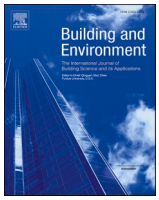
Building and Environment 266 (2024) 112067

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv



Bridging the gaps – A mixed methods approach to evaluating novel feedback surveys of children on school buildings

Vanessa Whittem [a,*], Michael T. Meehan [b], Astrid Roetzel [a], Akari Nakai Kidd [a], Abdul-Manan Sadick [a], Jo Raphael [a], Joanne O'Mara [a]

[a] Deakin University, Waterfront Campus, 1 Gheringhap Street, Geelong, VIC, 3220, Australia
[b] James Cook University, JCU Townsville, Bebegu Yumba Campus, 1 James Cook Drive Townsville, QLD, 4811, Australia

ARTICLE INFO

Keywords:
Feedback
Sustainable school design
Post-occupancy evaluation
Integral sustainable design
Children's surveys
Architecture

ABSTRACT

Feedback is critical to improve the sustainability of all buildings. Current post occupancy feedback is not useful for architects and designers and barriers to obtaining post-occupancy data have been well documented. In addition, there are delays in feedback of research conclusions appearing in Continuing Professional Development. Therefore, architects need timely feedback on their own building designs and methods they can use to obtain feedback for themselves. Previously, a literature review and survey of architects were conducted to identify gaps in feedback for school buildings compared to an Integral Sustainable Design (ISD) framework. A suite of ISD comprehensive on-line surveys were developed for various school user groups to target the identified gaps. This paper presents data from testing a novel survey of children in a case study and comparison of some questions to instrument measurement. The results show that the spatial questions with reasons yielded valuable insights. Some qualitative questions will require amendment to yield useful information. Univariate analysis shows that some thermal comfort questions would be suitable as a substitute for instrument measurement whereas lighting questions would not. Conversely, the question on vocal comprehension provided clear responses, supported by instrument measurement. Likert-style questions regarding sense of place, connection to outside, feelings of safety, etc. Were generally successful. Overall, the new ISD children's survey provides useful information for architects to address feedback gaps identified and will continue to improve with lessons from this case study.

1. Introduction – the need to improve feedback to architects on schools and our solution

Post-occupancy feedback on completed building projects is recognised in the literature as critical to improve the sustainability of future designs [1]. It is also acknowledged that all building projects are prototypes [2], each influenced by different contextual factors, such as geography, economics, social dynamics, and organizational aspects. Therefore, architects require feedback to assess whether a specific design change led to improved outcomes or conversely, had an adverse effect.

Despite the need for post-occupancy feedback, it frequently proves to be unhelpful, inaccessible, or presented in a format inappropriate for architects, for a variety of reasons, including a focus on energy performance and thermal comfort [3], lack of methods and agreement for qualitative assessment [4], omission of aspects important to architects [5], provision of general feedback from questionnaires without the location of specific successes and problems [6], published in inaccessible media or unsuitable formats without design guidelines [7] or a focus on a single aspect across many buildings [8]. There are exceptions to these criticisms, such as the CBE Survey, which provides an informative summary for the building architect, however, most CBE surveys are performed on Class A office buildings in North America [9]. Other feedback methods are the intellectual property of private firms, such as the BUS Occupant Survey (currently held by ARUP) [10] or the Victorian School Building Authority Post Occupancy Evaluations (POEs) (completed by Aurecon) (Delestrez 2022) and for the latter the architect is not permitted to access the results.

* Corresponding author. Deakin University, 1 Gheringhap Street, Geelong, VIC, 3220, Australia.
E-mail addresses: whittemv@deakin.edu.au (V. Whittem), michael.meehan1@jcu.edu.au (M.T. Meehan), roetzel.astrid@gmail.com (A. Roetzel), akari.nakaikidd@deakin.edu.au (A. Nakai Kidd), s.sadick@deakin.edu.au (A.-M. Sadick), jo.raphael@deakin.edu.au (J. Raphael), joanne.omara@deakin.edu.au (J. O'Mara).

https://doi.org/10.1016/j.buildenv.2024.112067
Received 25 April 2024; Received in revised form 31 August 2024; Accepted 6 September 2024
Available online 15 September 2024

In addition, there are numerous barriers to architects obtaining their own feedback acknowledged in the literature, including: a construction industry culture which views a building as complete at handover [11], no allocation for post-occupancy studies in project budgets [12], lack of resources in small architectural practices [13], constructors fear uncovering problems requiring liability or rectification [12] and architects' concerns of professional indemnity liability or reputational harm [14]. Further, research conclusions may take considerable time to filter down to Continuing Professional Development (CPD) for architects. Better and more timely feedback to architects and consultants from each project will increase the pace of improvement in all aspects of school building sustainability. Consequently, architects require new feedback methods that they can implement for themselves, offering the necessary information while demanding minimal time and resources.

School buildings were selected as an initial typology for investigating feedback topics, criteria, and methods for several reasons. First, it is understood that the design of schools significantly impacts the success of each student [15,16]. Second, learning spaces have been extensively researched and have an active research community [17]. Third, school buildings play a crucial role in shaping the sustainability attitudes of new generations [18], and last, the owners and facility managers of education assets typically have large portfolios and long-term interests.

This paper builds on previous work including a literature review by Whittem et al. [4], published in this journal. The literature review examined the comprehensiveness of building aspects examined in academic literature, sustainability rating schemes, and POE methods using the Integral Sustainable Design (ISD) framework for evaluation [4]. ISD, developed by Mark DeKay [19,20], emerged in response to the limited scope of sustainability rating schemes at the time, which primarily focused on quantitative and objective building aspects, neglecting qualitative and experiential factors. ISD is based on Integral Theory [21,22], which posits that all human knowledge can be encompassed by a matrix with axes of subjective-objective and individual-collective. Fig. 1 illustrates the application of Integral Theory to building design within the ISD framework, including the aims associated with each quadrant or perspective [23].

The authors have expanded the scope of ISD, as shown in Fig. 1, in alignment with contemporary conceptions of sustainability, which include aspects such as wellbeing, equity, social and cultural sustainability [25,26]. In this brief explanation of ISD, the building is regarded as the unit of study, thus the subjective-individual quadrant is about the individual's experience of the building, the objective-individual perspective refers to the building's own objective performance, the collective-subjective quadrant refers to how the building communicates meaning and supports culture, and the objective-collective perspective examines how the building integrates to larger systems [19]. With some deliberation, all building aspects to be assessed can be allocated to an appropriate perspective. The results of the literature review assessing comprehensiveness of sustainability assessment in the literature, traditional POE methods and sustainability rating schemes against the ISD framework were published in this journal [4] and are shown in Fig. 2.

The literature review informed the design of a suite of five on-line ISD surveys for categories of school user which are intended to cover a comprehensive range of topics when used together. Appendix 1 maps topics identified in the literature review to questions in the various adults' and children's surveys. The current paper focusses on assessing the effectiveness of the ISD on-line survey completed by children in providing the information sought.

A forthcoming article will report on the comparison of the ISD comprehensive surveys completed by adults (teachers, administrators, business manager and parents) to a traditional POE survey and walk-through interviews.

Each article focuses on a specific user category for a number of reasons. Firstly, distinct surveys were designed with different questions for children and teachers, reflecting their different perspectives of learning and teaching, as well as varying levels of understanding of architectural concepts. Secondly, certain gaps in feedback identified in the literature review were specific to particular stakeholder groups, for example, while questions regarding schoolyard/playground design were more relevant for children, suitability of spaces for pedagogical practices applied to teachers. Thirdly, while the population of children within a single school provides sufficient numbers for statistical analysis, the adult population within a school typically does not offer the same statistical robustness. Lastly, each user group provided a large quantity and

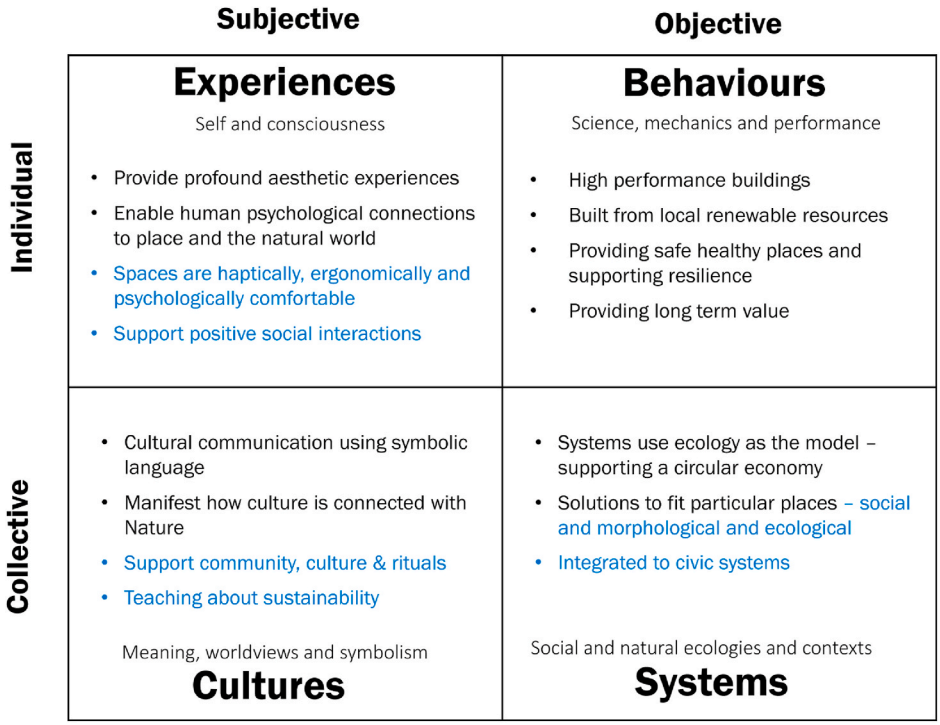


Fig. 1. Aims of ISD by perspective adapted by author from DeKay [24] as extended by authors [4].

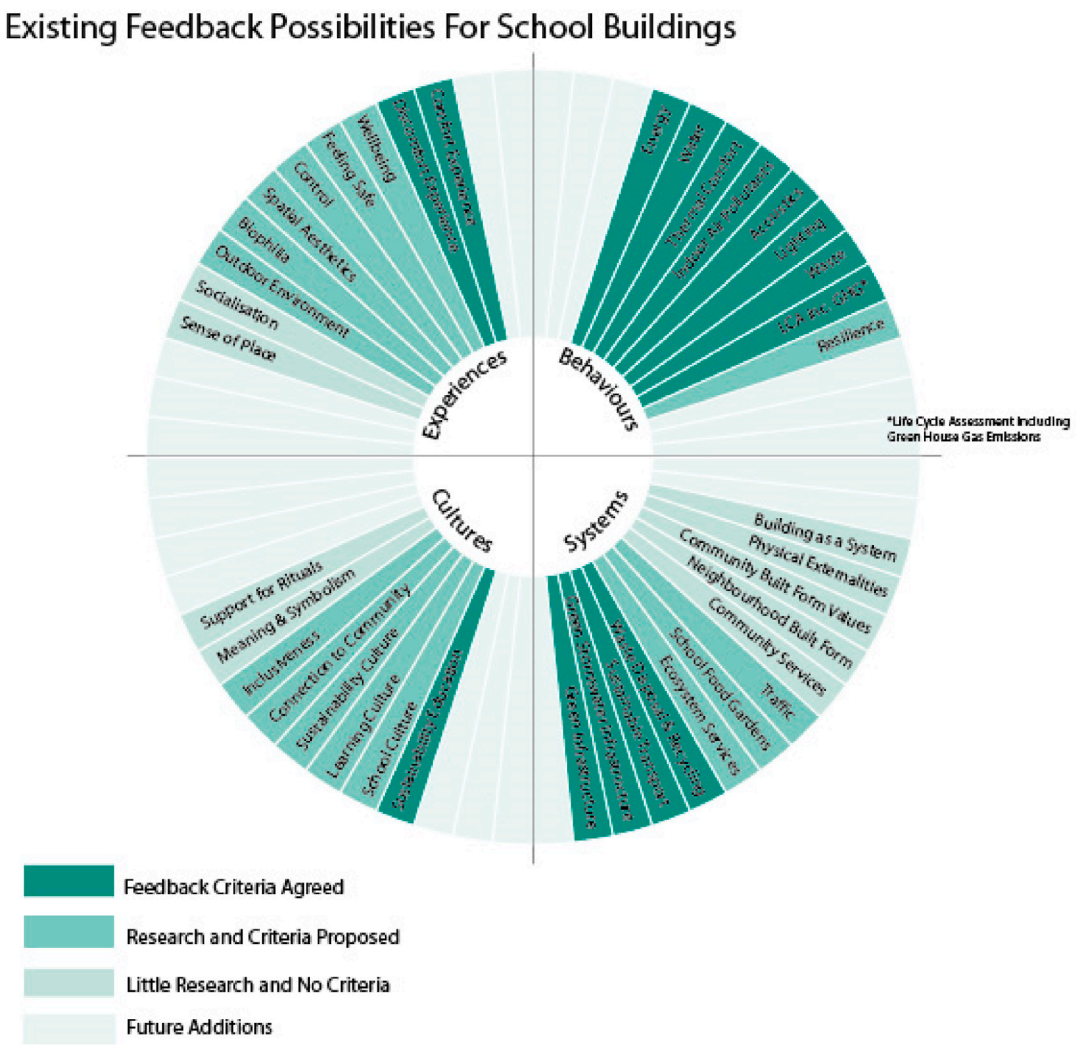


Fig. 2. Results of the literature review on feedback possibilities on school buildings [4].

richness of qualitative data, necessitating separate analyses to fully explore and comprehend the insights gathered. An overview of the development process and methodology selection for the entire case study has been detailed in a conference paper [27].

1.1. Understanding schools from a Child's perspective – why it is important

Understanding school building design from a child's perspective is important for several reasons. Firstly, children spend a considerable amount of time at school, underscoring the need for an environment that fosters comfort, safety, and a sense of welcome, while also supporting their learning needs [28,29]. Secondly, adults lack the unique perspective that children offer to school design [30] Thirdly, with the evolution of pedagogical practices in the early 21st century towards a constructivist, student-centred, active learning model, emphasis has shifted towards fostering creativity, critical thinking, communication, collaboration and problem-solving [31] and supporting 'deep learning' [32,33] which cannot be adequately assessed through academic tests alone. Fourth, proponents of participatory design argue that due to the complex and multi-dimensional effect of physical settings upon learning, involving the entire school community, with children at the centre, is crucial for successfully aligning the building with educational needs [34].

In summary, architects require feedback on school building designs and methods they can use to obtain feedback for themselves. A literature review and survey of architects were conducted to identify gaps in feedback needs. Subsequently, a suite of ISD comprehensive on-line surveys targeting various school user groups were developed to address the identified gaps. This paper focusses on the evaluation of the survey conducted with children, given their status as the largest and arguably most significant user group within the school environment.

2. Methodology

The suite of surveys was tested through a case study conducted in a primary (elementary) school in Victoria, Australia. The various surveys were designed to obtain feedback from representatives of all user groups within the school environment. These findings were then compared to feedback obtained from pre-existing established methods such as Indoor Environmental Quality (IEQ) instrumental monitoring, a conventional POE survey, walkthrough interviews and a picture-voice activity for the younger children. User groups included younger (Years Foundation to Year 2 approx. ages 5 to 7) and older children (Year 3–6 approx. ages 8–11), parents, generalist and specialist teachers (art, language, and physical education), developmental support teachers, administrators, and cleaners. It is important for comprehensive understanding of the school environment and lived experience that all stakeholders participate in the investigation [35]. In the case of schools, it is particularly important to obtain feedback from children and young people on school

designs as well as adults who have decision-making power.

The current paper reports only on the results of testing the children's ISD comprehensive survey. The overall research question posed is: *Is the newly developed children's on-line feedback survey satisfactory?*

For clarity, Fig. 3 shows an overall methodology flowchart for development and testing of the children's ISD survey.

The following sections describe the development of the on-line ISD survey designed for children. One analysis compares results related to thermal comfort, ventilation, lighting and acoustics obtained from the survey with instrument-recorded data. The aim was to assess whether the survey yielded sufficiently reliable data to highlight potential issues within specific spaces. This approach aligns with the overarching aim of developing a feedback system for architects that they can self-administer, and which demands minimal financial resources and analysis time.

A mixed methods approach was used for several reasons. Firstly, it aligns with the methodological pluralism inherent in ISD. Secondly, it facilitates comparison of qualitative and quantitative research findings, thereby aiding in validation or triangulation of survey results. Thirdly, it enables the use of suitable question types for different topics and respondents. Moreover, employing mixed methods for testing illuminates whether survey feedback methods provide efficient collection and analysis capabilities that architects can readily employ for themselves to obtain feedback to be used as guidance for future school projects Additionally, recognised benefits of mixed methods research, such as leveraging the strengths of one method to compensate for weaknesses in

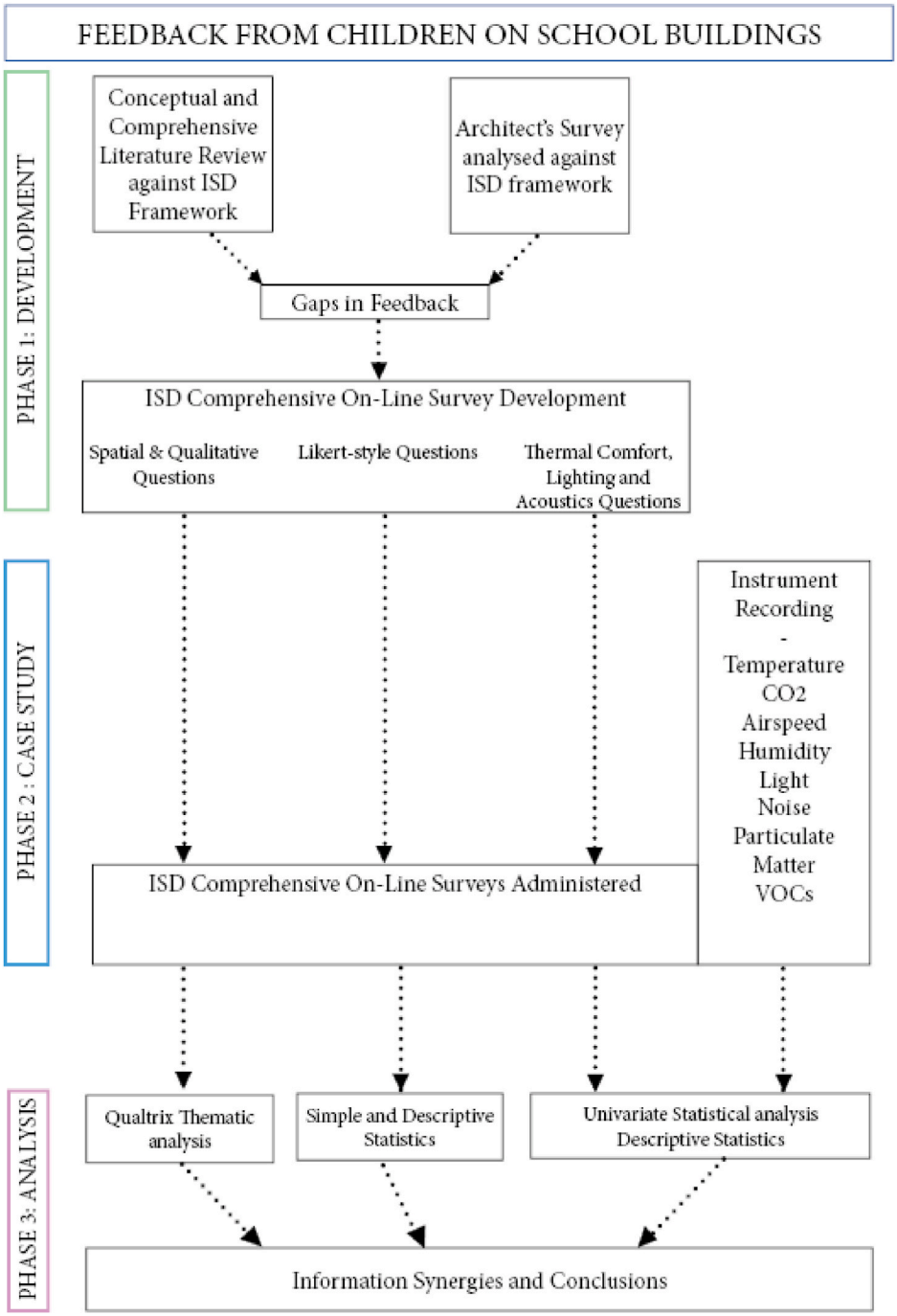


Fig. 3. Methodology flowchart for development and testing of the children's survey.

another, generating a more comprehensive understanding when used in combination, and improving confidence in findings, are recognised features of a case study approach [36,37].

2.1. Development of survey

Details of questions covered by the children's and adult ISD surveys are included at Appendix 1. Under the Experiences quadrant, the literature review found a lack of assessment methods for evaluating how school facilities support children's socialisation and sense of place [4]. Other gaps highlighted the need for more comprehensive feedback on user experience from both teachers and children, including user satisfaction with the building for various activities, gauging the level of flexibility and variety offered, capturing comfort experiences, including thermal, visual, and acoustic, evaluating factors such as colours, materials, tactility and furniture. Additionally, feedback is needed on the emotions generated and the success of connections to the natural world outside.

Based on these findings, children were presented with questions pertaining to thermal and visual comfort with seasonal components, acoustic efficacy, preference for colours, surfaces and furniture, elicited feelings, and their perception of connection to the outdoors. In addition, a spatial dimension was introduced through spatial questions to identify their own classroom and identify favourite and least-liked places. These spatial questions aimed to provide context or location for other responses, including qualitative and comfort-related questions.

Within the cultures perspective, the literature lacked methods for assessing how school buildings support community and school rituals, as well as and meaning or symbolism communicated to the school community [4]. Architects desired feedback around building support for current and innovative pedagogical approaches, building support for community engagement and inclusion, fostering a culture of sustainability, and meeting the cultural requirements outlined in the design brief. While the majority of these issues are more appropriately addressed with parents and adult users, the survey did include questions around digital devices support for pedagogy and feelings of belonging. Sustainability education regarding the building was addressed through a question about the availability of facilities such as recycling bins or energy-saving devices.

Quantitative building performance under the Behaviours perspective has been well covered in the literature, with agreed-upon assessment criteria, though there is a lack of agreement regarding methods for assessing the building's contribution to community resilience to climate change and natural disasters. Given the emphasis on low-resource feedback methods for architects, it was decided to evaluate children's answers to comfort questions against instrument values in this case study to determine the efficacy of the questions in identifying spaces requiring further investigation.

Under the Systems quadrant, the literature review and architects' survey identified many gaps in evaluation methods, particularly concerning physical externalities, site planning and services provided to the community. However, children are not suitable respondents for these questions, except regarding their perception of safe access for walking to school.

Two members of the research team from the Deakin University School of Education who are experienced in research with children, reviewed the children's survey and specific revisions were made, such as including graphics for Likert questions, prior to ethics approval. The leadership team of the case study school examined the children's ISD online survey and determined that children from Years 3–6 (approximate ages 8 to 11) would be able to confidently complete the on-line survey and that the alternative picture-voice activity would be suitable for years Foundation to Year 2 (approximate ages 5 to 7). In addition, the school Principal examined the question wording and suggested a couple of changes to ensure children's understanding.

The research was approved by Deakin University Human Ethics Advisory Group approval number SEBE 2022–53- and Victorian Department of Education and Training Approval Number 2022¬004648.

2.2. Case study school

The case study school is a Victorian Department of Education primary (elementary) school for children in years Prep to Year 6 (approximately 5–11 years old). Located in outer Melbourne, the school infrastructure consists of three recently constructed buildings, a BER (Building the Education Revolution) Programme building dating from around 2010, and an older multi-purpose hall. Completed in early 2020, the new buildings comprise a teaching building, a language/art block, and an administration block. Due to Covid-related remote learning requirements and extensive lockdowns in Victoria, the school community's transition to the new buildings was significantly delayed. Consequently, 2021 was the first full school year occupying the new buildings.

The new buildings are slab-on-ground construction with steel-framed brick veneer and double glazing for most windows. Similarly, the BER building is also slab-on-ground with a steel-framed brick-veneer, albeit with single glazing and louvred windows in strategic locations. All floors are at ground level, ensuring disabled access is accommodated.

Fig. 4 shows a simplified plan.

The school follows a traditional format with one teacher per class and does not have composite classes nor team-teaching. However, the new teaching building was designed to allow for team-teaching and other flexible arrangements, with all classrooms featuring doors connecting to interior Hub spaces, ("streetspace" [38]), labelled in Fig. 4. In each classroom, teachers have complete control over natural gas heaters, split system air conditioners, ceiling fans, and ventilation through window and door opening. All gas heaters are vented to the exterior and rated 0.00 for carbon monoxide. Additionally, each classroom is equipped with a particulate matter filter, introduced during the Covid-19 pandemic. There is no mechanical ventilation system.

The Hub spaces appear to be designed in response to the brief prepared in 2016 [39], which envisaged dedicated space outside the classroom for computer work and research projects. However, the installation of fixed tables in these spaces has limited the flexibility of use. Over the seven years since completion, the way digital devices are used has evolved significantly. Presently, tablets or laptops are used in the classrooms and charged on rolling racks which can be locked away outside school hours. To gain a comprehensive understanding of the usefulness of the Hub spaces, both teachers and children were asked about current uses and desired uses.

2.3. Data collection

2.3.1. Survey

Children in Years (Grades) 3–6 (ages approx. 8 to 11) completed the children's online ISD survey during class time in February 2023 (summer). Prior to administering the survey, the researcher provided an introduction, explaining the role of architects or building designers and the importance of obtaining the opinions of the children about the spaces at their school. The researcher remained present in each classroom while the children completed the survey on their devices, being available to answer any questions during the process.

2.3.2. Instruments

Instrument data was collected from each classroom continuously with durations ranging from one to two weeks during each winter (Aug–Sep 2022), spring (Oct–Nov 2022), and summer (Feb–Mar 2023) seasons. The monitoring equipment included two Ethera Mini XT KIT-060 devices installed at child desk height. A typical location is shown in Fig. 5. They measure Formaldehyde, Carbon Dioxide (CO2), LVOC

Fig. 4. Simplified plan of case study school buildings and grounds. Drawn by author based on plans supplied by architects.

Fig. 5. Typical location of Ethera Mini XT KIT-060 in new building.

(Light Volatile Organic Compounds), Temperature, Humidity, Air Pressure, Lux, Average and Maximum Noise.

In addition, air velocity was measured using two TSI AirPro AP500 sensors. The latter instruments were located out of reach on high cupboards due to the age of the children, the delicacy of the instruments and the need to leave them unattended to minimize disruption to classes. Two comfort carts, constructed according to ASHRAE Standard-55, which measure air temperature, globe temperature and air velocity at 0.1m, 0.6m, 1.1m, and 1.7 m heights and air humidity at 0.6m and recently calibrated were also used in some locations during the month of August 2022. Instrument specifications are shown in Table 1.

Although measurements were only made in one location, this location, away from direct sun and other sources of heat or cold can give a general indication of IEQ trends and patterns and strongly predict IEQ at the central part of the space [40].

Table 1
Specifications of instruments used Cal = Calibrated.

Type of Instrument	Parameter	Measuring Range and Accuracy
TSI AirPro AP500	Air Velocity	0–30 m/s greater of±3% or ±0.015 m/s
Ethera Mini XT MX-KIT060	Formaldehyde	0–2800 ppb sensitivity 1 ppb
	CO_2	0–5000 ppm ±50 ppm or 3 %
	LVOC	30 ppb to 5 ppm ±40 ppb
	Temperature	−55 °C–125 °C ± 0.5 °C
	Humidity	0–95 % ± 3 % btw 11%–89 %
	Barometric Pressure	260 to 1260 hPa ± 2 hPa
	Light	0–3000 lux ± 1 lux
	Noise	40–120 dB SPL ±1 dB
ASHRAE standard Comfort Carts		
TSI omnidirectional anemometers	Air Velocity	0.05–2.5 m/s ±3 %
Omega 44032 linear thermistor	Air Temperature	Cal 10 °C–35 °C ± 0.1 °C
HyCal integrated circuit sensor	Humidity	Cal 40%RH to 70 % RH ±2% RH
Omega 44032 linear thermistor	Globe Temperature	Cal 17 °C–27 °C ± 0.1 °C

2.4. Data analysis

Spatial responses corresponding with qualitative reasons were analysed using thematic analysis utilising Nvivo 14 software. Likert-style quantitative questions were analysed and graphed using Qualtrix and Microsoft Excel software. Descriptive statistics of instrument results utilised Microsoft Excel and Minitab 19. Statistical analysis of the effects of environmental variables on survey responses were performed using the R programming language in the RStudio Version 4.3.2 development environment.

An important question was raised regarding whether children have sufficient ability to understand and interpret plans of the school buildings and grounds. This was addressed in three ways. Firstly, comparison of time of completion of surveys from diary records of survey administration to entered class location on the first question (Click on your classroom). Secondly, detailed analysis of the reasons answers in the Favourite Places and Most Disliked Places spatial questions. Thirdly, comparison of the results of the "Places I Like" physical paper spatial activity with the results of the spatial questions. It is important to note that all plans (both on-line and on paper) were well labelled with class designations and playground locations, similar to Fig. 4 above. This was further aided by the plans showing matching markings to those on the ground for the running track, soccer pitch and basketball court. In addition, the principal advised to orient the plans for the inside questions to the direction the children would approach the building.

3. Results

The results section is divided into 3 sections for reporting: spatial & qualitative questions, Likert -style quantitative questions, and IEQ quantitative questions versus instrument analysis. Reasons for choosing favourite places and most disliked places were analysed thematically, providing the lists in the rows shown in Tables 2–4 and 6.

3.1. Spatial and qualitative questions

3.1.1. Favourite place inside and reasons

Table 2 summarises the answers to the question: Why is this your favourite place inside? for those locations which were selected by 4 or more students. Where a student stated more than one reason, these have been coded separately.

Under the "Read Books" category, students who selected the library on the plan made comments such as "I love to read", "Because I find very interesting books there", "I love reading and I love quiet places. The library is supposed to be quiet. The way it is set up at the moment is really cool." It is also notable that so many students also indicated the library is calm and/or quiet, for example, "I like it because the library is a very calm and it makes me feel good". Kelly Club is the after-school care program at the school and the reasons reflect enjoyment of the activities there. The memories category related to students' comments regarding locations of good memories, such as, "Because it is nice and big. Plus, I loved that year."

Table 2
Children's Reasons for Favourite Places Inside selected by 4 or more students.

Matrix of Reasons for Favourite Places Inside							
Location	Library	Kelly Club	G6	G5	G4	G3	3-4 Hub
1: Aesthetics	2						1
2: Calm & quiet place	13		1		1		
3: Can Pee							
4: Comfortable	3		1			1	
5: Cool	1		1			1	
6: Express self							
7: Favourite Teacher			1				
8: Feels Good	1						
9: Friends There			3				
10: Fun	1	1					1
11: Learning new things about world	3						
12: Like Furniture							
13: Like my Classroom - Belonging			3	1	2	2	
14: Memories						1	1
15: Multiple or favourite activities		2					1
16: play sports							
17: Private or empty							
18: Read Books	25				1		
19: Relaxing	1						
20: Room Arrangement	1						
21: Safe	1		1		1		
22: Shelter on wet days or extreme weather					1		
23: Spacious	1		1			4	1
24: Sunny, Natural Light							
25: use computer devices				1			
26: Watch movies		2					
Total Mentions	51	5	12	2	6	9	4

3.1.2. Most disliked place inside

Table 3 summarises the answers to the question: "Why don't you like this place?".

Eleven students did not mark any place as disliked, two of whom stated: "I like all the places" and "I don't have a place I don't like". The remainder gave no reason. The most disliked inside places being the toilets is an interesting phenomenon. Comments ranged from "Because it is very messy and people waste soap, toilet paper", "Because there's barely any soap and it smells horrid" to "Because people are being silly and makes a mess". It is notable that the boys' toilet elicited "loud or noisy" comments but the girls' toilet did not. An illustration of the differences in personal preferences are the selections of the 3–4 Hub. It was the favourite inside place for 4 students and most disliked for 7 students, but the reasons do not conflict.

3.1.3. Favourite place outside

Table 4summarises the answers to the question: Why is this your favourite part? Where a student stated more than one reason, these have been coded separately.

The Playground is an area in the school grounds with play equipment and bark chips for soft fall. The Gaga Pits are playground fixtures – octagonal depressions of approx. 600 mm (2 feet) depth with treated pine retaining walls, used for imagination games. These children would consider football to be Australian Rules Football. The child that selected

Table 3
Children's Reasons for Most Disliked Place Inside selected by 4 or more students.

Matrix of Reasons for Most Disliked Place Inside										
	3-4 Hub	4RS	5C	BER Spare & Other	Boys' toilet	Girls' toilet	Kelly Club	Library	Outside	Prep C
1: Aesthetics							1	2		
2: Books on floor										
3: Boring							1			
4: Bullied there			1							
5: Don't go there							2			
6: Don't Know What is										
7: Fairness in classroom size										
8: Furniture Placement										
9: Have to be quiet								1		
10: Hot	1									
11: Lack Privacy										
12: Lighting too bright	1									
13: Loud or noisy or echoes	2	2			2		2		1	2
14: Messy					1	1				1
15: Not allowed go there				1	3	4				
16: not refreshing										
17: NSF uses or suggest different uses	1									
18: Older students there										
19: Preferred books not avail								1		
20: small or narrow		3	3			3				2
21: Student Misbehaviour					2	2	2			1
22: Stuffy	1									
23: Lack of Toilet supplies or maintenance					1	6				
24: Unspecified dislike	2				1				2	
25: Unused Space				3					1	
Total Mentions	**8**	**5**	**4**	**4**	**10**	**16**	**8**	**4**	**4**	**6**

Table 4
Children's Reasons for Favourite Place Outside selected by 4 or more students.

Matrix of Reasons for Favourite Place Outside						
	Art Room	Basketball Court	Courtyard	Gaga Pits	Playground	Soccer Pitch
1: Aesthetics						
2: Books to Read						
3: Calming or Quiet						
4: Can make things	1					
5: Can Relax			1			
6: Cool	1					
7: Express Self or Be Creative	4					
8: Fun	2	1		2	4	1
9: Good Hiding Spot			1			
10: Learn Spanish						
11: Like to Play				3	4	
12: Lot of Space						2
13: Lots of Shade			1			
14: Memories						
15: Play Basketball		7				
16: Equipment			1		3	
17: Play Football						
18: Play Netball		1				
19: Play Soccer						19
20: Play Tennis			1			
21: Privacy						
22: Safe Space	1					
23: Seating						
24: Talk to Friends			1			
25: Walking Around						
Total Mentions	9	9	6	5	11	22

Table 5
Favourite Locations with 4 or more stickers from the Places I Like posters.

Location	Basketball Court	Soccer Pitch	Gaga Pits	Playground	Running Track
Number	8	16	8	19	6

Football marked the large open field within the north end of the school grounds.

Fewer children completed the Places I Like posters (n = 68). Locations with 4 or more "like" stickers are shown in Table 5.

The favourite places were thus similar to the on-line survey but in a different order.

3.1.4. *Most disliked place outside*

Table 6 summarises the answers to the question: "Why don't you like

Table 6
Children's Reasons for Most Disliked Place Outside selected by 4 or more students.

Matrix of Reasons for Most Disliked Place Outside						
	Gaga Pits	North End	Open Field	Playground	Sandpit	Soccer Pitch
1: Will get lost						
2: Weather restrictions						
3: Unspecified Dislike	1	1			2	3
4: Uneven Surface			1			
5: Too Many Ants						
6: Too far		1				
7: Student Misbehaviour						1
8: Smell					1	
9: Small				2		1
10: Slippery						2
11: Sand in your Shoes					4	
12: Old or Damaged Equipment				4	2	
13: Not good or feel uncomfortable					2	2
14: Not Fun				1	1	1
15: Not Allowed to Go There		1				
16: Noisy	3					
17: Never Been There						
18: Lonely		1	1			
19: Lack of Privacy						
20: Hard Surface						1
21: Fear of Injury	1		1	2	1	2
22: Don't Play Soccer or Sport						8
23: Don't play Basketball						
24: Dirty or Messy					4	
25: Crowded	2			1		2
26: Boring				1		1
27: Activity disallowed in location						
Total Mentions	7	4	3	11	17	24

to go there?" for those locations which were selected by 4 or more students. Where a student stated more than one reason, these have been coded separately.

The children also had strong opinions about the Gaga Pits. They are the favourite place for 6 children and most disliked place for 7 children. Perhaps this is two sides of the same coin, the children who have fun are excited and noisy, which other children dislike.

Fewer children completed the Places I Dislike posters (n = 61). Locations with 4 or more "dislike" stickers are shown in Table 7.

The disliked places were thus similar to the on-line survey, although in a different order.

3.1.5. Aesthetic & ergonomic comfort

3.1.5.1. Colours. A total of 31 students stated all colours were comfortable. Of the 13 students who ticked "None", four did not enter a disliked colour, which suggests that they were confused by the wording. This represents 4 % of respondents. The most uncomfortable colours named were black, yellow, white and grey with around 10 students for each. The yellow in the building is a light lemon-yellow paint on walls, which many teachers also disliked.

3.1.5.2. Surfaces. While 38 students stated all surfaces were comfortable, 15 ticked "Some" but did not specify the uncomfortable surfaces. Of the surfaces named, the floor received the most mentions (17), and where reasons were given (3 students) they mentioned how hard it is, especially if sitting for some time. Carpet was the next most mentioned (8), and reasons given that it is scratchy or itchy. This question would benefit from an answer box for Why? to give useful information to architects.

Table 7
Locations with 4 or more stickers from the Places I Dislike posters.

Location	Basketball Court	Soccer Pitch	Gaga Pits	Playground	Sandpit
Number	1	10	14	11	16

3.1.5.3. Furniture. To the question, "Do you like all the furniture in the building?" 37 students responded "Yes." Although this question specifically asked, "Name any furniture you don't like and say why", 16 students that answered "Some" did not name furniture, and of those that did name furniture, 10 did not say why. As these questions occurred in the middle of the survey, this is unlikely to be caused by survey fatigue. Of the named furniture, chairs received the greatest number of mentions (10), and reasons included size both too large or too small, lack of cushions or hardness, and:" My thighs stick to the surface of the chair and I feel uncomfortable getting up". Reasons for disliking tables (7) included too large or too short.

Once again, these questions would have been less confusing if the box for naming the problem items did not appear unless the student had ticked Yes, Some, or Most.

3.1.6. Feelings

Children were provided two boxes for entering feelings engendered by the classroom. Total mentions were 110 positive, 3 neutral and 41 negative. Most common positive descriptions were good, happy or enjoyable (60 mentions), calm, calming (15) and excited (12). Most common negative feelings were sleepy or tired (7), Sad (7) and bored (7).

Children's feelings from the Hub rooms entered were 112 positive, 10 neutral and 19 negative. Again, the most common were good, happy or enjoyable (55 mentions), Calm or calming (17), and freedom or fresh or space (8). Negative feelings about the Hub rooms with the most mentions were awkward, nervous or stressed (4 mentions), Sad (4) angry or frustrated (3) and lonely or empty (3).

3.1.7. Biophilia

The qualitative question related to biophilia asked: "Does any part of your building remind you of nature? Yes/No What is it?" 39 students answered Yes, 40 answered No and 9 clicked on both Yes and No (for future surveys, the software should ensure only one box can be selected).

In total 48 students wrote what part of the building reminded them of nature. Leaves, plants or flowers in the classroom received the most mentions (12), and windows or views outside, garden or trees outside and specific rooms received 6 mentions each.

3.1.8. Use of the hub

Children were provided 3 boxes for activities they use the Hub rooms for currently. Out of 206 mentions, 82 were for academics, such as reading (24), writing (12), maths (12) and guided reading (8). Other uses with many mentions included group or project work (13), playing (11), extra space or class division (11) and bag storage/lockers (10).

Activities children would like to use the Hubs for included academics as above (46), but interesting wishes included using devices including video games (11), sports (11), drawing or art or crafts (9), relaxing or sitting (8), free time (6), and cooking (6), and 8 wrote "Nothing" or "I don't know". Interestingly, one student wrote "calm down time space" which appears to indicate that the student wishes to use the space for re-regulation.

3.1.9. Spatial changes desired

In Question 7 the children were asked "If you had a choice is there something you would change or move around in the building?". This question was immediately after the Hub uses questions, which may have channelled the answers, however, only two children mentioned the Hubs so this appears unlikely. Out of 74 responses, eighteen of the students said "No" or "Nothing" they wanted to change. Seventeen children wanted changes to classrooms, such as switch classes' rooms (7), larger classrooms for some classes (5), utilise spare space (2) and have all classrooms the same size (2), with responses like "I would use the spare room for something" and "I would swap over the Year 5 classroom with Kelly club" (afterschool care). Sixteen students wished to make changes to furniture, such as moving items (7) around the library or within the classroom and 5 wanted to make changes to tables. This is another question where a "Why?" section would be appropriate because it is not clear whether they want to move the tables around or replace them. Further, four children wanted to change the library, but only two wrote "another library" and "Library should be in a separate building". Of interest to teachers, two children wanted to change rules, one wrote "There should be no soccer on the Oval" and the other "Enforce the rules

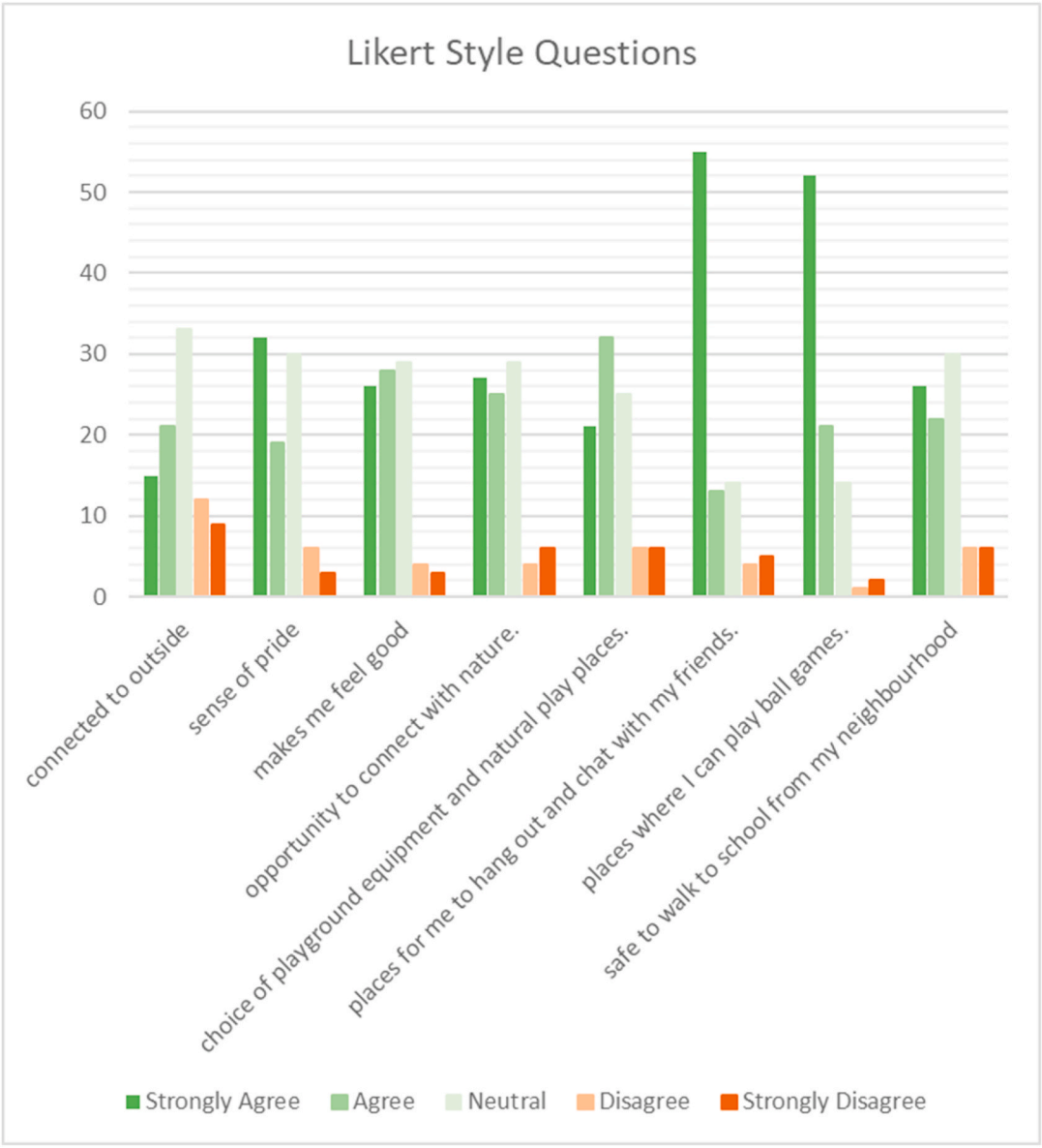


Fig. 6. Frequency graph of answers to Likert-style quantitative questions.

in the boys' toilets like not messing around."

3.2. Likert-style quantitative questions

Based on advice from the educational researchers on the team, these questions were presented with a graphic corresponding to the answers Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree.

Responses to the Likert-style quantitative questions are shown in Fig. 6.

3.2.1. Biophilia

For the statement: "I feel connected to the outside (weather, sky, sounds, plants) when I am in my building." responses clustered around neutral as can be seen from Fig. 1. In this school the conflict in design between provision of windows, display space and storage was partially addressed by using high windows which allow\ for natural light but do not permit children to see outside. Lack of outside views is compounded by teacher use of glass doors as display space.

3.2.2. Sense of place

A large proportion of children were positive about the statement: "I feel a sense of pride about this school building" with 51/90 agreeing and only 9 disagreeing. To the statement "I feel that the design of my school and its environment makes me feel good." 54/90 agreed and only 7 disagreed. In all cases approx. 1/3 of the students did not feel strongly either way. Although this statement endorses the general result for the architects, the results would need to be compared to results for many schools and a summary of design differences to be truly useful.

3.2.3. Support for pedagogy (digital devices)

The statement "My building has enough space for me to use digital devices" received a very positive response with 65/91 agreeing and only 8 disagreeing. However, support was less positive regarding internet speed: "My building has fast enough internet for when I use a digital device." received 43/88 agreement, 31/88 were neutral and 14 students disagreed. The senior teaching team advised that the children routinely use the term "digital device" to refer to laptops, tablets and desktops and would understand these questions. However, judgments of internet speed may be coloured by children's experience at home and in other venues. This question would be of limited use to the architects, because they are not responsible for Information and Communication Technology (ICT) infrastructure efficacy, only for allowing space for cabling, routers and Wi-Fi aerials.

3.2.4. Experience of outdoor environments/sports

From Fig. 6, it was observed for the statement "My school gives me opportunity to connect with nature." That 52/91 agreed but 29 or one third were neutral and 10 children disagreed. In addition, for the statement "There is a choice of playground equipment and natural play places." 53/90 or 59 % of children agreed but 25 or 28 % were neutral. These latter two questions may be a type of question subject to different interpretations of the wording. "Nature" can mean different things to different people. The statement "There are places where I can play ball games." received an overwhelming positive response, with 73/91 agreeing and only 3 disagreeing. This is a good internal check for the survey answers to favourite place outside and reasons.

3.2.5. Support for socialisation

There was also a strong positive response to the statement "There are places for me to hang out and chat with my friends." 68/91 students agreed with only 9 disagreeing. Provision of places for incidental meeting of children have been shown to assist in development of friendships and improve socialisation between school classes and year levels [41,42]. In addition, in-between spaces give younger children places for imaginative play [43], which suggests the need for a further question about places suitable for this kind of play at the school.

3.2.6. Wellbeing

The two 5-point Likert questions regarding toilets relate to the children's wellbeing. In addition to the above discussion regarding the toilets are the most disliked places inside, the Likert question: "The toilet facilities are clean and usually working", the answers had a strong central tendency to neutral (31/91), with 28 agreeing and 30 disagreeing.

Some educational philosophies, such as Montessori [44], advocate for children to have access to toilets throughout the school day, without having to obtain permission. This is the origin of the next Likert statement "I have access to the toilets during class without asking permission." The response was strongly negative, with 71/88 disagreeing, which clearly indicates that school practice is to require permission.

3.2.7. Feeling safe, community access, site planning and sustainable transport

When scoring the statement: "I feel it is safe for children to walk to school from my neighbourhood." More than half (58/90) agreed, 30 were neutral and 12 disagreed. It may be worth adding a qualitative reason to this question, because it is of little use to architects or educators at present, as they do not control the urban environment exterior to the school. There were many more questions under these topics asked in the parents' and teachers' surveys.

3.2.8. Sustainability education

In this case, the building does have all the devices asked about in the question, except measuring devices for lessons. The proportion of failure to answer the question, as shown in Fig. 7 increased as students moved down the list, from 14/91 for recycling bins inside to 60/91 for measuring devices. There was clearly a need for a "Don't Know" response option to the question. There is no signage around the school about the existence of these measures, so in their absence, the use of the building as a sustainability teaching tool can be facilitated or ignored by teaching practices.

3.3. IEQ quantitative questions v instrument analysis

The survey questions were designed to be used by architects to provide sufficient evidence to indicate whether more in-depth analysis of a building or space is required, without resorting to instrument measurement. Accordingly, we conducted univariate (mixed effects) logistic regression analyses between IEQ survey response outcome and relevant instrument data. Given the time window over which the responses were requested, we used the median value of each instrument variable for the corresponding time period. This prevented us from investigating more complex multivariate analyses because the median estimates were asynchronous. The relevant questions are shown in Fig. 8.

Note that the survey was undertaken in summer and the questions require the children to remember conditions from the previous winter. The previous winter they would have been in the previous grade, so, for example, children in the 5C classroom in summer would have been in the 4CR classroom the previous winter, those in 3V in summer would have been in 2C in winter and so forth. It was observed when partitioning the survey data into lines by season and time that 30 students had entered "No" and also selected a Season and Time of Day. It did not appear to have any relationship to age or year level. To check, all the statistical tests were processed firstly with all the students included and secondly with the "unreliable" students removed. This did not make a material difference to the univariate analysis results. Nevertheless, the results of the more reliable sample are reported in this paper. This deficiency in the survey setup could be addressed whereby the Season and Time of Day boxes for each question only appear if "Yes" is ticked. There were 10 students' responses where Yes was answered but they did not indicate a Season or Time of Day for at least one question.

Residuals plots for each regression analysis are included as Appendix

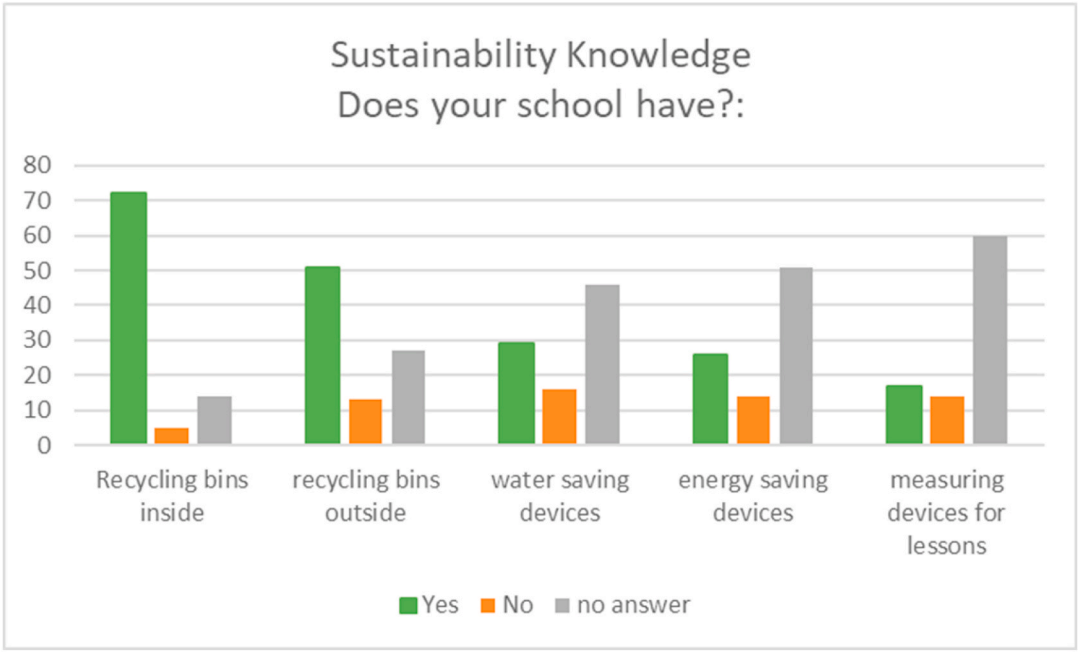


Fig. 7. Questions eliciting knowledge of sustainable features of the school. 2.

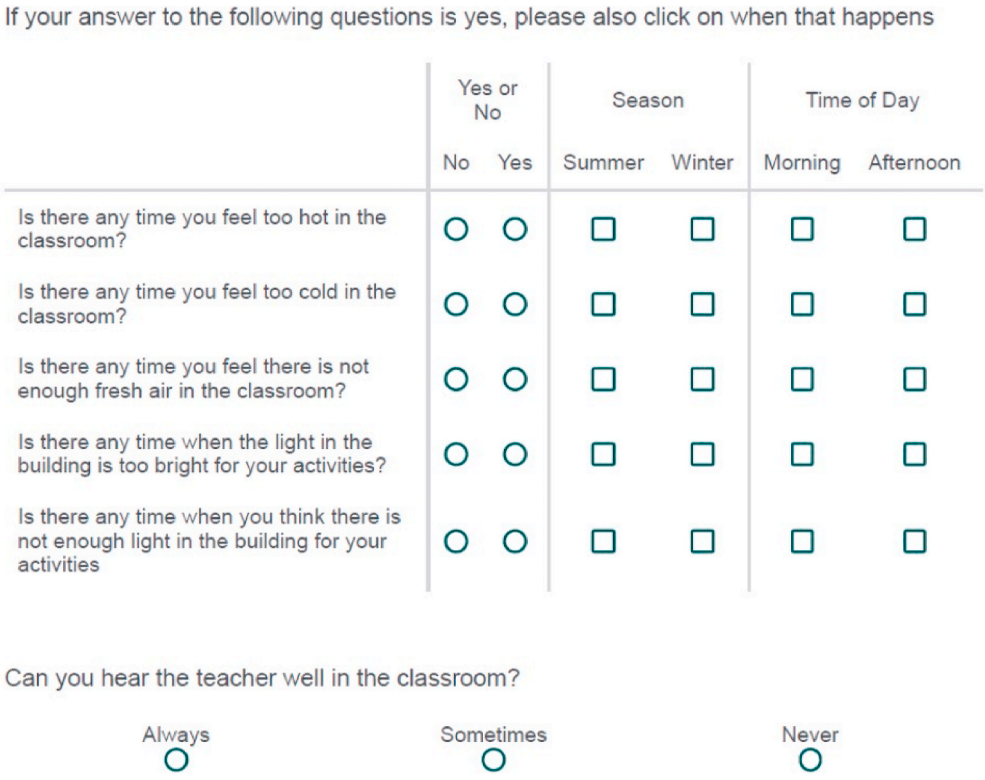


Fig. 8. Comfort questions from children's on-line survey.

2.

3.3.1. *Thermal comfort*

The results of the univariate analysis for student questions regarding thermal comfort are shown in Table 8.

Descriptive statistics of instrument readings of temperature support the results of the univariate analyses, as explained below. Winter morning temperatures during class time were generally lower than comfortable as per Fig. 9.

At the other extreme, summer temperatures are shown in Fig. 10.

The Year 5 and 6 classes are located in the BER building, which is showing temperature maintenance difficulties in winter, despite teacher control of equipment, which suggests it is a leakier building than the new building. It is important to note that relative humidity measured as a percentage appears to be correlated in the opposite direction to that expected against the student answers of Too Hot, and positively against

Table 8
Results of univariate analysis of thermal comfort questions. OR = Odds Ratio, CI = Confidence Interval. Green shading indicates a positive effect, orange shading indicates a negative effect.

Student Question	Parameter	Log (OR)	95 % CI	p-value
Too hot	Temperature °C	0.46	0.31, 0.60	<0.001
	Humidity RH%	−0.32	−0.43, −0.21	<0.001
	CO_2 ppm	−0.004	−0.005, −0.003	<0.001
	Air Velocity m/s	−8.1	−26, 10	0.4
Too cold	Temperature °C	−0.36	−0.47, −0.25	<0.001
	Humidity RH%	0.29	0.16, 0.43	<0.001
	Air Velocity m/s	44	14, 74	0.004
Lack of fresh air	Temperature °C	0.20	0.10, 0.29	<0.001
	Humidity RH%	−0.08	−0.13, −0.04	<0.001
	CO_2 ppm	−0.002	−0.003, −0.001	<0.001
	Air Velocity m/s	3.4	−16, 22	0.7

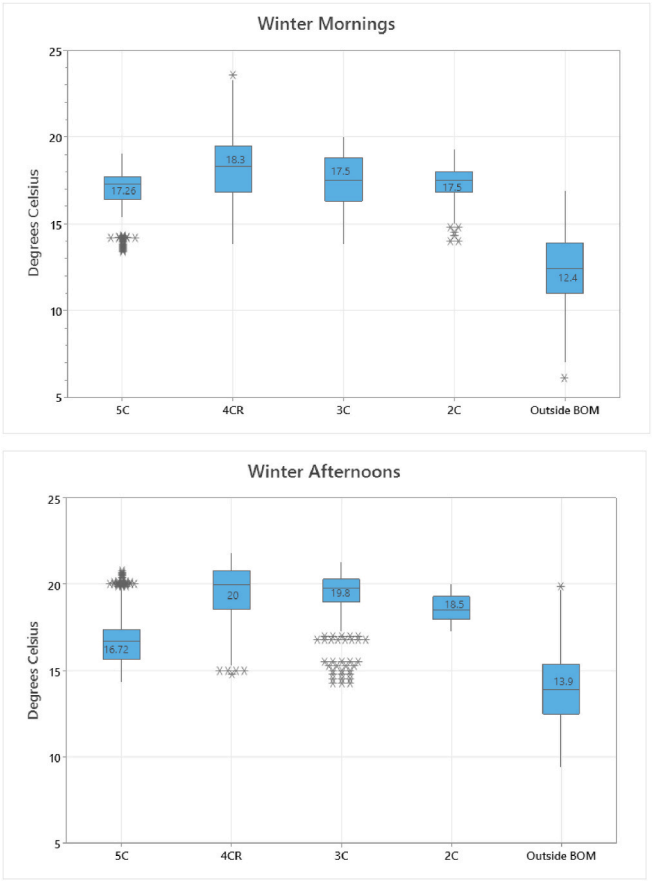


Fig. 9. Distribution of winter temperatures in classes who participated in survey (BOM - Bureau of Meteorology).

student answers of Too Cold in Table 8. As per Fig. 11, the full range of relative humidity readings are from 42 % to 80 % in winter school hours and 32 %–67 % in summer school hours. One would expect as humidity increases, a higher percentage of students would state being too cold or too hot at extremes of temperature. However, the instrument readings tell us that in summer the humidity is generally moderate in absolute terms, so we would not expect humidity to have an effect on feelings of heat. Instrument readings of humidity in winter were higher, which explains the observed positive effect of humidity on students' responses of Too Cold. Fig. 11 shows the distributions of humidity in the classrooms of the children completing the survey.

It should be noted that Melbourne receives the bulk of its precipitation in winter and spring, hence the higher humidity levels in winter.

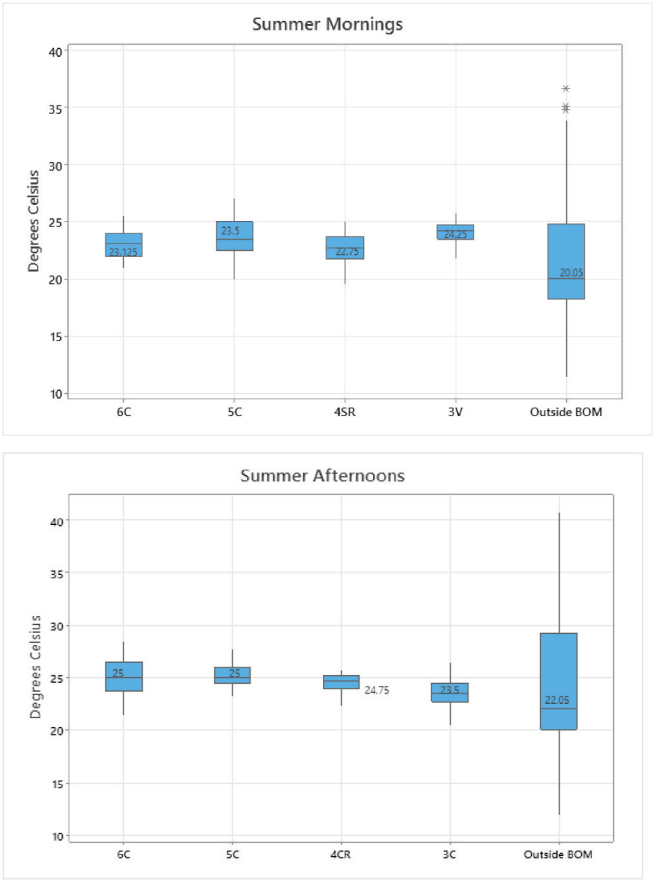


Fig. 10. Distribution of summer temperatures in classes that participated in the survey (BOM - Bureau of Meteorology).

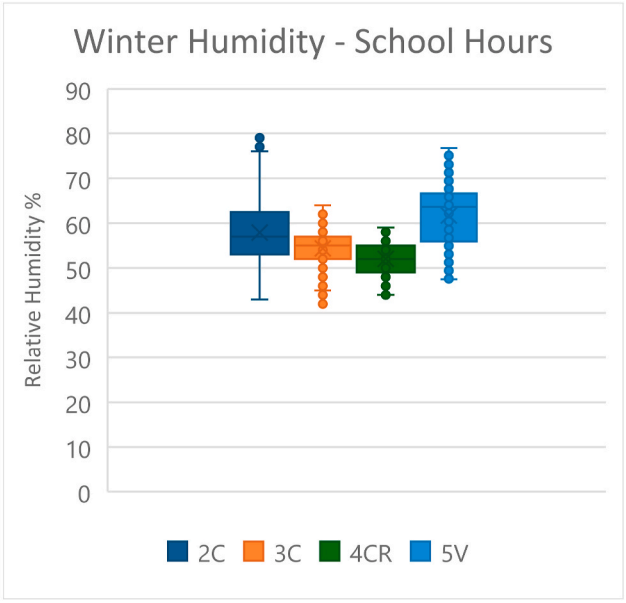
In addition, the Year 5 and 6 classes are located in the BER building, which appears to be leakier, as evidenced by temperature maintenance difficulties. Although there are large differences in psychological responses to discomfort caused by high humidity [45], the majority of humans experience discomfort when humidity rises above 70 % where temperature is above 26 °C [46]. As can be seen from the winter temperatures in Fig. 9, on the rare occasions humidity exceeded 70 %, temperature was well below 26 °C, so we would not expect this to affect student perceptions of temperature. In addition, ASHRAE states that humidity can be ignored at temperatures below 19 °C [47].

Children's responses to the lack of fresh air question were associated with high temperatures and associated negatively with humidity and CO_2. As discussed above, as humidity was at a low enough level in both summer and winter to cause no discomfort, we would not expect it to have an effect on perceptions of fresh air. Air velocities measured are shown in Fig. 12.

Airflow is regarded as perceptible by humans above 0.2 m/s [48]. With the exception of 25 time points for class 6C (each data point represents a 5-min average) the recorded air velocities would have been imperceptible to the children and therefore we would expect air velocity to have no impact on their perception of fresh air. This is supported by the univariate analysis showing no association between air speed and perceptions of fresh air.

Carbon Dioxide (CO_2) levels were recorded, however, as CO_2 concentration is imperceptible to humans unless it affects breathing, we would expect it to have no effect on perceptions of fresh air. While the regressions analysis did show a correlation between CO_2 measurements and responses of Too Hot and Lack of Fresh Air, the direction was negative which is opposite to what we would expect.

Interestingly, although air speed is low, there is a correlation



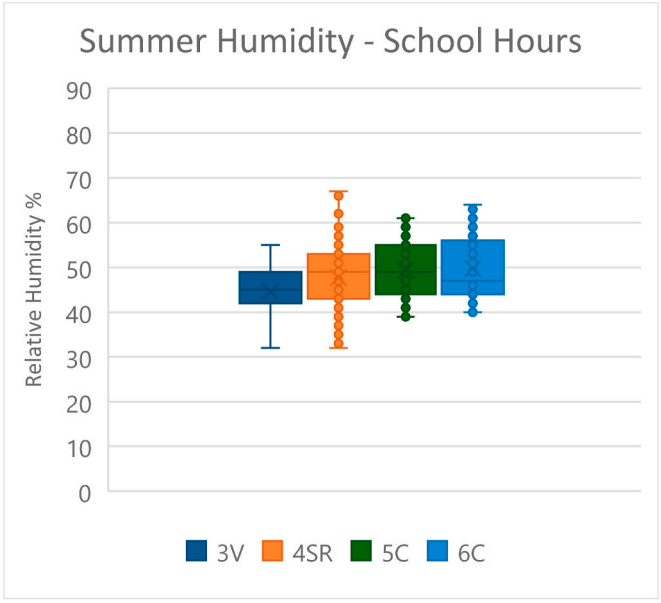


Fig. 11. Humidity measured during school hours in summer and winter by classroom.

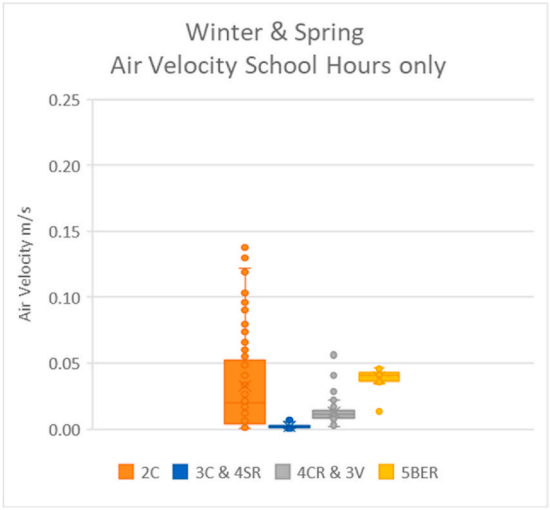
between airspeed and responses of Too Cold. This suggests that, although imperceptible, air movement contributes to feelings of cold.

3.3.2. *Visual comfort*

The results of univariate analysis of the parameters possibly associated with student perceptions of lighting are shown in Table 9.

This result shows that high temperature is associated with excess light (direct sun, for example) and low temperature is associated with inadequate light. As there is no correlation to actual light readings, it appears to indicate that children are not reliable respondents regarding perceptions of inadequate or excess light.

As described under Methodology, the light sensors were located on benches at the edges of classrooms, under overhead cupboards in the case of the new building, and on teacher bookshelves with no overhead cupboard in the case of the BER building. Therefore, we would expect the sensors to provide lower readings than they would on desks in the new building but provide similar readings to measurements on desks in the BER building.



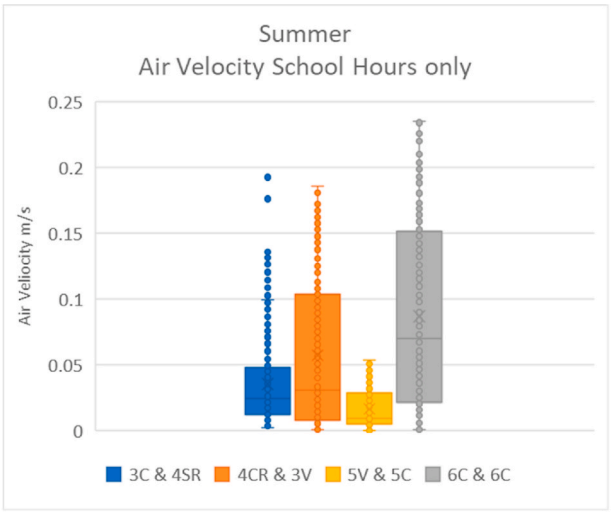


Fig. 12. Air velocity measurements by classroom and season.

Table 9
Results of univariate analysis of responses to lighting questions encompassing all classrooms.

Student Question	Parameter	Log (OR)	95 % CI	p-value
Too bright	Temperature °C	0.16	0.05, 0.26	0.005
	Light Illuminance (lx)	−0.001	−0.005, 0.003	0.6
Too dark	Temperature °C	−0.21	−0.37, −0.06	0.008
	Light Illuminance (lx)	−0.006	−0.013, 0.001	0.10

Instrument measurement results during school hours are summarised in Fig. 13.

It is apparent that the BER classrooms have lower ambient light despite the sensors being in a better position. In the paper reporting the results of the case study adult surveys (Intelligent Buildings International submission ID 249651192), several respondents described these two BER classrooms as dark. This was verified with handheld lux meters used on desk surfaces at various locations within the classrooms during lunchtime on a sunny summer day with the lighting switched on (optimal conditions). Sections of these classrooms measured well below the recommended 240 lux for classrooms (AS/NZS 1680.2.3) (Standards Australia 2008).

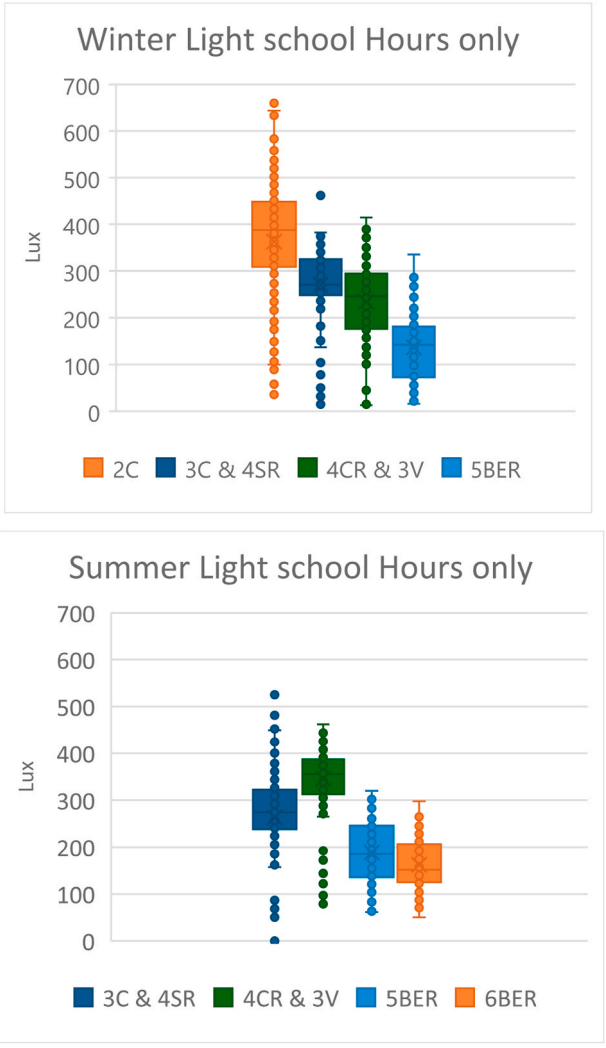


Fig. 13. Box plots of light measured during school hours by classroom.

3.3.3. *Acoustic comfort*

No association was found between answers to the question regarding ability to hear the teacher and instrument measurement of noise level by classroom as shown in Table 10.

However, the question: "Can you hear the teacher well in the classroom?" received a clear positive response with 91 % answering "Always" or "Mostly". This is supported by the instrument measurement of noise, as shown in Table 11 and Fig. 14, which is within the overall acoustic recommendations for Occupied Background Noise Level of <50 dBA Good and 50-55dBA OK [49].

In addition, average noise measured in each 10-min sample outside school hours (i.e. background noise) shows the third quartile reading less than 35 dB as shown in Fig. 14. This is lower than the guideline for teaching spaces' internal ambient noise of 35–40 dBA [50].

Thus, we may conclude that this question would be a good proxy for instrument measurement with useful information provided to architects.

Table 10
Response by classroom and results from Fisher's exact test.

Ability to hear the teacher - responses by classroom					
Classroom	Response				Total
	Always	Mostly	Sometimes	Never	
3V	17	10	2	1	30
4RS	11	9	2	0	22
5C	10	8	4	1	23
6C	7	7	0	0	14
BER	0	2	0	0	2
Total	45	36	8	2	91
Fisher's Exact Test for Count Data p = 0.7127					

Table 11
Average A-weighted decibel levels calculated from 10-min noise averages measured during Winter, Spring and Summer.

Average A-weighted decibel levels during school hours				
Classroom	3C/4SR	4CR/3V	5V/5C	6C
dBA	51.8	54.7	50.1	48.9

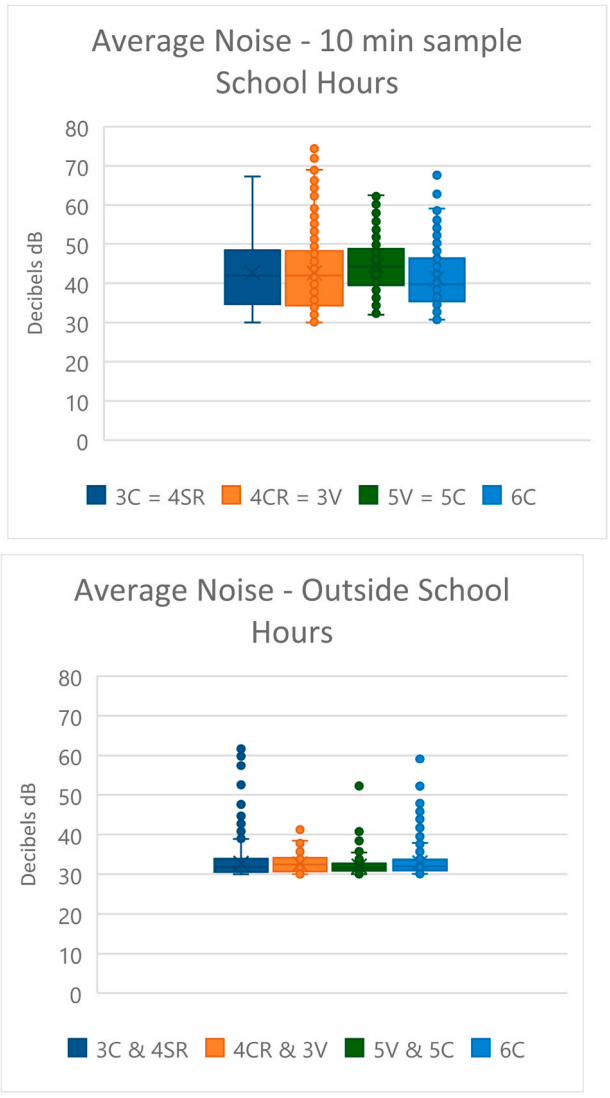


Fig. 14. Ten-minute average dB recorded during and outside school hours.

4. Discussion

Concerns were raised regarding research with children, and their ability to understand and interpret plans of school buildings and grounds. However, the results indicate that the children's location responses correspond with their written reasons for selecting favourite and most disliked places, as evidenced by Tables 2–7. Additionally, the accuracy of class location indicated by children on the plans was checked by cross-referencing the time of survey completion with the researcher's

calendar for the time surveys were completed by each class. Only two instances were found where children clicked on the BER building without specifying the Year 5 or 6 classroom. In cases where this detail is relevant to the results, it has been duly acknowledged. Notably, the researcher did not need to explain the plans to any children. This approach confirmed that children could easily identify and select locations on the plans without requiring additional explanation.

There were only two "Why?" answers that did not match the spatial location that had been clicked: one had clicked on the library, as the most disliked place inside, but wrote "I hate the boys toilet". Another clicked on the Portable as their favourite place outside and said "It has the best equipment" which could have referred to the sandpit or the playground. Thus, out of 91 children x 4 questions, only 2 answers or 0.5 % appeared to have a lack of spatial understanding. For one of those children, their other answers clearly relate to the spaces they indicated. The answers of the other child are "Spot" for both favourite and disliked places outside, being the soccer field and sports field, which may be a failure with English rather than spatial understanding. In any case 1/91 children misunderstanding is 1.1 % of the school population. This very low percentage supports the finding of this research that almost all children understand simple, well-labelled plans of places they know well.

The Places I Like and Dislike poster activities were intended to duplicate the same questions from the on-line survey. The researcher was not present to supervise this activity. The outdoor questions received similar responses to the on-line surveys, as shown in the results. For the indoor questions, children were shown only their own building, which means the posters cannot be compared to the on-line surveys. There are two deficiencies inherent in this paper activity. The first is the lack of collection of reasons for children's choices, which limits the information provided. The second is the possibility of "group think". Children have the opportunity to see where their classmates are placing stickers and have opportunity to discuss it, so may be swayed in their opinions by their friends' preferences.

Another question raised regarded whether children might perceive the survey as an academic test and attempt to give "right" answers that they believe will please the researcher, teachers, or architects [10]. To address this concern, the research team took several steps. Firstly, the survey commenced with questions about "Places I like" and "Places I Dislike," which are easy for children to respond to, because they relate to their personal feelings. This approach aimed to establish a mindset for the rest of the survey that is consistent with good survey design principles [51]. In addition, most questions were phrased to ask what children think or feel about a topic. There were no questions requiring calculations, and the only knowledge-based questions related to the existence of sustainable facilities at the school, which were presented towards the end of the survey. Further, the reasons given for "Favourite" and "Most Disliked" places are manifestly demonstrative of children's concerns and preferences.

The "Favourite Places" and "Most Disliked places" inside and outside spatial questions yielded valuable insights. They provided a clear picture of which spaces children liked and disliked, along with the reasons behind their preferences. When multiple children expressed similar responses to a particular space, it provided clear information to architects about the design of that space. For example, the most loved space, the library, has ample light, a raked ceiling, and a double-height north-facing window (for heat gain in a Melbourne winter). The library also features interesting and comfortable furniture, and the height of all book stacks are within reach of small children. This design aspect fosters a sense of safety and belonging, as both teachers and children can see over the book stacks to enable connections and help children feel safe and part of a community [52].

The number of children who don't play sports in the playground at school may not accurately reflect their overall activity levels, as many children participate in club sports or dance activities outside of school hours. However, it is concerning that almost 8 % of the total surveyed (7/91) expressed fear of injury while using the outdoor play spaces. To further interpret the responses related to outside spaces, inclusion of a demographic question regarding gender would be beneficial [53]. Understanding the gender differences in preferences related to outdoor activities would help to inform future design decisions aimed at promoting inclusive and safe play environments for all students.

The qualitative questions in the survey yielded mixed results, indicating areas for revision or adjustment to improve the survey protocol. For example, the question about the surfaces could benefit from refinement, potentially by asking separately about walls, floors, and stairs depending on the school design. Additionally, including a follow-up question asking "why" nominated surfaces are uncomfortable could provide deeper insight. Similarly, the questions about colours, surfaces and furniture would benefit from improved survey mechanics to ensure that naming boxes only appear when the "Yes" answer is selected, streamlining the survey process and enhancing clarity. The Feelings questions appeared to have limited use for architects, as they did not ask about the reasons behind the respondents' feelings. Including a follow up question asking "Why?" a particular classroom or Hub space engendered a specific feeling could provide valuable insight for architects. Conversely, questions about the "Uses of the Hub" (street-space [38]) would provide key information for architects to support or alter their intentions for the use of these spaces. In particular, insights into students' desires for hub uses, such as cooking lessons (the Hubs were provided with sinks and counters), could spark a conversation around the best way to provide facilities for such activities in primary (elementary) school settings. Similarly, the question about Spatial Changes Desired elicited largely functionality responses, except for two students wishing for rule changes. This question would also benefit from a follow up asking "Why?" as many answers named an item, e.g. tables, without specifying what aspect they wanted to change, such as the location, type of table, or comfort level.

The Likert-style questions proved to be successful, providing clear results, with responses often clustered around the "Neutral" option. These questions could highlight areas where architects or school administrators may need to enquire more closely, such as the adequacy of provision of natural play spaces. However, there are additional considerations, such as the interpretation of the term "nature" by children. To enhance result interpretation, it may be beneficial to include an exploratory, qualitative question to delve deeper into children's perceptions of this term. Some of the Likert-style questions would provide greater value to architects if comparisons could be made across different schools and allow understanding of differences in environmental factors alongside variations in Likert responses. Furthermore, certain questions, such as those about internet speed, may not be relevant for architects, as this factor is typically beyond their control. However, such questions may be necessary if future surveys are intended to also provide feedback to engineers or client building owners.

The quantitative questions regarding thermal comfort, which were tested against instruments to determine if they could serve as proxies for architects to identify areas requiring deeper investigation, were largely successful. However, there are areas where question mechanics require attention. For instance, the "Fresh Air" question appears to be unsuccessful. For this question it may be better to ask about smell or stuffiness because in the teachers' survey, some disliked rooms were described as "stuffy". This correlated to high CO_2 levels measured in those classrooms previously. Stuffiness is the converse to fresh air, and, as a negative, more likely to be observed and remembered by children. Similarly, the "Too Dark" and "Too Bright" questions were not associated with any measurements, aside from temperature. Therefore, in these case study buildings, these questions do not offer useful information to architects. However, given the association between the lux readings and teachers' survey responses, architects could obtain valuable information about lighting from the adult surveys instead. Conversely, the question regarding noise was successful, as it showed successful vocal comprehension, supported by instrument recording.

4.1. Limitations and scope of study

The results of this particular case study may not be generally applicable to other schools and contexts. However, the purpose of the study was to test the effectiveness of the feedback methods, with the feedback received on building design considered secondary. Furthermore, it is crucial to recognize the wording of questions, survey design and expressions used are connected to the specific context of a state education department school in a developed English-speaking country. Application to other contexts would require careful consideration of question wording, meaning, and respondent interpretation to ensure validity and relevance. A common understanding of survey aims would be necessary to allow widespread application of the survey to different contexts.

A limitation raised is that the wording of the research question *"Is the newly developed children's on-line feedback survey satisfactory?"* may have introduced a positive bias to the assessment of the success or failure of each question to provide the information sought. The authors acknowledge this possible bias and accept that only future assessment by architects will confirm whether the information provided is useful for them.

Instruments were purchased to record globe temperature, in order to make calculations of Operative Temperature for comparison of these results to thermal comfort studies, for example [54]. Unfortunately, due to misrepresentation of the devices by the vendor and manufacturer regarding ability to record globe temperature during unattended logging, we are not able to make these calculations.

4.2. Practical implications of this research

This research has shown that surveys of children, as the largest and most important user group in the school, can provide valuable information for architects. While in this case study, analysis of qualitative answers could be time-consuming, future developments in automatic coding may reduce this significantly. On-line surveys are simple to develop and administer and may provide more efficient feedback collection for architects and designers in the future.

5. Conclusion

The ISD comprehensive surveys of the children provide useful information for architects and designers, satisfying the research question. Although there are some questions that require some revision to

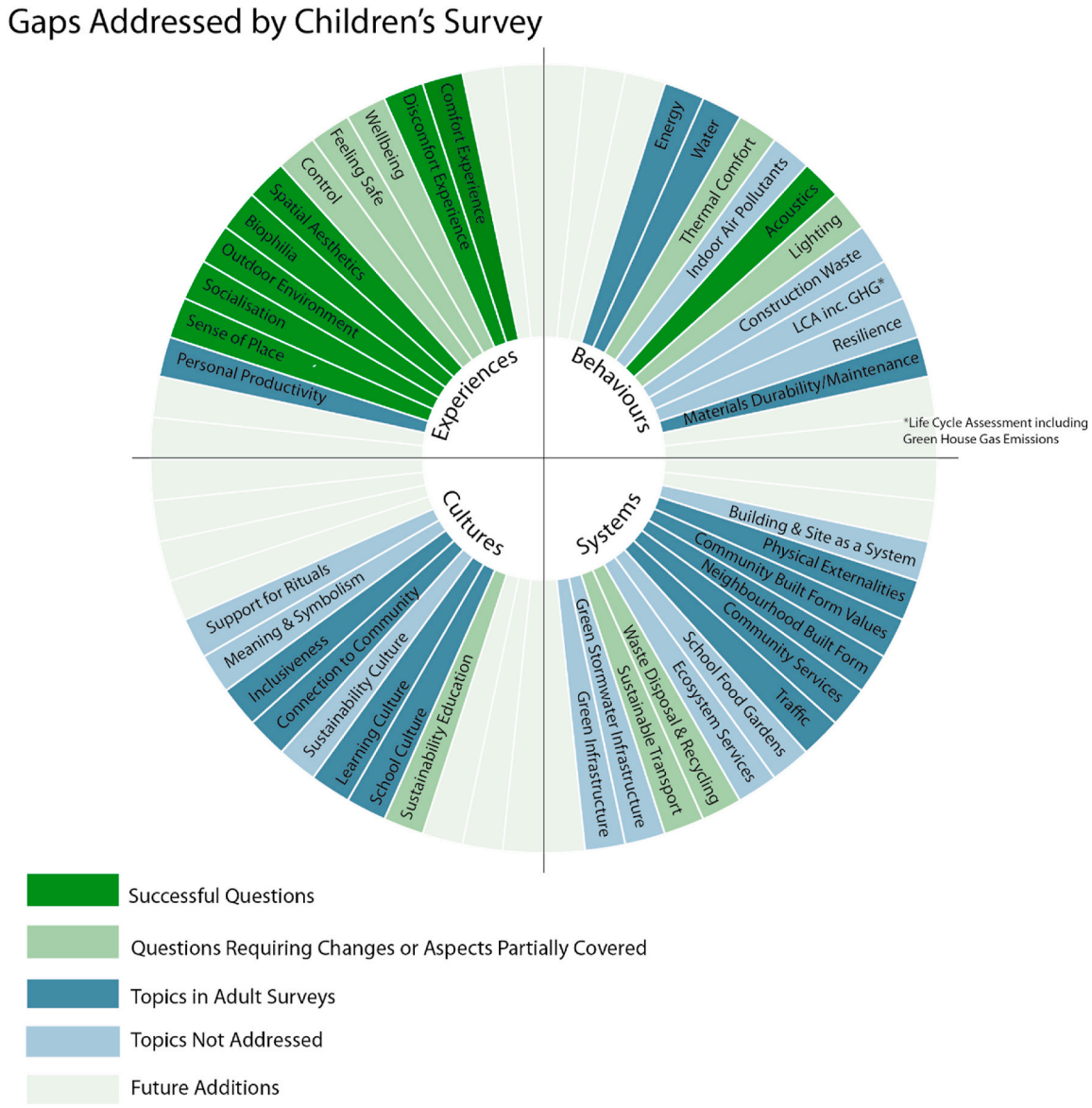


Fig. 15. Summary of feedback areas addressed by children's and adults' surveys.

mechanics or wording, the survey provided valuable information in areas desired by architects that are not currently included in post-occupancy feedback.

Fig. 15 shows which feedback topics, identified in the literature review and architects' survey were addressed by the ISD survey for children. It also shows topics addressed by the ISD comprehensive surveys for adult groups including teachers, administrators and parents, reported in an article previously submitted (Intelligent Buildings International Submission number 249651192).

Funding

This work was supported by School of Architecture & Built Environment, Deakin University, 2021 School Research Minor Equipment Grant.

CRediT authorship contribution statement

Vanessa Whittem: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Michael T. Meehan:** Writing – review & editing, Validation, Methodology, Formal analysis. **Astrid Roetzel:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Akari Nakai Kidd:** Writing – review & editing, Methodology, Conceptualization. **Abdul-Manan Sadick:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Jo Raphael:** Writing – review & editing, Methodology. **Joanne O'Mara:** Writing – review & editing, Methodology.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

Acknowledgments

This work is part of a programme of research leading to a PhD for the lead author. She would like to acknowledge the assistance of Prof. Mark Luther and his graduate student Quang Hung Do during calibration and for loan of the ASHRAE comfort carts during August 2022 which allowed for measurement in more locations simultaneously.

Appendix 1. Mapping of evaluation parameters from sources to questions

The aim of the suite of on-line surveys was to obtain post-occupancy feedback on the aspects identified by the literature review as gaps and on aspects identified as desires from the architects' survey. The ISD framework has been used to structure the appendix so there is a table for each perspective. Each table lists the evaluation parameter (building aspect) to be investigated. It then shows for adults and children, within each evaluation method, which question/response applied to that parameter. Some aspects are more appropriately examined through the adult surveys and other aspects in the children's survey. Blank cells indicate where a question on the parameter was not included in that evaluation method. Aspects of building design not canvassed in the surveys are highlighted in the tables in grey, along with reason for non-inclusion, or whether a question is needed.

Appendix 1 Table 1
Experiences Quadrant mapping from sources to questions

Evaluation Parameters			Evaluation Methodology		**Question Needed?**
Category	**Parameter identified through the literature review**	**Parameter identified through the architects' survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
Comfort Experience	Daylight quantity	Lighting/visual comfort	Favourite Space		
		Feelings/psychological comfort	Favourite Space, Classroom feelings, Hub feelings	Inside Favourite Space. Favourite Place Outside, Classroom feelings, Hib feelings	
Discomfort Experience	Uncomfortable Furniture	Furniture, tactility & materials	Fixed furniture in Hub and teacher work room	Uncomfortable Surfaces, Uncomfortable Furniture	
	Thermal Discomfort		Disliked Space, Too hot + Too cold at season & time of day	Too hot + Too cold at season & time of day	
	Insufficient Light		Disliked Space, Too dark at season & time of day	Too dark at season & time of day	
	Glare		Disliked Space, Too bright at season & time of day	Too bright at season & time of day	
	Smell or stuffy		Disliked Space, Lack fresh air at season & time of day	Lack fresh air at season & time of day	
Wellbeing	Noise	Acoustic Comfort	Disliked Space, Sound level is comfortable	Most Disliked Space Inside, Can you hear the teacher well	
	Indoor Dampness				Where appropriate for climate
	Schoolyard microclimate & weather protected spaces				Needs question
	Special and Neurodiverse needs	Support neurodiversity, Diversity of spaces for solitude & gathering & refuge			Needs question
	Toilet availability, maintenance, access			Most Disliked Space Inside, Toilets are clean & working, access during class without permission	
Feeling Safe	Wayfinding & spatial clarity				

(*continued on next page*)

Appendix 1 Table 1 (*continued*)

Evaluation Parameters			Evaluation Methodology		Question Needed?
Category	**Parameter identified through the literature review**	**Parameter identified through the architects' survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
	Fences/Feeling Safe from Strangers				Insufficient Research
	Teacher oversight of inside spaces				Needs question
	Teacher oversight of outdoor spaces	Passive Surveillance			Needs question
Control	Control of thermal environment - Teacher		I received instruction on a/c & heater		
	Control of spatial environment – Teacher – flexibility & adaptability	Flexibility & Variety	Uncomfortable furniture, current & desired Hub activities		
	Display spaces for student art		Disliked Space		Needs question
Functionality		Functionality - needs-uses	Disliked Space – Size Uncomfortable surfaces, Fixtures, What would you change or move?	Inside Most Disliked Space, current & desired Hub activities, What would you change or move? Space for digital devices	
		Affordances – student agency		current & desired Hub activities, What would you change or move?	
		Ease of use – windows & doors	Windows/vents easy to operate		
		Ease of maintenance			Needs question
Spatial Aesthetics	Bright Colours		Uncomfortable colours	Uncomfortable Colours	
		Diversity of spaces for solitude & gathering & refuge	Sound privacy	Inside Favourite Space	
Biophilia	Views to outside		Favourite Space, Connection	Does any part of building remind you of nature? Connection to outside	
	Natural patterns, forms and colours			Does any part of building remind you of nature?	
Outdoor Environment	Natural elements in school grounds			Choice of natural equipment and natural play places	
	In-between spaces for imaginative play	Use of spaces			Needs question
				Places where I can play ball games	
Socialisation	Private spaces		Sound privacy		
	Incidental interactions			Inside Most Disliked Space, Places for me to hang out & chat with friends	
Sense of Place	Affordances for whole-school cultural activities		Pride in school building, design lifts my spirits, Parents - like to visit	Inside Favourite Space, Sense of pride, makes me feel good	

Appendix 1 Table 2
Cultures quadrant mapping from sources to questions

Evaluation parameters			Evaluation Methodology		Question Needed?
Category	**Parameter identified through the literature review**	**Parameter identified through the architects' survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
Support for Pedagogy & Learning Community		Support for current pedagogy Support to try novel pedagogies Flexible/spaces for diverse needs/ activities	Spaces suitable for current teaching methods Building & furniture support me to try new pedagogy What would you change or move?		
Sustainability Culture	Congruence				Needs research
		Operational instruction for energy & user comfort	I received instruction on a/c & heater		
Sustainability Education	Factual Information, Physical Engagement, Social Interaction (e.g. gardens), Making visible, Passive engagement, Incidental encounters, Symbolic	Building as teaching tool	Have info to teach children about building sustainability, building helps teach about sustainability, Sustainability features knowledge	Sustainability features knowledge	
Meaning & symbolism	For children				Needs research

(*continued on next page*)

Appendix 1 Table 2 (*continued*)

Evaluation parameters			Evaluation Methodology		**Question Needed?**
Category	**Parameter identified through the literature review**	**Parameter identified through the architects' survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
	For Culturally & Linguistically Diverse people		Parent – entrance & reception welcoming		
Connection to community	Accessible	Facilitation of community engagement			
	Welcoming/Sitting Places	Feelings of welcome & acceptance	Parent – entrance & reception welcoming, space for parents waiting		
	Safe Access		Parents - Safe for children to walk to school		
Inclusiveness	Universal accessibility & regulation spaces	Appropriate spaces			Needs question
Support for Rituals	Appropriate spaces – from brief				Needs question

Appendix 1 Table 3
Behaviours quadrant mapping from sources to questions

Evaluation parameters			Evaluation Methodology		**Question Needed?**
Category	**Parameter identified through the literature review**	**Parameter identified through the architects' survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
Energy	kWh/m2/annum	Total before & after energy consumption	Business Manager - Total before & after energy consumption		
Water	litres/student/day	Total before & after water consumption	Business Manager - Total before & after water consumption		
Thermal Comfort	adaptive comfort model	Thermal comfort	Too hot + Too cold at season & time of day	Too hot + Too cold at season & time of day	
		Passive solar design/ seasonal variation	Too hot + Too cold at season & time of day	Too hot + Too cold at season & time of day	
Indoor Air Quality (IAQ)	ventilation rates or CO2 as proxy		Lack fresh air at season & time of day	Lack fresh air at season & time of day	
Acoustics	instrument reading		Disliked Space, Sound level is comfortable	Can you hear the teacher well? Always, Mostly, Sometimes, never	
Lighting	instrument readings - standards		Too bright, Too dark at season & time of day	Too bright, Too dark at season & time of day	
Life Cycle Assessment (LCA)	Calculation	Life cycle carbon			As required - Architect adjust design modelling for as-built changes
Waste	During building life cycle				NA for post-occupancy feedback
Building Materials		Durable materials			Need question
		Maintenance cost	Business manager before & after maintenance cost		
Resilience	Local risks – Earthquake, cyclone, etc.				Possible question
	Climate change resilience			Favourite Place Inside	Need question
	Power grid resilience				Possible question

Appendix 1 Table 4
Systems quadrant mapping from sources to questions to results

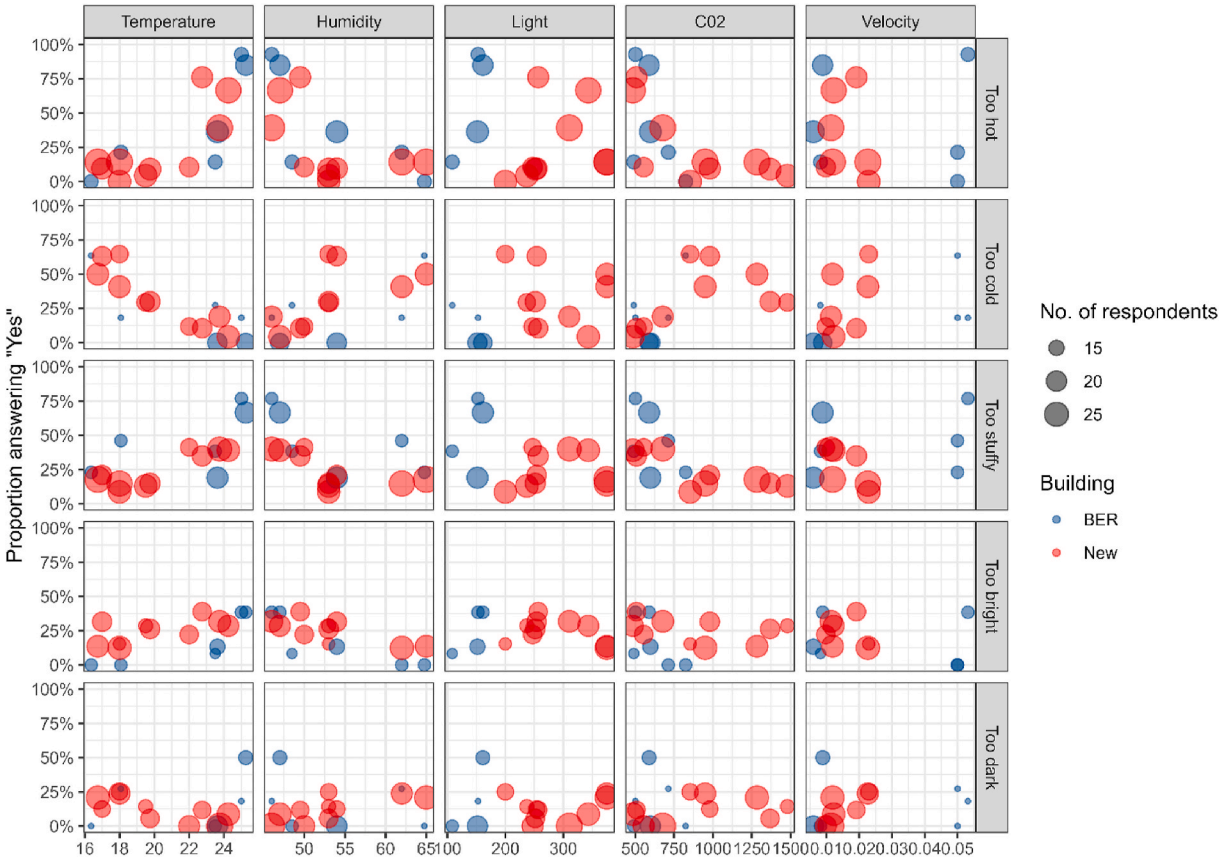
Evaluation parameters			Evaluation Methodology		**Question Needed?**
Category	**Parameter identified through the literature review**	**Parameter identified through the architects survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
Green Infrastructure & Ecosystem Services	Area of green space, proportion of green space % tree canopy cover				As required - Architect adjust design modelling for as-built changes
	Reserved/rehabilitated habitat				As required - Architect adjust design modelling for as-built changes

(*continued on next page*)

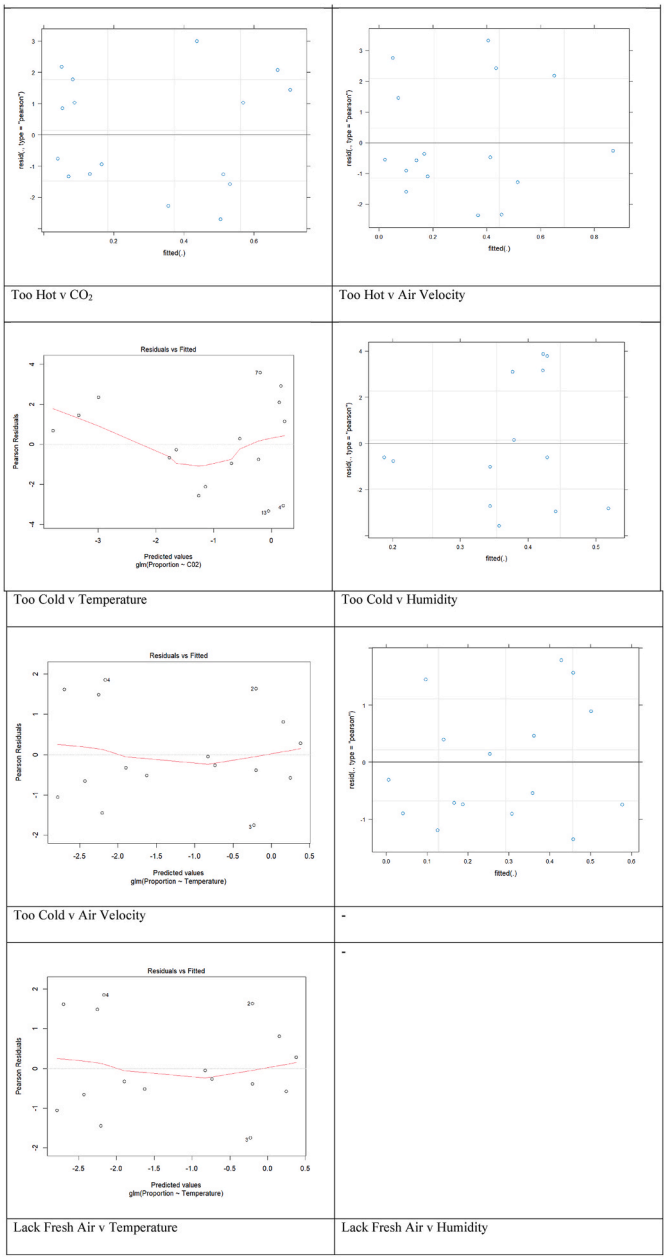
Appendix 1 Table 4 (*continued*)

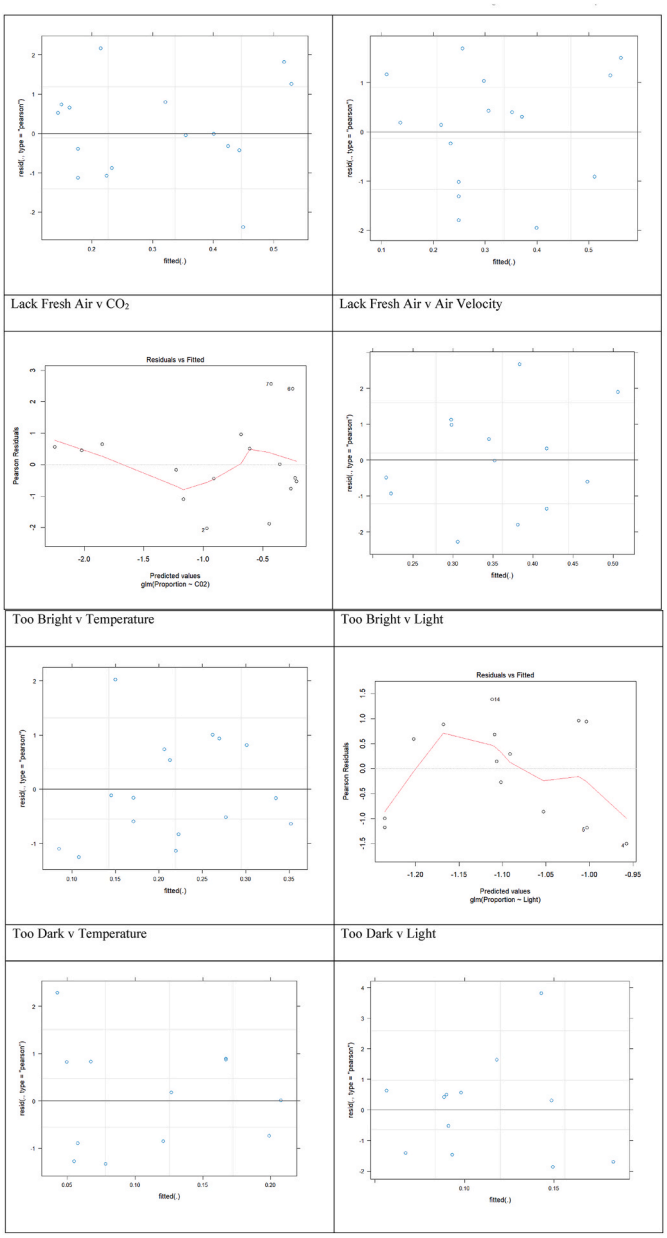
Evaluation parameters			Evaluation Methodology		**Question Needed?**
Category	**Parameter identified through the literature review**	**Parameter identified through the architects survey**	**Adult ISD Survey questions**	**Children ISD Survey questions**	
Green Stormwater Infrastructure	Provision of water absorption items/Reduction in volume of surface runoff				As required - Architect adjust design modelling for as-built changes
	Water tank volume/use of city water for gardens				Needs question
School food gardens	For education				Needs question
	For provisioning				NA in Australia
	Composted food waste				Needs question
Sustainable transport	provision of bus stops, bicycle racks, easy access to public transport, etc.				NA for post-occupancy feedback
	Proportion walking to school		Parents – safe to walk to school	safe to walk to school	
	Traffic flow & conflict issues	Site planning feedback	Parents – vehicle traffic flows smoothly, pedestrian access is easy, space for parents waiting		
Wase Disposal & Recycling	Provision of facilities		Sustainability Provisions question		
Community Services	Before & After school Care	Social support	Parents – access to before & after school care program is easy & safe		
	Actual Community Use (sporting, club, etc.)	Actual uses	Business manager question		
	Design provisions for community use – independent access, kitchen, gymnasium, etc.	New uses – responding to community needs	Business manager question		
Other external	Fit to local built form	Building contribution to place making	Parents – relates well physically to neighbourhood		
	Fit to community built culture		Parents - Looks attractive from street		
	Surface & other considerations				NA for users

Appendix 2. Graphs of survey response v instrument measurement



Appendix 3. Residual analysis graphs





Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.buildenv.2024.112067.

References

[1] Derek Clements-Croome, The role of feedback in building design 1980–2018 and onwards, Build. Serv. Eng. Res. Tecnol. 40 (1) (2019) 5.
[2] Robert Cohen, Mark Standeven, Bill Bordass, Adrian Leaman, Assessing building performance in use 1: the Probe process, Build. Res. Inf. 29 (2) (2001) 85–102, https://doi.org/10.100080/09613210010008018.
[3] T.L. Brown, A critical assessment of the place of post-occupancy evaluation in the critique and creation of socially responsible architecture, Intell. Build. Int. (2018) 1–12, https://doi.org/10.1080/17508975.2018.1437708.
[4] Vanessa Whittem, Astrid Roetzel, Abdul-Manan Sadick, Akari Nakai Kidd, How comprehensive is post-occupancy feedback on school buildings for architects? A conceptual review based upon Integral Sustainable Design principles, Build. Environ. (2022), https://doi.org/10.1016/j.buildenv.2022.109109.
[5] L. Fay, A. Carll-White, J. Harrell, Coming full cycle: linking POE findings to design application, Health Environments Research and Design Journal 10 (3) (2017) 83–98, https://doi.org/10.1177/1937586716672856.
[6] Graham Kelly, Robert Schmidt III, Andrew RJ. Dainty, Vicky Story, in: Improving the Design Process for Adaptability: Linking Feedback and Architectural Values, 2011.
[7] D. Kirk Hamilton, Bridging design & research, HERD-Health Environments Research & Design Journal 1 (1) (2007) 29–30.
[8] Peixian Li, Thomas M. Froese, Gail Brager, Post-occupancy evaluation: state-of-the-art analysis and state-of-the-practice review, Build. Environ. 133 (2018) 187–202, https://doi.org/10.1016/j.buildenv.2018.02.024.
[9] T. Graham Lindsay, Parkinson Thomas, Schiavon Stefano, Lessons learned from 20 years of CBE's occupant surveys, Buildings & Cities 2 (1) (2021), https://doi.org/10.5334/bc.76.
[10] Adrian Leaman, BUS Occupant Survey, 2021, 21 July 2021.

[11] Ian Cooper, Post-occupancy evaluation - where are you? Build. Res. Inf. 29 (2) (2001) 158–163, https://doi.org/10.1080/09613210010016820. Accession Number: 4394443.
[12] Bill Bordass, Learning more from what we build, in: S. Macmillan (Ed.), Designing better buildings: quality and value in the built environment, Spon, 2004.
[13] Vanessa Whittem, Astrid Roetzel, Learning from built projects–sources of post occupancy feedback used by architects in Victoria, Australia, Intell. Build. Int. 13 (4) (2019) 311–326, https://doi.org/10.1080/17508975.2019.1695192.
[14] R. Hay, F. Samuel, K.J. Watson, S. Bradbury, Post-occupancy evaluation in architecture: experiences and perspectives from UK practice, Build. Res. Inf. (2017) 1–13, https://doi.org/10.1080/09613218.2017.1314692. Accession Number: edselc.2-52.0-85018458248.
[15] Jin Woo, Priyadarsini Rajagopalan, Mary Myla Andamon, An evaluation of measured indoor conditions and student performance using d2 Test of Attention, Build. Environ. 214 (2022), https://doi.org/10.1016/j.buildenv.2022.108940.
[16] Peter Barrett, Alberto Treves, Tigran Shmis, Diego Ambasz, Maria Ustinova, The Impact of School Infrastructure on Learning: A Synthesis of the Evidence, The World Bank, 2019.
[17] Diksha Vijapur, Christhina Candido, Özgür Göçer, Shirley Wyver, A ten-year review of primary school flexible learning environments: interior design and IEQ performance, Buildings 11 (5) (2021) 183.
[18] Laura B. Cole, Elke Altenburger, Framing the Teaching Green Building: environmental education through multiple channels in the school environment, Environ. Educ. Res. 25 (11) (2017) 1654–1673, https://doi.org/10.1080/13504622.2017.1398817.
[19] Mark DeKay, in: Susanne Bennett (Ed.), Integral Sustainable Design : a Transformative Perspective, Earthscan, London ; Washington, DC, 2011, 2011.
[20] Christopher Moloney, Anastasia Globa, Rui Wang, Astrid Roetzel, Serious Games for Integral Sustainable Design: Level 1, Elsevier, 2017.
[21] Ken Wilber, The Eye of Spirit: an Integral Vision for a World Gone Slightly Mad, third ed., expanded ed., Shambhala, Boston, 2001.
[22] Sean Esbjörn-Hargens, Integral theory in action : applied, theoretical, and constructive perspectives on the AQAL model. SUNY Series in Integral Theory, State University of New York Press, 2010.
[23] Astrid Roetzel, Robert Fuller, Priyadarsini Rajagopalan, Visual Mapping of the Integral Sustainable Design Approach, University of Adelaide, 2016.
[24] Mark DeKay, in: Susanne Bennett (Ed.), Integral Sustainable Design : a Transformative Perspective, Earthscan, London ; Washington, DC, 2011, 2011.
[25] UN, United Nations, THE 17 GOALS, United Nations Department of Economic and Social Affairs, 2021. https://sdgs.un.org/goals. (Accessed 4 October 2021).
[26] Gary Clark, in: Alex Tait (Ed.), RIBA Sustainable Outcomes Guide, vol. 52, Royal Institute of British Architects, London RIBA, 2019.
[27] V. Whittem, A. Nakai Kidd, A.-M. Sadick, A. Roetzel, Testing of new feedback methods for architects on school design methodology and preliminary results, in: M. Dewsbury (Ed.), Architectural Science and User Experience: Sustainability: Sustainability and Health: the Nexus of Carbon-Neutral Architecture and Well-Being: 56th International Conference of the Architectural Science Association 2023 29th November – 2nd December 2023, D, 2023.
[28] Fatemeh Aminpour, Child-friendly environments in vertical schools: a qualitative study from the child's perspective, Build. Environ. 242 (2023), https://doi.org/10.1016/j.buildenv.2023.110503.
[29] Cream Wright, Changu Mannathoko, Maida Pasic, UNICEF. Child Friendly Schools, UNICEF, New York, 2009, p. 244.
[30] Veysel Şenyiğit, Hasan Basri Memduhoğlu, End-user preferences in school design: a qualitative study based on student perspective, Build. Environ. 185 (2020), https://doi.org/10.1016/j.buildenv.2020.107294.
[31] Terry Byers, Marian Mahat, Kirra Liu, Anne Knock, A Systematic Review of the Effects of Learning Environments on Student Learning Outcomes - Technical Report 4/2018, University of Melbourne, LEaRN, Melbourne, 2018.
[32] Fiona Young, Benjamin Cleveland, Wesley Imms, The affordances of innovative learning environments for deep learning: educators' and architects' perceptions, Aust. Educ. Res. (2019), https://doi.org/10.1007/s13384-019-00354-y.
[33] Wesley Imms, Marian Mahat, Terry Byers, Dan Murphy, Type and Use of Innovative Learning Environments in Australasian Schools, ILETC Survey 1 (2017). https://www.iletc.com.au/wp-content/uploads/2017/01/TechnicalReport_final_webv4.pdf.
[34] Pamela Woolner, Creating individualised optimal learning environments through participatory design, Educ. Child Psychol. 28 (1) (2011) 9–19.
[35] Ben Cleveland, Emerging Methods for the Evaluation of Physical Learning Environments, in: W. Imms, B. Cleveland, K. Fisher (Eds.), Evaluating Learning Environments: Snapshots of Emerging Issues, Methods and Knowledge, Sense Publishers, 2016. https://doi.org/10.1007/978-94-6300-537-1_7.
[36] Viswanath Venkatesh, Susan Brown, Yulia Sullivan, Conducting Mixed-Methods Research, 2023.
[37] Linda Groat, David Wang, *Architectural Research methods*: New York ; [Chichester], Wiley, 2002, p. c2002.
[38] K. Dovey, K. Fisher, Designing for adaptation: the school as socio-spatial assemblage, J. Archit. 19 (1) (2014) 43–63, https://doi.org/10.1080/13602365.2014.882376.
[39] Graeme Smith, Dinjerra Part B attach 4: AMP planning phase 1: educational direction and facilities analysis, in: Victoria Department of Education, 2016.
[40] Aniebietabasi Ackley, Measuring Indoor Environmental Quality (IEQ) in a National School Property Portfolio, Open Access Victoria University of Wellington| Te Herenga Waka, 2021.
[41] Jukka Sulonen, Krisse Sulonen, The grammar of a modern school building. A comparative study on schools and the changing ways of learning, in: Perspectives from Finland–towards New Learning Environments. Tampere, Finnish National Board of Education, Finnish National Board of Education, Helsinki: Finland, 2014, pp. 78–101.
[42] Celen Pasalar, The Effects of Spatial Layouts on Students' Interactions in Middle Schools: Multiple Case Analysis, North Carolina State University, Dissertation, 2004.
[43] Fatemeh Aminpour, Kate Bishop, Linda Corkery, The hidden value of in-between spaces for children's self-directed play within outdoor school environments, Landsc. Urban Plann. 194 (2020), https://doi.org/10.1016/j.landurbplan.2019.103683.
[44] Daniel H. Jacobs, Sargo Sharon, Designing the ideal children's house: how architecture can help children learn, Montessori Life 17 (1) (2005) 34–37.
[45] Naoshi Kakitsuba, Current knowledge on the effects of humidity on physiological and psychological responses, J. Hum. Environ. Syst. 20 (1) (2018) 1–10.
[46] T. Xu, Edward A. Arens, Fred Bauman, The effects of high-level air humidity on subjective perception of comfort, in: Second International Symposium on HVAC, 1995.
[47] ANSI, and American Society of Heating ASHRAE, Refridgeration and Air-conditioning Engineers, Inc, ANSI/ASHRAE standard 55-2017 thermal environmental conditions for human occupancy, in: Atlanta: ASHRAE, American Society of Heating, Refridgeration and Air-Conditioning Engineers, Inc, 2017.
[48] Li Huang, Qin Ouyang, Yingxin Zhu, Perceptible airflow fluctuation frequency and human thermal response, Build. Environ. 54 (2012) 14–19, https://doi.org/10.1016/j.buildenv.2012.02.004.
[49] Kiri Mealings, Classroom acoustic conditions: Understanding what is suitable through a review of national and international standards, recommendations, and live classroom measurements, Acoustics 2016 (2016), 9-11 November 2016, Brisbane, Australia, Australian Acoustical Society, Queensland Division, The Acoustical Society of New Zealand.
[50] Association of Australasian Acoustical Consultants, AAAC, Guideline for Educational Facilities Acoustics V2.0, Association of Australasian Acoustical Consultants, 2018. https://cdn.wildapricot.com/197081/resources/Documents/Public/AAAC%20Guideline%20for%20Educational%20Facilities%20Acoustics%20V2.0.pdf. (Accessed 15 September 2024).
[51] Patricia J. Labaw, Advanced questionnaire design, Abt Books (1981).
[52] Jill Blackmore, Debra Bateman, Jill Loughlin, Joanne O'Mara, Aranda George, Research into the Connection between Built Learning Spaces and Student Outcomes, 2011.
[53] Wang Ivy Wong, Sui Ping Yeung, Early gender differences in spatial and social skills and their relations to play and parental socialization in children from Hong Kong, Arch. Sex. Behav. 48 (5) (2019) 1589–1602, https://doi.org/10.1007/s10508-019-1415-8.
[54] Richard de Dear, Jungsoo Kim, Christhina Candido, Max Deuble, Adaptive thermal comfort in Australian school classrooms, Build. Res. Inf. 43 (3) (2015) 383–398, https://doi.org/10.1080/09613218.2015.991627.