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Understanding University Students' Perceptions of Classroom Environment: A Synergistic Approach Integrating Grounded Theory (GT) and Analytic Hierarchy Process (AHP)

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Abstract:

University classrooms play a crucial role in students' educational experience, as they spend a significant amount of time in these spaces. Understanding students' perceptions of the classroom environment is essential for improving classroom design and management. Adopting a user-centric approach, a novel research design combining both qualitative and quantitative research methods is employed to develop and validate an evaluation framework for classroom environment evaluation. Specifically, this study utilises grounded theory (GT) methodology to identify and prioritises the indoor environment parameters that students consider important. A classroom environment performance evaluation framework for the classrooms within a Hong Kong university was then developed based on the qualitative findings using the Analytic Hierarchy Process (AHP) method. The framework was then used to examine students' perceived importance of the university classroom performance among different sub-groups. The findings reveal that "facilities and services" emerged as the most critical parameter, emphasizing the importance of effective post-occupancy management. Intriguingly, there are minor differences in importance rankings between genders and education levels, with males emphasizing "indoor air quality" and females prioritizing "thermal comfort". Moreover, distinct priorities are observed between various classroom types; students in lecture theatres focus on "seating plans" and "temperature", while those in general classrooms prioritize "seating layout" and "fire safety". These findings emphasize the need for effective post-occupancy management, while also highlight nuanced preferences based on gender, education levels, and classroom types, thereby offer crucial insights for designers to tailor indoor environments that better align with diverse student needs and preferences. Furthermore, a human-built environment interaction model is developed to summarise the research findings and provide insights for future research directions. This comprehensive approach enhances understanding of students' preferences and experiences in university classrooms.

Keywords: University classroom; student perception; grounded theory; AHP; environment evaluation

Abbreviation	**Definition**
AC	Acoustic comfort
AHP	Analytic hierarchy process
CI	Consistency index
CR	Consistency ratio
E	Engineering
FCE	Fuzzy comprehensive evaluation
FGD	Focus group discussion
GT	Ground theory
IAQ	Indoor air quality
IEQ	Indoor environmental quality
LC	Lighting comfort
PMV	Predicted Mean Vote
POE	Post-occupancy evaluation
PPD	Predicted Percentage of Dissatisfaction
TC	Thermal comfort
U	User-centric

1 Introduction

The learning environment is a design consideration because it influences the health and academic performance of students. Constructivism has demonstrated the importance of the classroom in education [1]. Classrooms serve as "cultural hub" where students from all over the world congregate in addition to hosting educational activities. It is a unique educational ecosystem that facilitates the development of positive social relationships and social abilities among students. Godwin and Kim [2] indicates, based on place identity theory, that interactions with and comprehension of the classroom contribute to students' learning and self-identification. The nexus relationships between learning environment, students' psychological/physical condition and learning outcome have been comprehensively studied in education literature [3-5]. Yet, in these studies, the learning environment is vaguely defined, referring a hybrid place where learning activities occur. How students perceive the classroom indoor environment are seldom discussed in architectural and engineering literature.

University classrooms are semi-public spaces, and the higher education system allows students to make their own decisions regarding course attendance, including the right to choose their seats based on personal preferences. Students have sufficient freedom to express their opinions regarding the quality of their education, including the classroom environment. As frequent users of various classrooms, such as traditional lecture classroom, breakout style classroom, multi-media supported classroom, they are considered as "experts" of classroom environment. Recent research indicates that students' perceptions of the built environment vary for a variety of reasons [6]. It has been determined that personal characteristics, such as personal behavior, cultural backgrounds, gender, educational levels, and a few other variables, influence students' perceptions of the variance in the built environment's features [4, 7, 8]. It is essential to integrate a user-centric approach into human-built environment interaction studies in order to comprehensively address the perception differences between students with different characteristics [9, 10].

According to a comprehensive literature review, 50% of the university classroom environment studies (37 studies in total) focus solely on thermal condition, 10% on lighting condition, and 2% on acoustic condition. In addition, 21% of these studies (8 studies) [11-18] evaluate all four aspects of classroom environment performance: thermal condition, lighting condition, acoustic condition, and indoor air quality. The evaluation of architectural elements in classrooms, which have been shown to significantly impact students' learning outcomes, was absent from all of these studies. Furthermore, all of these studies conducted user surveys to evaluate the quality of indoor environment of university classroom. However, the evaluation framework utilized in these studies was developed by the research team, without the participation of students. In other words, the perceptions of students regarding the university classroom were not incorporated into the evaluation framework. The possibility that "what was asked may not be what we (students) want to say" may reduce the effectiveness of the questionnaire survey and therefore produce invalid evaluation results.

To address this limitation, it is necessary to adopt a user-centric approach to design a comprehensive framework for evaluating classroom environment performance from the students' perspective. This study makes significant contributions to the field of university classroom research. Firstly, it introduces a novel research design that seamlessly integrates grounded theory and Analytic Hierarchy Process (AHP) methods, enabling the collection of both qualitative and quantitative data. Secondly, the study contributes by developing and validating a comprehensive evaluation framework for university classroom environment performance. This framework is derived from the insights gained through focus group discussions and an AHP-based survey. Lastly, the research presents a third contribution in the form of a human-built environment interaction model. This model succinctly summarizes the research findings and provides valuable insights for future research directions.

2 Literature review

2.1 An overview on studies of university classroom indoor environment

Research on university classroom environments focuses on various factors such as indoor air quality, thermal comfort, lighting conditions, acoustics, furniture design, ergonomics and post-occupancy evaluation. These studies emphasise the importance of proper ventilation, temperature control, suitable lighting, optimised acoustics, ergonomic furniture, and gathering feedback for improving classroom design and management. The overall aim of these studies is to create conducive learning environments that enhance students' concentration, comfort, and overall satisfaction [11, 16, 19].

Indoor air quality (IAQ) is a critical factor in maintaining a healthy and comfortable learning environment [13]. Studies have examined ventilation rates, carbon dioxide levels, airborne pollutants, and microbial contaminants, with Liu et al. [20] noting the importance of proper ventilation, air filtration, and control of pollutant sources to prevent health issues and cognitive performance decline. Thermal comfort is another significant factor that affects students' concentration and well-being. Sarbu and Pacurar [21] highlight the importance of temperature, humidity, and air movement within university classrooms. Optimising temperature and humidity ranges helps promote comfort and prevent discomfort, as extreme conditions can have a negative impact on learning outcomes, as discussed by Ramprasad and Subbaiyan [12]. Lighting conditions significantly impact students' visual comfort and performance. Wang et al. [22] state that adequate illuminance levels, colour temperature, glare reduction, and utilisation of natural daylight are important factors in optimising lighting design. Singh et al. [23] emphasise the role of lighting in enhancing the learning environment by providing suitable illumination for reading and writing tasks. Acoustics also play a crucial role in effective communication and learning. Yang and Mak [24] underline the importance of ambient noise levels, reverberation time, and speech intelligibility in university classrooms. Optimising room acoustics helps ensure clear speech communication, reduce distractions, and improve students' ability to focus and comprehend lectures, as noted by Brink et al. [18].

The layout and design of classroom furniture and equipment impact students' comfort and engagement. Castilla et al. [25] highlight the significance of factors such as seating arrangements, desk design, writing surfaces, and accessibility of instructional materials. Yang, et al. [26] note that ergonomically designed furniture and well-planned classroom layouts contribute to better posture, reduced fatigue, and improved interaction between students and instructors. Post-occupancy evaluation (POE) studies involve assessing students' and instructors' satisfaction and perceptions of the indoor environment. Puteh et al., Mihai and Iordache, Andargie et al., Day et al., [27-30] emphasise the value of feedback surveys, interviews, and observational studies in gathering insights on comfort, functionality, and overall satisfaction. POE studies provide valuable feedback for optimising classroom design and identifying areas of improvement.

To summarise, thermal condition, lighting condition, acoustic condition, and indoor air condition are four performance factors that are commonly used to assess the quality of an indoor environment while furniture design, ergonomics, and classroom layout are design factors, which are less commonly researched in university classroom environment studies. However, they have been proved to have impacts on students' learning performance and comforts.

2.2 University classroom environment evaluation investigation approaches

Among the university classroom environment studies, the majority of them (37 literatures) focus on evaluating the environment based on IEQ factors. A three-step literature review is conducted to, first, reveal the relationships of the keywords by illustrating the keywords clusters extracted from the identified 37 literatures (as in Figure 1); second, summarise and categorise the environment factors under investigation, types of data, investigation approach, data size, and stream of study (as in Table 1); third, to illustrate the details of studies (8 literatures) that investigate all four environmental factors (thermal condition, lighting condition, acoustic condition and indoor air quality) (as in Table 2).

Figure 1 depicts the keywords clusters generated by Citespace software from the 37 literatures that examine the university classroom environment based IEQ factors from 2007 to 2023. The right-hand side of Figure 1 depicts keywords in these studies from 2007 to 2023. The larger the circle in Figure 1 indicates a higher keyword frequency in the cluster. Thermal comfort was most commonly mentioned keywords followed by acoustic comfort. Other frequently mentioned keywords are mostly related to thermal comfort, such as thermal preferences, Fanger's model, and mean vote. In addition, lighting condition was also quite frequently studied in the field of university classroom environment investigation as visual comfort, luminous environment, and lighting quality are also highly mentioned keywords among the 37 literatures.

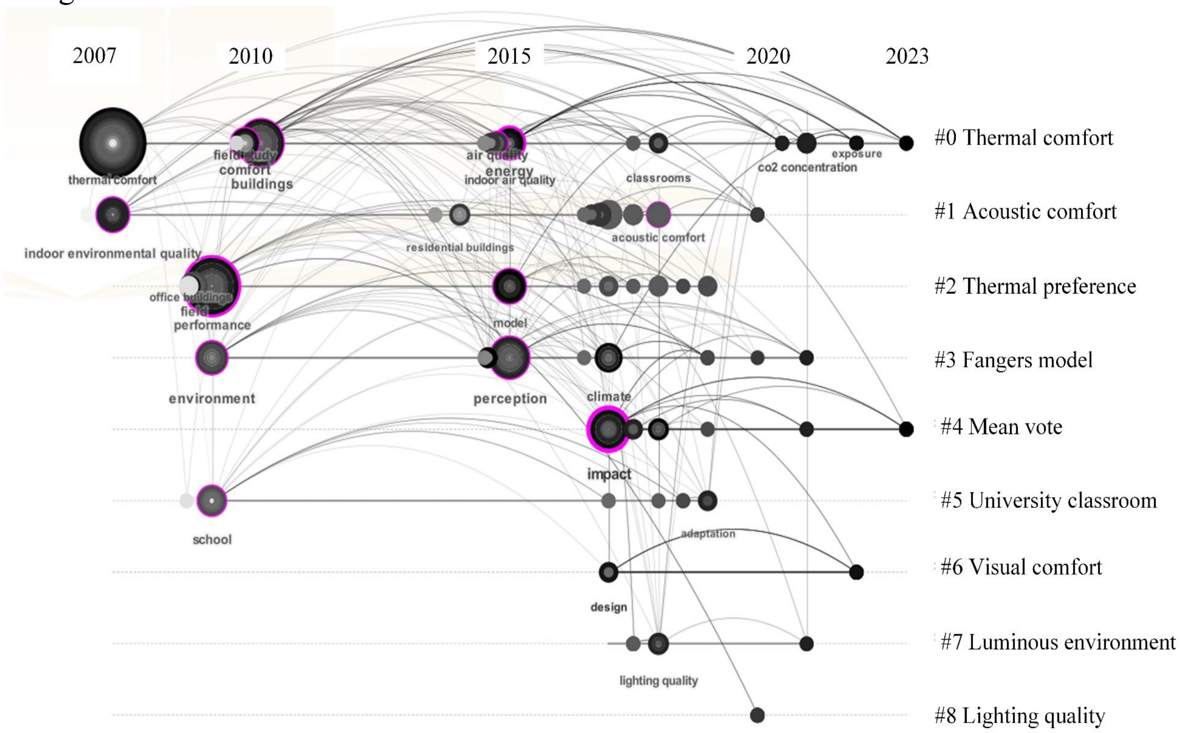


Figure 1 The keywords clusters extracted from the identified 37 literatures

Detailed information of the 37 literatures are outlined in Table 1. It outlines the environment parameters under investigation covered by each study, type of data collected, investigation approach and stream of study. This study divides the stream of study into two types: evaluation driven by an engineering perspective (E) and evaluation centred on users (U). For an evaluation of university classrooms from an engineering perspective, both objective and subjective data were collected to support a holistic assessment. The purpose of these investigations is to comprehend the quality of the classroom environment and the responses of classroom users to various aspects of the environment. For user-centric evaluation, the emphasis is on extracting the perceived importance and satisfaction of classroom users. The qualitative data gathered during the user-centric investigation are analysed to determine patterns, themes, and trends in the responses. In these studies, researchers employ diverse analytic techniques, such as content analysis and thematic analysis, to extract meaningful insights from data. They draw conclusions regarding IEQ in university classrooms based on their analysis of the questionnaire responses.

Table 1. Literature focusing on university classroom IEQ investigation

Source	TC	LC	AC	IAQ	Survey data	Environment data	Stream of study	Investigation approach
[31]	*				*	*	E	QS and OM
[11]	*	*	*	*	*		U	QS
[22]	*				*	*	E	QS and OM
[32]	*				*	*	E	Objective approach and subjective preference analysis
[33]	*		*	*	*	*	E	QS and OM
[34]	*				*	*	E	Experimental surveys and questionnaire surveys
[35]	*				*	*	E	QS, Physical observations and behavioral observations
[21]	*				*	*	E	Subjective judgments, experimental measurements and simulation model
[25]	*				*		E	QS
[12]	*	*	*	*	*	*	U	QS and OM
[36]	*				*	*	E	QS and OM
[37]	*				*	*	E	QS and OM
[24]			*		*	*	E	FCE-AHP based QS
[38]		*			*		U	QS
[39]	*				*	*	E	QS and OM and computer simulations
[40]	*				*	*	E	QS and OM
[41]	*	*	*		*	*	E	QS and OM
[23]	*				*	*	E	QS and OM
[42]	*	*	*		*	*	E	QS and OM
[13]	*	*	*	*	*	*	E	QS and OM
[43]	*				*	*	E	QS and OM
[20]	*			*	*	*	E	QS and OM
[44]	*				*	*	E	QS and OM
[45]	*				*	*	E	QS and OM
[46]	*				*	*	E	QS and OM
[14]	*	*	*	*	*	*	E	FCE-AHP based QS and OM
[47]		*			*		U	AHP-based QS
[15]	*	*	*	*	*		U	QS
[16]	*	*	*	*	*		U	LS

[48]		*			*		U	Simulation
[17]	*	*	*	*	*		U	AHP-based QS
[49]	*				*	*	E	QS and OM
[50]	*				*	*	E	QS and OM
[51]		*			*	*	E	QS and OM
[52]	*			*	*	*	E	QS and OM
[18]	*	*	*	*	*	*	E	QS and OM
[53]	*				*	*	E	Hierarchical and K-means clustering

Note:
- TC – Thermal comfort; LC – Lighting comfort; AC – acoustic comfort; IAQ – Indoor air quality; E – Engineering perspective; U – User-centric
- FCE-AHP based QS – Fuzzy comprehensive evaluation -Analytic hierarchy process based questionnaire survey; AHP based QS – Analytic hierarchy process based questionnaire survey; LR – Literature review; OM – Onsite-measurement; QS – Questionnaire survey;

According to Figure 1 and Table 1, thermal comfort is the most researched IEQ factor in the context of university classrooms. Fanger's (1970) thermal comfort model (also known as the Predicted Mean Vote model) is predominantly used in this these studies [54]. In these studies, the thermal sensation experienced by individuals in response to a variety of environmental factors is quantified. Using this method of investigation, air temperature, humidity, air velocity, clothing insulation and metabolic rate are measured to estimate thermal comfort. These data are used to calculate the Predicted Mean Vote (PMV) index, which represents the average thermal sensation felt by a group of people, using Fanger's thermal comfort model. In addition to PMV index, the model provides the Predicted Percentage of Dissatisfaction (PPD), which estimates the proportion of individuals who are likely to experience discomfort in the given thermal conditions. A PPD value below 10% is generally regarded as acceptable for majority of indoor settings. By comparing the calculated PMV and PPD values to established comfort ranges or standards, investigators can evaluate the thermal comfort conditions in a space and identify potential improvement areas. In these investigations, both questionnaire surveys and on-site environmental measurements were conducted [21, 22, 31, 34, 35]. In addition, the primary keywords in these studies are indoor air quality, acoustic comfort, and light comfort.

In the investigations of lighting and acoustic conditions in university classrooms conducted by Yang and Mak [24], Castilla et al. [38], Leccese et al. [47], Kong and Jakubiec [48], and Kong et al. [51], questionnaire surveys were the primary method for collecting qualitative data from classroom users. This methodology permits researchers to collect subjective responses and perceptions from occupants regarding their experiences with lighting and acoustic conditions. In these studies, questionnaires were designed to elicit pertinent information about lighting and acoustic conditions in university classrooms. The questionnaire may consist of questions about lighting levels, uniformity, glare, color rendering, sound levels, and speech intelligibility.

Among the 37 literatures, eight of the investigations cover all four classroom indoor environment parameters, as indicated in Table 1. Table 2 provides the detailed information of the eight studies.

Table 2. Summary of studies on comprehensive IEQ evaluation of university classrooms

Source	Objectives	Data collection method	Analysis	Main findings
[11]	To investigate the relationship between IEQ and students' satisfaction, perceived learning, and course satisfaction.	QS	Path analysis	IEQ of the classrooms, was associated with positive student outcomes
[12]	To explore the relationship between students' perceived importance of IEQ and their satisfaction, academic ambience, academic performance and brand name/image of the institution	QS and OM	EFA and SEM	IEQ had a positive influence on a classroom being perceived as conducive for learning.
[13]	To describe the evaluation process of indoor environmental conditions in a partially-retrofitted university building	QS and OM	CSO	Ad-hoc retrofitting of the façade did not make any significant difference to IEQ and occupants continued to adapt personally to the existing conditions.
[14]	To investigate the effects of the physical environment and residents' adaptive behaviors on their subjective feelings	QS and OM	FCE-AHP	A summary of prediction equations among environmental factors and satisfaction based on several previous studies. Indoor environmental quality is co-determined by various environmental factors.
[15]	To propose a benchmark to fill the gap in the literature on IEQ factor satisfaction in higher education environments as influenced by gender.	QS	CS	Significant gender influences on IEQ factor satisfaction, especially for lighting conditions, view conditions, cleaning and maintenance, and acoustic conditions.
[16]	To determine the influence of indoor air, thermal, acoustic, and lighting conditions, on the quality of teaching and learning and on students' academic achievement	LR	CCM	IEQ factors can contribute positively to the quality of learning and short-term academic performance of students.
[17]	To determine weighting schemes through literature review and subjective investigation.	LR and QS	AHP	Subjective surveys tailored to the specific case remain the most effective approach for determining appropriate weighting schemes.
[18]	To explores if multiple alterations of the classrooms' indoor environmental conditions result in a positive effect on students' perceptions and performance.	QS and OM	CSO	The reduction of the reverberation time (RT) positively influenced students' perceived cognitive performance. A reduced RT in combination with raised horizontal illuminance (HI) improved students' perceptions of the lighting environment, internal responses, and quality of learning.

Note:
- CCM – Cochrane collaboration method; CS - Correlation analysis using the subjective data sets; CSO - Correlation analysis using the subjective and objective data sets; EFA - Exploratory factor analysis; FCE – Fuzzy comprehensive evaluation; LR – Literature review; OM – Onsite-measurement; QS – Questionnaire survey; SEM - Structural equation modelling

Among these eight studies, three studies only collected subjective data to reflect the IEQ performance [11, 15, 17] while the rest four studies collect both subjective and objective data to conduct integrative analysis [12-14, 18]. Notably, there is one study literature review-based study [16]. With the exception of this review, the subjective data collected in these eight studies reflect how classroom occupants perceive the classroom environment.

Notable is the fact that four studies (Table 1) utilised the Analytic Hierarchy Process (AHP) or AHP-Fuzzy Comprehensive Evaluation (AHP-FCE) to examine students' perceptions of the classroom environment. The AHP and AHP-FCE methods are primarily quantitative decision-making techniques that involve structuring and ranking alternatives and criteria. In these studies, they were used as part of an evaluation process to assess and rank various aspects of indoor environmental quality (IEQ) in university classrooms.

These studies demonstrate the suitability of applying AHP method in university classroom environment studies. First, it allows for the consideration of multiple evaluation criteria simultaneously and it provides a structured framework to assess and prioritise these criteria effectively. Also, the fundamental rationale of AHP is to integrate objective assessment into subjective decision-making process. In addition, AHP can be customised to suit the specific context and requirements of investigating the university classroom environment. It allows for the inclusion of diverse stakeholders' perspectives, accommodating their preferences and priorities. For example, applying the same evaluation framework in studying classrooms in different universities may not be appropriate as the classroom design in different universities can vary significantly. Thus, developing an evaluation framework for classrooms in the specific university and applying it for evaluation is necessary. AHP method is considered as a scientific tool to support the university classroom environment evaluation activities.

2.3 Allowing user expression by adopting a user-centric investigation approach

The above literature review suggests that user-centric approach is increasingly adopted in indoor environment quality evaluation studies. In the context of indoor environment quality (IEQ), it refers to an approach that prioritises occupants' needs and preferences when evaluating and enhancing the indoor environment. It acknowledges that the well-being, health, and productivity of individuals are influenced by their built environment and emphasizes customising the indoor environment to meet unique needs [9, 55]. This approach has been used to comprehend the needs and preferences of users in relation to the indoor environment, particularly in specialised facilities such as hospitals, offices, and dormitories.

In healthcare facilities, for instance, the user-centric approach acknowledges that patients and healthcare professionals have distinct requirements for their well-being and productivity [56]. Assessing the indoor environment in healthcare settings includes air quality, noise levels, illumination conditions, thermal comfort, and layout design, all of which can affect patient recovery and staff performance. Similarly, in office environments, the user-centric approach acknowledges employees' varying comfort, concentration, collaboration, and well-being needs [57]. To increase the productivity and satisfaction of office workers, research focuses on indoor air quality, lighting quality, acoustic conditions, ergonomic elements, and spatial design [58, 59]. In addition to hospital and offices, the user-centric design methodology is also applicable to student dormitories and learning spaces. Understanding the comfort, concentration, and learning environment preferences of students assists in optimising the indoor conditions for improved academic performance and well-being.

User-centric approach places the needs and preferences of users at the centre of indoor environment assessment for ensuring that the design, operation, and maintenance of facilities meet the occupants' expectations and prerequisites. Thus, it is important to have the users to express their needs and preferences by themselves. The AHP framework should be developed by the users as it should reflect what the users emphasise. Furthermore, the AHP framework development should involve the users' opinion and the development process should be scientific to ensure that the framework is representative of a specific group of users. In this study, students from the university under investigation will be selected to participate in the university classroom environment framework development and AHP method will be used to enable the evaluation content in a structured manner.

3 Methodology

The exhaustive review of the literature has revealed two research gaps: First, studies on comprehensive evaluation of university classroom environment performance are limited, with the majority of university classroom environment studies focusing solely on indoor thermal conditions (as shown in Table 1); Second, individual perception of the performance of the classroom environment has been increasingly emphasised but remains limited. This necessitates an approach centered on the user in order to investigate how classroom users perceive the classroom environment and how their personal characteristics influence their perception preferences. Instead of evaluating the actual performance of specific university classroom, the purpose of this study is to develop a framework for measuring the performance of university classroom environments from a user-centric perspective and to determine the perceived importance of various environment parameters by students.

In this study, a novel research design using mixed research methods, including a comprehensive literature review, grounded theory (GT) and analytic hierarchy process (AHP), was adopted to: first, examine the investigation approach and research methods of university classroom environment in previous studies; second, interpret occupants' opinions regarding classroom environment evaluation parameters and construct a systematic evaluation framework to suit the university classroom environment; and third, evaluate the effectiveness of the classroom environment evaluation framework. Figure 2 illustrates the study's research design framework. This study focuses on the classrooms of a Hong Kong university.

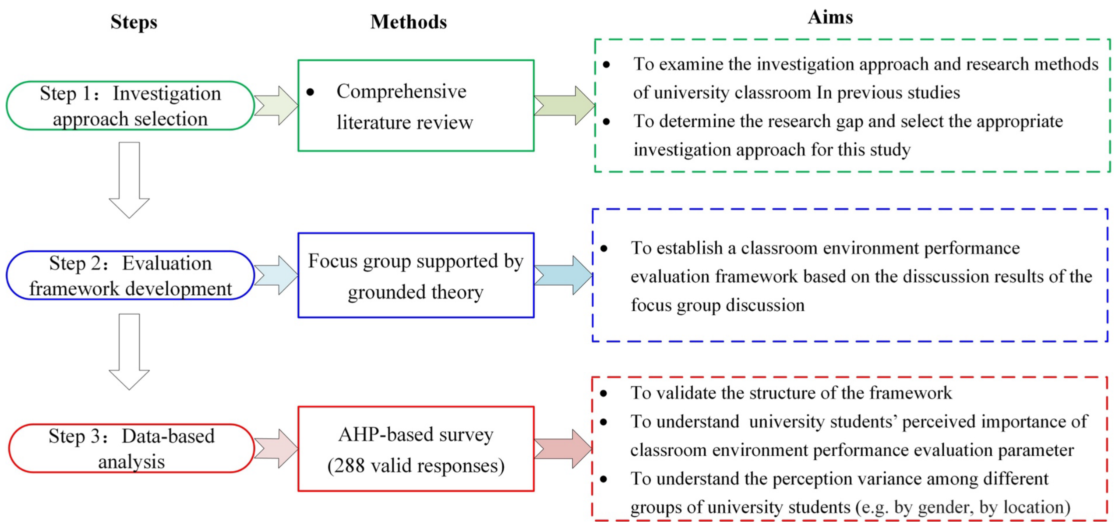


Figure 2 Research design framework

Section 3.1 introduces grounded theory and describes qualitative data collection process design. Section 3.2 illustrates how the AHP method was used to convert the evaluation framework into a survey questionnaire and determine how students, as the primary occupants in the classrooms, perceive the performance of the classroom environment.

3.1 Ground theory and qualitative data collection design

Numerous disciplines have extensively adopted and refined grounded theory as a legitimate research methodology [60]. Even though grounded theory has become more prevalent in urban planning, architecture design, and construction management disciplines in recent years [61], its application to the study of human-built environment interactions remains limited.

Grounded theory, which is defined as “the discovery of theory from data” [62], is both a methodology and a method. Methodologically, grounded theory asserts that the researcher must rely on the real-world experiences of actors in order to comprehend and respond to the issues at hand. It is an inductive “theory-discovery methodology” [63] that allows for the concurrent development of empirically grounded theoretical insights. It allows the researcher to concentrate on the context, processes, and interpretations of key players [64] when there is insufficient theoretical guidance to support the research inquiry or when the meanings and relationships of concepts are fragile [65, 66].

As a methodology, grounded theory emphasises constant comparison and theoretical sampling [67]. Researchers engage in an inductive process of coding, categorizing, and connecting newly collected data through constant comparison. Comparing newly collected data with previously collected data and identifying similarities and differences is the objective of this analysis. The data can be examined for similarities and differences in conditions, consequences, key events, incidents, and patterns. Theoretical sampling, on the other hand, involves the systematic selection of participants who are more likely to contribute to theory development through data collection. In theoretical sampling, the focus is on the quality of information rather than the quantity of participants, so there is no minimum participant requirement. The purpose of participant selection is to foster the emergence of new categories and the expansion of existing ones. This is accomplished by selecting participants who have the potential to provide answers with minimal and maximal differences, thereby ensuring a broad range of perspectives [67, 68].

To evaluate the classroom environment from the perspective of occupants, it is necessary to “hear the word” directly from the occupants. In other words, the evaluation framework for the classroom environment should be developed by the students. Under the guidance of the grounded theory, the process of collecting qualitative data should incorporate two important theory attributes: constant comparison and theoretical sampling. Focus group discussion (FGD) was chosen as the qualitative data collection method. FGD enables participants to engage in constructivist ideation through direct interactions. Throughout FGD, participants interacted and influenced one another positively. Each time a participant spoke, they either reaffirmed a previously-discussed opinion or presented new arguments based on prior contributions. The very nature of discussion compels participants to engage in spontaneous comparison and synthesis. In addition, the selection of participants adheres to the “theoretical sampling” principle.

To select suitable participants for the FGDs, a purposive sampling technique was applied. Students with diverse academic backgrounds and levels were considered to be the targeted FGD participants, as the objective of the FGDs is to encourage diverse viewpoints from students from varying needs and experiences. Students in the selected university campus were randomly identified by the research team, and they were firstly asked to provide background information and their willingness to participate in the FGD. For the purpose of the FGD, a total of 29 students from the selected university in Hong Kong were identified and divided up into five groups. Table 3 depicts the profiles of the participants in the five FGDs.

Table 3. Profile of focus group discussion participants

	No. of participants	Education level	Background of the participants	Outcome
FGD-1	4	UL: 4	FH: 1; FB: 1; FCE:1; SHMM: 1	V1
FGD-2	4	ML: 1; UL:3	FCE: 1; FE: 2; FH:1	V2

FGD-3	6	ML: 3; DL:2	FCE: 3; FE:1; SD:2	V3
FGD-4	5	DL:5	FCE:1; FE:2; FB:1; FHSS:1	V4
FGD-5	10	UL: 10	FCE: 5; FE: 2; FH:2; FB:1	To decide which version of the framework from V1-V4 to be adopted

Note: UL - Undergraduate level; ML – Master level; DL – Doctoral level;

FH - Faculty of Humanities; FB - Faculties of Business; FCE - Faculty of Construction and Environment; SHMM - School of Hotel and Market Management; FHSS – Faculty of Health and Social Science; FE – Faculty of Engineering; SD – School of Design

V1 – Classroom environment performance evaluation framework version 1; V2 – Classroom environment performance evaluation framework version 2; V3 – Classroom environment performance evaluation framework version 3; V4 – Classroom environment performance evaluation framework version 4;

During the process focus group discussion (FGD), the researcher provided a brief overview of the significance of classroom performance. Subsequently, the participants were presented with several discussion questions aimed at validating the reliability of critical classroom environment elements and their respective categorizations.

1 How do you perceive the indoor university classroom environment at a university? Any specific environmental elements you wish to discuss?
2 Based on your explanation, how would you classify these environmental elements?
3 Are you able to collaborate and develop a hierarchical evaluation framework capable of incorporating the environment elements you discuss? (A sample of hierarchical evaluation framework was provided at this point in the discussion with the focus group)
4 Can you explain this framework?

The initial two questions were designed to foster a relaxed environment, allowing the researcher to delve into the outcomes of the discussion. Subsequently, participants were encouraged to construct a hierarchical evaluation framework. The researcher assumed the role of a moderator during the FGD, maintaining objectivity with regard to participants' opinions.

A total of five FGDs have been implemented. The purpose of the fifth FGD was to discuss the results of the previous four FGDs composed by student participants. At the conclusion of the fifth FGD, participants were asked to vote on the most appropriate evaluation framework. Using an AHP-based survey, the most preferred framework was used to evaluate the actual performance of the classrooms at the chosen university.

3.2 AHP method for investigating the classroom environment performance

AHP method is a quantitative and qualitative decision analysis technique that has been widely used in studies to facilitate decision-making. The AHP, which was first proposed by Saaty [69] is used to obtain the weighting vectors of the three-level multi-criteria evaluation model. It commonly includes three steps:

Step 1 involves using the established classroom environment evaluation framework as a foundation for the AHP method. The final version of the framework comprises three hierarchical levels. In this phase, a hierarchical structure was created, and pairwise comparisons among performance parameters were constructed based on this structure. Figure 3 depicts the pairwise comparisons between the performance parameters at the first and second levels.

To elaborate, the first hierarchical level consists of three performance parameters, each being compared with the others. The comparison scale spans from one to nine, following Saaty’s 1-9 point scale. A rating of one indicates equal importance between the two elements, while a rating of nine suggests extreme importance of one element over the other in the pairwise matrix. The specific scale and the corresponding importance values for each number are outlined in Table 4.

Classroom indoor environment quality																		
Spatial design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Building physical environment**
Spatial design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Facilities and services**
Building physical environment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Facilities and services**
Spatial design																		
Structure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**User interface**
Building physical environment																		
Thermal comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Visual comfort**
Thermal comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Aural comfort**
Thermal comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Indoor air quality**
Visual comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Aural comfort**
Visual comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Indoor air quality**
Aural comfort	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Indoor air quality**
Facilities and services																		
Furniture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Electronic devices**
Furniture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**IT support**
Furniture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Hygiene**
Furniture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fire safety**
Electronic devices	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**IT support**
Electronic devices	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Hygiene**
Electronic devices	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fire safety**
IT support	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Hygiene**
IT support	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fire safety**
Hygiene	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fire safety**

Figure 3. An illustration of the pairwise comparison in the AHP-based survey

Table 4. Scales for the important of performance parameters

Importance scale	Definition of importance scale
1	Equally important preferred
2	Equally to moderately important preferred
3	Moderately important preferred
4	Moderately to strongly important preferred
5	Strongly important preferred
6	Strongly to very strongly important preferred
7	Very strongly important preferred
8	Very strongly to extremely important preferred
9	Extremely important preferred

Step 2 involves collecting perceived importance data for the identified performance parameters. In the selected university, the survey targeted students occupying a specific type of classroom, as depicted in Figure 4, showcasing various classroom types at the institution. The research team employed an online questionnaire created using Microsoft Forms and visited classrooms not in use for ongoing classes within university education buildings.

During the data collection phase, students were approached for voluntary participation. The research team utilized an iPad to show students an introductory video that presented the performance evaluation framework. Subsequently, students were provided with the online survey link to complete the questionnaire. To ensure a high level of consistency along the comparisons, the researcher provided detailed explanations on how to compare pairwise performance parameters and select the appropriate scale number to indicate their importance preferences.

The survey comprised two parts of information: Part 1 gathered general information about participants, including gender, local/non-local status, year of study, and classroom number. Part 2 focused on the pairwise comparisons developed based on the selected classroom environment performance evaluation framework.

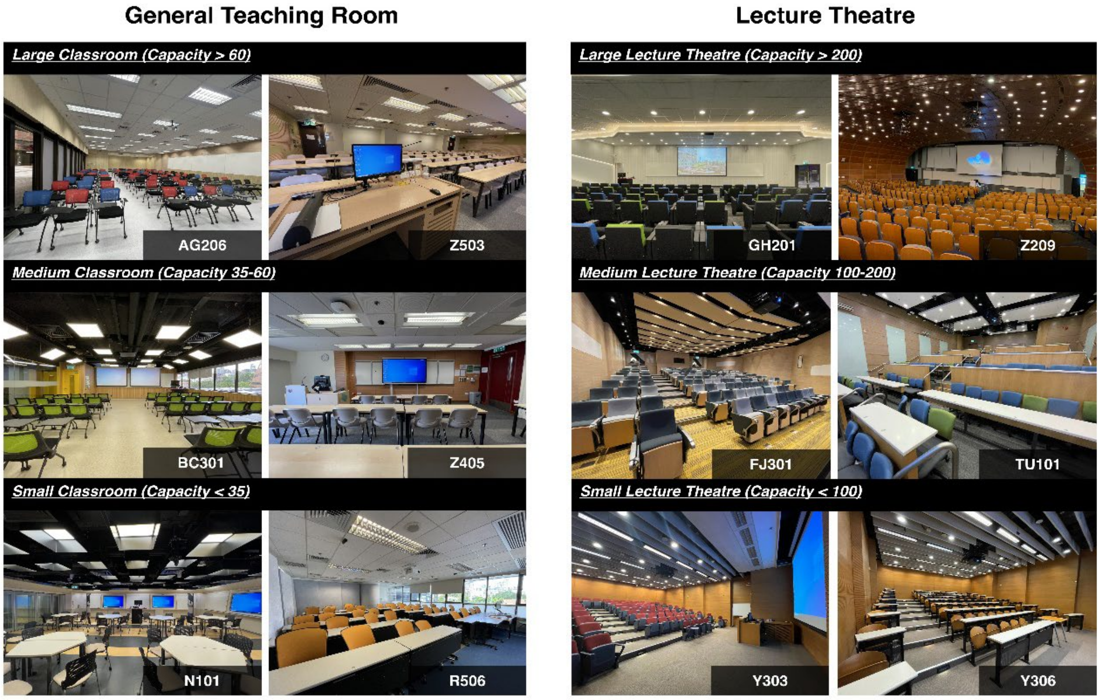


Figure 4. Types of Classrooms in the Selected University

Following the establishment of the hierarchical structure, the next step involves creating a pairwise comparison matrix using *Equation (1)*. Subsequently, the weightings of indicators for each level are calculated through *Equation (2)*, where w_i denotes the weighting of each factor.

The final step entails assessing consistency using two metrics: the consistency index (CI) and the consistency ratio (CR), as outlined in *Equation (3)*. In this equation, λ_{max} represents the eigenvalue, and "n" signifies the number of factors in the pairwise comparison matrix. Generally, a CR value of ≤ 0.1 is considered acceptable, indicating satisfactory consistency of the pairwise comparison matrix.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix}, a_{ij} = 1/a_{ji} (i = 1,2,3, \dots n, and\ j = 1,2,3, \dots m) \quad (1)$$

$$W=[w1, w2, \dots ,wn], w_i = \frac{\sum_{j=1}^{n} \bar{a}_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{n} \bar{a}_{ij}} \quad (2)$$

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI} \quad (3)$$

In this study, it was used to solicit students' stated preference between pairs of the aspects of classroom environment parameters based on their experience with the classroom environment. After completing a series of pair-wise comparisons composed by the performance parameters from the evaluation framework, the student's ranking of the performance parameters is obtained, which indicate his / her perception of the performance of the classroom environment.

A number of 364 responses were collected, among which 288 passed the consistency check ($CR \leq 0.1$). The overall useable rate (consistency rate) is 79%. The 288 students who provided valid responses are listed in Table 5's demographic breakdown.

Table 5. Background information

Information	Category	Number (%)
Gender	Female	177 (61.46%)
	Male	111 (38.54%)
Local or non-local student	Local	255 (88.54%)
	Non-local	33 (11.46%)
Undergraduate or Postgraduate	Undergraduate	228 (79.17%)
	Postgraduate	60 (20.83%)
Year of study	Year 1	115 (39.93%)
	Year 2	50 (17.36%)
	Year 3	65 (22.57%)
	Year 4	8 (2.78%)
	Master/PHD	50 (17.36%)
Types of classroom (where the students filled in the questionnaire survey)	Lecture theatre	158 (54.86%)
	General classroom	130 (45.14%)
AHP consistency rate	Total sample	364 (100%)
	Useable sample ($CR \leq 0.1$)	288 (79.12%)
	Non-useable sample ($CR > 0.1$)	76 (20.88%)

Note: N – Number of responding students.

4 Results

4.1 Focus group discussion (FGD) findings

For FGDs 1 through 4, each group developed a framework for evaluating classroom performance (Figures 5 – 8). According to the findings of FGD 5, version 4 of the classroom environment performance evaluation framework (V4) was deemed the most suitable framework out of all four versions.

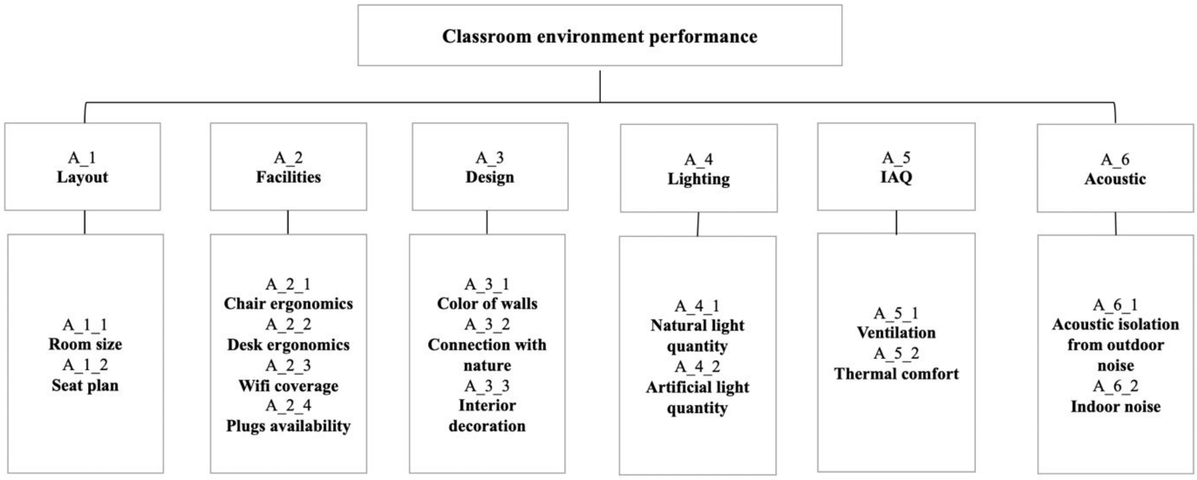


Figure 5. Performance evaluation framework version 1 (V1)

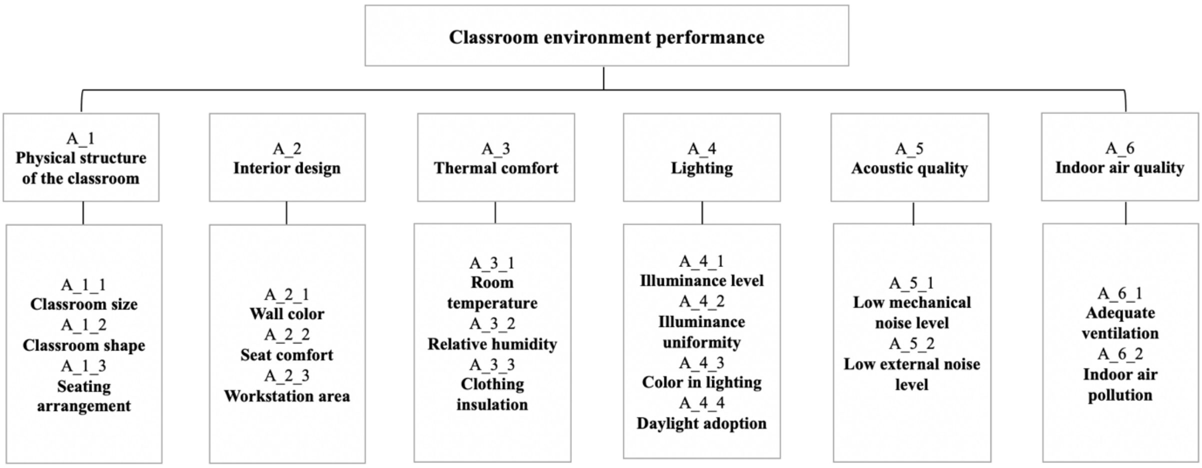


Figure 6. Performance evaluation framework version 2 (V2)

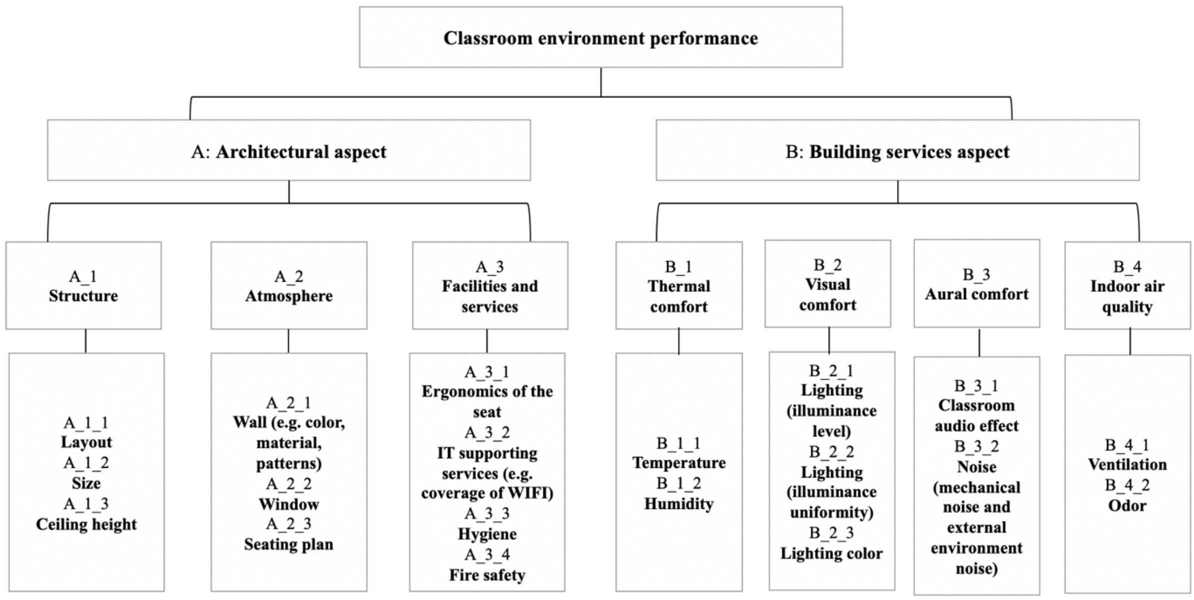


Figure 7. Performance evaluation framework version 3 (V3)

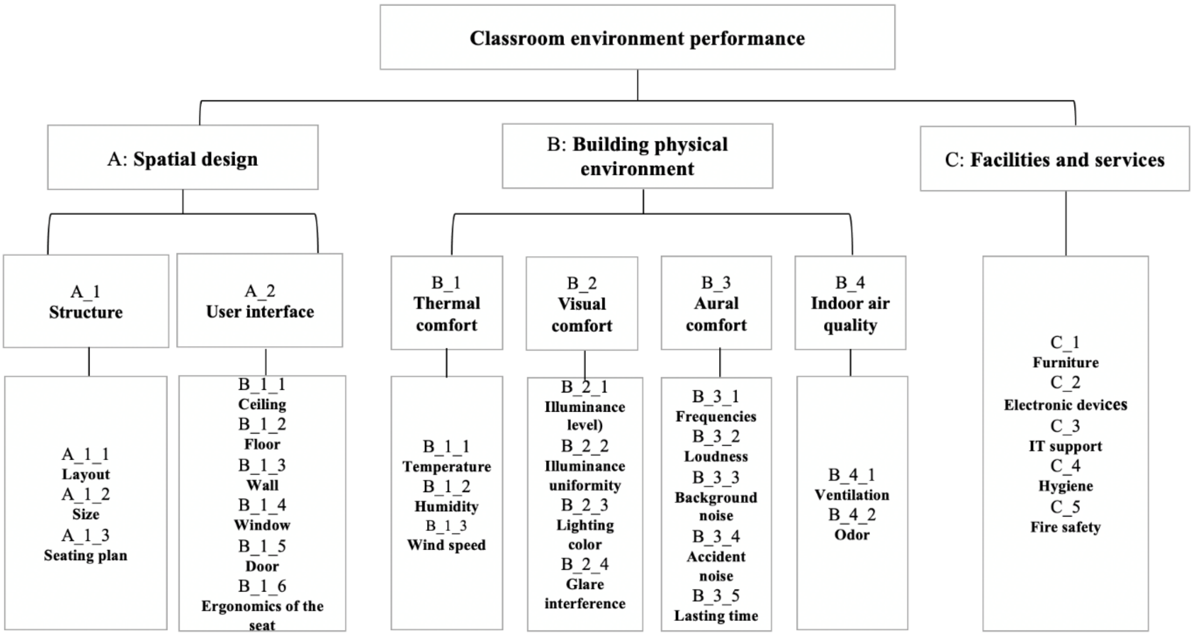


Figure 8. Performance evaluation framework version 4 (V4)

Both the first (V1) and second (V2) versions of the framework have a similar two-tiered structure. But there are some clear distinctions between the two. The term "thermal comfort" was listed under "indoor air quality" rather than being a major performance component in the V1. Participants in FGD-1 emphasised how interior temperature affects indoor air quality, which led them to propose that "thermal comfort" is a better indication of indoor air quality. The micro-level characteristics of environmental performance, such as "chair ergonomics", "desk ergonomics", "wifi coverage", and "plug availability", were also a focus of V1. Participants in FGD-1 put more focus on their personal interactions with the classroom setting, which led to the use of simpler terminology that are more in line with the viewpoint of the average layperson. Participants in FGD-2 with engineering knowledge, in contrast, used terms more cautiously. During the conversation, they looked up information online in search of professional words. The performance characteristics under "thermal comfort" and "lighting" in V2 demonstrate this.

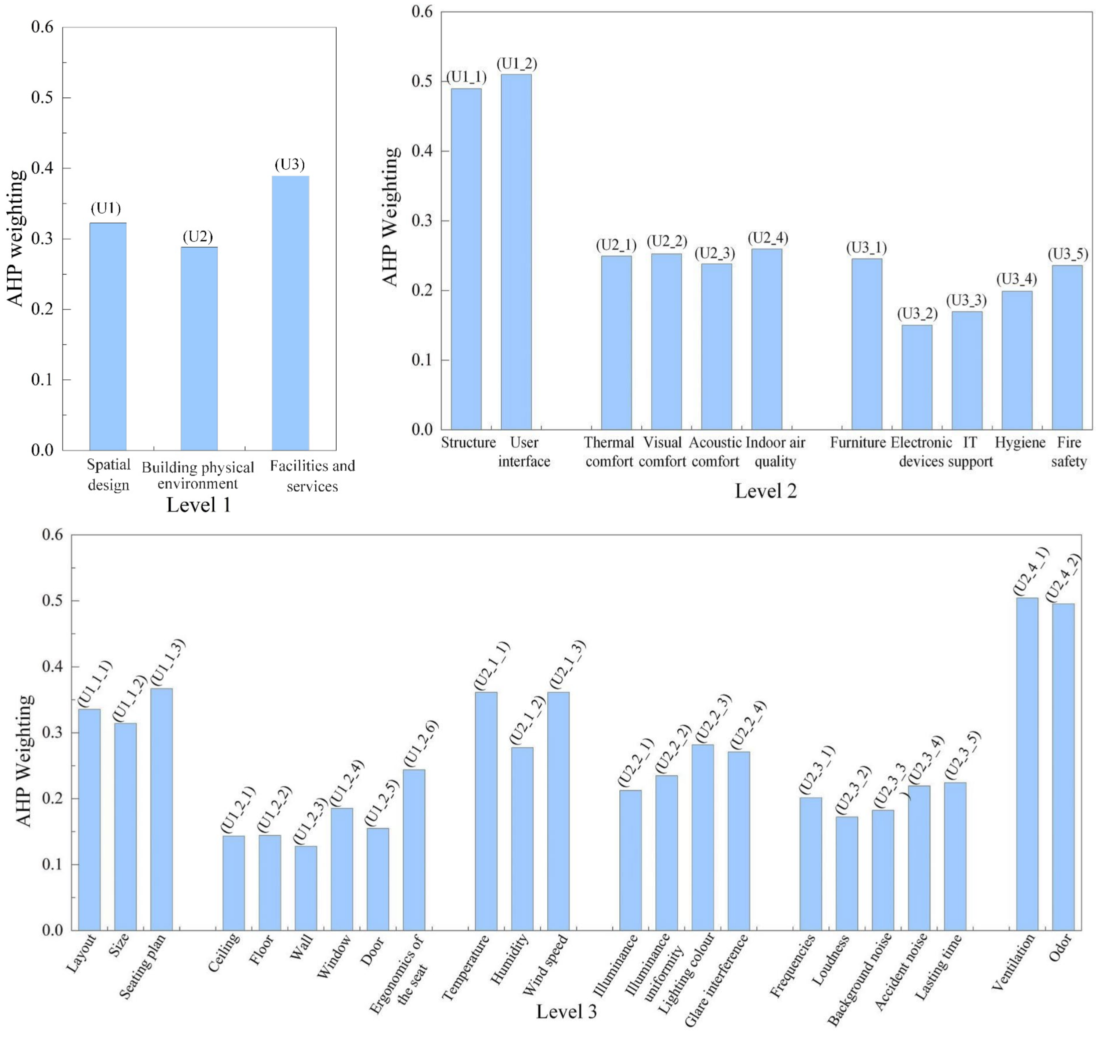
Three levels of hierarchy for performance factors were introduced in the third (V3) and fourth (V4) versions of the framework. Participants in FGD-3 divided the performance of the total classroom environment into two categories: "architectural aspects" and "building service aspects". Participants in FGD-4, on the other hand, classified it into three performance categories: "spatial design", "building physical environment", and "facilities and services". Participants in FGD-4 distinguished "facilities and services" from "spatial design" and "building physical environment" as separate performance characteristics, whereas "facilities and services" was deemed to be a component of "architectural aspects" in FGD-3. Participants from both FGD-3 and FGd-4 identified "thermal comfort", "visual comfort", "acoustic comfort", and "indoor air quality" as significant elements influenced by building systems with regard to specific performance parameters connected to comfort and indoor environmental quality. These elements were therefore grouped together by participants in both FGD-3 and FGD-4.

The FGD-5 participants were invited to discuss the four framework versions. They believed that V4 offered a more accurate and thorough portrayal of the many elements of the learning environment. Additionally, they argued that separating "facilities and services" from "spatial design" and "building physical environment" into their own category enables a more detailed examination. They believed that this distinction better captured the distinctive characteristics and capabilities of the services and facilities offered in the classroom, such as the technology tools, furnishings, and amenities. Participants in FGD-5 also felt that V4 more properly captured their own opinions and experiences and addressed students' objectives and concerns with relation to the learning environment, making sure that all crucial elements were fully covered.

4.2 AHP importance ranking findings

4.2.1 Importance ranking of university classroom performance aspects

In Figure 9, the weightings and rankings of performance parameters are organized according to hierarchy levels, allowing for explicit comparisons both within and between levels. It reveals that "facilities and services" received the highest importance weighting, accounting for 38.93%, followed by "spatial design" and "building physical environment", at 32.25% and 28.83%, respectively. While "facilities and services" (U_3) have received less attention in the building design and construction stage, it is actually emphasised the most by students in the university under investigation. On one hand, this finding reveals the importance of post-occupancy operation management; on the other hand, it also reflects that the framework development is scientific. Versions 1-3 do not include "facilities and services" in the same level of other environment factors. If adopting either of them, the perceived importance of "facilities and services" (U_3) by students may not be reflected. This suggest that students pay higher level of attention on "facilities and services" (U_3) comparing to "spatial design" (U_1) and "building physical environment" (U_2).



Note: the numbers represent the ranking of each aspect at each level.

Figure 9. Overall importance ranking of classroom environment performance attributes

At the second level, the weighting gap values between "structure" (U_{1_1}) and "user interface" (U_{1_2}) are similar, less than 3% of difference. But students tended to put more importance on "user interface" (U_{1_2}). Same is applied to the parameters: "indoor air quality" (U_{2_4}), "visual comfort" (U_{2_2}), "thermal comfort" (U_{2_1}) and "acoustic comfort" (U_{2_3}), while "indoor air quality" (U_{2_4}) was perceived slightly more important than the other three.

Both the weightings and rankings have directly indicated students' perceived importance of these environment parameters at each level and each category. It aids the facilities managers to have a direct overview of students' needs and preferences of the classroom environment.

4.2.2 Comparison of the perceived importance of the classroom environment among sub-groups

From a user-centric perspective, it is important to evaluate how users from various backgrounds perceive the quality of the indoor environment and examine how users' background information influences how they perceive the same indoor environment. In this study, the survey respondents' personal data was acquired, including their gender, educational level, year of study, background (local or not), and the types of classrooms in which they completed the questionnaire.

In contrast to other personal information features, Table 4 shows that the distribution of student numbers by gender and by types of classrooms is comparatively more equal (Female: 177 vs. Male: 111; lecture theatre: 158 vs. general classroom: 130). Students in their junior year (years 1-2) and those in their senior year (years 3 and above) are further separated into two groups. Based on the AHP survey results by gender, education level, and classroom type (where the students filled out the questionnaire survey), comparative analysis was carried out. The sub-group comparison of the important ranking by gender and educational attainment is shown in Figure 10 and Figure 11 respectively. Figure 12 contrasts how important each classroom type is.

4.2.2.1 Perceived importance ranking comparison by gender and by education level

According to Figure 10, the key findings include the following: first, there is a ranking difference between male and female students and between junior and senior year students for the classroom environment performance parameters; and second, the weighting gap values between the performance parameters under each level are relatively small, ranging from 0.01% to 10%.

Students' perception of "spatial design" (U_1), "building physical environment" (U_2), and "facilities and services" (U_3) are comparable between male and female students. Female and male students differ considerably in the second level's three groups for "thermal comfort" (U_{2_1}), "visual comfort" (U_{2_2}), "acoustic comfort" (U_{2_3}), and "indoor air quality" (U_{2_4}). Male students thought "indoor air quality" (U_{2_4}) was more significant than the other three performance measures, while female students said "thermal comfort" (U_{2_1}) was the most significant. Due to the very tiny weighting gaps between each pair of performance indicators, emphasis is put on the sub-groups for "thermal comfort" (U_{2_1}) and "indoor air quality" (U_{2_4}).

"Temperature" ($U_{2\_1\_1}$), "humidity" ($U_{2\_1\_2}$), and "wind speed" ($U_{2\_1\_3}$) are all included under "thermal comfort" (U_{2_1}). The weightings for the three criteria as indicated by female students are 37.34%, 27.21% and 35.45%, while the weightings as indicated by male students are 33.78%, 28.41%, and 37.81%. It is obvious that female pupils were more concerned with the temperature in the classroom while male students were more with the wind speed. Female students somewhat preferred "odor" ($U_{2\_4\_2}$) over "ventilation" ($U_{2\_4\_1}$) under indoor air quality" (U_{2_4}), but male students disagreed. The fact that male students gave ventilation the highest importance in two categories, which is significant because ventilation affects wind speed, suggests that they are more sensitive to the air flow in the classroom. Additionally, female students are more sensitive to temperature.

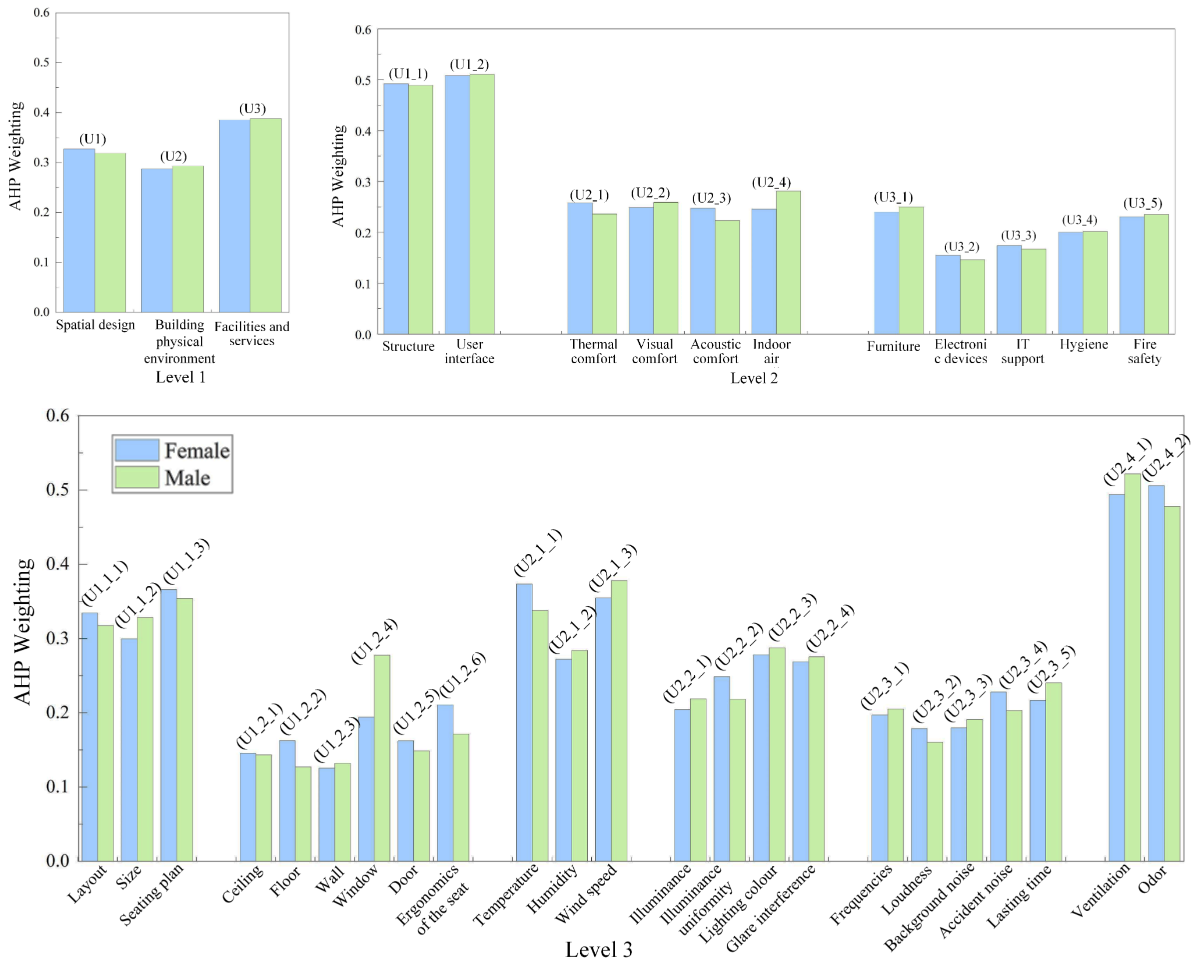


Figure 10. AHP weightings between different genders

Regarding whether students at different education levels (junior year and senior year levels) have significant diverse perceptions (as seen in Figure 11). The results indicate that while there are minor differences in ranking, the weighting values are quite similar. For instance, junior year students under "structure" (U_{1_1}) believe "layout" ($U_{1\_1\_1}$) is more significant than "seating plan" ($U_{1\_1\_3}$), although senior year students answered otherwise. The weightings for the two students' groups, however, are quite similar: For "layout" ($U_{1\_1\_1}$), junior year students received a ranking of 2 (32.51%) while seniors received a ranking of 3 (32.54%), and junior year students received a ranking of 3 (32.31%) while seniors received a ranking of 3.

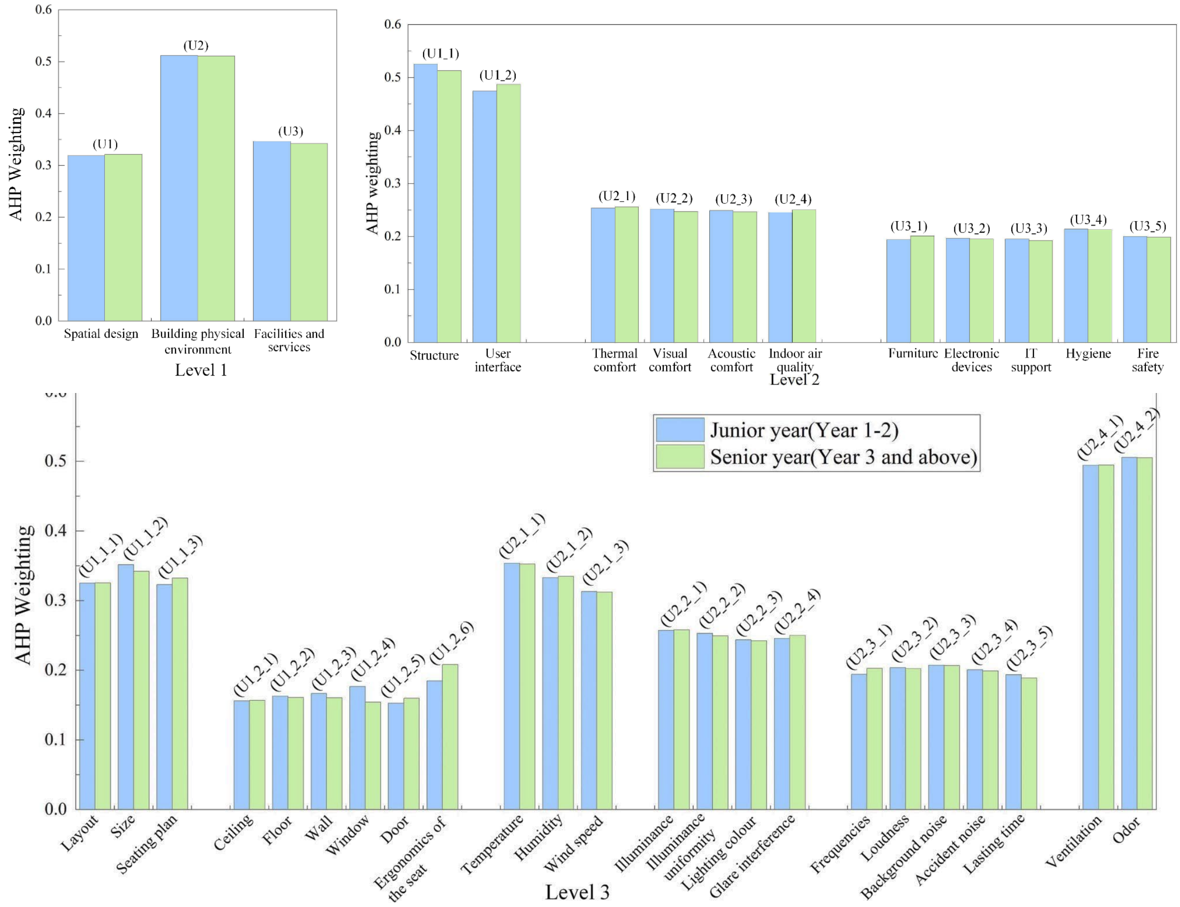


Figure 11. AHP weightings between different education levels

4.2.2.2 Perceived importance ranking comparison by classroom type

In order to collect data, students who remained in various types of classrooms are approached to take part in the questionnaire survey. The university under investigation has a mix of distinct classroom formats that are used for diverse teaching and learning objectives. For instance, lecture theatres are used to teach large classes, whereas smaller classrooms can assist teaching of smaller classes and facilitate interactions between students and teachers. Students who continued to attend these particular classrooms were approached by the researcher and asked to filled out the questionnaire. In order to determine the type of classroom, students were requested to enter the classroom number in the questionnaire.

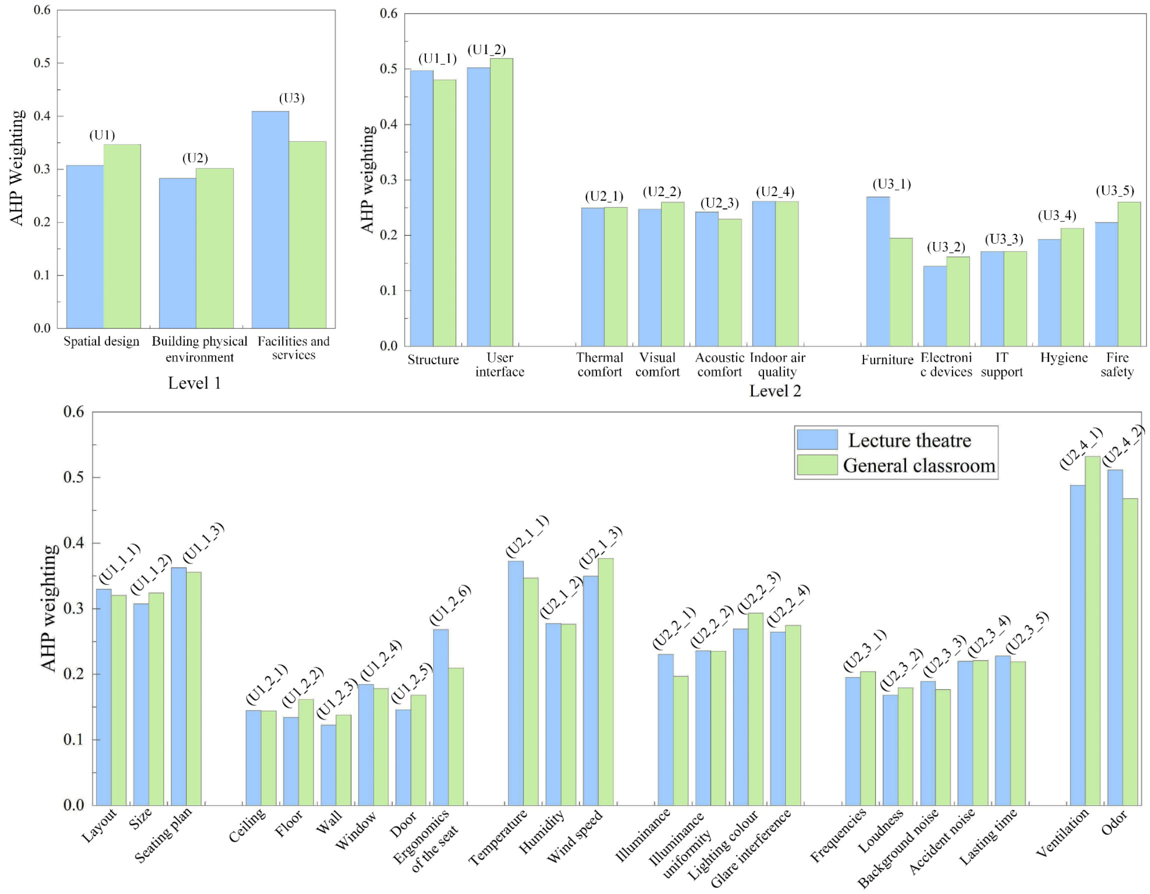


Figure 12. AHP weightings between different classroom type

Between the two groups of students, there are negligible differences in the ranking of the performance parameters. It is important to note that the dimensions, design, and seating arrangements of a lecture theatre set them apart from general classroom (as seen in Figure 12). According to the Figure 12, “seating plans” ($U_{1\_1\_3}$) were considered to be the most significant by both groups of students. Students who remained in the lecture theatre rated “layout” ($U_{1\_1\_1}$) as being more significant than “size” ($U_{1\_1\_2}$), in contrast to those who remained in the general classroom. The findings suggest that because students feel that there is enough room in lecture theatre and they do not consider it to be scarce, they considered the “size” of lecture theatre to be a less significant quality.

Another noteworthy finding is that students who remained in the lecture theatre rated “temperature” ($U_{2\_1\_1}$) as the most significant factor, but those who remained in the general classroom rated “wind speed” ($U_{2\_1\_3}$) as the most significant factor. In other words, when staying in the lecture theatre rather than the general classroom, students were more sensitive to the temperature. Additionally, students who remained in the lecture theatre expressed more concern over “furniture” (U_{3_1}) than “fire safety” (U_{3_5}). Students who remained in the general classroom ranked “fire safety” (U_{3_5}) as the most crucial factor, followed by “hygiene” (U_{3_4}) and “furniture” (U_{3_1}). In addition, students who remained in the lecture theatre gave “Odor” ($U_{2\_4\_2}$) a higher ranking than “ventilation” ($U_{2\_4\_1}$), in contrast to those who remained in the general classroom.

5 Discussion

The discussion section delves into three critical facets derived from the research findings, each contributing unique insights into understanding user preferences and interactions within the university classroom environment. Firstly, the discussion focuses on the development of systematic grouping criteria, which serves to enable a nuanced understanding of distinct preferences among students despite their shared university affiliation. Secondly, an emphasis is placed on the innovative research methods employed – grounded theory and Analytic Hierarchy Process (AHP) – that collectively facilitated a multifaceted approach in comprehending users' perspectives and developing an evaluation framework. Lastly, the section presents a human-built environment interaction model synthesized from the study's findings, elucidating the interactions between the built environment elements and human responses or reaction (e.g. sensation, cognitive perception, and behavior), highlighting avenues for further investigation and assessment of the built environment's impact on individuals. These components collectively contribute to a comprehensive understanding of users' perceptions and interactions within university classroom settings.

5.1 Developing systematic grouping criteria to support analysis

One of the contributions of this study is that a systematic grouping method would aid in eliciting specific information about the user preferences from a group of classroom users with a high degree of homogeneity in attributes. In this study, students who are from the same university shared a high degree of homogeneity. With a systematic grouping method, it helps to understand the specific preference differences among the students. The discrepancies in the discussion findings were first organised in this study's series of five FGDs, and they were then expressed in terms of the performance evaluation frameworks developed in each group. Different frameworks were developed by each group. Despite coming from the same university, the FGD participants' academic backgrounds had an impact on how they viewed the learning environment. According to the FGD results, students who majored in building engineering or design gave more specifics in their frameworks. When analysing survey results, gender and educational level are two often utilised grouping criteria to comprehend inter-group disparities. Despite having similar perceptions of general classrooms, students from the two groups (female vs. male / junior vs. senior year students) in this study. However, certain modest perceptual discrepancies on a few environmental factors represent the reasonable preferences of a particular student group. For instance, while male students ranked indoor air quality as the most crucial factor, female students prioritised thermal comfort. This result is consistent with prior research on interior environment quality that looked at how males and females perceive indoor thermal conditions differently. Understanding users' personal characteristics is the first step for conducting user-centric investigation approach and understanding user' preferences.

This study uses "location" as one of the grouping criteria to examine if users' perceptions are influenced by the external surrounding. Students who remained the lecture theatre and the general classroom in this study had similar perceptions of the university classroom setting, but a careful analysis of those perceptions between the two groups of students could disclose significant information. Size, layout, and seating arrangement are the three factors that set apart lecture theatre from other types of classrooms the most. A comparison of how these three criteria were ranked by the two groups of students showed that they might not view their current favorite activity as the most crucial consideration. For instance, students who remained in the lecture theatre thought that "size" was the least significant. Additionally, students who stayed in larger-scale space placed higher emphasis on "reachable" criteria like "seating plan" and "furniture". These findings suggest that the characteristics of the indoor environment have an impact on users' subjective experience. From a design standpoint, comprehending how a particular type of environmental feature affects users' perception helps building designers modify their design plan and makes it easier for building managers to update the indoor environment condition based on users' subjective perception.

Recognizing that students with diverse academic backgrounds, such as those studying building engineering or design, possess more specific preferences, underscores the importance of tailoring designs to accommodate the varied expertise and expectations within the user community. Furthermore, the study's examination of the impact of gender, academic level, and physical location on perceptual differences emphasizes the necessity for designers to take these factors into account when developing adaptable and inclusive classroom environments. Insights into how specific environmental features, including size, layout, and seating arrangement, influence subjective experiences provide valuable guidance for designers to refine their plans and for building managers to implement updates aligning with users' preferences, ultimately contributing to an enriched learning environment in university classrooms.

5.2 Innovative research methods

This study used both grounded theory and AHP to direct data collection after conducting a thorough literature review. This research methodology helps to gather information from users in the classroom, understand their top issues, and obtain different viewpoints from distinct user groups. Combining these two approaches offers a distinctive and potent method for decision-based evaluation processes.

New discoveries can be described and coined in a theoretical framework that explains the phenomena in this study by applying grounded theory. With its organised approach, the AHP technique enables classroom participants to match their preferences with the theories derived from grounded theory (the classroom environment performance evaluation framework developed based on the results of FGDs). Grounded theory emphasises the significance of gathering and analysing scientific qualitative data in order to pinpoint pertinent categories and concepts. It aids in the deep and complex interpretation of the facts by scholars. The findings might reflect not just the quantitative features but also the qualitative insights and perspectives derived through grounded theory by merging this understanding with the AHP method. Researchers can use the grounded theory findings to guide the selection of criteria and alternatives within the assessment hierarchy by applying the AHP technique. By doing this, it is made sure that the evaluation process is based on actual data and incorporates the important dimensions and aspects discovered through grounded theory analysis.

5.3 Human-built environment interaction model

Based on the university classroom research findings obtained with the support of grounded theory and AHP, a human-built environment interaction model is developed, as shown in Figure 13.

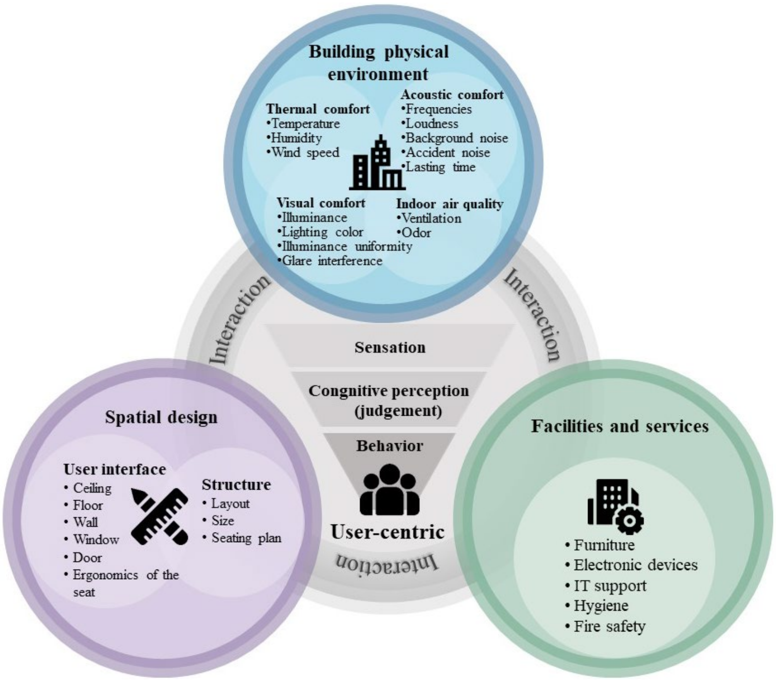


Figure 13. Human-built environment interaction model

This model demonstrates the common elements of the indoor built environment that go into building the performance evaluation framework and the reaction of people to the built environment. Grounded theory and the AHP technique were used to facilitate the development of the performance evaluation framework. The performance evaluation framework was built more easily using the grounded theory, and it was validated using the AHP approach.

The findings of the literature review, on the other hand, point to three categories of human reactions to the built environment: sensation, cognitive perception, and behaviour. The word "sensation" refers to the bodily experiences that people have, such as "hot or cold", "bright or dim", "quiet or loud", etc. For "cognitive perception", it refers to subjective evaluation of the effectiveness of the built environment. A satisfaction survey can be used to gauge how people feel about the built environment. Positive or negative assessment is part of it. For "behaviour", it is the dynamic interactions with the constructed environment. Examples of typical interior environment behaviour include the length of time spent indoors, where a person chooses to stay indoors, how the air conditioner is set, whether windows are opened or closed, etc. These behaviours show how people react to the built environment.

This model summarises the study's findings and offers guidance for further investigation into the interactions between the built environment and people. For future human-built environment interactions studies, three different forms of human responses should be combined in order to accurately assess how people feel about the built environment and evaluate its effectiveness.

6 Conclusion

This study demonstrates the significance of innovative research methods in understanding university students' preferences and perceptions of university classroom environments. By organising focus group discussions and AHP-based survey, a comprehensive evaluation framework was developed and verified. This framework considers the perspectives of various students, incorporate a hierarchical structure, focuses on crucial elements for comfort and environmental quality, and reflects the objectives and experiences of students to ensure an effective assessment of the classroom environment.

Using this framework in a case study based on a university in Hong Kong, students' perceived importance of classroom environment parameters was revealed. The importance ranking of university classroom performance parameter is examined based on different sub-groups, including gender, education level, and classroom type. The findings reveal that “facilities and services” received the highest importance weighting, indicating the significance placed on post-occupancy operation management. There are minor differences in rankings between male and female students, with males emphasising “indoor air quality” and females prioritising thermal comfort. Similarly, students at different education levels show slight variations in rankings but have comparable weightings. When comparing different classroom types, students in lecture theatres focus more on “seating plans” and “temperature”, while students in general classrooms prioritise “seating layout” and “fire safety”. These comparisons provide insights into the perceived importance of classroom performance parameters among different sub-groups, aiding facilities managers in understanding students' needs and preferences regarding the indoor environment. Leveraging this framework, designers can tailor indoor spaces based on nuanced user preferences, with a specific focus on post-occupancy management and the diverse needs of sub-groups, including gender, education level, and classroom type.

This study also introduces the human-built environment interaction model, which illustrates the components of the performance evaluation framework and human responses towards the built environment. The introduction of the human-built environment interaction model offers designers a powerful tool to understand the intricate relationship between design features and user responses, enabling them to create more user-centric and optimized indoor environments that enhance the overall learning experience for university students. Also, by combining grounded theory and the AHP method, the study provides a unique and powerful approach to build environment performance evaluation.

In conclusion, this study contributes to the understanding of user preferences and perceptions of university classroom environments. The systematic grouping criteria, innovative research methods, and the human-built environment interaction model presented provide valuable insights for future research and design considerations. By considering users’ characteristics and impact of the environment features, designers and facilities managers can create more user-centric and optimised indoor environment. Albeit the findings of this study proved that the methodology proposed for classroom environment is valid and useful, this study has its limitation. First, it confines to a specific type of university setting, which may limit broader generalizations to diverse educational environments. Second, regarding the sample size of 288 students in the AHP survey might restrict the comprehensiveness of the findings, potentially, overlooking perspective from a more extensive student population. As participants ranked attributes based on their then located classroom, the study might have excluded insights from students in unpresented or unexamined classroom settings. Third, this study specifically concentrates on comparing performance attributes within individual sections. This approach is chosen to ensure a focused analysis, as comparing the 37 performance attributes across three hierarchical levels and multiple sections might not offer practical insights to practitioners. Regarding the above limitation, future studies can be designed to enlarge the sample size and include students from a broader array of representative classrooms for enhancing the study’s inclusivity and potentially for capturing a more diverse range of perspectives. Comparative studies among universities in varied regions or countries, considering factors like climate, culture, and educational systems, could enrich the analysis by offering insights into how these diverse environments impact students’ perceptions and preferences regarding classroom environment performance. Furthermore, future studies will adopt a more nuanced approach to analyze performance attributes. This may involve conducting separate analyses for specific hierarchical levels and individual sections to yield targeted insights. The refined methodology aims to strike a balance between depth and breadth, ensuring that the findings offer more precise and actionable recommendations for practitioners in the field.

Acknowledgements

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