Post-Pandemic Study Spaces: Post Occupancy Evaluation of BREEAM Excellence Rated University Building

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Abstract: This paper presents preliminary findings from a Post Occupancy Evaluation research of a BREEAM excellence-rated university building, to understand the experience of the students using university study spaces under a post-pandemic teaching and learning context. The research uses a combined qualitative and quantitative method and focuses on occupancy patterns, thermal comfort, air quality, noise and lighting level of the study spaces within the building, as well as the students' preferences and experiences of the study spaces. The research collected over 200 questionnaire survey data from students who use the study areas, as well as monitored environmental data and observation data over 5 working days prior to the exam period. The study also compares the field research with the predicted performance simulation model data made before the pandemic, to understand the difference the pandemic has made to the designed usage and environmental comfort of the building. The result suggests that the post-pandemic occupancy level is significantly different from the pre-pandemic design assumptions and environmental control strategies need to be re-evaluated to provide optimum thermal comfort. Furthermore, the result raises questions in relation to overheating predictions in the performance simulation model, suggesting a need to re-evaluate overheating calculation criteria in educational buildings.

Keywords: University buildings, Post-occupancy evaluation, thermal comfort, occupant behaviour

1. Introduction

The recent pandemic and subsequent lockdown have resulted in an eight-fold increase in the number of people working from home in the UK (Felstead and Reuschke, 2020). This change has also affected higher education in terms of teaching modes, forcing courses to be delivered online, where students took lectures and studied at home for the majority of the time over the past two years. As we move towards a post-pandemic world, many universities nationwide are facing the issue of transitioning from online teaching to face-to-face or hybrid teaching. The university learning spaces are occupied in ways that were never anticipated. Previous research suggested that university campuses have become more focused on social-oriented learning and less on traditional lecture-based learning, as a result of the maturity and accessibility of online teaching (Gui et al., 2021). Such a blended model of teaching and learning would

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still be relevant in future scenarios. The changing approach to teaching and learning impacts the occupants' behaviour in terms of space use: there may be an increasing need for private/undisturbed spaces for online teaching and learning. On the other hand, it is likely that study spaces may also be used as a group or social space more often than pre-pandemic.

University buildings are occupied predominantly by a group of occupants (students) with a small range of age differences, different daily timetables and study disciplines, the occupancy pattern is very different than in other building typologies and is difficult to predict (Franceschini and Neves, 2022). Therefore, understanding the students' behaviour is significant to overcoming the discrepancies between the predicted and actual environmental comfort and performance (Shi et al., 2019). Previous review articles Franceschini and Neves, 2022; Carlucci et al. (2020) identified a literature gap in the study of occupant behaviour and building performance simulation studies of educational buildings. Out of the 278 identified studies on occupant behaviour and building performance, only 5% were on educational buildings (Carlucci et al., 2020). This is due to the complexity of estimating occupant behaviour in educational buildings. Moreover, Lawrence, R., Keime, C. (2016) highlights the significance of occupancy patterns to a complete understanding of energy efficiency and comfort. Meanwhile, environmental factors, thermal comfort in particular are proven to be impactful on students' intellectual performances (Ricciardi and Buratti, 2018). Thermal discomfort causes distraction and reduction in the students' academic performance and mental tasks (Jowkar et al., 2020; Barbhuiya and Barbhuiya, 2013; Ricciardi and Buratti, 2018). Therefore, measuring the post-pandemic in-use occupant behaviour and understanding students' environmental evaluation of the study spaces, in comparison with predictions made pre-pandemic, are critical in predicting and optimising the environmental comfort and performance of university buildings.

This project has carried out a Post Occupancy Evaluation (POE) on the study spaces of a newly-built university building that has achieved a BREEAM excellence rating (BREEAM, 2022) for its design scheme. The rating was achieved based on a simulation model (produced by an external specialised company) prior to the buildings' completion. However, since the university building was completed in March 2021 during the pandemic, the actual occupancy pattern and environmental control were very different from when it was designed for. As universities slowly returned to face-to-face teaching, the occupancy pattern has again changed dramatically. There were no restrictions by the time of the study however, the restrictions were lifted only recently which may have affected students' habit to use study place. The preliminary findings from this research show students' preferences for study spaces in a post-pandemic setting in comparison with the building performance simulation assumptions, in terms of environmental factors, as well as their strategies in navigating discomfort.

2. The building

The studied building is located in the East Midlands in the U.K. It is a 5-storey building with a gross internal floor area of approximately 5746m^2. The design of the building adopted a principle to maximise sustainability through informed decisions on site, layout, massing, orientation, building fabric, elevational treatment and Integrated renewable energy systems, as well as biophilic design principles including natural lighting and ventilation, visual links to natural landscape features and natural materials. The thermal parameters of the main building components are listed in Table 1 below:

Table 1: Thermal parameters of the main building components.

Construction Element	U-Values [W /m²/K]	G-Values	Light Transmittance [LT]
External Walls	0.22		
Floor	0.24		
Roof	0.16		
Windows	1.40	0.45	71%
Doors	2.20		

2.1. Layout and Occupancy

The common study areas are located on the first and second floors of the building and can be accessed directly via the main staircase. For the purpose of this research, we have divided the study spaces into 5 different zones that have distinctive characteristics (Figure 1). Zone 1, 2, and 3 belong to the library (Firstly floor), zone 1 is dedicated to studying using university computers, with some group work areas. Zone 2 is a quiet study area and zone 3 is a silent area. Zone 4 is dedicated to group work (Second floor) comprising eight rooms, among which only two of them have windows. Zone 5 is a tutorial space (Second floor), furnished to allow group seating. It also has direct access to the terrace located on the second floor. The majority of the openable windows face southeast and southwest.

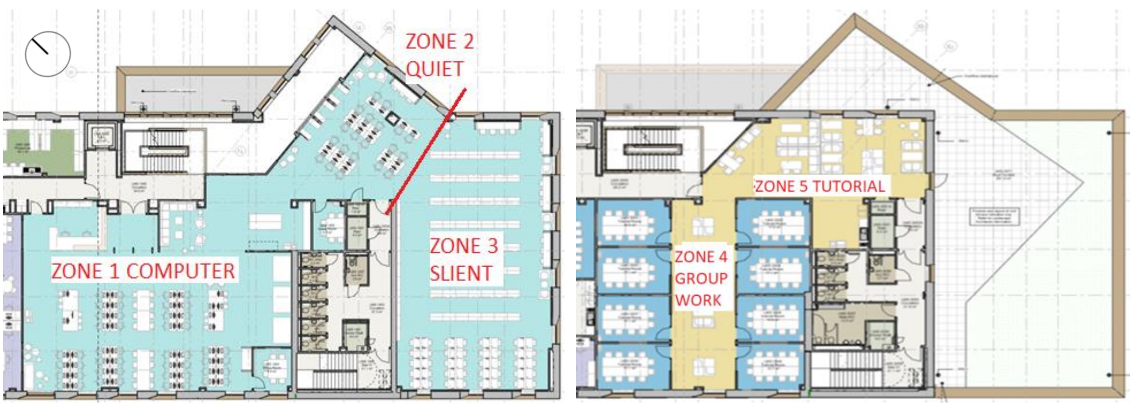

Figure 1: Frist floor (left) and second floor (right) study spaces and surveyed zones

Table 2 shows data used for the simulation model of the study spaces, including the area of each zone, the number of openable windows, design maximum occupancy, ventilation rate and lighting setpoint. Zone 1,2,3 were modelled as one zone in the simulation model.

Table 2 Occupational setpoints per zone.

Zone	Area m^2	Design maximum occupancy	Ventilation rate l/s/person	Lighting lux	Openable windows
Zone 1, 2, 3	658	256	6.1	500	17
Zone 1	320	150	6.1	500	6
Zone 2	90	50	6.1	500	2
Zone 3	248	56	6.1	500	9
Zone 4	18x8	10x8	10	300	2
Zone 5	161	30	5	500	2+1(door)

2.2. Environmental control strategies

The study spaces adopt a hybrid ventilation system. Due to the acoustic constraints of the local environment and to achieve compliance with Building Bulletin 93 (BB93, 2015), the use of natural ventilation throughout the year is not possible. A hybrid ventilation system is provided to library spaces to provide ventilation of the areas without compromising internal acoustic requirements (55dBA). Learning spaces are heated 24 hours during term times based on a setpoint of 21°C between 7:00-18:00 and 19°C throughout the rest of the day and night. Although the ventilation system has the active cooling capability, when assessed against CIBSE overheating criteria (CIBSE TM52, 2013), considering manually openable windows and the threshold of allowed overheated hours, overheating risk was not detected in the model for the studied areas. Therefore, all the studied zones are equipped with no active cooling.

The hybrid ventilation units are located at a high level within the window module. They are hard connected to intake and exhaust louvres within the window module to provide fan-assisted supply and extract to each space. There is no separate mode for winter or summer ventilation. The units are provided with a wall-mounted controller with integral temperature and CO_2 sensors, accessible by the occupants. The control allows the ventilation system to be boosted temporarily (for an hour) or turned off. The first-floor library has LCD interface screens with remote temperature and CO_2 sensors controlling groups of three hybrid vent units. However, the LCD screens are located behind the library reception and are only allowed to be controlled by library staff. The ventilation system is also automatically controlled and is triggered by the CO_2 levels. If the CO_2 level in the zone exceeds 1000ppm concentration level, the system will increase the flow of external air into the room until the CO_2 level is reduced to under 900ppm. The hybrid ventilation unit has a sound pressure level of 31.9 dBA MAX during daytime hybrid mode (180 l/s).

Lighting strategy follows (CIBSE LG05, 2011)– Lighting for Education. Lighting controls operate based on daylight availability. Lighting controls can automatically detect absence and can be manually turned off or dimmed.

3. Research design

The research design incorporates both quantitative and qualitative data collection. The first part of the data is collected using a questionnaire survey. The questionnaire survey includes two sections: Demographics (age, gender, how much time spent in the study per day and week, students' preferred study area, thermal sensitivity, clothing level and metabolism level prior to entering the study space), as well as environmental comfort (thermal comfort, ventilation, humidity, lighting and acoustics). Each category of the environmental comfort questions adopted a similar structure. It asked the occupants to rate their sensations using a 7-point Likert scale (ANSI/ASHRAE 55, 2020), and their adaptive behaviour, followed by any further comments they wanted to express. Qualitative comments were analysed using a statistical analysis software NVivo (NVivo, 2022).

The survey was conducted by student researchers between 11.05.2022 and 17.05.2022 on 5 weekdays from 9 am to 5 pm. This period was chosen to maximise the respondent rate, as it was just before the exam period. The respondents were chosen randomly based on their availability and handing the surveys to the same students were avoided by asking whether they have filled in a survey before. The researchers visited the learning spaces 7 times a day at one-hour intervals. In total, 206 questionnaires were filled in by students who use the study spaces, which gives a confidence level of 95% and a margin of error of 5% (based on the 500 students population – total number of students who have access to the study spaces- using the study spaces). Questionnaires have been collected on-site using paper forms and later transferred to a digital platform for analysis.

The second part of the data collection is the on-site observation made by student researchers. Their observation includes the number of occupants per zone, how many windows were open, as well as temperature and CO_2 values displayed on the screens in each zone at one-hour intervals.

4. Questionnaire survey results

4.1. Demographics and space preference

Demographic questions showed that more females (67%) than males (31%) answered the questionnaire. 49% were aged between 18-20; 41% were 21-25 and 10% were above 25 years old. As shown in Figure 2**Error! Reference source not found.**, more female participants (45%) were sensitive to cold than males (27%). The clothing level for over half of the respondents is moderate, a quarter of the respondents wear heavy clothing. The majority have engaged in a low metabolic rate activity.

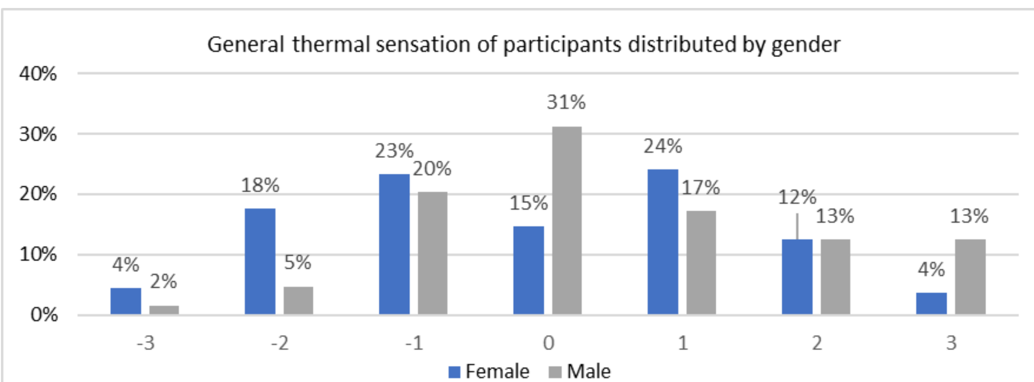

Figure 2 General thermal sensation of participants distributed by gender (-3 very sensitive to cold, 3 very sensitive to heat)

The majority of the students (43%) do mixed group and individual work in the study areas, and 38% of respondents use the study spaces mainly to do individual work (90% of the time). Students' preferences for study space show a bigger demand for focused and private space (31.1%). At the same time, 15% of the answers reveal a need to be able to choose a space where they can socialise with their fellow students. Environmental concerns (lighting, thermal and acoustic) are mentioned in 36.3% of the answers. Spatial quality appeared in 25% of the answers (including the size of the space/work surface, cleanness, window view, comfortable seating, and colour of the wall), in which window view and comfortable seating were the most mentioned qualities. 13.8% of the answers refer to the facilities and connectivity of the study space (such as computers, charging ports, etc).

4.2. Environmental conditions

53% of the respondents found natural light neutral and evenly distributed. Whereas artificial lighting was found to be significantly brighter (Figure 3). Only 29% of the respondents felt that they could adjust the lighting when needed. More than half of the respondents who felt they couldn't adjust the lighting reported that they didn't know where the controls were, and 15% of them didn't know how to use the controls.

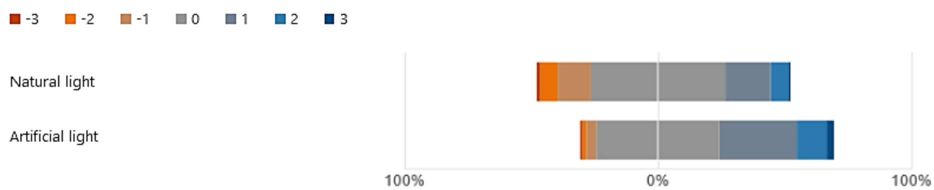

Figure 3 Responses on lighting (-3 too dull, 3 too bright)

Although the majority of the respondents found the temperature was neutral, 23% of the respondents stated it was warm and 10% stated very warm. As shown in Figure 4, Zone 1, 4 and 5 were found to be particularly warmer than other zones in general. Students have reported that it can get too warm and stuffy in smaller rooms (Zone 4). Some students reported that the temperature could get cold during the night and on cold days and stated 'I appreciate windows need to be opened For covid / Fresh air but should be minimised on cold days.

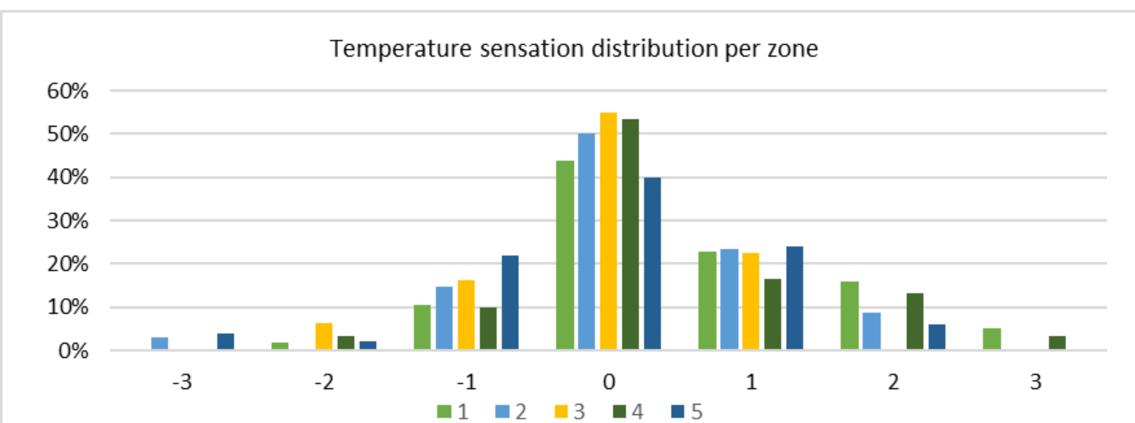

Figure 4 Temperature sensation distribution per zone (-3 too cold, 3 too warm)

To a multiple-choice question on how to mitigate thermal discomfort, the majority of the respondents showed sufficient adaptive behaviours such as changing clothing (58%) and/or opening/closing windows (48%) and having a hot or cold drink (27%). However, 17% of the respondents indicated they were unable to adjust the indoor temperature. They found the control to be ‘confusing’, and were only able to adjust the fan speed rather than temperature. 81% of the respondents felt neutral about the humidity, and only 15% of respondents considered the indoor environment to be slightly humid.

While over half of the responders found the ventilation neutral. Zone 1 (computer area) was found to be slightly stale in general. 64% of respondents stated that they would open/close the window to adjust the ventilation rate if they felt discomfort. 18% would change their location instead. One respondent located in Zone 4 stated that ‘the rooms without windows have poor ventilation, causing headaches’. It is not surprising because, in Zone 4, only two study rooms have external windows. students in those rooms that do not have windows can only use a mechanical system to boost the ventilation for a short period of time. Food odour has been mentioned by many students in the survey where increased ventilation was desired.

Although 58% of the respondents found noise levels neutral, Zone 1 computer area and Zone 5 tutorial area were found to be slightly noisy. The main cause of the noise was believed to be generated indoors by the users of the study areas (62%), and road/traffic noise (25%). Noise generated from mechanical services (including computer noise) was only reported by 8% of the surveyed users. The majority (80%) of the respondents chose the option of ‘putting on headphones’ in mitigating the unwanted noise whereas a small portion of the users (21%) also indicated the option of changing location.

5. Observation results

Occupancy level per zone and the number of open/closed windows were documented by the researchers. Zone 1 (computer area) is the busiest space throughout the observation period. It is not surprising considering Zone 1 has the largest capacity among all five zones. However, the maximum occupancy level in Zone 1 and 2 (quiet) are both less than 40% of the design maximum occupancy. Zone 3 (silent) has reached a higher 61% of the designed capacity. Zone 4 (group work) has not reached its capacity either, with only 27.5% at the maximum level. Zone 5 (tutorial) has demonstrated a higher usage rate of 57%.

As can be seen from Figure 5, the gradual increase of the external temperature over the monitored 5-day period has been reflected in the internal temperature across all zones. Zone 1 has the highest average and maximum temperature, followed by Zone 5. The highest temperature was recorded to be more than 25 °C on multiple occasions. It is unsurprising given that Zone 1 has the highest occupancy rate, as well as additional internal gains from the computers. This also correlates with the questionnaire survey where Zones 1 and 5 were considered to be warmer than other zones.

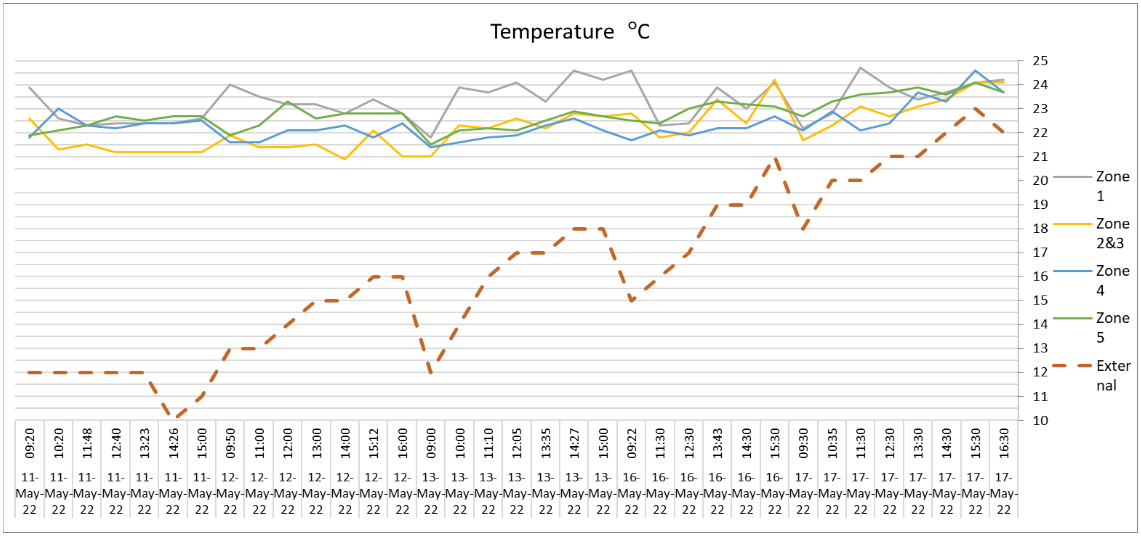

Figure 5 Monitored temperature per zone and exterior temperature throughout 5 days (Zone 2 and Zone 3 were monitored together with one data logger

The monitored CO_2 data (Figure 6) shows a general fluctuation between 400 ppm and 900 ppm, except for Zone 5. The highest CO_2 levels are observed in Zone 4 and 5, in one case reaching 1048ppm, which is over the ventilation trigger set point.

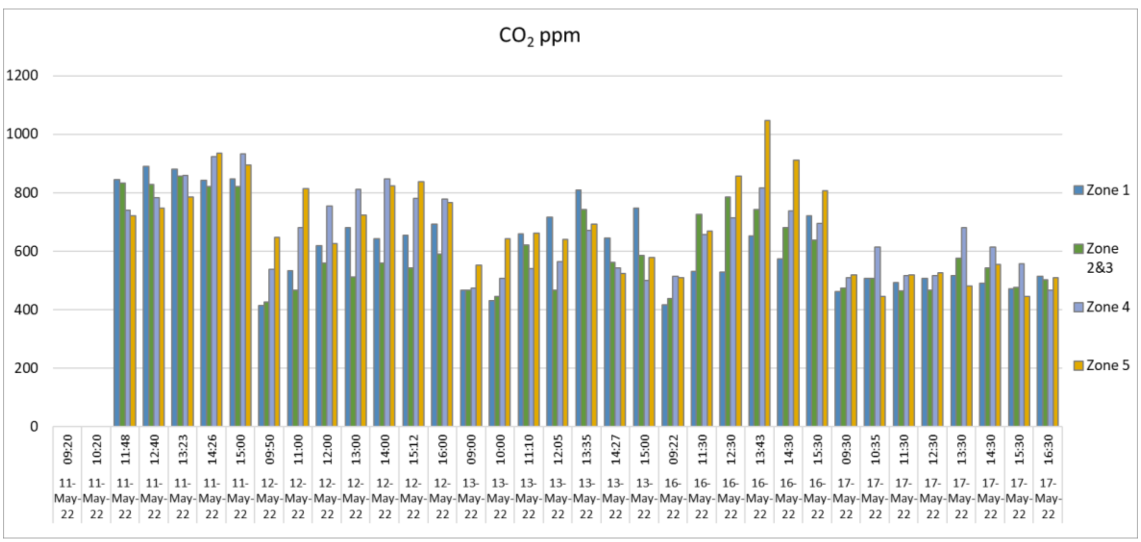

Figure 6 Monitored CO2 meter readings per zone throughout 5 days

Window openings were also recorded during the observation period. Over 50% of the windows were open on the fifth day when the internal temperature across all zones reached 24°C. However, during the time period when the recorded CO_2 level in any zone reached over 900ppm (Zone 4 and 5 on day 1 and

Zone 5 on day 4), no window was open. In other words, the occupants were more likely to open windows based on thermal comfort rather than air quality.

6. Discussion and Conclusions

The comparison of the simulated model result based on pre-pandemic predictions and the result of the post-pandemic POE research shows a few discrepancies. During the observed period, which was also predicted to have one of the highest volumes of occupancy, the occupancy level on average across all 5 zones remained far below the design maximum occupancy level. Therefore, the hybrid ventilation system, which was set to be triggered by CO_2 levels, was activated only once throughout the observation period. The simulation model did not predict overheating risk based on CIBSE TM52. Therefore, no cooling was set despite the system having the capability. However, the questionnaire survey revealed that approximately a third of the surveyed occupants found the spaces warm or very warm, despite the majority of the occupants self-identified as sensitive to cold. Most of the occupants preferred opening/closing windows to mitigate thermal discomfort. This behavioural adaptation was observed clearly across all zones, at multiple times throughout the day when internal temperatures were 21 °C-25 °C. Since the designed hybrid ventilation system is triggered only by CO_2 measurement rather than the indoor temperature, the passive cooling strategy became insufficient when the indoor temperature is above comfort level. It relied on behavioural adaptations such as window opening to achieve thermal comfort. As a result, the occupants who preferred quiet or silent study zones reported noise concerns due to the traffic noise being carried through the opened windows from the adjacent busy road. Therefore, despite building simulations failing to detect overheating, the result suggests that the ventilation systems need to be reconfigured to minimise the need for opening windows and could also be activated by temperature instead of solely relying on CO_2 levels.

Adaptive comfort model advocates occupants’ behavioural adaptations and personal controls (Baker, 1995). However, providing personal control in open-plan spaces was found to be usually costly and impractical. This leads to temperature and lighting being controlled automatically based on average standards (Myerson et al., 2010). In this research, the respondents repeatedly stated that they do not know how to operate environmental controls. As occupants were only allowed to boost ventilation for a limited time and operate the lighting within a limited range. Behavioural adaptations such as opening/closing windows may be effective for negotiating thermal comfort for those who sit next to the windows. For those who sit in the middle of an open-plan library, however, there are fewer means to adapt.

Furthermore, educational buildings, university buildings, in particular, are occupied at a minimum level, if not completely empty, out of academic term. Unoccupied term falls within the hottest summer period - June, July, and August, when overheating is most likely to occur. Therefore, using CIBSE overheating criteria is unlikely to predict overheating risk. However, study spaces are most likely occupied by. Even though no overheating was predicted in the building performance simulation, high-temperature days still occur during those two months where thermal discomfort would affect students’ learning greatly. Adaptive behaviour such as opening windows might not be always suitable due to the outside noise level. This raises the question of whether overheating criteria should be tailored to suit the usage of the building in question and the sensitivity of the occupants’ task to thermal discomfort. On the other hand, the window-opening behaviour will become more interesting to examine on colder days and in winter when the legacy of the pandemic could guide such behaviour in a way that bypasses occupants’ thermal comfort and ventilation need. More research is needed to explore such occupancy and behaviour patterns and the potential for more energy-efficient practices that are more suitable for a post-pandemic teaching and learning space.

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