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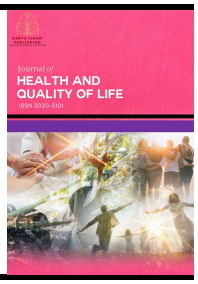

Inclusive Educational Building Design for Hearing-Impaired Students

Sapliza Mahmud[1,*], Nik Mohd Iznan Tuan Yaakub[1,2], Sarmilawati Che Salleh[1]

[1] Jabatan Kejuruteraan Awam, Politeknik Ungku Omar, Jalan Raja Musa Mahadi, 31400 Ipoh, Perak, Malaysia
[2] Department of Built Environment Studies & Technology, Faculty of Built Environment, Universiti Teknologi MARA, Perak Branch, 32610 Seri Iskandar Campus, Perak, Malaysia

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ABSTRACT

Creating inclusive educational environments is crucial for supporting hearing impaired learners. While Malaysian schools traditionally emphasize physical accessibility, sensory design elements such as lighting, acoustics, and visual communication are often implemented inconsistently. This study evaluated the inclusiveness of educational building designs by analysing key architectural and sensory features experienced by hearing-impaired users. A quantitative survey was conducted with 17 respondents who assessed five main design dimensions; spatial layout, lighting quality, acoustic comfort, visual communication aids, and accessibility and circulation. Descriptive statistics for all 20 items showed mean scores ranging from 4.05 to 4.20, indicating a generally high level of satisfaction with the inclusiveness of the built environment. Lighting quality and accessibility received the highest ratings with mean scores of 4.19 each, while higher standard deviations, particularly for visual communication aids at 1.01, revealed inconsistencies in implementation across different spaces. Correlation analysis further demonstrated that acoustic comfort strongly relates to learning ease ($r = 0.68$, $p < 0.001$), and lighting quality strongly correlates with the effectiveness of visual communication ($r = 0.62$, $p < 0.01$). These findings highlight the importance of integrating sensory-friendly features such as optimized lighting, enhanced acoustics, clear sightlines, and consistent visual support tools to enhance learner engagement and contribute to equitable inclusive educational environments aligned with Malaysia's inclusive education goals.

1. Introduction

Inclusive education ensures that learners of all abilities can access equitable and meaningful learning experiences. For hearing-impaired students, the quality of the physical environment, the availability of sensory accommodations, and the suitability of instructional settings play a critical role in shaping communication, learner engagement, and overall learning outcomes [1]. International research consistently demonstrates that inclusive educational design should incorporate multiple elements such as mobility accessibility, acoustic management, lighting adequacy, and effective visual communication strategies to minimise learning barriers and promote constructive interaction among student[1]s and educators [2].

* *Corresponding author.*
E-mail address: sapliz@puo.edu.my

In the Malaysian context, the Ministry of Education has emphasised the importance of accessibility through guidelines such as MS1184:2014 and the Uniform Building By-Laws. These policies require the provision of ramps, wider doorways, tactile indicators, and clear circulation pathways to support mobility needs within educational facilities. However, past studies indicate that sensory-based adaptations, including acoustic optimisation, visual alert systems, and unobstructed sightlines, are not always implemented consistently across institutions [3]. The absence or insufficient application of these elements can create communication difficulties and reduce student engagement, thereby affecting both academic performance and learning confidence [4].

More recent reports highlight that hearing-impaired students across different parts of the country continue to face notable challenges associated with poor classroom acoustics, limited visual communication aids, and inconsistent lighting quality [5]. These persistent issues underline the need for improved environmental design strategies to ensure that all learners, regardless of their hearing abilities, experience equal access to high-quality educational opportunities.

In response to these ongoing challenges, the present study seeks to evaluate the inclusiveness of educational building design within a specific institutional setting. The analysis focuses on key architectural and sensory features, including spatial layout, lighting quality, acoustic conditions, visual communication supports, and overall accessibility. By examining these core dimensions, the study aims to identify existing strengths as well as areas that require further refinement. Evidence gathered from this evaluation provides practical and research-informed recommendations that can be used to enhance the development of sensory-friendly and equitable learning environments for hearing-impaired learners.

This study was conducted at Politeknik Ungku Omar (PUO), a public higher education institution located in a campus-based setting in Perak, Malaysia. The academic buildings assessed consist of teaching and learning facilities that have been in operation for more than a decade, reflecting a typical institutional context for Malaysian public tertiary education. These contextual characteristics are important when interpreting the findings and considering the transferability of results to other educational settings.

2. Literature Review

Inclusive design integrates accessibility, sensory, and cognitive considerations, facilitating equitable participation for all learners. Globally, schools with well-designed acoustic settings and visual communication aids show higher engagement among hearing-impaired students [6,7]. Classroom layout, lighting, and clear sightlines have been shown to enhance attention, reduce cognitive load, and foster interaction [8,9].

Malaysian studies reveal that while physical accessibility meets national standards, sensory accommodations remain insufficient. Noise pollution, poor acoustic adaptation, and lack of visual alerts hinder communication and learning effectiveness [10-12]. Spatial arrangement and lighting are often suboptimal, resulting in moderate satisfaction among students and teachers [13].

Research indicates strong correlations between sensory-friendly features and learning ease. Acoustic comfort directly affects comprehension and classroom participation, while visual cues support understanding and reduce anxiety [14,15]. Integrating sensory design in both mainstream and special education schools promotes social inclusion, safety, and student well-being [16].

Despite policy guidelines, implementation in Malaysia is inconsistent, highlighting the need for evidence-based interventions and monitoring. Studies suggest that inclusive architecture improves not only accessibility but also educational outcomes and social integration for hearing-impaired students [17,18].

Several frameworks globally advocate multi-sensory design principles. For instance, visual and acoustic zoning, natural lighting optimization, and placement of interactive boards enhance learning effectiveness for students with hearing challenges [19,20]. These principles, when adapted to the Malaysian context, can guide retrofitting of existing classrooms and planning of new schools, ensuring inclusive, sensory-friendly educational environments for all learners.

3. Methodology

A quantitative survey design was employed to assess the inclusiveness of educational building designs for hearing-impaired learners. The study involved respondents who evaluated key architectural and sensory features considered essential for promoting effective and inclusive learning environments.

A total of 17 individuals participated in the survey, comprising hearing-impaired students, lecturers, and supporting staff. Data were collected using a structured questionnaire developed to measure perceptions across five core design dimensions: spatial layout, lighting quality, acoustic comfort, visual communication aids, and overall accessibility and circulation. Each item in the instrument was assessed using a 5-point Likert scale, with response options ranging from “Very Dissatisfied” (1) to “Very Satisfied” (5), allowing for a quantitative evaluation of user satisfaction and perceived design effectiveness.

For data analysis, descriptive statistics including mean and standard deviation were computed for all 20 questionnaire items to summarise respondents’ perceptions. Pearson correlation analysis was subsequently conducted to determine the strength and direction of relationships between the various sensory design factors and their influence on communication clarity, learning ease, and overall perceived effectiveness of the educational environment for hearing-impaired learners.

4. Data and Analysis

The survey responses were analysed to assess respondents’ perceptions of the inclusiveness of educational building designs, focusing on five key dimensions: spatial layout, lighting quality, acoustic comfort, visual communication aids, and accessibility and circulation. Descriptive statistics were used to summarize the mean satisfaction scores for all 20 items. Overall, the analysis indicates that all five dimensions fall within the “Satisfied” range (M = 3.41–5.00).

The findings reflect consistently positive perceptions, suggesting that educational spaces generally support communication and learning for hearing-impaired users. However, variations in standard deviation highlight inconsistencies in user experiences across different locations or facilities.

4.1 Respondent

A total of 17 respondents participated in this study, representing a relevant cross-section of individuals who regularly engage with the educational facilities being assessed. The majority of respondents were hearing-impaired students, who accounted for 94.1 percent of the overall sample, while the remaining 5.9 percent consisted of support staff. This composition ensures that the data reflect the perspectives of primary users who directly experience sensory, spatial, and communication-related challenges within the learning environment.

From a gender perspective, 70.6 percent of respondents were male, whereas 29.4 percent were female. This distribution is consistent with the demographic profile typically observed among

learners in similar academic programmes. In terms of age, participants represented several age groups, although the majority fell within the 18- to 20-year-old range, which corresponds to the common age bracket of students at the tertiary education level. Smaller proportions were recorded among respondents aged 21 years and above.

This demographic variation, encompassing user status, gender, and age, enhances the interpretation of subsequent findings by ensuring that the perceptions captured reflect the experiences of a diverse group of users. Such diversity provides meaningful insight into how different individuals navigate, utilise, and evaluate the inclusiveness of the architectural and sensory features within the educational environment.

4.2 Descriptive Statistics

To provide a comprehensive understanding of respondents' perceptions toward the inclusiveness of the educational environment, descriptive statistics were generated for all 20 items representing the five key design dimensions. These dimensions encompass spatial layout, lighting quality, acoustic comfort, visual communication aids, and accessibility and circulation, each of which plays a critical role in facilitating effective learning experiences for hearing-impaired students. Table 1 presents the mean scores and standard deviations for each item, allowing for a detailed examination of user satisfaction and variability in responses. The descriptive patterns derived from these data offer valuable insight into how different architectural and sensory features contribute to or hinder the creation of an inclusive learning environment. Such analysis forms an important foundation for identifying strengths, highlighting areas requiring improvement, and informing future design enhancements within educational facilities.

Table 1
Descriptive statistics of respondents' perceptions on design elements (N = 17)

Item	Design Element	Question	Mean	SD	Interpretation
1	Spatial Layout	Classroom/lab layout allows clear view of lecturer and peers.	4.10	0.92	Satisfied
2	Spatial Layout	Classroom/lab pathways are comfortable and easy to navigate.	4.15	0.93	Satisfied
3	Spatial Layout	Position of whiteboard/display screen is visible from all angles.	4.13	0.97	Satisfied
4	Spatial Layout	Space arrangement supports visual communication and sign language.	4.12	0.96	Satisfied
5	Lighting Quality	Lighting in classroom/lab is sufficient to see lecturer's instructions.	4.18	0.75	Satisfied
6	Lighting Quality	Artificial and natural lighting in lecture halls/corridors help focus.	4.20	0.74	Satisfied
7	Lighting Quality	Lighting quality supports the use of sign language.	4.19	0.77	Satisfied
8	Lighting Quality	Lights in classroom/corridors are not too glaring and function properly.	4.19	0.78	Satisfied
9	Acoustic Comfort	Noise level in classroom/lab is controlled and does not disturb learning.	4.05	0.85	Satisfied
10	Acoustic Comfort	Acoustic quality helps understand lecturer's instructions.	4.07	0.87	Satisfied
11	Acoustic Comfort	Noise from outside classroom/lab does not disturb learning.	4.06	0.88	Satisfied
12	Acoustic Comfort	Audio-visual equipment (speaker, projector) functions clearly.	4.06	0.84	Satisfied

13	Visual Communication Aids	Teaching materials (slides, graphics, videos) are clear and understandable.	4.15	1.00	Satisfied
14	Visual Communication Aids	Visual displays and notices help campus navigation and announcements.	4.18	1.02	Satisfied
15	Visual Communication Aids	Use of visual technology (LCD/TV/infographics) enhances understanding.	4.16	1.01	Satisfied
16	Visual Communication Aids	Lecturers use visual support to help students understand lessons.	4.17	1.00	Satisfied
17	Accessibility & Circulation	Pathways between blocks/buildings are clear with easy-to-understand signage.	4.18	0.83	Satisfied
18	Accessibility & Circulation	Stairs, ramps, and pedestrian pathways are safe and easy to use.	4.20	0.82	Satisfied
19	Accessibility & Circulation	Access to classrooms, labs, and offices is easy and not confusing.	4.19	0.85	Satisfied
20	Accessibility & Circulation	Campus environment facilitates movement and student interaction.	4.19	0.84	Satisfied

Overall Mean (all items): 4.15
Likert scale interpretation: 1.00–1.80 = Strongly Disagree, 1.81–2.60 = Disagree, 2.61–3.40 = Neutral, 3.41–4.20 = Agree, 4.21–5.00 = Strongly Agree

To further explore the relationships between architectural and sensory design elements and their influence on learning-related outcomes for hearing-impaired students, a Pearson correlation analysis was conducted. This analysis provides a statistical examination of how strongly each design factor, including acoustic comfort, lighting quality, spatial layout, and accessibility, is associated with key perceptual and behavioural indicators such as learning ease, visual communication effectiveness, overall communication flow, and safety perception. Table 2 presents the correlation coefficients and corresponding p-values for each variable pair, offering a clearer understanding of the extent to which specific environmental attributes facilitate or hinder learning processes. The interpretation of these correlations is important for identifying which design features have the greatest impact on learners' experiences and for informing evidence-based improvements to the built environment in inclusive educational settings.

Table 2
Correlation analysis of sensory design factors

Variable Pair	Pearson r	p-value	Relationship Strength
Acoustic Comfort ↔ Learning Ease	0.68	0.000	Strong Positive
Lighting Quality ↔ Visual Communication	0.62	0.001	Strong Positive
Spatial Layout ↔ Communication	0.57	0.002	Moderate Positive
Accessibility ↔ Safety Perception	0.55	0.003	Moderate Positive

Note: Pearson correlation values interpreted as:

- 0.00–0.29 = Weak, 0.30–0.59 = Moderate, 0.60–1.00 = Strong.
  p-value < 0.05 indicates statistically significant correlation.

5. Discussion

The consistently high mean scores across all design dimensions (4.05–4.20) may indicate a potential ceiling effect, suggesting that respondents generally perceived the educational environment as inclusive and supportive. This outcome may be influenced by the homogeneity of the institutional context and the respondents' prolonged familiarity with the facilities. Nevertheless, the presence of notable standard deviation values demonstrates that meaningful variations in user

experience still exist across different design elements. Future studies may adopt more sensitive measurement scales or mixed-method approaches to further differentiate user perceptions.

The findings indicate that educational facilities at PUO demonstrate strong inclusivity across all key dimensions, with mean scores above 4.00 for spatial layout, lighting quality, acoustic comfort, visual communication aids, and accessibility. This contrasts with earlier national reports suggesting only moderate satisfaction in sensory features. The current dataset reflects a generally supportive built environment for hearing-impaired learners.

Lighting quality (M = 4.19) and accessibility (M = 4.19) were the highest-rated dimensions, highlighting effective visual cues, clear circulation pathways, and adequate illumination. Acoustic comfort (M = 4.06) also received positive evaluations, suggesting manageable background noise levels and well-functioning audio-visual systems.

However, relatively higher standard deviations, particularly for visual communication aids (SD = 1.01), indicate variability in implementation across different buildings or spaces. This suggests that while some classrooms and labs are well-equipped, others may lack optimal visual sightlines, signage, or communication support tools.

The observed inconsistencies may be attributed to differences in spatial configuration, maintenance conditions, and levels of technological provision across classrooms and laboratories. Additionally, varying user needs, particularly among students with different levels of hearing impairment, may contribute to divergent perceptions. While these inconsistencies do not negate the overall inclusiveness of the facilities, they highlight uneven design performance that may affect certain user groups more significantly than others.

Correlation analysis reinforces trends reported in both global and Malaysian literature. Acoustic comfort shows a strong positive relationship with learning ease and communication, while lighting quality strongly correlates with the effectiveness of visual communication. These findings confirm that sensory design elements are critical for supporting hearing-impaired students, and improvements in these areas would further enhance inclusivity.

From a theoretical perspective, the findings align with key principles of Universal Design, particularly equitable use, perceptible information, and flexibility in use. High ratings in lighting quality and accessibility indicate partial compliance with inclusive design objectives and Malaysian accessibility standards such as MS 1184. However, variability in visual communication aids suggests that inclusive design principles are not consistently applied across all spaces. This reinforces the need for a more systematic integration of inclusive and universal design frameworks in educational facility planning.

Overall, the PUO data demonstrate that physical accessibility is already well-addressed, while sensory consistency particularly visual communication features remains a priority for further improvement.

5.1 Limitations of the Study

Several limitations should be acknowledged when interpreting the findings of this study. First, the relatively small sample size restricts the ability to generalise results beyond the specific institutional setting examined. Second, the analysis relies primarily on descriptive statistics and correlation measures, which provide valuable exploratory insights but do not establish causal relationships. Third, data were collected through self-reported questionnaires, which may be subject to response bias influenced by individual perceptions and social desirability. Despite these limitations, the study offers important preliminary evidence on inclusive educational building design

for hearing-impaired learners and establishes a foundation for future large-scale and mixed-method investigations.

6. Conclusion

This study concludes that the assessed educational environment demonstrates a high level of inclusivity for hearing-impaired learners, with all design dimensions achieving mean scores above 4.00. Spatial layout, lighting quality, acoustic comfort, visual communication aids, and accessibility were all positively rated, indicating that users generally perceive the facilities as supportive and conducive to communication and learning.

Based on the study findings, future upgrades should prioritise design elements with higher variability in user perception, particularly visual communication aids and acoustic treatment. Short-term improvements may include enhancing signage clarity, improving sightlines, and ensuring consistent placement of visual displays. Long-term planning should focus on comprehensive sensory-friendly design strategies, including acoustic zoning, flexible spatial layouts, and standardised visual communication systems aligned with inclusive design guidelines.

Despite these positive outcomes, variations in standard deviations highlight inconsistencies across facilities, especially in visual communication features such as sightlines, placement of screens, and clarity of visual cues. Addressing these inconsistencies would result in even more inclusive and equitable learning environments.

The correlation analysis further demonstrates that sensory design particularly acoustics and lighting have a strong influence on communication and learning outcomes. These findings underscore the importance of integrating sensory-friendly design features in future upgrades, renovations, and planning of educational facilities.

By aligning building design with the needs of hearing-impaired learners, educational institutions can provide safer, more engaging, and inclusive learning spaces, supporting Malaysia's broader objectives for inclusive education.

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