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Research Article

The significance of indoor thermal comfort on occupants' perception: in university buildings in Auckland, New Zealand

Sameh Azzazy [a], Amirhosein Ghaffarianhoseini[a], Ali GhaffarianHoseini[a], Nicola Naismith[a], Dat Tien Doan[a] and Justin B. Hollander[b]

[a]School of Future Environments-Auckland, University of Technology, Auckland, New Zealand; [b]Department of Urban and Environmental Policy and Planning, Tufts University, Medford, USA

ABSTRACT
Any building creates a unique micro-environment. Educational buildings tend to offer a wide range of purposes, with more operational functions than most other buildings. This paper focuses on the occupant's experiences of Indoor Thermal Comfort (TC) in educational buildings in Auckland, New Zealand. The TC can impact the occupant's experience and thus affects student learning. This survey-based study examines users' experience of the educational building's comfort levels. The collected data from educational building users (n = 109) was analysed to evaluate the relationship between the perceived experience and the building's function. The key findings of the survey were: (a) Identifying TC as the most significant factor that directly impacts the occupants' mood or mental state, even when compared to more cognitive factors; (b) Identifying the lecture room as the most critical space for occupants' thermal perception; and (c) the deviation between the preferred and experienced mental state, in the selected campus were relatively matching. This study contributes to the existing knowledge of educational buildings by quantifying the impact of TC on the occupant's experience.

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KEYWORDS
Educational buildings; building function; indoor environment; thermal comfort survey; building performance

Introduction

The predominant goal of any functional building is to create a suitable micro-environment for the occupants to pursue the intended building function (e.g. work, education, leisure, etc.) (Allen & Macomber, 2020; Chism, 2006). Respectively, buildings deliver the temperature, humidity, lighting, and ventilation necessary for people to live, learn and work effectively (Curwell et al., 2005; Wu et al., 2022). For educational buildings, the indoor spaces are expected to offer a broader range of different purposes, i.e. learning, collaboration, inspiration, leisure, etc … Conversely, the primary theoretical educational purpose of a building is to contribute to the quality of the educational experience by offering a good relationship between the occupants and their surrounding environment (Anderson & Holloway-Libell, 2014; O'Brien et al., 2020).

Accordingly, governments are now particularly interested in the evaluations and assessments of educational buildings' performance, seeking to increase the effectiveness of educational programmes and to improve economic efficiency (Khalil et al., 2016; Rothwell et al., 2018). These assessments have introduced regulations, building codes, and rating systems. However, the new growing academic studies with focus on the human behaviour and health is rarely included in building performance evaluations (Azzazy et al., 2020; Stamper et al., 2016). A recent study conducted in a tertiary education institution in New Zealand underscored the importance of considering a holistic approach to building design and facility management, emphasizing the need for tailored solutions to address occupants' diverse needs and preferences (Liu et al., 2023).

The lack of thermal comfort standards in educational facilities is due to the complexity of these surroundings; current regulations such as ISO 7730 (ISO, 2005), ASHRAE 55 (ASHRAE, 2004), and EN 16798-1 (CEN, 2019) seem to fall short of meeting the needs of students and teachers in terms of thermal comfort and thermal perception. These standards, which do not take into account the preferences of students and teachers, refer to data gathered in laboratories (ISO, 2005) or field studies using comfort data obtained on healthy adults in buildings around the world (Humphreys et al., 2015). Standards are frequently based on dose–response models, which are unable to account for people's unique

CONTACT Sameh Azzazy sameh.azzazy@aut.ac.nz

preferences and demands, as they were often developed for environments like offices and do not take into consideration the peculiarities of educational facilities (Lamberti et al., 2021). Meanwhile, Van Note Chism and Stanley (1999) defined the environment of learning as 'Environments or spaces that provide experience, stimulate the senses, encourage the exchange of information, and offer opportunities for rehearsal, feedback, application and transfer are most likely to support learning'. These definitions are rarely reflected in any building code, assessment, or rating schemes (Doan et al., 2017; Taleghani et al., 2013; Xue et al., 2019)

The initial stage, of this study, involved a comprehensive literature review through multiple scholarly databases, namely Scopus, Web of Science, and web search engine Google Scholar. The keywords used for conducting the initial search encompassed a wide range of terms corresponding to the objectives of this paper, including thermal comfort, thermal perception, adaptive thermal comfort, and thermal comfort index. To address the oversight of seminal works in thermal comfort research, it is imperative to recognize the foundational contributions of pioneers like Fanger and their impact on shaping our understanding of indoor environmental quality (Fanger, 1970). Fanger's development of the Predicted Mean Vote (PMV) model and subsequent research has provided invaluable frameworks for objectively assessing thermal comfort in various built environments. Acknowledging these contributions in the early stages of this paper is essential to contextualize the study within the broader landscape of thermal comfort research and to underscore the significance of exploring subjective perceptions alongside established methodologies.

While traditional methods of assessing thermal comfort emphasize objective measurements of environmental parameters, this study ventures into prioritizing occupants' subjective experiences. This approach is rooted in the recognition that individuals' perceptions and psychological responses play a significant role in determining their comfort levels and overall well-being within indoor spaces (Schweiker et al., 2020). By adopting a qualitative lens to explore the interplay between thermal perception and occupants' mental states, this research aims to shed light on the nuanced aspects of indoor thermal comfort that may be overlooked by traditional, quantitative approaches. Thus, while building upon the foundation laid by established methods, this study seeks to broaden the scope of inquiry and contribute to a more holistic understanding of thermal comfort dynamics in educational settings.

It is essential to acknowledge the complexity of thermal comfort assessment in university buildings and the variety of approaches available in the literature. While the paper highlights the limitations of the PMV/PPD approach for this specific building typology, it is important to recognize alternative methods that have been adapted to similar contexts (Lau et al., 2019; Zaki et al., 2017). Adaptive thermal comfort models, for instance, offer a more flexible framework for assessing occupants' comfort in variable environmental conditions, which may be particularly relevant for university office buildings where occupants have diverse preferences and activities (Humphreys et al., 2015; Xiaoyue Lang et al., 2022). Additionally, other analytical methods derived from PMV, such as the thermal sensation scale and the thermal comfort indices, provide alternative avenues for evaluating thermal comfort in this typology (Broday et al., 2019; Rupp et al., 2021).

Most of the reviewed literature has focused on reducing the total energy demand, building envelope, recovery/reduction of the building's wasted energy, optimization of utility consumption, etc. (de Wilde, 2019; Jain et al., 2020; Mallory-Hill et al., 2012). Even occupant behaviour studies have focused on energy consumption (Correia da Silva et al., 2013; Li et al., 2019). This predominant focus has been reflected in the current engineering codes and buildings' rating/certification guidelines such as; Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), or Green Star New Zealand (Doan et al., 2017; Ncube & Riffat, 2012). Even with several regulations that promote a healthy environment, i.e. governing the indoor air quality, natural light exposure, etc., there are no national or global regulations or guidelines that focus on the long-term effect of the built environment on mental health, or that aims to address impacts on the occupant's state of mind (Azzazy et al., 2020). Since the thermal environment can significantly impact students' well-being, providing thermal comfort in classrooms is crucial to enhance students' productivity and health (Lamberti et al., 2020).

Several studies have further considered thermal comfort in educational buildings based on natural ventilation and energy savings or bioclimate architecture, e.g. (Costa et al., 2019; Ge et al., 2018; Jing et al., 2019; Lau et al., 2019; Sanguinetti et al., 2017). Most studies have concluded that thermal comfort is critical for educational buildings. Providing an adequate microclimate environment significantly enhanced the occupants' performance (Astolfi & Pellerey, 2008; Zaki et al., 2017). However, the primarily identified gap in the literature is the absence of investigating the subjective perception of Indoor Thermal Comfort (TC) and its impact on the occupants' state of mind, which drives their performance (Doan et al., 2017; Jiang et al., 2021; Kar et al., 2019; Li et al., 2019). Several occupants' behaviour studies have solely focused on energy consumption (Correia da Silva et al., 2013; Li et al., 2019), without in depth analysis of the occupant performance.

From a climate-focused perspective, most of the reviewed literature concerning TC in educational buildings focused on highly humid or hot tropical climate weather, e.g. (Buonocore et al., 2020; Guevara et al., 2021; Lau et al., 2019; Talukdar et al., 2020; Zaki et al., 2017). Consequently, another fundamental identified gap in the literature is the shortage of studies conducted in countries with climates similar to New Zealand, considered subtropical weather with mild temperatures and moderate rainfall (Sturman & Tapper, 1996; Watt et al., 2019). This climate specific limitation of the literature is critical, considering the individual perception of thermal comfort. For example, Yang et al. (2015) discovered a deviation of the Predicted Mean Vote (PMV) caused by overestimating the warm sensation brought on by previous thermal experience from long-term residence in a particular region, which could stimulate psychological adaptation. This fluctuating psychological adjustment could neutralize the occupants' perceived thermal sensation by controlling the skin's thermal sensibility, consequently causing a hedonic thermal offset of the PMV ratings.

Furthermore, while the paper suggests a lack of specific studies on comfort in university buildings in mild climates, it is worth noting that there exists a substantial body of literature addressing thermal comfort in educational environments across various climatic regions (Lamberti et al., 2021). Studies investigating thermal comfort in university buildings in mild climates, although fewer in number compared to those in extreme climates, do exist and can provide valuable insights into the unique challenges and considerations of this context (Costa et al., 2019; Guevara et al., 2021; Talukdar et al., 2020). By acknowledging and incorporating findings from existing literature on thermal comfort in similar building typologies and climatic conditions, future research can build upon established knowledge and contribute to a more nuanced understanding of indoor environmental quality in university buildings.

The critical shortage of the reviewed studies is the association of thermal perception and the occupant's overall thermal perception and corresponding mood or state of mind, which is the main objective of this study. Addressing these mentioned gaps, this research aims to quantify the impact of TC on the occupants' state of mind and the variation between the perceived and preferred state of mind. This subject is crucial for enhancing general and educational building evaluations. IEQ in educational facilities is essential to attaining a specific state of mind since it impacts users' general behaviours, achievements, and happiness (Earthman, 1996; Wang & Degol, 2016).

To bridge these gaps, this research aims to delve into the subjective perception of Indoor Thermal Comfort (TC) in educational buildings and its impact on the occupants' state of mind. By exploring the interplay between thermal perception and mood, this survey-based study seeks to quantify the variations between perceived and preferred states of mind within a university campus. The survey, a central component of this research, serves as a vital tool for gathering firsthand insights from the occupants of educational buildings within the university campus. Through carefully designed questionnaires, participants will be invited to share their experiences and perceptions regarding the indoor thermal environment and its connection to their mental states. This approach allows for a nuanced understanding of how occupants subjectively interpret and respond to the thermal environment, shedding light on aspects often overlooked in traditional building assessments.

The survey methodology is chosen to facilitate a comprehensive exploration of the nuances in occupants' experiences, providing more perspectives on the occupant thermal perception. The survey aims not only to quantify the variations in perceived and preferred states of mind but also to uncover the underlying factors influencing these perceptions. This multifaceted approach enhances the robustness of the study's findings, offering valuable insights for policymakers, building designers, and educators striving to create optimal environments for learning and well-being in educational settings. The subsequent sections will provide a detailed account of the literature review, survey methodology, and analysis procedures employed in this research to contribute meaningfully to the existing body of knowledge in the field.

Methodology

Understanding how occupants perceive their built environments is critical for this study. The neural receptors connecting neurosensory information to the brain play a central role in the perception of various aspects of IEQ, including TC (Lan et al., 2022; St-Jean et al., 2022). However, it is essential to recognize that the current thermal indices may not fully account for the impacts of perceived thermal comfort (PTC) due to their limited scope in considering the neuropsychological effects of thermal sensation (Jiang et al., 2021; Lamberti et al., 2021).

The current measurement methods of TC is relative to the occupants' perception and often depends on the overall statistical significance of a selected sample (Földváry Ličina et al., 2018). Table 1 summarizes methods

Table 1. Relevant research methodologies in TC.

Method	Example of reported studies	Description	Measured factors
Epidemiological approach	(d'Ambrosio Alfano et al., 2019; Johnson et al., 2011; Kishi & Araki, 2020; O'Lenick et al., 2019; Riley et al., 2016)	Questionnaires combined with biological measurements (e.g. blood, urine) creating physiological data representing the human body's reaction to external stressors	• Physiological changes. • Personal factors.
Field studies	(Bluyssen, 2020; Kotopouleas & Nikolopoulou, 2018; Ormandy & Ezratty, 2012; Taleghani et al., 2013; Thai et al., 2019)	A general or a smaller sample of the public studied against environmental records	• Subjects' behaviour. • Measured environmental parameters.
Laboratory Studies	(Čulić et al., 2021; Ismail et al., 2021; Lang et al., 2022; Lv et al., 2017; Song et al., 2019; Zhang et al., 2018)	The subjects are exposed to controlled environmental parameters while their physiological and psychological behaviour are studied. New research is utilizing machine learning algorithms to create human TC models.	• Various factors. • Can vary from observation to brain mapping.

implemented to measure the TC and the occupant's comfort and dissatisfaction with the surrounding indoor environment (Bluyssen, 2004; Bluyssen et al., 2011).

As shown in Table 1, most of these methods depend on sampling of small number of participants and rarely consider the variation of personal thermal perception over a larger population. Studies developed based on the adaptive thermal comfort theory have pointed out that the perceived thermal comfort varies depending on hedonic and adonic factors (Aizawa et al., 2019; Farrell et al., 2011; Humphreys et al., 2015). In addition, these methods are often considered brief observations and are exclusive of the resulting impacts of TC on the occupants' perception. Hence, our methodological approach in this study, is to collect occupants' overall perceptions of the TC and quantify the significance of the TC on the occupants' experience in universities building.

Our novel approach, in this study, is that we have asked the participants to complete the survey online from any location. The design of the survey questions was exclusive of any momentary data collection, i.e. the participants were asked to report their overall thermal perception of the building and spaces and not their momentary thermal experience or feelings. There for in this study there was no environmental data monitoring of evaluation of any environmental parameter, as the study main objective is to quantify the significance of the TC on the occupant performance.

Furthermore, thermal perception surveys are critical to estimate the 'actual' response of a large population of subjects from an accurately estimated / relatively small sample (Maas & Hox, 2005). Statistically, there are two types of evaluation of the true response, point estimation (by unique value), or interval estimation. The most considered method in subjective thermal surveys is interval estimation using the probability of Confidence Intervals since it provides more information than point estimation and enables critical statistical analysis for a large sample (Ferguson, 2016).

The key advantage of objective thermal perception surveys is the minimal requirements for measuring the physical characteristics of the environment (i.e. temperature, noise, light, etc.) during the evaluation since the main objective is to evaluate the overall occupant's perception of the thermal performance of the building. These types of surveys primary focus on obtaining an unbiased and unfiltered assessment of occupants' perceptions regarding the thermal performance of the building. Unlike traditional approaches that may heavily rely on specific environmental metrics, objective thermal perception surveys prioritize capturing the subjective experiences and responses of occupants without preconceived notions or predetermined criteria. This methodology allows for a more holistic and occupant-centric evaluation of thermal comfort within a built environment. Additionally, TC survey studies are significantly comprehensive for building performance (Nicol & Roaf, 2005; Song et al., 2019).

In this study, the quantitative survey was carried out using an online questionnaire. Besides the demographic data, the questions aim to collect data to answer the following research objectives:

- Identify the most significant spaces in the educational building (by time spent) to optimize the overall thermal performance of the building.
- Quantify the significance of TC against various factors impacting the experienced mental state in an educational building.
- Compare the preferred vs perceived mental state of the occupants.

This study was conducted at [institution name removed]. The survey was advertised to the targeted population ($n = 2657$) twice over three months to ensure a high return rate. Participants could only take the survey once using the unique link feature. The survey was advertised on the university's digital online learning management system and was voluntary without compensation or promotional advertising.

The survey was published on Qualtrics.com through university-provided access. The total number of questions was 15, including several slide bars and matrices. The first page of the survey was a consent form and an information sheet in accordance with [institution name removed] ethics committee requirements and aligned with the granted ethical approval for the entire study. Ethical approval was obtained by the [institution name removed] Ethics Committee under Ethics Application 20/5.

This survey focused on the overall thermal perception of the occupants and did not include any building environment monitoring. The focus of this research is perceived thermal comfort. It did not include any momentary questions and was not restricted to a particular room. The participants were not advised to answer the online survey in any particular location, as the focus of the study is to evaluate the overall impact of the TC on the occupant's state of mind (or perceived experience) beyond the momentary limitation of the external thermal stimuli.

The psychological questions for the perceived and preferred mental state were designed based on a rating of 11 different mental states; 5 positives, 5 negatives, and one neutral. This approach was based on the reviewed literature for psychological surveys (Alarcão & Fonseca, 2019; Schwarz, 2007; Varela et al., 2017). The ratings of the 11 mental states will quantify the relative significance of each perceived and preferred mental state and allow the statistical description in terms of thermal comfort.

The chosen methodology for this study integrates a quantitative survey approach to delve into the intricate dynamics of Indoor Thermal Comfort (TC) and its impact on the mental state of occupants within an educational building. While the traditional approach in thermal comfort studies often combines questionnaires with physical measurements, our unique focus on perceived thermal comfort distinguishes this research. The decision to forego physical measurements aligns with the specific objectives of the study, which are cantered on understanding the occupants' subjective experiences and perceptions of thermal conditions rather than objective environmental metrics.

The objectives of the study are meticulously aligned with this chosen methodology. The first objective, identifying the most significant spaces in the educational building to optimize thermal performance, directly necessitates capturing occupants' subjective experiences in various spaces. The second objective seeks to quantify the significance of TC against various factors impacting the experienced mental state, emphasizing the need for a survey-based approach to understand the nuanced interplay between thermal comfort and the overall indoor experience. The third objective, comparing preferred versus perceived mental states, aligns with the study's focus on occupants' subjective assessments.

Sample size

The survey participants were chosen from among the regular users of the same educational buildings, providing a representative sample to quantify the survey objectives across the university's various buildings. Hence, the comprehensive sample frame of this study (population – N) is the enrolled students in the School of Engineering, Computer and Mathematical Sciences, a total of 2657 students. The selection of a specific school was to guarantee purposive sampling and ensure homogeneity of the independent variables (i.e. Indoor Thermal Environment) across the results as all the students at the identified school share similar facilities; therefore, all participants were subject to a similar thermal environment (Collins, 2010).

The returned survey response was 109, with a proportion of (4.1%). Additionally, the adopted purposive sampling technique is considered nonrandomized sampling, where primary statistical theories or a defined number of participants are not critical to validate the results since participants' exposure to the study variables is indistinguishable (Etikan et al., 2016). This adopted technique is also referred to as 'Homogeneous sampling' and is often used to optimize resources or in conjunction with qualitative analysis to collect accurate and specific insight into the subject (Palinkas et al., 2015) as the purpose of this study.

In our selection methodology of students, we are expected to have a lower variance (Var) since our population is more unified and shares the same common purpose and environment. In purposive sampling settings, the sample size will have a lower impact on the stander error (SE) and the variability of the results. These criteria should yield less than 6% variability (De Vaus, 2013; Fowler, 2013). This selection of participants ensured the returned surveys' precision and quality, which will increase the accuracy of the result, even with a lower population of participants (Anderson & Holloway-Libell, 2014; Nardi, 2018).

Furthermore, the returned ratio of the survey ($P = 0.041$) was used to calculate the confidence intervals for one proportion from a finite population (N) using power analysis for sample size (PASS) software. This routine calculates the sample size necessary to achieve a specified interval width at a stated confidence level

Table 2. Summary of the sample simulation.

Input	Values
N (Population Size)	2657
P (Sample Proportion)	0.041
d (Precision, Half-Width)	0.020
	0.030
	0.040
Confidence Level C.L (1 − Alpha)	0.900
	0.950
	0.990

for a confidence interval of one proportion estimated from a finite population (Machin et al., 2011), the summary of the input data is in Table 2. Accordingly, the returned proportion of the survey has a confidence level (C.L) of 96% with a precision (d) of 0.04.

Survey design

The research team designed the electronic survey to cover the three research objectives mentioned in the methodology section. Additionally, the survey was designed to be completed in a short period (less than 10 minutes) to avoid any invalid results due to boredom or fatigue (Groves et al., 2011).

The summary of the survey questions is presented in Table 3. The main categories of the questions are demographics, behavioural (i.e. based on time spent) – (C1), psychological (C2) and thermal perception questions – (C3). The thermal comfort questions have been designed based on recommendations of ISO 10551/7730 (ISO, 1994, 2005). The questions depended on the Likert scale, slider bars, and rating matrices to quantify the survey objective and maintain a practical visual presentation for the participants. The thermal sensation questions were based on the common ASHRAE & ISO 7730 Seven-point thermal sensation scale; Cold, Cool, Slightly Cool, Neutral, Slightly Warm, Warm and Hot (ISO, 2005; The American Society of Heating, 2004). It should be stated that, in this study, the thermal comfort questions were not momentary. It was generic and used to compare the occupants' overall thermal perception of different spaces with the time spent in those spaces. Accordingly, the participants were not instructed to take the survey in a specific room or building since this study aims to quantify the overall thermal perception of the occupants across the six selected indoor areas, that represent the key activities in any educational building.

The behavioural/time spent questions were percentages based on the total time spent in the university. The ratings included all possible six subcategories of spaces, see Figure 1, to quantify the relative significance of each space and match it with the similarly quantified and weighted thermal perception. The time spent analysis is also used as a weighting factor in each subcategory of space specific thermal comfort questions to reflect the level of exposure to each space (Elnabawi & Hamza, 2020; Nikolopoulou & Steemers, 2003). The detailed statistical analyses are in following sections, which included four main categories of ANOVA analysis; test of robust homogeneity, nonparametric test of homogeneity based on ranks, symmetry and normality test.

The primary rationale for this research is to ensure a detailed and in-depth exploration of the occupants' thermal perception within a certain functional environment, allowing for a nuanced analysis of the chosen spaces in that environment. By concentrating on a single institution, we aimed to create a more homogenous sample that would provide targeted insights into the

Table 3. Summary of the survey questions excluding the demographic questions by category.

Main question	Type	Sub questions	Category
Overall, what percentage of your time (in campus) do you spend in indoor spaces (inside buildings)? – Time inside [institution name removed] buildings (indoor)	percentage bar		C1
Overall, what percentage of your time (in campus) do you spend in the following spaces	percentage bar	Lecture rooms, Open study areas (indoor), Quiet study rooms, Laboratories, Indoor recreation areas, Food and drinks outlets (indoor)	
Overall, while inside [institution name removed] buildings, how often do you feel	percentage bar	Relaxed, Focused, Creative, inspired, Deep in thought, positively excited, frustrated, disappointed, sad, anxious, angry, bored	C2
How often do you notice your mood (feelings) changing while inside [institution name removed] buildings? – My mood changes	Likert scale		
Which of the following factors impact your mood, select multiple options: (Noise, Thermal sensation (hot or cold), Interaction with colleagues, Interaction with [institution name removed] staff, Study load, Exposure to sunlight, Bad news)	multiple selection		
In your opinion, how do you describe the preferred state of mind in educational buildings. What is your favourite combination? – Relaxed	percentage bar	Relaxed, Focused, Creative, inspired, Deep in thought, positively excited, frustrated, disappointed, sad, anxious, angry and bored	
Overall, how hot or cold do you often feel, in [institution name removed] Buildings: – I am often; (Cold, Cool, Slightly Cool, Neutral, Slightly Warm, Warm and Hot)	slider bars for each	Lecture rooms, Open study areas (indoor), Quiet study rooms, Laboratories, Indoor recreation areas, Food and drinks outlets (indoor) and in General	C3

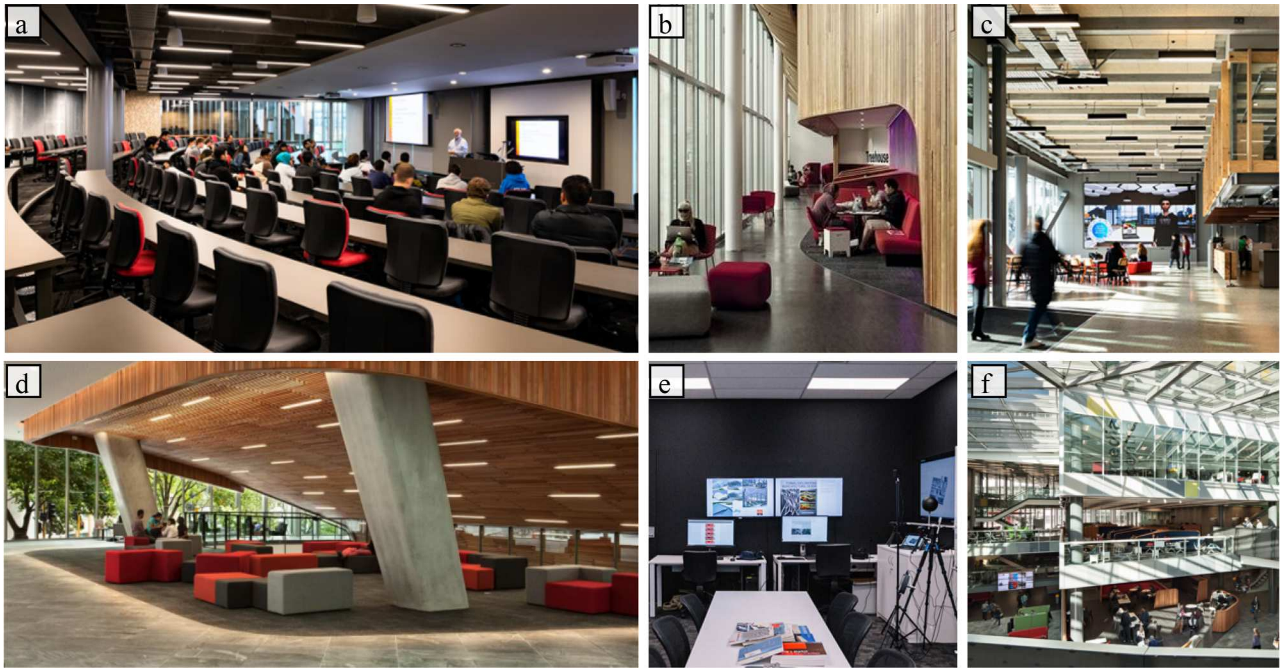


Figure 1. Different indoor spaces in images from (a) Lecture room (Credit to Jason Mann), (b) Quiet study rooms (Credit to Simon Devitt), (c) Food and drinks outlet (Credit to Jason Mann), and (d) Open study area (indoor), (e) Laboratory and (f) Indoor recreation areas.

thermal experiences of students within the unique context of that particular academic environment.

The selection of spaces in the questionnaire was based on a comprehensive understanding of the diverse yet representative areas typically found in universities. The inclusion of lecture rooms, open study areas, quiet study rooms, laboratories, indoor recreation areas, and food and drinks outlets reflect a thoughtful classification of spaces commonly encountered in educational buildings. Each of these spaces plays a distinct role in the daily activities of students and including them in the questionnaire allows for a comprehensive exploration of the various thermal experiences within the academic setting, as shown in Table 3.

The decision to opt for a homogenous convenience sample aligns with the objectives of the study. The goal is to gain in-depth insights into the perceived thermal comfort of students within their immediate educational environment. A homogenous sample, in this context, ensures a focused and detailed examination of the specific conditions and characteristics of the chosen institution, enhancing the internal validity of the findings (Jager et al., 2017).

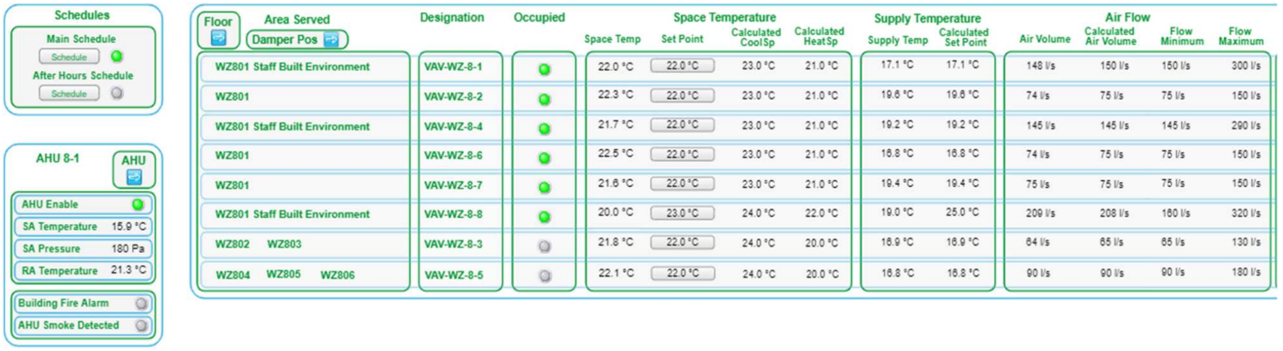
In this study, the selection of the indoor spaces limits our research to the occupant's perception of indoor spaces. The analysis of the time spent in indoor spaces is not considered as a behavioural indication of thermal comfort. Since we considered the students to be a passive recipient of thermal environmental conditions within the buildings enclosed envelope (closed ventilation) design in [institution name removed]. This was also disregarded as insufficient supporting evidence in the reviewed literature (De Giuli et al., 2012).

Another reason to disregard the time spent as an indication of thermal comfort is the configuration of the selected building's (WZ) HVAC system, see Figure 2. The HVAC system is considered a swift response central system with available Chilled/Hot water at 8.9 °C /25.7 °C, respectively, at each space which retains the average set temperatures (between 22-23°C) to actual temperatures of 20-22.5°C.

Results and analysis

The returned results of the survey extended for 5 months. Arguably this extended period would entail various seasonal weather fluctuations. However, as the below temperature graph for the survey period, the entire survey period is considered on the lower spectrum (winter) of the total year temperature fluctuation, see Figure 3.

The participants' leading demography percentages were 42% between 20–24 years old, 66% males, and 68% undergraduates, refer to Table 4. This demographic distribution reflected the overall demography of the enrolled students, which validated the returned



Area Served / Damper Pos	Designation	Occupied	Space Temp	Set Point	Calculated CoolSp	Calculated HeatSp	Supply Temp	Calculated Set Point	Air Volume	Calculated Air Volume	Flow Minimum	Flow Maximum
WZ801 Staff Built Environment	VAV-WZ-8-1		22.0 °C	22.0 °C	23.0 °C	21.0 °C	17.1 °C	17.1 °C	148 l/s	150 l/s	150 l/s	300 l/s
WZ801	VAV-WZ-8-2		22.3 °C	22.0 °C	23.0 °C	21.0 °C	19.6 °C	19.6 °C	74 l/s	75 l/s	75 l/s	150 l/s
WZ801 Staff Built Environment	VAV-WZ-8-4		21.7 °C	22.0 °C	23.0 °C	21.0 °C	19.2 °C	19.2 °C	145 l/s	145 l/s	145 l/s	290 l/s
WZ801	VAV-WZ-8-6		22.5 °C	22.0 °C	23.0 °C	21.0 °C	16.8 °C	16.8 °C	74 l/s	75 l/s	75 l/s	150 l/s
WZ801	VAV-WZ-8-7		21.6 °C	22.0 °C	23.0 °C	21.0 °C	19.4 °C	19.4 °C	75 l/s	75 l/s	75 l/s	150 l/s
WZ801 Staff Built Environment	VAV-WZ-8-8		20.0 °C	23.0 °C	24.0 °C	22.0 °C	19.0 °C	25.0 °C	209 l/s	208 l/s	160 l/s	320 l/s
WZ802 WZ803	VAV-WZ-8-3		21.8 °C	22.0 °C	24.0 °C	20.0 °C	16.9 °C	16.9 °C	64 l/s	65 l/s	65 l/s	130 l/s
WZ804 WZ805 WZ806	VAV-WZ-8-5		22.1 °C	22.0 °C	24.0 °C	20.0 °C	16.8 °C	16.8 °C	90 l/s	90 l/s	90 l/s	180 l/s

Figure 2. a snapshot of the key operating settings in different spaces, source: [institution name removed] facility management dashboard.

responses with an adequate demographic representation of the overall population.

Further cluster analysis was conducted for the demographic description of the returned survey to identify the main leading demographic groups and the statistical significance of each group. Two central clusters were identified; Cluster 1: 69.8% of males between 20 and 24 years enrolled in Undergraduate (Full-time) and Cluster 2–65.2% of males between 25–30 years enrolled in Postgraduate (Full-time). The Silhouette Score of the two identified clusters is (0.41) considered in the moderate relativity range due to the limited sample size and the number of variables in the cluster (Fowler, 2013) These two clusters were the most significant, as in Table 5, they reflect similar gender percentages (as the overall gender distribution). The main variation of these two selected clusters is age group. Cluster 1 respondents mostly were aged 20–24 and Undergraduate (Full-time), while cluster 2 respondents mostly chose ages 25–34 and Postgraduate (Full-time). These two groups also match the overall university

Table 4. Demographic breakdown of the survey response.

Gender	Count	Percentage
Male	72	66.3%
Female	37	33.7%
Age		
Less than 16	3	02.3%
16–19	20	18.6%
20–24	46	41.9%
25–34	30	27.9%
35–44	8	07.0%
45–54	3	02.3%
Programme		
Undergraduate (Full-time)	74	68.2%
Undergraduate (Part-time)	6	05.9%
Postgraduate (Full-time)	24	22.4%
Postgraduate (Part-time)	4	03.5%

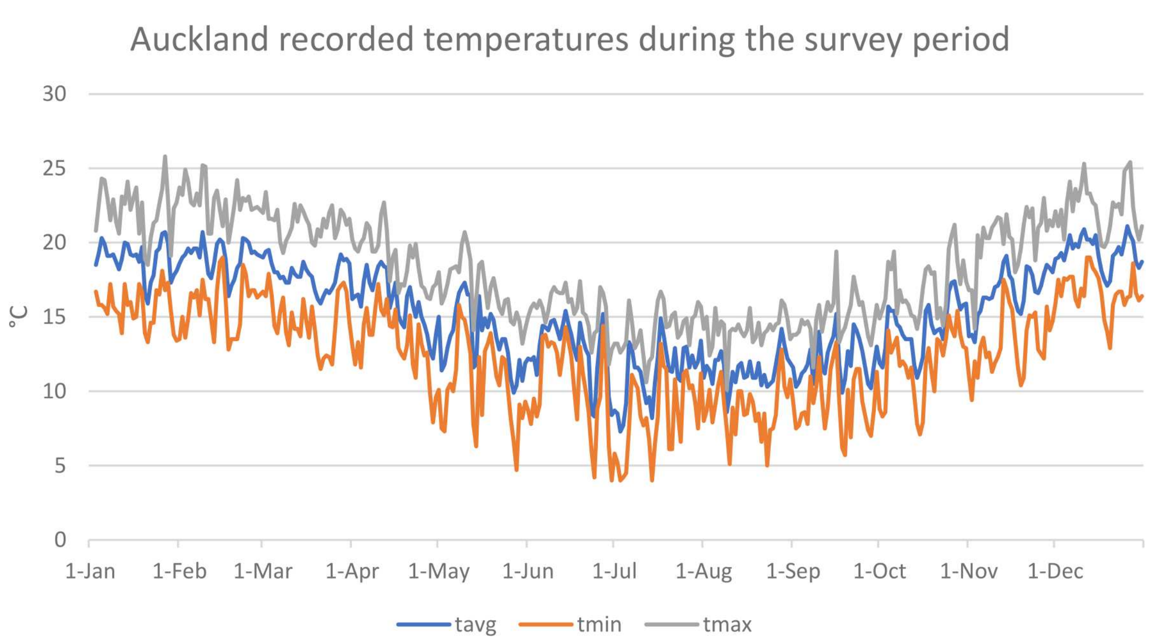


Figure 3. Auckland recorded temperature in the year 2020. Extracted form (https://www.metservice.com/).

Table 5. Results of the cluster analysis of the demographic data.

Category	Cluster 1*	Cluster 2**	Overall
Less than 16	02.3%	00.0%	01.5%
16–19	27.9%	00.0%	18.2%
20–24	**69.8%**	00.0%	45.5%
25–34	00.0%	**73.9%**	25.8%
35–44	00.0%	26.1%	09.1%
Undergraduate (Full-time)	**88.4%**	**26.1%**	**66.7%**
Undergraduate (Part-time)	02.3%	13.0%	06.1%
Postgraduate (Full-time)	09.3%	47.8%	22.7%
Postgraduate (Part-time)	00.0%	13.0%	04.5%
Male	**69.8%**	**65.2%**	**68.2%**
Female	30.2%	34.8%	31.8%

distribution for age and study programme (postgraduates/undergraduates).

Significant space

To identify the significance of the different spaces on campus, we have used two different time spent questions with percentage sliders. The first question was to quantify the significance of the total indoor time spent. The returned results had an average mean of 78.5% and a median of 85.5%, indicating a significant ratio of the occupant's time is spent indoors. The second question details the percentage of the main six indoor spaces on campus; the results shown in Figure 4, rated lecture rooms as the most used. The average percentage of the participants' time spent in the lecture room was 54%. Comparing the lecture rooms to other spaces, weighted to the overall time distribution between all other spaces, it scored the highest percentage of 27% from six different spaces, see Figure 4.

Further ANOVA analysis was conducted to identify the significance of two variables, the percentage of time spent in a lecture room as a response variable and the total indoor time spent, as a factor variable, using the statistics software NCSS. The primary method was the F-test from a one-way (single-factor) analysis of variance. These analyses were only conducted for the lecture room as it was the most selected and have the highest time spent percentage, to validate its significance. The results of the analysis are summarized in Table 6.

The occupant's response to the time spent in the lecture room was statistically significant compared to all other indoor spaces. All result of Tests of the Equality of Group Variances Assumption indicates that there is no significant difference in variances among the groups. Skewness: The p-value is 0.06557, suggesting a slight departure from normality. The F-ratio is 0.30, with a corresponding p-value of 0.9. This indicates that there is no significant difference in means among the groups, considering unequal variances. Overall, based on the given results, there is no significant difference in means or variances among the groups for the variable.

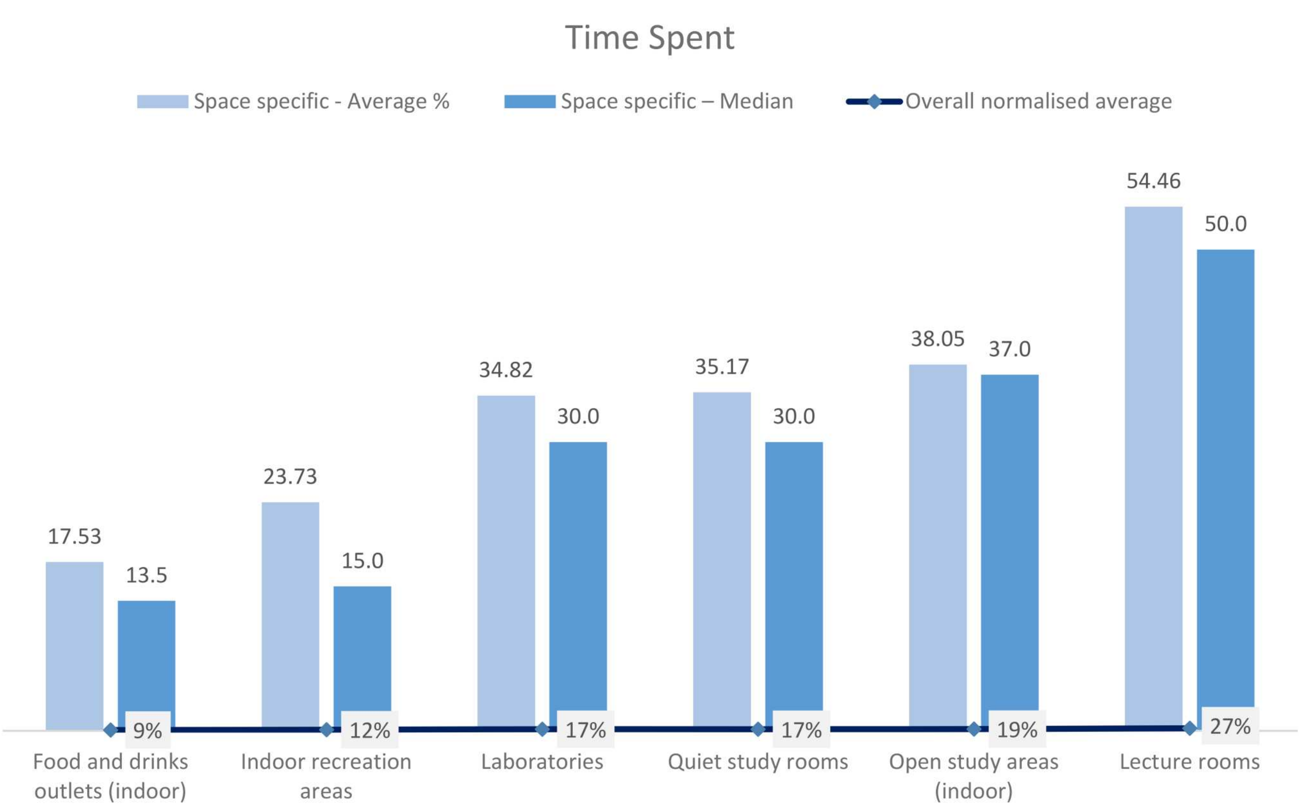


Figure 4. Average percentage (%) of occupants' time spent in different indoor spaces. The overall normalized average is scaled against the total time spent in all indoor spaces to reflect the relative significance of each space.

Table 6. Summary of the ANOVA analysis of total indoor time vs. lecture room time (null hypothesis).

Tests of the equality of group variances assumption

Test name	Test Value	Prob Level	Reject equal variances (α=0.20)	Note
Brown-Forsythe (Data – Medians)	0.8714	0.54645	No	1
Levene (Data – Means)	1.2282	0.30162	No	1
Conover (Ranks of Deviations)	32.8421	0.16673	Yes	2
Bartlett (Likelihood Ratio)	12.6571	0.98682	No	1

Tests of the normality of residuals assumption

Normality attributes	Test Value	Prob Level	Reject normality? (α=0.20)	
Skewness	1.8414	0.06557	Yes	3
Kurtosis	1.0551	0.29137	No	3
Skewness and Kurtosis (Omnibus)	4.5039	0.1052	Yes	3

Analysis of variance table and F-test

Model Term	DF	Sum of squares	Mean square	F-Ratio	Prob level	Reject equal means (α=0.05)	Power (α=0.05)
Percentage of indoor time TOTAL	26	15061.24	579.27	0.87	0.635	No	0.616
Adjusted Total	81	51423.61					
Total	82						

Welch's test of means allowing for unequal variances

Model Term	Numerator DF	Denominator DF	F-Ratio	Prob level	Reject equal means? (α=0.05)
Between Groups	26	53.33	0.30	0.9	No

1: Test of robust homogeneity.
2: Nonparametric test of homogeneity based on ranks.
3: Symmetry and normality test.

These findings signify the importance of TC settings in educational buildings based on the functionality and usage time of each space. The currently used TC indices, such as ISO 7730 (ISO, 2005) and ASHRAE Standard 55 (The American Society of Heating, 2004), to determine the operating parameter for TC are based on the rational and adaptive thermal comfort models. However, these standards categorize the indoor spaces in educational buildings based on three categories. The lecture rooms are considered a secondary category (as classrooms). Moreover, several studies have challenged the pertinency of the adopted indices in lecture rooms (Lamberti et al., 2021; Trebilcock et al., 2017; Zomorodian et al., 2016).

Our finding in this survey is the identification of lecture rooms as the most critical indoor space in terms of time spent and thermal perception, as further discussed in the following section. This finding is critical to our research to prioritize our stimulation of the TC efficiently with significant output that improves the overall thermal performance of the building.

The perceived thermal comfort in an educational building

To identify the user's thermal perception, two main questions were asked to scale their awareness of the thermal environment. The first question was a Likert scale, 'how often you notice mood changes indoors?' followed by multiple selection questions 'What of the following factors impact your mood?'. The sequence of these two questions was to indicate the significance of thermal comfort and quantify its relativity. The results are shown in Figure 5.

The key finding was that the students were exceptionally aware of their mood changes (55.1%) due to TC compared to other key conscious/cognitive factors (i.e. study load 48.3%, interaction with colleagues 29.2%, etc.). There was not any acknowledged study in the literature that compared the thermal perception to other cognitive factors that may impact the occupant's actual, and perceived experience. These findings, the frequency and selected factors, highlights the significant influence of indoor thermal conditions on the mental state and performance of students and underscores their acute sensitivity to the connection between thermal comfort and mood. It suggests that students are highly attuned to the fluctuations in their emotional well-being induced by variations in indoor thermal conditions, emphasizing the critical role of thermal comfort in shaping the student experience and performance in educational building.

These findings have important implications for educational institutions and educators, as they underscore

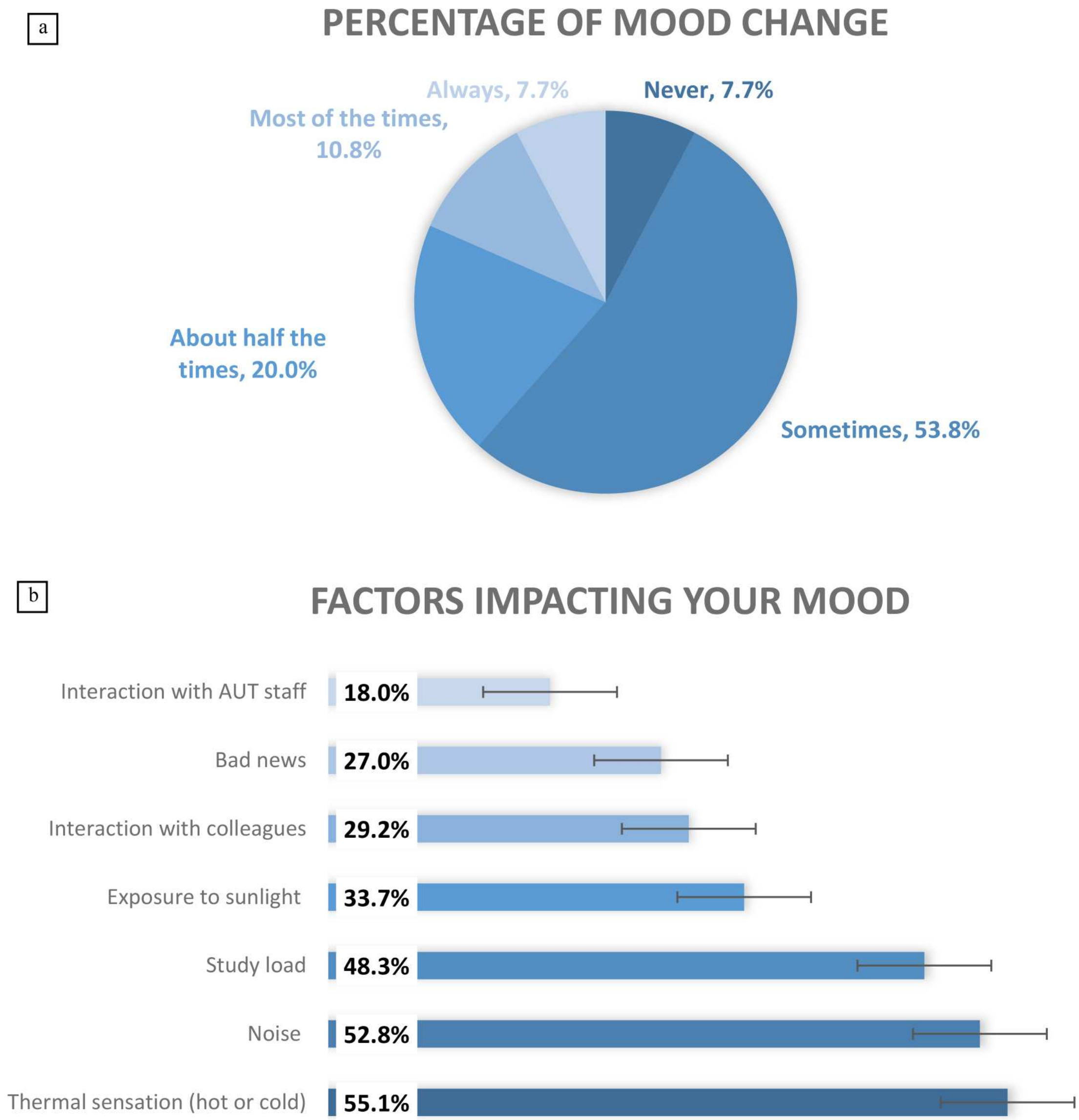


Figure 5. Summary of the factors and frequency of the occupant mood change. (a) the frequency of the occupants' mood changes. (b) The ranking of the selected factors as drivers for mood change, with thermal sensation selected as the leading factor-in this selection the participants were allowed to select multiple factors.

the need to prioritize indoor thermal comfort in educational settings. Providing optimal thermal conditions that promote comfort and well-being can have a positive impact on students' emotional experiences, ultimately enhancing their overall mood, concentration, and academic performance. By recognizing the significance of indoor thermal comfort and its influence on students' emotional states, educational institutions can create learning environments that prioritize the well-being and success of their students. as the focus of this paper is TC, further weighted cluster analysis of thermal comfort over all other factors is shown in Table 7.

Most of the participants who selected 'Thermal sensation (hot or cold)' as the most significant factor also indicated that the frequency of their mood change is in the higher spectrum. Additionally, the highest two percentages for the frequency rating 'Most of the time' and 'Always', 8.6% and 5.2%, respectively, corresponded to participants who also selected 'Thermal sensation (hot or cold)' as the most significant factor. This further insinuates the impact of the indoor thermal comfort on the occupant's state of mind. Several reported studies in the literature have indicated a direct relationship between the indoor environment and the occupants' state of mind (Amirbeiki Tafti et al., 2018; O'Brien et al., 2020; Zomorodian et al., 2016).

The actual perceived thermal sensation was collected from two similar sequenced questions. The first was an overall indoor thermal sensation (7 points), and the second was for each indoor space. The significance of

Table 7. Cluster analysis of the TC factor against the frequency of mode change.

	Thermal sensation (hot or cold)		
My mood changes	Total	Blank	Selected thermal sensation
Never	8.3%	2.0%	13.8%
Sometimes	41.3%	27.5%	53.4%
About half the time	13.8%	9.8%	17.2%
Most of the time	7.3%	5.9%	8.6%
Always	4.6%	3.9%	5.2%
Overall Stat Test of Percentages	**0.724**		
Silhouette score	**0.48**		

the time spent was reflected in the thermal sensation in total vs lecture room. The thermal sensation in a lecture room, amongst all other indoor spaces, had the most significant match to the overall indoor thermal sensation, as shown in Table 8. This further signify the importance of lecture room thermal settings on the overall thermal performance of educational buildings. The basic contingency analysis summary between the two thermal sensations (overall and in each selected space) is below in Table 8.

This crossmatch also accentuates the importance of the thermal perception of the participants. For instant, all the highlighted values indicate a consistent match between the two thermal perception (overall and space specific). Only the lecture room results matched, in all thermal perception ratings, with the overall thermal perception with high statistical significance of *P*-Value of (5.66471E-08) indicating a very clear significance. This psychological association between time spent and thermal sensation (matching the time spent ratings) is another indicator of the importance of thermal comfort on the occupant's perception. Consequently, future research and designs should focus on the thermal performance of lecture rooms to optimize the overall thermal performance of educational buildings. As was shown in this study the occupants' thermal perception of lecture rooms is critical to the overall thermal perception of the educational building.

It should be noted that the thermal sensation questions in this section and over the entire paper were not momentary. It was drafted as an overall sensation as our objective is to capture the occupant's awareness of thermal sensation and how it affects their mode.

The preferred mood or state of mind of the occupants

Two different rating methodologies were used to quantify the mental state of the occupants. The first one was the Likert scale to rate 11 perceived mental states as 'how often do you feel … '. In the second method, the participants were asked to rate the 11 different mental states on percentage slider bars as their preferences 'describe your preferred mental state', the results of the preferred state of mind are summarized in Figure 6. The leading state of mind was 'Focused' 68.28% followed by 'Relaxed' 58.83%, the following four states (Interested, Excited, Deep in thought and Engaged) were relatively close (5.80-53.97%).

The results of the 6 top preferred mental states were clustered and analysed against the perceived mental state. A Likert rating was used to quantify the deviation between the perceived vs preferred mental state, as in Table 9. The results indicated that all the significant Confidence Intervals and medians correspond to most of the time or always categories, indicating a strong statistical significance between the perceived and preferred mental states, e.g. the most selected preferred state (Focused) has an average of 75% and median of 89% of participants who selected most of the time they feel focused as the perceived state of mind.

The analysis results did not indicate any statistically significant variation between the preferred and the perceived state of mind. However, this is considered a verification of the delivered building function, in general, in terms of all the other indoor design and operational variables. Even though thermal comfort was identified as the most significant factor, the wordings of the mood question were specific to the overall perception, and the identified moods are inclusive of all possible indoor stimulants. These results are significant in identifying the building function and purpose from the design to the operation of educational buildings.

The leading state of mind in both questions was 'Focus'. This state of mind should be identified as the primary function of the educational building. The survey results (significance of lecture room) further stipulate the importance of this state of mind to the occupants' experience and preferences for educational buildings. Additionally, identifying the TC as a significant factor for the occupant's perceived experience should guide future research to efficiently utilize TC to achieve the principal building function.

Furthermore, the top-rated preferred states of mind were analysed against the overall time spent, and with focus on participants who selected thermal sensation as the leading factor for their state of mind, see Figure 7. The results indicated a very strong statistical correlation for 'focused' with *P*-values <0.05. This finding should guid future building designs to target the 'focused'

Table 8. Thermal sensation in selected spaces vs overall thermal sensation.

	Lecture room						
Overall	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
Cold	50.0%	36.4%	15.4%	0.0%	0.0%	0.0%	0.0%
Cool	25.0%	45.5%	7.7%	3.6%	11.1%	0.0%	0.0%
Slightly cool	25.0%	18.2%	46.2%	25.0%	0.0%	22.2%	20.0%
Neutral	0.0%	0.0%	0.0%	53.6%	33.3%	11.1%	0.0%
Slightly warm	0.0%	0.0%	15.4%	10.7%	55.6%	22.2%	0.0%
Warm	0.0%	0.0%	15.4%	3.6%	0.0%	22.2%	20.0%
Hot	0.0%	0.0%	0.0%	3.6%	0.0%	22.2%	60.0%
Chi-Squared Test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			Very clearly significant			2.38822E-08	
Effect size (Cramér's V)			Large			0.465749958	
Overall				**Open study areas (indoor)**			
	Cold	**Cool**	**Slightly Cool**	**Neutral**	**Slightly Warm**	**Warm**	**Hot**
Cold	37.5%	33.3%	7.1%	0.0%	0.0%	0.0%	0.0%
Cool	12.5%	44.4%	7.1%	3.7%	7.1%	25.0%	0.0%
Slightly cool	50.0%	22.2%	35.7%	18.5%	28.6%	0.0%	0.0%
Neutral	0.0%	0.0%	42.9%	44.4%	14.3%	0.0%	0.0%
Slightly warm	0.0%	0.0%	7.1%	11.1%	42.9%	0.0%	0.0%
Warm	0.0%	0.0%	0.0%	14.8%	7.1%	25.0%	0.0%
Hot	0.0%	0.0%	0.0%	7.4%	0.0%	50.0%	0.0%
Chi-squared test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			Very clearly significant			5.66471E-08	
Effect size (Cramér's V)			Large			0.422850009	
Overall				**Quiet study rooms**			
	Cold	**Cool**	**Slightly cool**	**Neutral**	**Slightly warm**	**Warm**	**Hot**
Cold	66.7%	0.0%	8.3%	2.9%	0.0%	0.0%	0.0%
Cool	16.7%	25.0%	50.0%	5.9%	9.1%	0.0%	0.0%
Slightly cool	16.7%	50.0%	8.3%	41.2%	27.3%	0.0%	0.0%
Neutral	0.0%	25.0%	16.7%	23.5%	27.3%	0.0%	0.0%
Slightly warm	0.0%	0.0%	8.3%	17.6%	18.2%	50.0%	0.0%
Warm	0.0%	0.0%	8.3%	8.8%	0.0%	25.0%	0.0%
Hot	0.0%	0.0%	0.0%	0.0%	18.2%	25.0%	0.0%
Chi-squared test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			clearly significant			1.08E-09	
Effect size (Cramér's V)			Large			0.3801769	
Overall				**Laboratories**			
	Cold	**Cool**	**Slightly cool**	**Neutral**	**Slightly warm**	**Warm**	**Hot**
Cold	80.0%	0.0%	9.1%	3.4%	0.0%	25.0%	0.0%
Cool	0.0%	20.0%	9.1%	13.8%	7.7%	0.0%	33.3%
Slightly cool	20.0%	70.0%	36.4%	27.6%	15.4%	0.0%	0.0%
Neutral	0.0%	0.0%	45.5%	17.2%	23.1%	0.0%	0.0%
Slightly warm	0.0%	10.0%	0.0%	20.7%	30.8%	25.0%	33.3%
Warm	0.0%	0.0%	0.0%	13.8%	7.7%	25.0%	33.3%
Hot	0.0%	0.0%	0.0%	3.4%	15.4%	25.0%	0.0%
Chi-squared test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			clearly significant			3.95E-05	
Effect size (Cramér's V)			Large			0.420488	
Overall				**Indoor recreation areas**			
	Cold	**Cool**	**Slightly cool**	**Neutral**	**Slightly warm**	**Warm**	**Hot**
Cold	25.0%	0.0%	0.0%	4.3%	0.0%	50.0%	0.0%
Cool	50.0%	50.0%	0.0%	10.6%	16.7%	0.0%	0.0%
Slightly cool	25.0%	50.0%	20.0%	25.5%	16.7%	0.0%	0.0%
Neutral	0.0%	0.0%	50.0%	17.0%	50.0%	0.0%	0.0%
Slightly warm	0.0%	0.0%	20.0%	25.5%	16.7%	25.0%	0.0%
Warm	0.0%	0.0%	10.0%	6.4%	0.0%	25.0%	0.0%
Hot	0.0%	0.0%	0.0%	10.6%	0.0%	0.0%	0.0%
Chi-squared test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			clearly significant			0.000686	
Effect size (Cramér's V)			Large			0.403645	
Overall				**Food and drinks outlets (indoor)**			
	Cold	**Cool**	**Slightly cool**	**Neutral**	**Slightly warm**	**Warm**	**Hot**
Cold	50.0%	25.0%	0.0%	9.3%	0.0%	0.0%	0.0%
Cool	0.0%	12.5%	22.2%	9.3%	8.3%	0.0%	0.0%
Slightly cool	50.0%	12.5%	11.1%	25.6%	25.0%	0.0%	0.0%
Neutral	0.0%	25.0%	33.3%	20.9%	41.7%	0.0%	0.0%
Slightly warm	0.0%	0.0%	33.3%	16.3%	25.0%	50.0%	0.0%
Warm	0.0%	25.0%	0.0%	7.0%	0.0%	50.0%	0.0%
Hot	0.0%	0.0%	0.0%	11.6%	0.0%	0.0%	0.0%
Chi-squared test			**Basic**			**Advanced**	
Statistical significance (*P*-Value)			Clearly significant			0.110166	
Effect size (Cramér's V)			Large			0.32196	

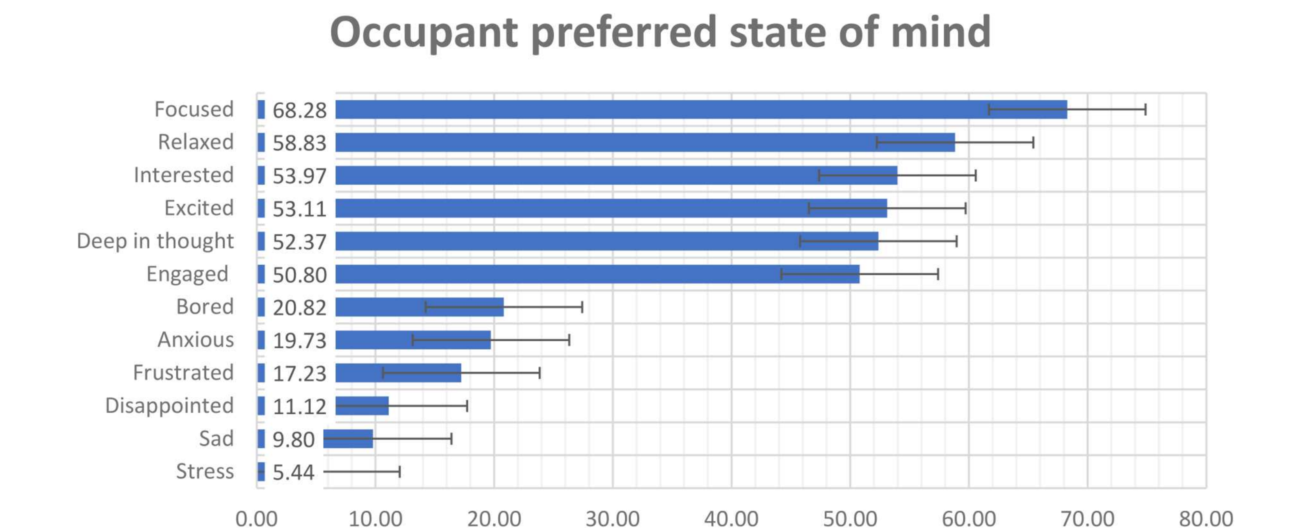


Figure 6. Occupant preferred mood or state of mind, rated on the percentage slider bar for their experince in educational buildings.

state of mind as the predominate building purpose. Moreover, for any post occupancy assessment, the inclusion of a benchmark state of mind is critical to benchmark the building performance.

Discussion

This study introduces a noteworthy departure from conventional research by identifying thermal comfort as the primary parameter influencing the occupant's state of mind, distinguishing it from other cognitive factors. Notably, the existing literature primarily focuses on behavioural or psychological aspects, overlooking the nuanced interplay between thermal comfort and cognitive parameters. This novel perspective underscores the importance of considering thermal sensation and comfort in post-occupancy studies to comprehensively evaluate the occupants' perceived experience. From a psychological standpoint, understanding the subjective and objective elements of thermal perception becomes pivotal, emphasizing the need for more comprehensive thermal indices that go beyond conventional

Table 9. Preferred vs perceived mental state of the top 5 rated states. The preferred state % based on percentage slider bar for each state.

Perceived mental state		Preferred state %			
		Average	Median	Confidence interval of average	Standard deviation
Often feel interested	Never	41.83	45.0	9.03–74.63	31.26
	Sometimes	53.76	50.0	42.42–65.11	32.52
	About half the time	49.73	50.0	34.33–65.14	27.82
	Most of the time	**60.80**	**73.0**	41.93–79.67	34.07
	Always	**67.75**	**68.5**	8.46–127.04	37.26
Often feel creative	Never	43.75	32.0	4.12–83.38	24.90
	Sometimes	47.07	50.0	36.72–57.43	26.18
	About half the time	48.10	50.0	35.21–60.98	28.30
	Most of the time	**66.12**	**66.0**	51.86–80.38	27.74
	Always	42.00	42.0	− 4.26–88.26	29.07
Often feel focused	Never	50.00	50.0	50.00–50.00	00.00
	Sometimes	71.00	80.0	53.84–88.16	25.55
	About half the time	58.88	57.5	48.62–69.13	24.29
	Most of the time	**75.31**	**89.0**	65.78–84.85	27.76
	Always	66.83	68.5	33.04–100.63	32.20
Often feel relaxed	Never	47.00	47.89	45.67–53.28	00.00
	Sometimes	70.29	78.0	53.84–88.16	25.23
	About half the time	56.78	56.5	46.22–70.17	23.68
	Most of the time	**72.36**	**89.8**	64.76–86.88	26.75
	Always	64.32	65.2	32.24–98.76	31.10
Often feel excited	Never	18.50	17.5	1.64–35.36	10.60
	Sometimes	45.44	43.0	33.93–56.95	27.88
	About half the time	58.47	60.0	40.52–76.41	32.41
	Most of the time	62.08	60.0	45.16–79.01	26.64
	Always	**80.50**	**86.0**	58.51–102.49	13.82

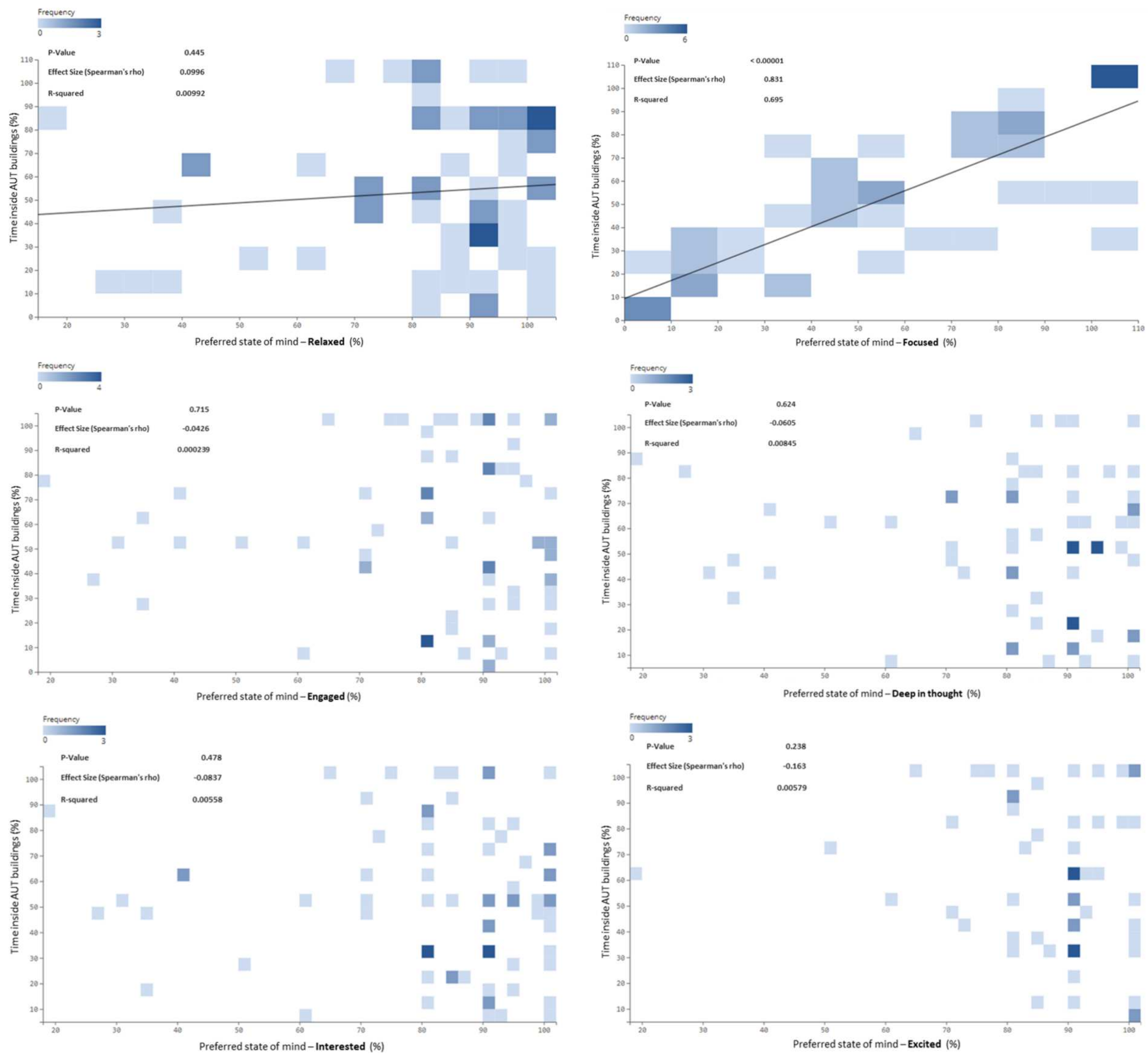


Figure 7. Top 6 preferred state of mind against time spend, all filtered to participants who selected thermal sensation as a factor that changes their state of mind.

metrics such as the Predictive Mean Vote (PMV), as discussed in the introduction section.

The survey's key finding was the identification of thermal comfort as the main parameter, in comparison to other cognitive parameters, that impacts the occupant's state of mind. This identification is a novelty in this study, and there was no similar study in the literature comparing TC to other cognitive factors, most of the reviewed studies concerning the occupant state of mind were behavioural or psychological based (Medlicott et al., 2021; O'Brien et al., 2020). This identification was evident in the results and analysis section, compared to more cognitive variables such as study load or encountering others.

From a psychological perspective, the human perception evoked by thermal stimulation includes thermal sensation and thermal comfort (Hensel, 1981). Thermal sensation is a subjective response associated with the temperature information of external objects or the environment, evoked by warm and cold receptors in the skin (de Dear et al., 2013). And thermal comfort is usually considered a combination of subjective sensation and objective environmental interaction (Nakamura et al., 2008). These subjective and objective sensations are often neglected when standardizing the thermal sensation and formulating indices (Bluyssen, 2020; Kishi & Araki, 2020; Taleghani et al., 2013). Identifying this thermal sensation as more critical than other cognitive factors signifies the impact of neural pathways and cellular mechanisms of thermal processing, which remain poorly understood (Bokiniec et al., 2018). This signifies the importance of post-occupancy TC studies, especially with the focus on the fulfilment of the building function, not only from an energy performance perspective but also considering the entire perceived experience of the occupants.

For instance, the Predictive Mean Vote (PMV), the most recent/popular indoor thermal comfort index (Hasan et al., 2016), has the critical disadvantage of not considering the individual perception of thermal comfort. For example, Yang et al. (2015) have found a deviation of the PMV by overestimation of the warm sensation due to the past thermal experience of long-term living in a specific region that could stimulate psychological adaptation. The fluctuating psychological adjustment could neutralize the occupants' perceived thermal sensation by controlling the skin's thermal sensibility, consequently causing a hedonic thermal offset of the PMV ratings. Hence, including more comprehensive thermal sensation parameters in thermal indices is critical to improving the occupant's indoor experience. This rationale regarding the objective and subjective thermal perception should be further exploited to optimize the building function.

The second key finding of this survey was the significant space inside educational buildings, the lecture room. This was reflected in the Significant space section. with a leading median of 50 and 13% over the second rated space. Furthermore, as shown in Table 7, the only significant match between the overall thermal sensation and the space specific thermal sensation was in the lecture room. Besides emphasizing the significance of the lecture room, this cross match also accentuates the importance of thermal perception. This psychological association between time spent and thermal sensation (matching the time spent ratings) is another indicator of the importance of thermal comfort on the occupant's perception.

The findings in this study are critical for future research in educational buildings as they achieve the first two objectives of this research and the identified literature gap. In addition, quantifying the significance of thermal comfort and the key spaces in educational buildings and how the occupants perceive the surrounding thermal environment is critical for future research focusing on the mental state of the occupant in the educational building. This research topic has been subject to significant interest, as highlighted in the Introduction section.

The psychological (mental state) findings of this survey indicate the preferred mental states of the occupants, see Figure 7, to favour the five positive and the one neutral (deep in thought) states. The ANOVA analysis, in Table 8, between the preferred and the perceived/experienced mental state did not indicate any significant differences, as all the significant values of the preferred percentages were corresponding to always or most of the time in the experienced states. The critical findings of this analysis are the relative significance of the mood/state of mind 'Focus' to be the occupants' most preferred and experienced. The absence of deviation between the experienced states and the preferred states could also signify the ratings of these states and further enforce the leading state of mind to be the most critical in identifying the building function during the lifecycle of the educational building.

Even though the participant's self-reported mood or state of mind may become superficial or impacted by subjective experiences, internal expressions, or external factors (Gunes et al., 2011), Independent self-reporting about the participant's state of mind should stipulate important information with limited validity (Bethel et al., 2007). Since the participants may not describe exactly their actual experienced state of mind, they report what others would answer (Gunes et al., 2011). Therefore, these reported cognitive results will be subject to further function brain mapping experiment to analyse the measured changes due to thermal stimuli, leading to more accurate results (Alarcão & Fonseca, 2019).

Several novel methods for recognizing emotions through brain mapping signals have been found in the literature (Alarcão & Fonseca, 2019; Brouwer et al., 2015). Utilizing those methods with further detailed thermal comfort studies focused on a more refined range of thermal alteration will yield more productive output that can be a steppingstone for indoor thermal studies based on the actual/measured thermal perception. Such studies are critical in the future built environments, particularly in shared functional buildings, e.g. Schools, Museums, public indoor areas, etc. This functionality of the studied indoor environments reflects another research gap. It should be investigated against the desirable state of mind of the occupants and how minor changes in the thermal settings may impact it.

While this study contributes valuable insights into the relationship between thermal comfort and occupants' mental states within educational buildings, it is essential to recognize several limitations that may impact the broader applicability and depth of the findings. One significant limitation lies in the study's focus on a single educational institution in Auckland, New Zealand. While this approach facilitates a detailed examination of the specific context, the generalizability of the findings to other educational settings may be limited. Variations in building designs, climates, cultural factors, and occupant demographics across different institutions could influence occupants' thermal comfort perceptions and mental states differently. Therefore, caution should be exercised when extrapolating the study's findings to diverse educational environments, and future research should aim to incorporate a broader range of institutional contexts to enhance the generalizability of the results.

Additionally, while the survey provides valuable insights into occupants' perceived mental states, it is important to acknowledge the potential influence of other factors within the indoor environment that were not explicitly addressed in this study. Internal factors such as noise levels, air quality, spatial layout, and external factors like outdoor views and daylighting can significantly impact occupants' perceptions and well-being in addition to thermal comfort. By focusing solely on thermal comfort and occupants' mental states, this study may overlook the multifaceted nature of indoor environmental quality and its effects on occupants' experiences. Future research endeavours should consider incorporating a broader range of environmental parameters and employing multidisciplinary approaches to provide a more comprehensive understanding of occupants' experiences within educational buildings. Addressing these limitations will be crucial for advancing knowledge in the field and informing evidence-based design strategies for creating healthier and more supportive indoor environments in educational settings.

The study's cross-sectional design provides a snapshot of occupants' perceptions, limiting the ability to discern causality or account for temporal variations in the dynamic indoor environment. Furthermore, the absence of real-time physiological measurements, such as continuous EEG monitoring, poses a limitation in capturing the dynamic nature of occupants' mental states. Future research endeavours should consider addressing these limitations by incorporating diverse institutional contexts, employing longitudinal designs, and integrating objective physiological measures to enhance the robustness and generalizability of the findings.

Conclusion

Indoor thermal sensation is often standardized in building codes and operations. The greater context of the actual thermal perception and its impact on the occupant state of mind, which contributes to fulfilling the building's predominant function, is rarely considered throughout the building lifecycle. In this survey study, it was evident that indoor thermal comfort is a significant factor in the occupants' experience, even when compared to more cognitive factors.

In this study, we aimed to (1) Identify the most significant spaces in the educational building (by time spent) to optimize the overall thermal performance of the building, (2) Quantify the significance of TC against various factors impacting the experienced mental state in an educational building, and (3) Compare the preferred vs perceived mental state of the occupants. Accordingly, the results of this survey study have:

- Relatively ranked the significance of the indoor functional spaces for the overall thermal performance in the educational building to optimize any future investigations,
- Quantified the impact of TC on the occupants' state of mind and against several cognitive factors, and
- Identified the occupants' state of mind preferences for educational buildings.

The significance of the lecture room was reflected in both the time spent and by comparing the thermal perception of overall and the space specific thermal perceptions. In this study, the perception association of the occupants between the perceived thermal comfort and the time spent is critical findings. This could efficiently increase the overall performance of the educational buildings; moreover, it signifies the impact of TC on the overall occupants' experience. These findings guide future research to focus on the simulation of the TC, e.g. in lecture rooms, to efficiently achieve the desired educational building function.

In this study, there was no significant deviation between the respondents' perceived and preferred state of mind. This finding should only be valid to the limitation of this study in [institution name removed] buildings since the overall perceived state of mind is inclusive of various controlled and uncontrolled stimuli. However, the relativity of the rated states of mind is indicative, beyond the study's limitation, of the objective function of the university building. These top-rated states of mind will be the reference for further brain mapping experiments to quantify the impact of TC on the measured brain waves. This future research interest would bridge the gap between neuroarchitecture and building performance by measuring the neurological signals in different stimulated indoor environments to achieve the predominant building function.

In conclusion, the future of indoor thermal comfort indices and building performance assessments must include a greater context of thermal perception. This holistic view would result in future indices and comprehensive codes that promote mental health and wellbeing within the educational building. It could even impact the current energy savings and green building ratings when adopting the distinctive thermal perception of the occupants and its consequential state of mind.

Furthermore, the building performance should be evaluated based on the building function beyond the energy performance currently dominating the building performance assessments. Thus, further rational and adaptive thermal studies, focused on the actual thermal perception in lecture rooms, are essential to achieve higher performance and thermal comfortability inside the educational buildings.

This study aimed to quantify the significance of thermal perception on the occupants of educational buildings and did not include any environmental monitoring or momentary measurements. This research focuses on the overall perceived thermal comfort within the selected educational building. The participants were not advised to answer the online survey in any particular location, as the focus of the study is to evaluate the overall impact of the TC on the occupant's state of mind (or perceived experience) beyond the momentary limitation of the external thermal stimuli.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Sameh Azzazy http://orcid.org/0000-0003-3076-5269

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