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A Pilot Study on Window Opening Behaviour in Auckland, New Zealand


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Occupant behaviour is a significant factor affecting the quality of the indoor environment (IEQ), which can have implications on the comfort and cognitive function of children in educational settings. The New Zealand (NZ) Ministry of Education (MoE) oversees more than 35,000 classrooms within 2,538 schools distributed across six climatic regions. These climatic regions are influenced by factors such as latitude, prevailing winds, surrounding ocean, and the Southern Alps, all contributing to diverse weather conditions across the elongated geography of the nation. Temperature variations in NZ are significant, with extremes ranging from −9.0°C to 41.6°C, accompanied by widely varying patterns of rainfall NIWA (2023a). These diverse climates pose a challenge for suitable educational spaces.

Keywords: Airing; natural ventilation; occupants' behaviour; primary schools; windows opening.

In Auckland, a mild, temperate maritime climate predominates, with average summertime (December to February) daytime temperatures ranging from 20 to 25°C, and winter (June to August) daytime temperatures spanning 11 to 15°C, as reported by NIWA (2023a).

According to Swarbrick (2012), the bulk of NZ's school infrastructure was built in the 1950s and 1960s. These structures were intentionally crafted for natural air circulation, consisting of single-story, timber-framed buildings equipped with large, single-glazed windows that could be opened to usher in daylight and airing for ventilation. Notably, these buildings were constructed without insulation, a feature that only became a NZ standard requirement in 1978.

A 2015 survey reports just 40% of teachers in Auckland primary schools actively use windows for airing (Gully, 2015; Liaw, 2015). Despite the minimal use, the NZ MoE still promotes natural ventilation over mechanical means.

The COVID-19 pandemic underscored the critical role of ventilation in maintaining healthy indoor environments, particularly in educational settings. To this end, the NZ MoE provided guidelines for schools to optimize classroom airing, which covered practices such as the appropriate opening of windows (MoE, 2021). A key measure implemented at our pilot school was the introduction of NZ MoE Internal Environment Monitoring (IEM) devices. These devices offer the advantage of collecting real-time data on IEQ, a capability not possible without such technology. It is challenging for educators to recognize increasing CO_2 levels during active instruction. Typically, awareness arises only when conditions worsen, indicated by a stuffy atmosphere and drowsiness amongst learners. The IEM devices aim to empower teachers to monitor and respond to changes in IEQ proactively, allowing for timely interventions to enhance IEQ and sustain an optimal educational atmosphere. The NZ MoE IEM device can alert users when thresholds for these measurements are exceeded, prompting them to act, such as opening windows for airing, or managing the number of students in an indoor space to improve air quality. Regrettably, the data regarding IEQ is not gathered by the individual schools themselves. Instead, it is collected by the NZ MoE, which, at present, does not share this information with the public. Posters were circulated to the school from the NZ MoE, discussed at school meetings and then displayed in classrooms.

A pilot study conducted in a primary school in Auckland, NZ, assesses the patterns of window operation to better understand the relationship between teacher behaviours and the resulting IEQ within the classroom setting.

Research methodology

The chosen primary school, located in the temperate and generally mild climate of North Shore, Auckland, experiences an average annual temperature of 15.6°C and receives around 1,231 mm of rainfall, according to NIWA's (2023b) report. As depicted in **Figure 1**, the school caters to 160 students between the ages of 5 and 11 in multi-age group classes, which are positioned approximately 90 m from the main road, which helps to reduce auditory disturbances. The classrooms designated for this study are marked R1–R7 to maintain confidentiality. The facility includes seven classrooms of equal floor area and a single library space. All classrooms

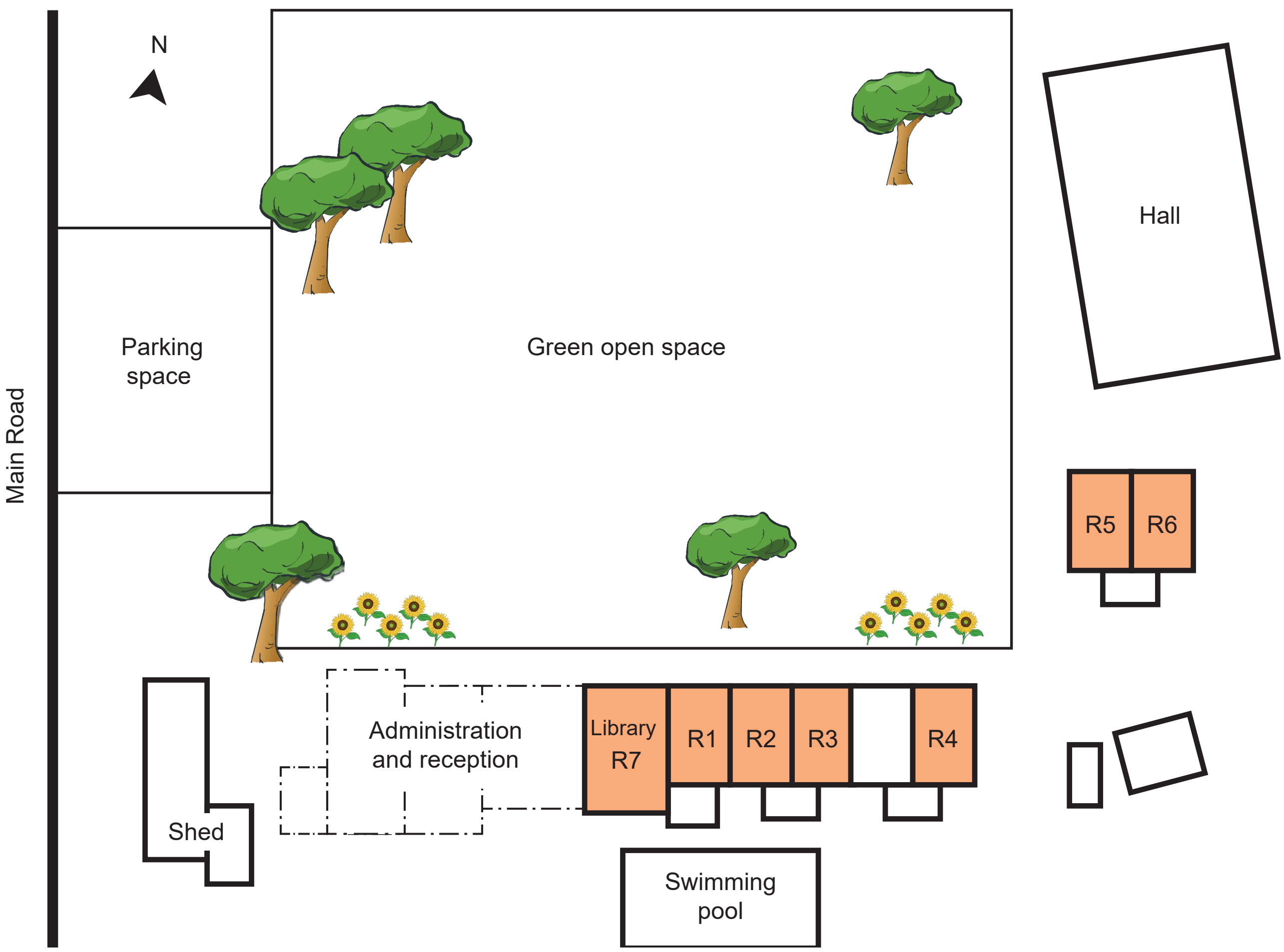

Figure 1. Site Map of School and Location and Study Classrooms

are situated on the first floor and feature doors on the North side that open directly to the play area. A system for cross ventilation is possible thanks to the presence of windows on both the North (front) and South (back) sides of the classrooms. One classroom was removed from the study due to the presence of mould mid-term.

The study involved observation sessions held on the 20th, 23rd, and 27th of March 2023 (**Figure 2**), from 9 am to 3 pm (NZ school time). The status of doors and windows was noted at 20-minute intervals to evaluate airing within the classrooms. Environmental conditions outside were recorded every three hours, with data obtained from the local North Shore station managed by NIWA (NIWA, 2023b). Temperature, relative humidity, and carbon dioxide (CO_2) levels were monitored using the Massey University IEM device (Weyers, 2017).

An observation form was developed (**Figure 3**) to obtain information on the door/window status. Visual observations were conducted to provide a general overview of the space and identify explanatory predictors influencing operations on windows and external doors. Before the commencement of the observational studies, the lead author was informed by two of the teachers that the students manage the opening/closing of the windows during the day based on the teacher's requests. To prevent teachers from being interrupted, the reasons for opening or closing windows were grouped into broad categories such as occupancy patterns, indoor environmental quality, or external factors like noise that could be easily observed without needing to ask questions. If it was unclear why a window had been adjusted, the principal investigator would inquire about it at the end of the teaching session.

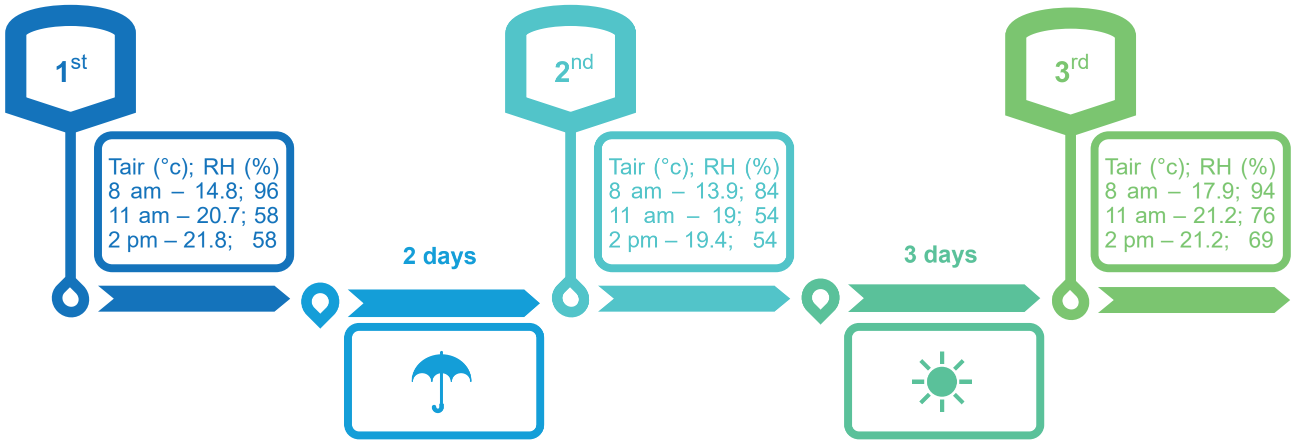

Figure 2. Air Temperature and Relative Humidity for Three Observation Days

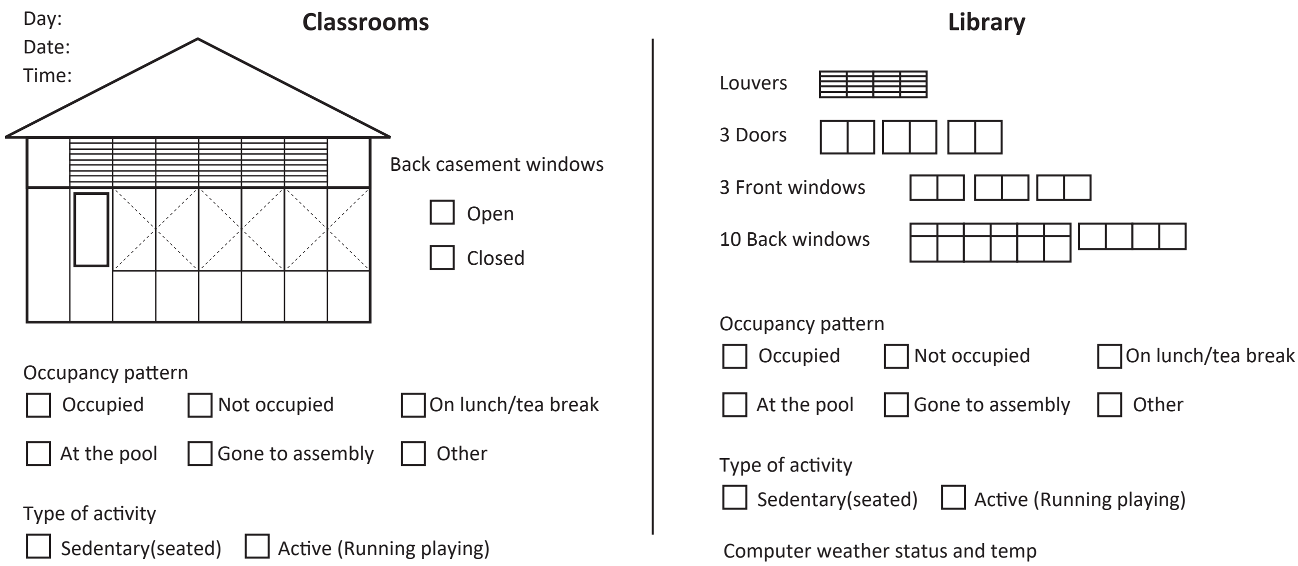

Figure 3. Observation Form for Occupancy Patterns and Window Opening Behaviour.

Results

A table with all descriptive statistics is freely available through the Research Gate Link provided at the outset, however, to set the scene, the highest temperature reached 26.9°C – typical for late March in NZ. Notably, R2 experienced a CO_2 surge on Day 1, likely linked to increased window closure caused by noise from nearby swimming lessons, as confirmed by teacher communication (20th March 2023). **Figure 2** illustrates the air temperature, relative humidity (RH), and intervening weather conditions over the seven-day observation period.

The initial day of observation was overshadowed by the prospect of rain. 11.4 mm and 5.4 mm of rain fell over the next two days respectively (NIWA, 2023b). Evidence of the impending rainfall is seen in the closure the windows at the conclusion of the first day (**Figure 4**), a precaution not deemed necessary on the subsequent days, as conditions improved. There was no rain on the second day of observations, even with an 84% RH and the dry sunny spell extended over the following three days. In a similar pattern, the third day of observation enjoyed clear skies. Rain was recorded after the third day of observations. These wetter conditions align with the high relative humidity measurements recorded at 96% (**Figure 2**) on day one and 94% on day three (NIWA, 2023b). Each day saw a gradual rise in temperature, contributing to the need to open windows. Meanwhile, wind speeds remained below 10 km/h, which was conducive to not only opening but also keeping the windows open for extended periods.

The school caretaker opened the external doors before the start of the school day and would leave them open throughout. Windows were not manipulated until the arrival of the teachers, typically around 8:30 am, to ventilate classrooms before students arrived, accounting for 43% of the window operations. **Figure 4** visually represents the frequency of window openings in each room, considering the number of windows available for opening and how often they were operated each hour. A thorough inspection of all windows was carried out at the beginning of the project, confirming all were operational. Indoor environment prompted 38% of the actions. In classroom R2, 10% of the instances where windows were closed were in response to noise disruptions, particularly during swim time (**Figure 4**, far right image) at the nearby pool. Generally, windows stayed open unless noise or poor weather conditions prompted their closure.

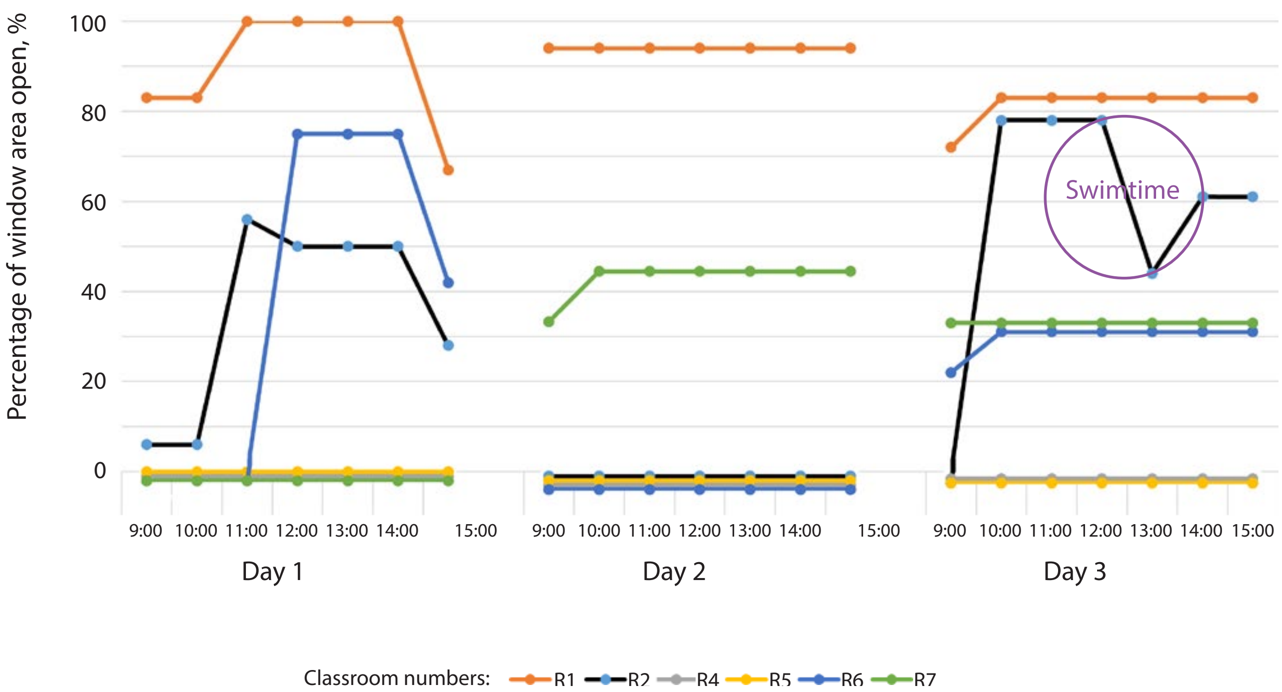

Figure 4. Percentage of window area that is open over the school day (by class) during the observation study.

The data reflects a variety of practices at the school regarding airing. Throughout the observation period, the north-facing front doors of all classrooms remained open. The behaviour in rooms R1 and R2 demonstrated consistent window opening, contributing to adequate ventilation. In contrast, the windows in R4 were usually kept closed. The teacher was unavailable for comment. R5 and R6, which share a space with a partition often function as a single teaching area (R6), showed variable window and door usage, possibly because of the team-teaching approach in this space. The PI has noted this irregularity for further investigation. Compared to the 2015 Auckland survey, the average window opening durations at this school over the observation period correspond to 30%, which is 10% lower than the pre-COVID-19 teacher survey.

A Spearman correlation tested the relationship between window open area (WOA in m^2) and environmental factors to analyse window usage in reaction to IEQ (stuffy environment, thermal comfort). With visual data indicating 38% of window operations tied to IEQ, variables like indoor/outdoor temperature, humidity, CO_2 levels, and wind speed were correlated with WOA. Operations not linked to the environment, such as end-of-day closures, were omitted from this analysis. Spearman's correlations confirm significant links: a strong positive correlation between openable window area and indoor temperature ($\rho = 0.758$, $p < 0.018$), and a notable positive correlation with outdoor temperature ($\rho = 0.893$, $p = 0.001$). But an inverse, but not significant, relationship with relative humidity ($\rho = -0.341$, $p = 0.370$), and CO_2 levels ($\rho = -0.613$, $p = 0.079$) were noted.

Conclusions

The contrast in window opening routines between classrooms within one school (R1/R2 compared to R4) considering post-COVID-19 guidelines is striking, indicating a significant divergence despite receiving the same school-wide information from the principal. This outcome highlights that window opening practices are predominantly driven by individual choices, influenced by external factors such as temperature. These relationships emphasize the impact of window operation on indoor climate and air quality.

To potentially alleviate the necessity for teachers to constantly monitor IEM devices and consider the IEQ of classrooms, installing trickle vent systems could be advantageous. These systems, by regulating the temperature within the classroom, can establish a more agreeable environment for teachers, preventing overheating in warmer months and addressing stale air concerns in colder periods. As a result, trickle vent systems enhance comfort and productivity for teachers, fostering alertness and concentration in a well-ventilated setting. Additionally, these systems offer energy-efficient benefits by enabling controlled ventilation without requiring windows to be opened, contributing to the preservation of energy while maintaining a pleasant and healthy classroom atmosphere.

References

Gully, F. (2015). *Windows and Doors in Schools: A study of low-decile primary schools in Auckland* (Final Year Project Report). Auckland, NZ: Massey University.

Liaw, F. (2015). *Doors and Windows Needs for School* (Final Year Project Report). Auckland, NZ: Massey University.

Ministry of Business, Innovation and Employment. (2023). *Building Code Handbook: H1 Energy Efficiency* [Brochure]. Retrieved from https://www.building.govt.nz/assets/Uploads/building-code-compliance/h1/h1-energy-efficiency/building-code-handbook-h1-energy-efficiency.pdf.

Ministry of Education. (2022). *Designing Quality Learning Spaces - Indoor Air Quality and Thermal Comfort.* Wellington, NZ: New Zealand Ministry of Education.

NIWA. (2023a). Retrieved from https://niwa.co.nz/education-and-training/schools/resources/climate/overview.

NIWA. (2023b). *Cliflo Database*. Retrieved from https://www.niwa.co.nz/climate/cliflo.

Weyers R., Jang-Jaccard J., Moses A., Wang Y., Boulic M., Chitty C., Phipps R., Cunningham C., the Healthy School Research Team, (2017). Low-cost indoor air quality platform for healthier classrooms in New Zealand: engineering issues. *In the 4th Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE).* Nadi, Fiji. ■