Proceedings of International Structural Engineering and Construction, 13(1), 2026
Addressing Social and Environmental Challenges Through Responsible Construction Technologies
Edited by Villacís, E., Ayarza, C., Singh, A., and Yazdani S.

www.doi.org/10.14455/ISEC.2026.13(1).EPE-15

INDOOR ENVIRONMENTAL QUALITY ASSESSMENT THROUGH PARTICIPATORY METHODS

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This paper presents a pilot study that explores monitoring techniques and creative, participant-led methods inspired by citizen science to assess indoor environmental quality (IEQ) in educational buildings. The study focused on key environmental factors—air quality, lighting, and thermal comfort—and involved undergraduate students from a built environment program. A mixed-method approach was employed, combining real-time monitoring using handheld sensors (measuring temperature, humidity, carbon dioxide, and lighting) with creative tools such as participatory mapping and observation diaries. These methods enabled students to assess their own learning spaces while generating contextualized insights that complemented the quantitative data. The study aimed to evaluate the effectiveness of this approach in identifying IEQ challenges and raising awareness among students. Findings show that integrating sensor-based data with creative, experiential methods provides a more comprehensive understanding of indoor conditions. This combination also promotes critical reflection and strengthens environmental literacy among participants. The results highlight the potential of citizen science-inspired strategies not only to enhance environmental monitoring but also to foster active learning and student engagement in sustainability practices. Implications for broader application in educational and community contexts are discussed.

Keywords: Indoor Environment Monitoring, Citizen Science, Air quality, Thermal comfort, Lighting.

1 INTRODUCTION

Active, participatory approaches that mirror citizen science methods have the potential to promote the integration of Indoor Environmental Quality (IEQ) concepts into undergraduate architecture courses. The importance of good indoor environmental quality (IEQ) in buildings is widely recognized. Good thermal conditions enhance concentration and performance while hot or cold environments hinder attention, learning outcomes, and cognitive function (Chatzidiakou et al., 2014; Wargocki & Wyon, 2017). Elevated carbon dioxide (CO_2) levels are linked to adverse health effects such as fatigue, headaches, and respiratory problems (Haverinen-Shaughnessy et al., 2015; Wargocki and Wyon, 2017). Lighting conditions affect eye health; poor lighting conditions led to discomfort, annoyance and reduced cognitive performance (Boyce, 2010; Hwang and Kim, 2011; Fostervold and Nersveen, 2008). Promoting the understanding of IEQ among architecture students is fundamental to foster responsible professionals capable of designing healthy buildings. Engaging students in real-life experiences leads to the integration of health and behavioral perspectives into design as argued by Gharipour and Trout (2020). Sukkar et al. (2022) note that nontraditional teaching techniques bolster motivation and deepen understanding of theoretical concepts, while Domínguez-Amarillo et al. (2018) detail how problem-based learning bolsters improves the retention of sustainability and energy efficiency principles. Practical applied learning helps to acquire technical skills; as shown by Santillán-Rosas et al. (2019) in their work with engineering students using PM10 and PM2.5 sensors to build various competencies. Approaches to enhance environmental awareness have been explored by Lee (2023) to familiarize students with pollutant and ventilation concepts and the ties between air quality and health. These studies indicate that active, citizen science–inspired teaching methods can improve students' awareness and practical grasp of health-centered design and sustainable built environments.

Citizen science methods empower participants to co-produce knowledge about their own environments, fostering a sense of agency and ownership over the findings. In educational settings, this participatory dimension aligns with pedagogical goals of active learning, critical thinking, and environmental citizenship. There is growing interest in applying these principles to investigate IEQ and resulting occupants' comfort; with examples of participative indoor environment projects that highlight the learning opportunities and the technical skills gained by participants (Barros et al, 20023; Zagatti et al 2020; Hoefner and Schutze, 2021).

This paper reports on a pilot study applying these principles to investigate IEQ in a university setting in Quito, Ecuador. Undergraduate architecture students combined sensor-based monitoring with participatory mapping and sensory narratives to explore thermal comfort, air quality, and lighting conditions. The study examines how integrating objective measurements with students' lived experiences deepens understanding of IEQ issues and supports more holistic approaches to health-centered, sustainable design education.

2 METHODOLOGY

The study took place in June 2025 at a university in Quito, Ecuador, a city located at 2,800 meters above sea level with an average annual temperature of around 14°C. The research involved 25 undergraduate architecture students enrolled in Bioclimatics and Sustainability modules, both with a focus on sustainable design. Participation was voluntary and integrated into course activities. Students worked in groups of four to five, selecting spaces they were familiar with, including classrooms, a cafeteria, a workshop, and a social area. These spaces differed in orientation, construction, occupancy, activity, and environmental control, offering varied conditions for analysis. The study adopted a mixed-method, participatory research design combining quantitative monitoring with qualitative, creative methods inspired by citizen science and environmental built environment design. This study sought to capture both objective environmental data and subjective occupant experiences, acknowledging the complexity of IEQ as both a measurable and lived phenomenon.

Participants were trained to use hand-held sensors to measure key IEQ parameters including: (1) Temperature (°C) and Relative Humidity (%)-measured with a digital thermo-hygrometer; (2) Carbon Dioxide (CO_2) concentration (ppm)-measured with Envisense devices; (3) Illuminance (lux)-measured with portable light meters; and, (4) Surface temperature differences -using FLIR C2 and FLIR One thermal cameras (smartphone-compatible). The measurements were taken one afternoon during a teaching session where students explored the selected space. Data were recorded manually and plotted to examine spatial variations within the studied spaces. Participatory records were discussed and cross-checked within each group against sensor readings to ensure consistency before results were consolidated.

In parallel, participatory methods were used to elicit students' perceptions and sensory experiences including participatory mapping and analytical observations. During the participatory mapping the students drew floor plans of the studied spaces and annotated them with observations about areas of discomfort, such as "too hot," "drafty," "dark," or "stuffy." Color codes and symbols were used to represent different environmental issues. Each group made notes recording their sensory impressions and emotional responses to the learning spaces, noting when and where they felt comfortable or uncomfortable, and reflecting on how this affected their concentration and wellbeing based on their past experience using the space.

Quantitative data were analyzed descriptively, comparing measured values to relevant guidelines (e.g., standards for thermal comfort, CO_2, and lighting). Qualitative data from maps and notes helped to identify recurring perceptions and connections between sensory experience and environmental factors. Students reported their findings in a form and a digital presentation that included proposals for space improvements.

The scope of the study was defined by its focus on diverse spaces located in a context where climatic conditions present unique IEQ challenges. The study involved one teaching session to investigate the selected spaces and another session to report results in order to balance feasibility, curricular integration, and the exploratory aims of the research. The sample size (25 participants), though modest, was appropriate given the participatory and pedagogical framing as working in small groups enabled simultaneous exploration of multiple space types and generated both quantitative and qualitative data. This qualitative, mixed-methods pilot study investigates the pedagogical value of citizen science approaches for supporting learning about indoor environmental quality and sustainability within the built environment. While the scope of the study restricts the broader applicability of its findings—due to the small sample size, reliance on a single institutional setting, a limited data collection framework, and one-time data gathering—it nonetheless offers meaningful contributions. In particular, the study advances an exploratory educational approach that engages students in hands-on experimentation and systematic observation, fostering the development of environmental literacy by connecting lived experiences with objective assessments of familiar learning spaces.

3 RESULTS

The evaluation revealed noticeable spatial differences in thermal comfort, air quality, and lighting across the five analyzed university spaces. Data from sensors, thermal imaging, and participatory mapping highlighted patterns that students later discussed collectively, relating them to their own perceptions (Figure 1).

3.1 Comfort measurements

Regarding thermal conditions and comfort, all measured spaces maintained air temperatures within or slightly above the recommended thermal comfort range (18–22 °C), with values ranging from 18.7 °C to 22.9 °C. Students' sensory experiences aligned with these readings: areas near windows or external walls were often described as colder or draftier, while central zones felt warmer and more stable. Surface temperature variations captured through infrared imaging helped students better understand heat loss through building envelopes, the influence of solar exposure, particularly in west-facing rooms, and internal heat gains.

Relative humidity levels ranged from 47% to 59%, remaining mostly within the optimal comfort zone of 40% to 60%. CO_2 concentrations were generally acceptable (400–1000 ppm), except in one location (Group 2 – social area), where levels briefly exceeded the recommended threshold, peaking at 1045 ppm. However, students noted sensations of stuffiness and stale air in certain areas, especially in spaces with limited air movement. Notably, these elevated readings occurred even in partially occupied rooms, suggesting inadequate ventilation in some cases. Students associated these conditions with sensory perceptions of "heavy air" and musty odors, particularly in back corners and near less ventilated zones. Concerns were also raised about external pollution from nearby traffic, which may limit opportunities for effective natural ventilation.

Figure 1Field measurements and results presentations

Lighting conditions exhibited the most significant deviations from recommended standards (300–750 lux). Only one space (Group 3 – Classroom 110) consistently met these criteria. Other spaces showed notable inconsistencies, with illuminance levels ranging from as low as 102 lux to over 1100 lux. Students reported that insufficient lighting in deeper interior areas made tasks like reading or drawing difficult, while excessive brightness near windows caused discomfort due to glare. Participatory maps highlighted these spatial imbalances, with zones perceived as "dark" or "harshly lit" matching the extremes observed in the data.

3.2 Integration of Quantitative Data and User Perception

Students' sensory notes and participatory maps revealed clear spatial patterns of discomfort that closely aligned with the environmental measurements. For example, back corners were consistently described as cold and poorly ventilated confirmed by lower surface temperatures and higher CO_2 level (figure 2). The approach enabled students to directly connect quantitative readings with their personal experiences across three domains: thermal comfort (warmth or chill), air quality (musty smells or heavy air), and lighting (glare or dimness). This active engagement enhanced student awareness of IEQ. Many expressed surprise at how environmental issues, particularly uneven lighting and air quality, impacted their comfort and ability to concentrate. The creative mapping tools were especially effective in helping students articulate subjective perceptions often missed by quantitative methods.

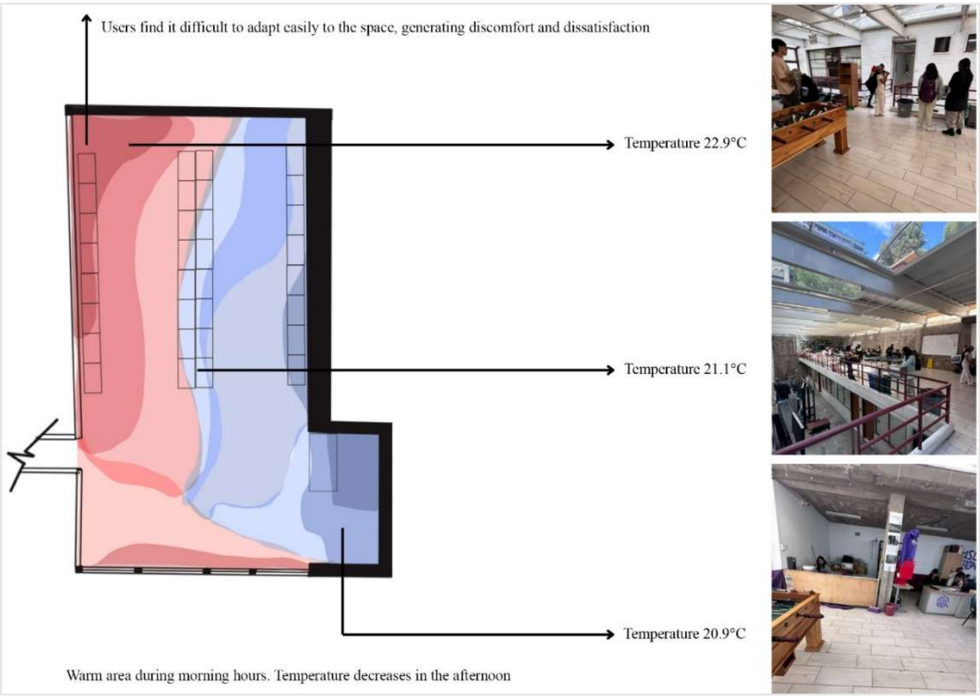

Figure 2. Thermal map of the studied space (social area) showing temperature gradients and reference photographs illustrating spatial context. Adapted from Group 2.

4 CONCLUSIONS

This study shows that combining sensor-based monitoring with creative, student-led methods can provide a deeper and more contextual understanding of IEQ. Students successfully connected their sensory experiences with measurable environmental parameters, demonstrating awareness of how physical conditions affect comfort. Quantitative data exposed specific challenges—especially in lighting and ventilation—while participatory tools uncovered spatial discomfort patterns not captured by measurements alone; particularly in relation to CO_2 and the diversity of IEQ within single spaces. The process encouraged critical reflection of students to become informed advocates for healthier, more sustainable learning environments.

The study's methodological contribution lies in integrating quantitative measurements with participatory mapping and sensory narratives, revealing tensions often overlooked in traditional IEQ assessments. While quantitative data indicated CO_2 levels were generally acceptable, perceptions of "heavy air" and musty odors in under-ventilated zones suggest the inadequacy of instrumental data alone to account for experiential dimensions of air quality. Students described sensations of draftiness, stuffiness, and spatial imbalances that highlighted localized discomfort not captured by averaged readings. Similarly, the lighting explorations showed that spaces meeting guideline averages still elicited lighting issues, with participatory maps exposing spatial unevenness that conventional lux measurements obscured. By exposing these divergences, the study suggests that combining instrumental and experiential approaches can enrich IEQ analysis, offering a more holistic understanding of IEQ experience in learning spaces.

The researchers acknowledge that longer-term monitoring would be required for temporal generalizability and the study limitations in relation to discipline-specific participant pool, scale, and reliance on portable instruments. Yet, the study provides insights into the intersection of measured conditions and lived experience; establishing the foundation for more extensive future research. Despite its modest scale and duration, the study points to the value of integrating citizen science-inspired strategies into built environment education. Ultimately, merging empirical data with lived experience fosters deeper learning and prepares students to address environmental challenges in design and practice.

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