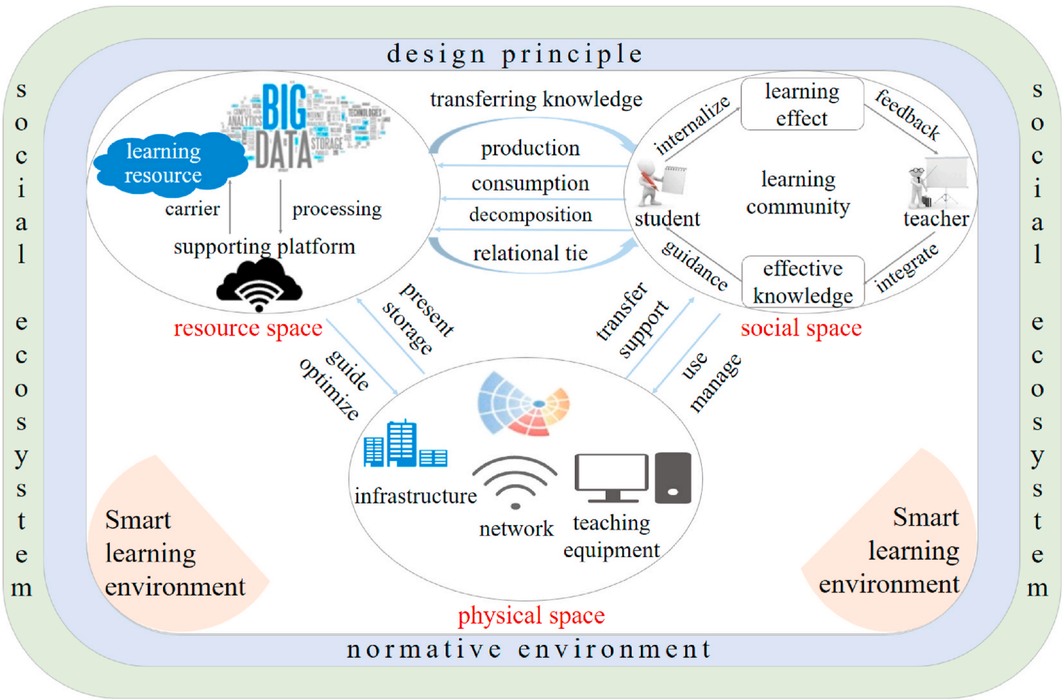

Fig. 1. Ecological model of smart learning environment.

3.2. Conceptual model of learning space preferences

The ecological model of smart learning environment - physical space, resource space and social space will affect teachers and students' preference for personal learning space. Teachers are the implementers of teaching, students are the main body of individual learning, and they have different needs for space preference. Relevant studies have also shown that sociodemographic characteristics, such as gender, age, grade and other sociodemographic characteristics, can also affect individual learning space preferences [27]. Therefore, in order to further understand the relationship between the physical space, resource space and social space of smart learning environment and the characteristics of teachers and students, starting from the demographic variables such as teachers' age, gender and subject category, and demographic variables such as students' gender, grade and subject category, this paper constructs a conceptual model of learning space preferences. As shown in Fig. 2.

4. Case design

The ecological model of smart learning environment integrating physical space, resource space and social space has a wide range of applications. According to the teaching needs and actual conditions, the model can provide a variety of learning environment construction cases. The classroom is a space for teaching and learning. The traditional multimedia classroom is gradually changing into a smart classroom with rich technology. Many schools and institutions have explored the construction and application of smart classroom. Ming Chuan University, an international university in North Taiwan, has several context-aware smart classrooms. The number of occupants in a classroom is usually between 60 and 80 [3]. Smart classrooms equipped with advanced multi-functional and mobile technologies have been built in primary and secondary schools in an underserved area in South Korea [60]. Combined with the characteristics of virtual reality interaction, State Grid of China Technology College designed and constructed virtual reality interactive classroom based on deep learning algorithm [61]. Central China Normal University (hereinafter referred to as the "school") has built 60 smart classrooms and has been fully put into use. The term "normal university" describes teacher-training and preparation institution of higher education. It is different from other schools in the following aspects: In terms of quantity, the number of smart classrooms in the school is relatively large, with a total of 60, which are divided into small classrooms, medium-sized classrooms and large classrooms. In terms of technology and function, although each classroom adopts roughly the same technology and function, classrooms of different sizes and types has been customized according to their characteristics, so as to realize different functions and meet the needs of different types of courses. From the perspective of dimension, the smart classroom of the school is not only limited to the renewal and accumulation of technology in the physical space, but also expanded to the resource space and social space, so as to improve the experience of teaching and learning from multiple dimensions. This section takes this as an example to introduce the practice path of the ecological model of smart learning environment, as shown in Fig. 3.

Physical space includes infrastructure, teaching equipment and systems, and sensing equipment, which is the basic support of the whole smart classroom. To be specific, (i) Infrastructure includes classroom space, dynamically combined tables and chairs, power supply and distribution, decoration layout, controllable lighting, curtains, air conditioning and fresh air system, etc. (ii) Teaching equipment and system are the hardware conditions to ensure the smooth development of teaching, including interactive whiteboard, projector, multiscreen teaching system, student intelligent terminal, network equipment, recording and broadcasting equipment and system, Internet of Things centralized control system, multi-touchscreen, multimedia desk, public address equipment, teacher assistant, VR/AR/mixed reality (MR) equipment, electronic class card and electronic clock. (iii) Sensing equipment is the core channel to obtain data in the smart classroom, including High Definition (HD) camera, face recognition camera, temperature and humidity sensor, particulate matter 2.5 (PM2.5) sensor, microphone, all-in-one card reader, CO2 sensor and illumination sensor. The collected data includes classroom environment data, teaching process data, identity recognition information, etc. The physical space layout of the smart classroom is shown in Fig. 4.

Resources are the core elements of implementing smart teaching in smart classroom. This case adopts cloud architecture technology to provide various application services in smart teaching, course management, user social interaction and smart resources through unified platform, unified authentication and unified data, and finally realize the unified deployment and hierarchical management of multi-level cross domain platforms. The teaching platform independently developed by the school provides rich resources for the resource space, such as rich media materials, high-quality question bank, classroom environment data, equipment use data,

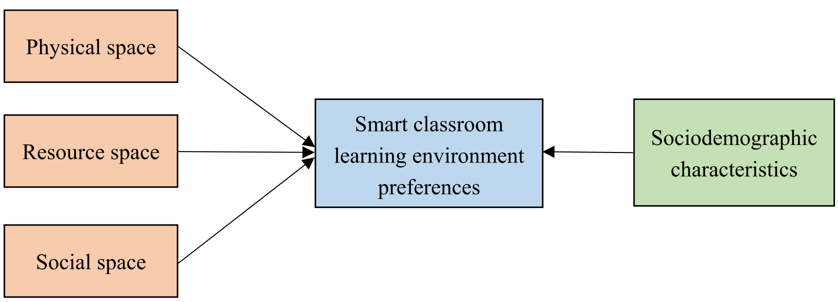

Fig. 2. Conceptual model of learning space preferences.

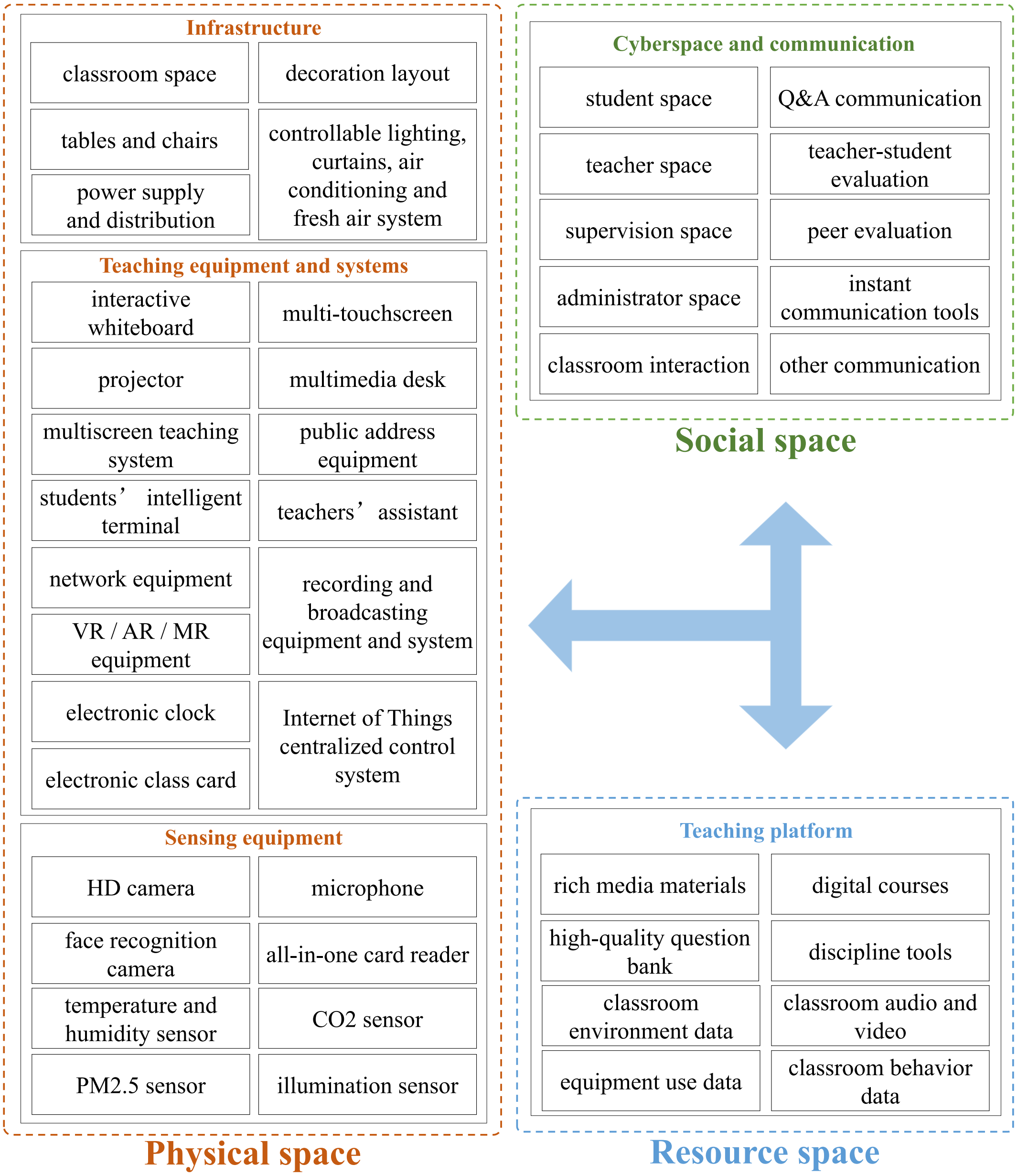

Fig. 3. Practice path of ecological model of smart learning environment.

digital courses, discipline tools, classroom audio and video and classroom behavior data. At the same time, the teaching platform can also gather a large number of external high-quality resources, and comprehensively carry out the blended teaching of online and offline connection, in class and extracurricular combination and entity virtual integration through one person and one space for teachers and students. A large number of excellent teachers in the school have actively carried out fruitful innovative practice of information-based teaching, and formed mature models such as "1 + N" (one teacher with multiple classrooms) and "1 + M + N" (one teacher with multiple schools and multiple classrooms) blended classroom under the information-based environment, which has accumulated a great amount of excellent practical and innovative achievements, significantly promoted the sharing of high-quality teaching resources, realized accurate learning situation diagnosis, learning process tracking, learning effect evaluation and personalized resource push based on big data, and explored personalized teaching under the premise of large-scale.

The "cloud terminal integration classroom teaching platform" constructed by the school is the supporting service platform of the smart classroom. It provides a variety of teaching management services such as user management, digital course on demand, learning materials and subject tools, and gathers data such as teaching situation and teaching behavior of teachers and students in the whole teaching process. The behavior data of teachers and students is comprehensively recorded through the classroom teaching system, which can be uploaded to the data service platform as the basis for classroom quality analysis and evaluation. Through the data

Fig. 4. Physical space layout of smart classroom.

acquisition system, students' individual and overall attendance, focus analysis, learning process, learning effect analysis and other reports are obtained to provide support for teachers' accurate teaching and students' personalized learning. Teaching resources and user modules cooperate with each other. In the teaching process, teachers can immediately adjust teaching strategies and resource content display according to the teaching situation, so as to fully reflect the student-centered teaching concept.

Additionally, smart learning environment is a learning space enhanced by technology and an efficient interactive learning space with interaction as the core, whose advantage is that it can improve students' classroom interaction. Social space is a cyberspace mainly composed of learning communities (students and teachers) to communicate, exchange and share various learning resources to complete specific learning tasks, mainly including student space, teacher space, supervision space, administrator space, classroom interaction, question and answer (Q&A) communication, teacher-student evaluation, peer evaluation, instant communication tools and other social space. The interaction of learning community in smart classroom application reflects both offline and online aspects. Offline interaction refers to classroom interaction, including group discussion supported by information technology, real-time feedback, remote synchronous classroom ("1 main classroom + N auxiliary classroom"), etc. Online interaction is mainly carried out through the support service platform. For example, students can enter the course home page to complete the assignments and tests published by teachers, query teachers' correction and performance feedback, and also communicate and interact on topics of interest in the course in the discussion area.

5. Method

5.1. Participants

A total of 2125 paper questionnaires were collected. The incomplete questionnaires and all the same answers were regarded as

Table 1
Descriptive statistics of students.

Background Information		Number	%
Gender	Female	1264	65
	Male	673	35
Grade	Freshman	710	37
	Sophomore	474	24
	Junior	701	36
	Senior	52	3
Subject	L, H&P	54	3
	S&E	757	39
	E&M	893	46
	A&S	133	7
	E&P	100	5

invalid questionnaires, which were marked and eliminated. Finally, 2044 valid questionnaires and 81 invalid questionnaires were obtained. The effective rate of the questionnaire was 96%, which was in line with the predetermined sample size. The descriptive results on the participants' demographic characteristics were evaluated by using the frequency distribution, and the results are shown in Table 1 and Table 2. The participants in this study were college students (N = 1937) and teachers (N = 107). Among them, the demographic data of students were as follows: 673 were male (35%), and 1264 were female (65%). A total of 710 (37%) were freshman, 474 (24%) were sophomore, 701 (36%) were junior, and 52 (3%) were senior.

5.2. Measures

In order to explore the research questions, the questionnaire was used to collect the experimental data required for this study. Specifically, based on the literature review and the ecological model of smart learning environment, we designed "Questionnaire on Teachers' and Students' Preferences for Smart Learning Environment", which mainly involved the following two parts. The first part aimed to collect the demographic data of respondents, mainly including gender, age, identity, subject category and other information, a total of 6 items. The second part aimed to investigate participants' satisfaction with the smart learning environment, which was mainly based on the ecological characteristics of the smart learning environment [27]. There are 14 items in total. This questionnaire adopted Likert 5 scale, from 1 "very dissatisfied" to 5 "very satisfied". Teachers and students marked it according to their actual ideas. The scale was then tested to verify the validity and reliability. The results showed the Cronbach's Alpha (α) = 0.917 and the square root of α that used to determine the validity = 0.949 [62], which indicated that reliability and validity values were acceptable as specified by Heale and Twycross [63].

5.3. Procedures

Before data collection, this study was approved by the Ethic Committee of Central China Normal University (IRB Number: CCNU-IRB-202109-040) and informed consent was obtained from all participants. Once approval has been granted, the study's main objective was clearly explained to participants. All participants were requested to grant consent for the use of their data in this study. It was also emphasized that all data would be kept confidential and would not be divulged apart from the purposes of this study. The empirical part of this study was conducted in Central China Normal University. These data came from students and teachers with one semester's learning experience in 60 smart classrooms on the 1st-3rd floors. After a semester of use experience, it was suitable for the object of this survey. Teachers and students voluntarily filled in a questionnaire without name and student number within 10 min, which had no connection with the course content and academic achievement.

The data collection lasted for two weeks. During the first week, we invited two experts to evaluate the content of the questionnaire and carried out a pilot test before collecting the original data. Specifically, a pilot test in this study was conducted with 133 participants who were taking classes in the smart classroom, and 98.5% response rate was finally achieved. The reliability and validity of the instrument were tested. The preliminary results showed that the Cronbach's alpha value was 0.878 and the KMO coefficient was 0.879, demonstrating that the acceptable reliability and validity were achieved. Subsequently, during the second week, the expression of some items of the questionnaire was appropriately modified according to the pilot test results.

5.4. Data analysis

The data in this study were analyzed using a two-step data analysis program. Blanca et al. found through simulation research that, regardless of whether the data distribution is normal or not, analysis of variance is the best choice for multiple independent group difference testing methods [64]. Therefore, first of all, we conducted an analysis of variance on the demographic variables of participants, including gender, age, grade, discipline, and other characteristics of teachers and students. Before the analysis, it is necessary to conduct a variance homogeneity test on the experimental data. Among them, the "average based" test is the most widely used currently. If the test is $p < 0.05$, it indicates that the variance between multiple groups is uneven, and it is necessary to check the results of the "mean equality robust test", i.e. Welch Inspection [65]; If $p \geq 0.05$, it indicates that there is homogeneity of variance among

Table 2
Descriptive statistics of teachers.

Background Information		Number	%
Gender	Female	37	35
	Male	70	65
Age	<30	6	5
	31–40	47	44
	41–50	37	35
	51–60	17	16
Subject	L, H &P	7	7
	S&E	45	42
	E&M	33	31
	A&S	14	13
	E&P	8	7

multiple groups, and it is necessary to check the "*ANOVA*" results. If the Welch test is $p < 0.05$, it indicates that the mean difference between multiple groups is statistically significant. After detecting differences in the mean values between multiple groups, post hoc comparisons of the variables are required; If no differences are detected, there is no need for post mortem comparisons. The item by item analysis used in this study includes performing an analysis of variance on items that meet the Tukey post game program variance homogeneity hypothesis, and performing a Welch's w test on items that do not meet the Games Howell post game program variance homogeneity hypothesis [66]. SPSS 27.0 version was used for data analysis. A = 0.05 for all statistical tests. SPSS version 27.0 was used for the data analysis. An a = 0.05 was used for all statistics tests.

6. Research findings

6.1. Overall analysis of satisfaction with smart learning environment

In order to obtain the overall satisfaction of front-line teachers of the university with the smart learning environment, this study investigated and analyzed the satisfaction of teachers in the three dimensions of physical space, resource space and social space of the smart learning environment. According to the statistical results of mean and standard deviation, the average values of teachers in the three dimensions of physical space (M = 3.8178), resource space (M = 3.6355) and social space (M = 3.8551) are at a high level, especially their satisfaction with the teaching process (M = 3.9534), infrastructure (M = 3.9346), teaching activities (M = 3.9346) and teaching effect (M = 3.9159) in the smart teaching environment is close to a good level.

In order to understand students' real views on smart learning environment, this study also carried out a questionnaire survey on three dimensions. According to the analysis of the survey results, it is found that the average values of students in the three dimensions of physical space (M = 3.8255), resource space (M = 3.5418) and social space (M = 3.7432) are above the medium level. Students' satisfaction with teaching equipment (M = 3.8596), teaching content display (M = 3.8580), learning process (M = 3.8286), teaching activities (M = 3.8064) and infrastructure (M = 3.8023) in the smart teaching environment is close to a good level.

Therefore, teachers and students have high satisfaction with the smart learning environment, but in most aspects, teachers' satisfaction is slightly higher than students' satisfaction. On the whole, students pay more attention to physical space, which is closely related to the beautiful and comfortable space design of the smart classroom learning environment, the reasonable and humanized overall layout, the comprehensive coverage and diversified functions of ICT infrastructure, and the perception of the environment in the space (location, temperature, humidity, CO_2, light intensity, etc.), while teachers pay more attention to resource space and social space, which is consistent with the following difference analysis results.

6.2. Demographic difference analysis of satisfaction with smart learning environment

In order to further understand the relationship between the physical space, resource space and social space of smart learning environment and the characteristics of teachers and students, starting from the demographic variables such as teachers' age, gender and subject category, this study uses two group and multi group difference analysis to clarify the satisfaction and difference of teachers under different variables. At the same time, starting with the demographic variables such as students' gender, grade and subject category, this paper uses the difference analysis of two groups and multiple groups to explore the situation and difference of students' satisfaction under different variables. The results are as follows.

6.2.1. Gender differences in teachers' and students' satisfaction with the smart learning environment

In terms of teachers' gender variables, there is no significant difference between male and female teachers in the satisfaction of smart learning environment, but male teachers' satisfaction with physical space, resource space and social space is slightly higher than female teachers. In terms of students' gender variables, there is no significant difference between male and female students in all dimensions, but in most dimensions, the average value of male students is higher than that of female students.

Table 3
Grade differences in students' overall satisfaction with the smart learning environment.

	Grade	N	M(±SD)	Welch		p		
				F	p	1	2	3
Physical space	Freshman	710	15.862 (±2.157)	20.441	0.000			
	Sophomore	474	15.059 (±1.983)			0.000		
	Junior	701	14.897 (±2.164)			0.000	0.678	
	Senior	52	15.327 (±2.610)			0.603	0.952	0.775
Resource space	Freshman	710	7.447 (±1.305)	23.358	0.000			
	Sophomore	474	6.903 (±1.285)			0.000		
	Junior	701	6.832 (±1.310)			0.000	0.888	
	Senior	52	7.173 (±1.438)			0.585	0.612	0.356
Social space	Freshman	710	31.262 (±4.141)	30.208	0.000			
	Sophomore	474	29.342 (±4.004)			0.000		
	Junior	701	29.004 (±4.397)			0.000	0.652	
	Senior	52	30.154 (±4.180)			0.357	0.670	0.325

6.2.2. *Grade differences in students' overall satisfaction with the smart learning environment*

GamesHowell is used for post analysis, and the comparison results are shown in Table 3. In the three dimensions of physical space, resource space and social space, freshmen have the highest satisfaction in all dimensions, and there is a significant difference compared with sophomores and juniors, indicating that sophomores and juniors have greater needs for the satisfaction of smart learning environment. The average satisfaction of senior students is also high, however, the proportion of senior students in the survey object is low (52/1937) and senior students have less class time (need work practice), so it has little reference value.

6.2.3. *Age differences in teachers' overall satisfaction with the smart learning environment*

According to the analysis results, in terms of age variables, teachers under the age of 30 have the highest mean in the three dimensions of physical space, resource space and social space, while teachers aged 51–60 have the lowest satisfaction, indicating that young teachers' satisfaction with the smart learning environment is slightly higher than that of other teachers.

6.2.4. *Subject differences in teachers' and students' overall satisfaction with the smart learning environment*

As shown in Table 4, on the one hand, in terms of teachers' subject categories, the pairwise comparison results show that there is no significant difference in the satisfaction of teachers of literature, history and philosophy, science and engineering, economics and management, art and sports, and education and psychology with physical space, resource space and social space. However, comparing the average of the above three dimensions, it can be found that the satisfaction of education and psychology teachers is slightly higher than that of other subject teachers. On the other hand, in terms of students' subject categories, the pairwise comparison results show that students of various subject categories have significant differences in three dimensions, and the satisfaction of art and sports students is higher than that of students of other subject categories, especially in obtaining learning resources, improving learning methods, obtaining learning support, improving learning efficiency, human-computer interaction feedback and pleasant learning process.

Generally speaking, the satisfaction of teachers and students of art and sports in physical space, resource space and social space is high, followed by education and psychology, while the satisfaction of teachers and students of science and engineering is relatively low, indicating that teachers and students of science and engineering have great demand for the overall satisfaction of smart learning environment.

7. Discussion and conclusions

7.1. *Discussion*

This study aims to deeply explore the spatial preferences of different groups through difference analysis, so as to better find the shortcomings and improvements of the current smart learning environment.

On the one hand, students pay more attention to the infrastructure, teaching equipment, etc. in the physical space. At the same time, students have the highest satisfaction with the dimension of physical space, which is consistent with the research results of Yang [40], indicating that students' perception depends heavily on the attributes of physical space. The relevant literature also shows that well-designed buildings or campuses may attract students, indicating that the color and decoration of higher education buildings are not insignificant [67]. Well-designed learning space is relevant, especially due to the current experience economy and the growing expectations of students for higher education university buildings and facilities [27]. At present, many studies also involve the physical aspects of the learning environment that may affect learning and teaching, especially comfort and aesthetics [68]. This study shows that compared with the traditional multimedia classroom, the physical space in smart classroom learning environment of the university, with beautiful and comfortable space design, reasonable and humanized overall layout, ICT infrastructure with comprehensive

Table 4
Subject differences in teachers' and students' overall satisfaction with the smart learning environment.

	Subject	N	M(±SD)	Welch		p			
				F	p	1	2	3	4
Physical space	L, H&P	61	15.443 (±1.566)	9.259	0.000				
	S&E	802	15.085 (±2.333)			0.470			
	E&M	926	15.296 (±2.022)			0.957	0.269		
	A&S	147	16.198 (±2.100)			0.040	0.000	0.000	
	E&P	108	15.639 (±1.892)			0.950	0.048	0.395	0.175
Resource space	L, H&P	61	7.016 (±1.133)	9.344	0.000				
	S&E	802	6.997 (±1.351)			1.000			
	E&M	926	7.084 (±1.301)			0.995	0.637		
	A&S	147	7.714 (±1.239)			0.005	0.000	0.000	
	E&P	108	7.093 (±1.364)			0.996	0.953	1.000	0.002
Social space	L, H&P	61	30.197 (±3.673)	12.17	0.000				
	S&E	802	39.537 (±4.591)			0.676			
	E&M	926	29.946 (±4.072)			0.986	0.295		
	A&S	147	32.068 (±4.151)			0.014	0.000	0.000	
	E&P	108	30.824 (±3.423)			0.810	0.005	0.103	0.070

coverage and diversified functions, and environmental perception in the space (location, temperature, humidity, CO_2, light intensity, etc.), has provided students with a comfortable and modern learning site, which is more conducive to students' learning, discussion and communication anytime and anywhere.

On the other hand, teachers have the highest satisfaction with the dimension of social space, which is consistent with the role of teachers as the implementer of teaching. Teachers pay more attention to the teaching process, the development of teaching activities and the teaching effect in the social space of the smart classroom [69]. They agree that the smart classroom is more "smart" than the traditional multimedia classroom. Relying on the smart classroom, students' interaction and teacher-student interaction can be better realized, and the teaching content can be presented in various forms, personalized teaching support services meet diversified teaching needs, teaching forms are more diversified, teaching methods have been more flexible, teaching efficiency has been greatly improved, and the teaching process is more pleasant and relaxed [70].

However, the preference of teachers and students for the resource space of the smart classroom is obviously insufficient, especially the average value of "easy access to resources" is low, which shows that the supply and openness of the smart classroom for resources have not met the needs of teachers and students. Educational institutions should fully consider and strive to create resource space that meets the needs of students, and promote diversity in the ways of obtaining resources [56].

7.2. Conclusions

Taking the university in central China as an example, this study explores the preference of teachers and students for smart learning environment in higher education. The results show that teachers and students hold a positive attitude towards the smart learning environment, and college students prefer the physical space under the smart learning environment, which is closely related to the beautiful and comfortable space design of the smart classroom learning environment, the reasonable and humanized overall layout, the comprehensive coverage and diversified functions of ICT infrastructure, and the perception of the environment in the space (location, temperature, humidity, CO_2, light intensity, etc.); While teachers prefer the social space, and their preference for resource space is obviously insufficient. Through the analysis of relevant demographic variables, we know that there is no significant difference between male and female teachers and male and female students in the preference of smart learning environment. In the grade variables of students, there are significant differences in the preference of smart learning environment between freshmen, sophomores and juniors. In terms of teachers' age variables, young teachers' preference for smart learning environment is slightly higher than that of other teachers. In the subject category, the preference of teachers and students majoring in art and sports is higher, while that of science and engineering is the lowest.

The main contributions of this study include (1) **models constructed**: based on the ecological theory and the research results of the existing learning environment, this paper constructed an ecological model of smart learning environment (physical space, resource space and social space) and a conceptual model of learning space preferences; (2) **an empirical study of large samples**: based on the survey of 1937 undergraduates and 107 teachers in the university, an empirical study was conducted to deeply understand the spatial preferences of different groups through the difference analysis; (3) **possible influence**: the results of this study can be used for higher education managers and decision-makers who have certain needs for the construction and management of smart learning environment, so as to support the construction of a suitable learning environment in the future that is more in line with the preferences and needs of teachers and students, to better meet the needs of "learning" and "teaching".

8. Limitation and further research

This study is not without shortcomings. It only explores the environmental preferences of teachers and students, but their preferences are not static and may change over time. Therefore, further research is necessary to extend the duration of this study to test the robustness of its results. In addition, due to the large sample size and wide range of people involved in this study, the current analysis is relatively basic, and more dimensional analysis can be conducted in the future to obtain more interesting research results.

Based on the research results, it can be seen that different groups have different preferences and needs for smart learning environment. Therefore, the results of this study can be used for managers and decision-makers in higher education to build and design the smart learning environment, providing services and support to teachers and students in a more scientific manner. In addition, this study also has a certain reference value for researchers in different fields such as environmental psychology, educational science, enterprise property management, facility management and so on.

With the continuous new requirements for the cultivation of smart talents in the information age, the smart learning environment is gradually in-depth and widely used in higher education. The follow-up research will try to explore the correlation between the smart learning environment and learning attitude, learning motivation and learning results, to provide a useful reference for the construction of smart learning environment and the development of smart education.

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Author contribution statement

Zhicheng Dai: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Junxia Xiong: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Liang Zhao: Analyzed and interpreted the data.

Xiaoliang Zhu: Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. Material/referenced in article.

Additional information

Supplementary content related to this article has been publish online at [URL].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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