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PERCEIVED INDOOR ENVIRONMENTAL QUALITY AND CLASSROOM CONDITIONS IN HIGHER EDUCATION: IMPLICATIONS FOR IMPROVING LEARNING ENVIRONMENTS IN A NIGERIAN UNIVERSITY

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ABSTRACT

Indoor environmental quality (IEQ) is a critical part of any learning environment. It affects how comfortable students feel, how well they cope, and how well they learn. A quantitative cross-sectional survey was used, supported by a qualitative component. Data were collected from 110 undergraduate students using a structured questionnaire covering indoor air quality, thermal comfort, noise, lighting, and classroom characteristics. After screening, 97 valid responses were analysed using descriptive statistics, Cronbach's alpha, the Kruskal–Wallis H test, Spearman's rank-order correlation, and thematic content analysis. Classroom characteristics, particularly overcrowding and reliance on open-window ventilation, recorded the highest mean perception score (M=3.49, SD=0.90), followed by noise (M=3.15, SD=0.89) and lighting (M=3.15, SD=0.95). Perceptions were broadly similar across academic levels, though noise perceptions differed significantly between 200-level and 400-level students (H=8.396, p=0.015). All five IEQ dimensions showed a statistically significant positive relationship with students' perceived learning experience, and thermal comfort had the strongest association (ρ=0.520, p<0.001). Students identified better ventilation, better furniture, and better lighting as their top priorities for improvement. The findings show that listening to how students experience their classrooms gives practical, context-specific evidence for improving university learning spaces, especially in resource-constrained institutions like those in Nigeria. Based on these findings, the study recommends a tiered set of interventions for architects, facilities managers, and institutional planners, prioritising low-cost measures such as improved ventilation management and routine maintenance while directing medium- and long-term investment toward thermal comfort and indoor air quality, the two dimensions most strongly linked to perceived learning.

Keywords: indoor environmental quality; classroom conditions; student perceptions; thermal comfort; higher education; Nigeria

1. INTRODUCTION

Universities are expected to provide students learning spaces that support their health, comfort, and academic success. Architects usually judge educational buildings by function, structural performance, appearance, cost, and how well the space is used. But a building can meet all of these standards and still fail as a learning environment if students are too hot, too cold, breathing poor air, straining to hear the lecturer, or working under bad lighting. These conditions shape how well students concentrate, participate, and stay engaged in class. They should be treated as a core part of learning environment quality, not just as technical details of building performance (Mendell & Heath, 2005; Brink, Loomans, Mobach, & Kort, 2021).

IEQ gives us a way to evaluate these conditions as a whole. It covers indoor air quality, thermal comfort, lighting, acoustics, and classroom characteristics, all of which shape how students experience a learning space (Frontczak & Wargocki, 2011; Brink, Loomans, Mobach, & Kort, 2021). These factors do not act in isolation. They combine and interact during teaching and learning, which is why classrooms need to be assessed as complete environments rather than as a list of separate variables.

International research has already shown that IEQ affects students' comfort, satisfaction, cognitive performance, and learning outcomes (Brink, Loomans, Mobach, & Kort, 2021; Wargocki & Wyon, 2020). But two gaps remain. First, most of this evidence comes from Europe, North America, and parts of Asia, where school buildings are built and run under very different climatic and infrastructural conditions from those found in many developing countries (Kalisa, Clark, Ntakirutimana, Amani, & Volckens, 2023). Second, much of the research studies one IEQ factor at a time instead of asking students how they experience the classroom as a whole.

These gaps matter for Nigerian public universities in particular, where ageing buildings, overcrowded classrooms, and heavy reliance on natural ventilation create environmental challenges of their own. IEQ research in Nigeria has grown, but few studies have asked how students experience their classroom environment as a whole, or how that experience can guide improvements. Students are the ones using these spaces every day. Their experience adds evidence that pure technical assessment cannot give, and it can support better decisions in architectural and facilities planning.

This study uses the University of Jos as a case study of a naturally ventilated Nigerian public university. It examines students' perceptions of IEQ and classroom conditions as indicators of learning environment quality. Specifically, the study: (i) evaluates students' perceptions across five IEQ and classroom dimensions; (ii) checks whether these perceptions differ by academic level; (iii) examines the relationship between perceived classroom quality and students' perceived learning experience; and (iv) identifies the improvements students themselves prioritise. By putting students' perceptions at the centre of the evaluation, the study shows how this kind of evidence can support architectural design, facilities management, and institutional decisions aimed at building healthier, more effective learning environments in resource-constrained settings.

2. LITERATURE REVIEW

2.1 Indoor Environmental Quality in Educational Settings

A learning environment is made up of physical, social, and pedagogical conditions that together shape a student's education. Within the built environment, IEQ has become the standard framework for judging how well a building supports the health, comfort, and learning of the people using it. IEQ covers indoor air quality, thermal comfort, lighting, acoustics, and other classroom characteristics that shape how students experience a space (Frontczak & Wargocki, 2011; Toyinbo, 2023).

Research consistently shows that these conditions affect students' comfort, satisfaction, cognitive function, and learning experience. The different IEQ dimensions do not work alone. They interact to determine the overall quality of a classroom, which is why classrooms need to be assessed as whole environments rather than through single parameters (Brink, Loomans, Mobach, & Kort, 2021). This is also why students' own perceptions of their classrooms matter. They add occupant-centred evidence that complements technical building assessments and supports real improvements to learning spaces (Mendell & Heath, 2005; Wargocki & Wyon, 2020).

2.2 Indoor Environmental Quality Dimensions and Students' Learning Experiences

Of these dimensions, indoor air quality and thermal comfort are consistently linked to students' concentration, comfort, and cognitive performance. Poor ventilation, high temperatures, and indoor pollutants have all been associated with fatigue, headaches, reduced attention, and weaker learning outcomes (Mendell & Heath, 2005; Tran, Park, & Lee, 2020; Wargocki & Wyon, 2020). Stafford (2015) studied a school district in the United States and found that improving indoor air quality produced measurable gains in standardised academic performance, which shows how directly air quality can affect learning outcomes. In the same way, excessive noise and poor lighting reduce speech intelligibility, cause visual discomfort, and make it harder for students to sustain attention in class (Brink, Loomans, Mobach, & Kort, 2021).

Classroom characteristics such as occupancy levels, seating arrangements, ventilation strategy, and available space also shape how students experience their learning environment. Overcrowded classrooms tend to intensify heat, noise, and poor air quality while limiting students' comfort and their ability to interact during lessons (Toyinbo, 2023). Taken together, these findings show that learning environment quality is shaped by how all these conditions combine in a student's daily experience, not by any one factor on its own.

This is why researchers increasingly combine objective environmental measurements with students' own perceptions of their classrooms. Students are the primary users of these spaces, so their experience is valuable evidence for identifying weaknesses and prioritising the improvements that will actually make classrooms healthier, more comfortable, and more effective for learning (Brink, Loomans, Mobach, & Kort, 2021; Frontczak & Wargocki, 2011).

2.3 IEQ Research in Sub-Saharan Africa and Nigeria

Most of the evidence linking IEQ to students' health, comfort, and learning comes from Europe, North America, and parts of Asia, where school buildings operate under different climatic, infrastructural, and regulatory conditions from those in Sub-Saharan Africa (Kalisa et al., 2023). It is not clear how well these findings transfer to resource-constrained institutions like those found in Nigeria.

In Nigeria, rising student enrolment, ageing infrastructure, overcrowded classrooms, and heavy dependence on naturally ventilated buildings all create unique challenges for maintaining good learning environments. Recent evidence from university student accommodation points to similar pressures, with poor environmental conditions linked to rising enrolment (Akande et al., 2026). Existing Nigerian studies have mostly focused on single environmental parameters or health outcomes, and few have asked how students perceive their classroom environment as a whole. Early evidence from other Nigerian institutions points to the same gap in occupant-centred assessment (Ibeh, 2025). As the people who use these spaces every day, students can offer evidence that complements technical building assessments and supports better architectural design, facilities management, and institutional planning. This study addresses that gap by examining students' perceptions of IEQ and classroom conditions in a naturally ventilated Nigerian public university.

2.4 Theoretical Framework

This study draws on two theoretical perspectives that explain how physical environments shape occupants' experiences and responses in learning spaces.

2.4.1 Person-Environment Fit Theory

Person-Environment Fit (P-E Fit) theory holds that a person's psychological and behavioural outcomes depend on how well their needs match the environment they are in (Edwards, Caplan, & Van Harrison, 1998; Lewin, 1936). In a university classroom, students' comfort, engagement, and learning depend on how well conditions such as air quality, thermal comfort, lighting, and acoustics meet their needs. When this fit is poor, environmental discomfort pulls attention away from learning. This supports the study's focus on students' perceptions as a meaningful indicator of learning environment quality.

2.4.2 Environmental Stress Theory

Environmental Stress Theory holds that prolonged exposure to poor environmental conditions creates psychological and physiological stress that reduces a person's capacity to perform cognitive tasks (Evans & Cohen, 1987). In a classroom, excessive heat, poor ventilation, bad lighting, and noise can act as stressors that reduce concentration and learning effectiveness. This theory gives a useful lens for understanding how students' perceptions of classroom conditions relate to their perceived learning experience.

2.5 Research Gap

Existing research shows that IEQ affects students' comfort, health, and learning. Three gaps remain. First, most of the evidence comes from developed countries whose school buildings differ substantially from naturally ventilated, resource-constrained universities in Sub-Saharan Africa (Kalisa et al., 2023). Second, many studies look at single environmental parameters instead of asking how students experience their classroom as a whole. Third, students' perceptions remain an underused source of evidence for architectural design and facilities management decisions in higher education.

This study addresses these gaps by evaluating how students perceive IEQ and classroom conditions in a Nigerian public university. Rather than assessing building performance alone, it treats students' experience as evidence in its own right for understanding learning environment quality and identifying what needs to improve. This position underpins the framework in Figure 1 and guides the methodological approach used in the rest of the study.

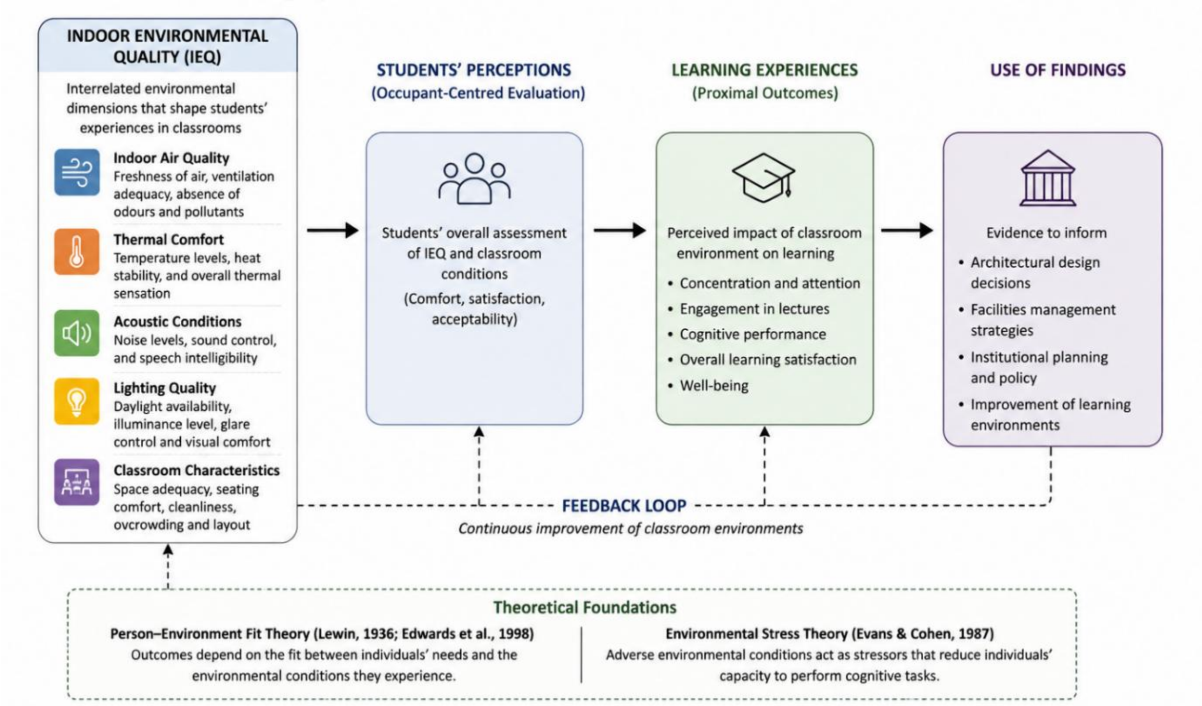

Figure 1: Conceptual framework linking indoor environmental quality, students' perceptions, and learning experiences.

Note. Solid arrows indicate hypothesized directional relationships between constructs. Dashed arrows indicate the feedback pathway from application of findings back to indoor environmental quality.

3. MATERIALS AND METHODS

3.1 Research Design

This study used a quantitative cross-sectional survey design, supported by qualitative content analysis of students' open-ended responses, to evaluate perceptions of indoor environmental quality (IEQ) and classroom conditions as indicators of learning environment quality. A cross-sectional design suits the task of assessing students' perceptions and their relationship to learning experience at a single point in time (Field, 2018). The quantitative component addressed the first three objectives through structured Likert-scale items, while the qualitative component addressed the fourth objective through analysis of students' open-ended recommendations.

Students' perceptions were treated as the primary unit of analysis rather than as a compromise for instrumented measurement, since perceptions capture how a classroom is actually experienced during learning and shape comfort, attention, motivation, and perceived learning in ways objective measurement alone cannot fully predict (Brink, Loomans, Mobach, & Kort, 2021). This is consistent with established occupant-centred approaches to IEQ assessment (Frontczak & Wargocki, 2011; Brink, Loomans, Mobach, & Kort, 2021).

3.2 Study Area

The study was conducted in the Department of Architecture (Faculty of Environmental Sciences) and the Department of Microbiology (Faculty of Natural Sciences) at the University of Jos, Plateau State, Nigeria (approximately 9.92°N, 8.89°E), selected on the basis of researcher accessibility. The University of Jos is a federal public university established in 1975, serving around 40,000 students; Architecture runs from 100 to 400 level and Microbiology from 100 to 500 level. Teaching spaces in both departments rely mainly on passive ventilation through windows and doors rather than air conditioning, making them well suited to studying naturally occurring indoor conditions within Jos's highland climate of mild temperatures, distinct dry and wet seasons, and shifting dust and humidity levels.

3.3 Population, Sample, and Sampling Procedure

The target population was undergraduate students registered in these two departments at the time of data collection. A convenience sampling approach was used: the survey link was shared through existing class WhatsApp groups with the help of departmental contacts. Data collection began in the Department of Architecture; a low initial response rate led to the sample being expanded to the Department of Microbiology partway through the two-week collection period. Because department was not recorded as a variable before some responses had already been submitted, it was not possible to retrospectively disaggregate the analytic sample by department, which limits generalizability. This remains a common and accepted approach in exploratory, single-institution IEQ perception studies (Brink, Loomans, Mobach, & Kort, 2021; Toyinbo, 2023). No minimum sample size was set in advance, since the aim was to capture responses across available levels rather than to hit a statistical power target.

A total of 110 consenting responses were received. After screening, 12 were excluded for missing CGPA data (all 100-level students without an academic performance record) and one further response for uniform straight-line responding across all items, a pattern signalling disengagement rather than genuine response. This left a final analytic sample of 97 valid responses.

3.4 Research Instrument

Data were collected using a structured questionnaire developed by the researchers and administered digitally through Google Forms, comprising four sections. Section A collected demographic and background information (gender, academic level, and self-reported class size). Section B contained 15 Likert-scale items, rated from 1 (Strongly Disagree) to 5 (Strongly Agree), across five dimensions: Indoor Air Quality (4 items), Thermal Comfort (3 items), Noise Conditions (3 items), Lighting Conditions (2 items), and Classroom Characteristics (3 items). Section C contained two items on perceived learning impact, also rated on a 5-point scale. Section D collected a self-reported CGPA band using the Nigerian 5-point grading scale (4.50–5.00 First Class; 3.50–4.49 Second Class Upper; 2.50–3.49 Second Class Lower; 1.50–2.49 Third Class); self-reported CGPA introduces some measurement imprecision through over- or under-estimation (Nunnally & Bernstein, 1994), a limitation acknowledged further under Limitations. An open-ended item asked respondents to describe, in their own words, the changes that would most improve their classroom environment. The questionnaire was fully anonymous, collecting no names, matriculation numbers, or email addresses, to reduce social desirability bias.

3.5 Ethical Considerations

Participation was entirely voluntary. A consent statement on the first page of the Google Form explained the study's purpose, the anonymity of responses, and the intended use of data for research and academic publication only; proceeding past this page and submitting the questionnaire counted as implied informed consent, consistent with standard practice for anonymous online survey research. No incentives were offered, and no personal data were collected.

3.6 Reliability Assessment

Internal consistency of the five perception constructs was assessed using Cronbach's alpha: 0.509 for Indoor Air Quality (4 items), 0.438 for Thermal Comfort (3 items), 0.461 for Noise Conditions (3 items), 0.166 for Lighting Conditions (2 items), and 0.522 for Classroom Characteristics (3 items). All values fall below the conventional 0.70 threshold recommended for psychometric scales (Nunnally & Bernstein, 1994), a pattern consistent with the small number of items per construct, since Cronbach's alpha is sensitive to scale length (Field, 2018). The especially low coefficient for Lighting Conditions ($\alpha=0.166$) may also reflect the conceptual distinction between perceived lighting adequacy and glare-related discomfort; accordingly, this study treats the item-level results reported in Table 3 and discussed in Section 4.3, rather than the composite score, as the primary evidence for this dimension.

These coefficients mean composite scores should be interpreted with some caution. That said, the instrument was designed to capture students' perceptions across dimensions of classroom quality rather than to build formal psychometric scales, and the findings remain useful for understanding students' experience of their learning environment.

3.7 Data Analysis

Data exported from Google Forms were screened for completeness, duplicate entries, and response validity before analysis; composite scores for each construct were calculated as the mean of the relevant items. Descriptive statistics (frequencies, percentages, means, and standard deviations) summarised respondents' characteristics and perceptions, addressing the first objective. Differences in perception across academic levels were examined using the Kruskal–Wallis H test, a non-parametric alternative to one-way ANOVA suited to ordinal, non-normally distributed data (Field, 2018); significant results were followed by Mann–Whitney U post-hoc comparisons with Bonferroni correction, and effect sizes were calculated as epsilon-squared (ε^2), interpreted using conventional thresholds for small, medium, and large effects (Tomczak & Tomczak, 2014).

Spearman's rank-order correlation, chosen for its suitability to ordinal and non-linear monotonic data (Field, 2018; Agresti, 2010), examined relationships between the five perception constructs and students' perceived learning impact, addressing the third objective; 95% confidence intervals were calculated using Fisher's z-transformation (Field, 2018). These five correlations were planned a priori and were not corrected for multiple comparisons, unlike the unplanned pairwise post-hoc tests following the Kruskal–Wallis analysis, which were Bonferroni-corrected. Responses to the open-ended question were analysed using thematic content analysis: codes were generated inductively and grouped into broader themes, with theme frequencies calculated to indicate how prominent each recommendation was. Descriptive statistics and composite scores were computed in Microsoft Excel; Kruskal–Wallis, Mann–Whitney, and Spearman analyses were run in Python 3 (SciPy), with statistical significance set at the 5% level ($p < 0.05$).

4. RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Respondents

Of the 110 responses received, 13 were excluded after screening: 12 for missing CGPA data (all 100-level students with no cumulative grade record yet) and one for uniform straight-line responding across all items. This left a final analytical sample of 97 respondents. Table 1 presents the demographic profile of the sample.

Male respondents made up 64.9% of the sample (n=63), and female respondents 35.1% (n=34). Most respondents were 200-level students (n=45, 46.4%), followed by 400-level (n=30, 30.9%), 300-level (n=15, 15.5%), 100-level (n=4, 4.1%), and 500-level (n=3, 3.1%). For self-reported academic performance, half the sample reported a CGPA band of 3.50–4.49, Second Class Upper (n=49, 50.5%), followed by 2.50–3.49, Second Class Lower (n=34, 35.1%), 4.50–5.00, First Class (n=10, 10.3%), and 1.50–2.49, Third Class (n=4, 4.1%). On perceived class size, 45.4% of respondents (n=44) reported a typical class of 90 or more students, while 30.9% (n=30) reported classes of 50–69 students. Only 1.0% (n=1) reported a class size under 30.

Table 1: Demographic Characteristics of Respondents (n=97)

Variable	Category	n	%
Gender	Male	63	64.9
	Female	34	35.1
Academic Level	100 Level	4	4.1
	200 Level	45	46.4
	300 Level	15	15.5
	400 Level	30	30.9
	500 Level	3	3.1
CGPA Band	4.50–5.00 (First Class)	10	10.3
	3.50–4.49 (2nd Class Upper)	49	50.5
	2.50–3.49 (2nd Class Lower)	34	35.1
	1.50–2.49 (Third Class)	4	4.1
Typical Class Size	Less than 30	1	1.0

Variable	Category	n	%
	30–49	10	10.3
	50–69	30	30.9
	70–89	12	12.4
	90 or more	44	45.4

Read alongside the results that follow, this profile carries two implications for interpreting the study's findings. First, the sample skews heavily toward 200- and 400-level students and toward male respondents, a pattern that most plausibly reflects who was reachable through the departmental WhatsApp groups used for recruitment rather than a deliberate sampling choice; the perception findings reported below should therefore be read as most representative of these subgroups; and, given the convenience sampling procedure described in Section 3.3, some caution is warranted before generalising them evenly across the whole student population. Second, that 45.4% of respondents report typical class sizes of 90 or more students is itself substantive evidence for this study's central concern: it corroborates, independently of the perception items themselves, the high rates of perceived overcrowding reported in Section 4.3, and suggests that class size is a structural condition worth measuring directly, rather than only inferring from self-reported comfort, in future work.

4.2 Internal Consistency of Constructs

Table 2 presents the Cronbach's alpha coefficients for each of the five perception constructs. Alpha values ranged from 0.166 (Lighting Conditions) to 0.522 (Classroom Characteristics). As discussed under Methodology, these values fall below the conventional 0.70 threshold and should be read with caution. Composite scores from these constructs were still retained for analysis given the exploratory nature of the study and the small number of items per construct, with the findings interpreted accordingly. For Lighting Conditions specifically, whose alpha (0.166) is markedly lower than the other four constructs, the individual item-level results presented in Table 3 are treated as the primary evidence, with the composite score serving only as a summary reference point.

Table 2: Internal Consistency Reliability of Constructs (n=97)

Construct	No. of Items	Cronbach's α
Indoor Air Quality	4	0.509
Thermal Comfort	3	0.438
Noise Conditions	3	0.461
Lighting Conditions	2	0.166
Classroom Characteristics	3	0.522

4.3 Students' Perceptions of Indoor Environmental Quality and Learning Environment Conditions

Table 3 presents descriptive statistics for individual questionnaire items and composite scores across the five dimensions. Ratings are based on a five-point scale, where 1 = Strongly Disagree and 5 = Strongly Agree.

Table 3. Descriptive Statistics for Students' Perceptions of Indoor Environmental Quality and Learning Environment Conditions (n = 97)

Learning Environment Dimension / Item	M	SD
Classroom Characteristics (Composite)	3.49	0.90
— Windows usually open during class	3.76	1.18
— Classroom feels overcrowded	3.63	1.36
— Classroom is adequately ventilated	3.09	1.24
Noise Conditions (Composite)	3.15	0.89
— External noise disrupts learning	3.34	1.34
— Internal noise disrupts learning	3.31	1.28
— Can hear lecturer clearly	2.80	1.23
Lighting Conditions (Composite)	3.15	0.95
— Glare or poor lighting hinders visibility	3.27	1.37

Learning Environment Dimension / Item	M	SD
— Lighting is adequate for reading/writing	3.02	1.21
Indoor Air Quality (Composite)	3.06	0.78
— Classroom often feels stuffy	3.14	1.19
— Notice dust in classroom	3.66	1.26
— Notice unpleasant odours	2.76	1.28
— Air generally feels fresh	2.67	1.18
Thermal Comfort (Composite)	3.04	0.85
— Classroom often feels too hot	3.14	1.30
— Difficulty concentrating due to heat	3.07	1.29
— Temperature comfortable for learning	2.90	1.09

Note. Composite scores represent the mean of the constituent questionnaire items.

Among the dimensions assessed, Classroom Characteristics recorded the highest composite mean (M=3.49, SD=0.90). This was driven mainly by students reporting that open-window ventilation was the main way air moved through the classroom (M=3.76, SD=1.18), and by high perceptions of overcrowding (M=3.63, SD=1.36). Open-window ventilation had the highest mean score of any item in the questionnaire, which shows that natural ventilation is still the main strategy for managing classroom conditions.

Noise Conditions and Lighting Conditions recorded identical composite means (M=3.15), with standard deviations of 0.89 and 0.95 respectively. Both external noise (M=3.34, SD=1.34) and internal noise (M=3.31, SD=1.28) were seen as disruptive to learning, while the mean score for hearing the lecturer clearly (M=2.80, SD=1.23) suggests a fair number of students struggled with speech intelligibility during lectures.

Indoor Air Quality (M=3.06, SD=0.78) and Thermal Comfort (M=3.04, SD=0.85) recorded the lowest composite means. Within Indoor Air Quality, perceived dust (M=3.66, SD=1.26) was one of the highest-rated concerns, followed by classroom stuffiness (M=3.14, SD=1.19). Perceived air freshness, on the other hand, recorded one of the lowest means (M=2.67, SD=1.18), showing that students generally did not experience the classroom air as fresh. Within Thermal Comfort, perceptions of excessive heat (M=3.14, SD=1.30) and difficulty concentrating because of heat (M=3.07, SD=1.29) both sat above the scale midpoint, while perceived temperature comfort sat just below it (M=2.90, SD=1.09).

Students generally felt that classroom conditions affected both their learning and their academic work. The mean score for the statement that classroom conditions affect overall learning was 3.22 (SD=1.33), and the mean for perceived impact on academic work was 3.43 (SD=1.28). In all, 46.4% of respondents agreed or strongly agreed that classroom conditions affected their learning, and 55.7% agreed or strongly agreed that these conditions affected how well they could carry out academic work.

Taken together, these results show that students experience university learning environments through the combined effect of indoor environmental quality and classroom conditions, not through any one factor on its own. That Classroom Characteristics recorded the highest composite mean of the dimensions assessed, driven largely by perceptions of overcrowding and reliance on open-window ventilation, suggests that the most immediate challenges in this study relate to the physical characteristics of the learning space itself rather than to a single environmental parameter.

The heavy reliance on natural ventilation reflects how many Nigerian public university buildings are designed: indoor conditions depend largely on outdoor climate and occupant behaviour rather than on mechanical ventilation. In the same way, perceptions of overcrowding point to the pressure rising enrolment places on existing teaching facilities. These findings match earlier studies that identify inadequate classroom capacity and limited environmental control as recurring problems in resource-constrained higher education institutions (Toyinbo, 2023).

Indoor Air Quality and Thermal Comfort recorded lower composite scores, but students still consistently raised concerns about dust, stuffiness, excessive heat, and difficulty concentrating because of heat. This supports earlier work showing that naturally ventilated buildings in warm climates are particularly exposed to conditions that affect students' comfort and engagement (Mendell & Heath, 2005; Tran, Park, & Lee, 2020; Wargocki & Wyon, 2020). The prominence of dust in particular lines up with World Health Organization (2021) guidance identifying particulate matter as a leading indoor pollutant of concern, which means this is not just a comfort issue but one with real implications for occupant health.

Taken together, these findings show that a learning environment is experienced through the interaction of several conditions at once, not through isolated aspects of building performance. Improving educational environments requires looking at classroom design, ventilation, thermal comfort, acoustics, lighting, and occupancy together, rather than addressing each one on its own.

Because the sample was expanded to include a second department partway through data collection, some of the pooled variation in classroom perceptions may also reflect differences between the two departments' buildings and teaching formats, rather than purely academic-level or occupant-perception effects.

4.4 Differences in Perceptions Across Academic Levels

The Kruskal–Wallis H test was used to check whether perceptions of classroom conditions differed across 200-level, 300-level, and 400-level students, the three levels with enough respondents for meaningful comparison (n=45, 15, and 30 respectively). Table 4 presents the results.

Table 4: Kruskal–Wallis H Test Results Comparing IEQ Perceptions Across Academic Levels (n=90)

Construct	H	p	200L M	300L M	400L M	ε²
Indoor Air Quality	0.055	.973	3.06	3.10	2.98	0.000
Thermal Comfort	1.937	.380	2.86	3.36	3.06	0.000
Noise Conditions	8.396	.015*	2.85	3.29	3.48	0.074
Lighting Conditions	1.888	.389	3.01	3.50	3.13	0.000
Classroom Characteristics	0.022	.989	3.41	3.56	3.43	0.000

*Note. df=2 for all tests. * $p < .05$. M = mean composite score. ε² = epsilon-squared effect size (Tomczak & Tomczak, 2014); values below zero are a known artefact of the formula when H is smaller than $k-1$ and are reported as approximately 0.00.*

A statistically significant difference across academic levels was found only for Noise Conditions (H=8.396, p=.015). Perceptions of noise disruption rose steadily from 200-level (M=2.85) to 300-level (M=3.29) to 400-level (M=3.48), suggesting students find noise increasingly disruptive as they move through the programme. Post-hoc Mann–Whitney U tests with Bonferroni correction (α adjusted to .017 per comparison) showed the significant difference was specifically between 200-level and 400-level students (p=.015); the 200-level vs 300-level (p=.365) and 300-level vs 400-level (p=1.000) comparisons were not significant after correction. Perceptions of Indoor Air Quality, Thermal Comfort, Lighting Conditions, and Classroom Characteristics did not differ significantly across levels. The effect size for the noise difference was small (ε²=0.074), meaning academic level explained only a modest share of the variance in noise perception. Effect sizes for the other four constructs were negligible (ε²≈0.00), consistent with the lack of significant differences.

A likely explanation for the rise in noise perception is the studio-based nature of architecture teaching: upper-level students spend more time in shared design studios, where group discussion, model-making, and critique sessions generate more internal noise than a typical lecture. This lines up with earlier research showing that classroom acoustic conditions affect students' learning experience and performance (Haverinen-Shaughnessy, Moschandreas, & Shaughnessy, 2011).

Because this study used a cross-sectional design, these differences should be read as variation between cohorts at one point in time, not as evidence of cumulative exposure building up over the years. This caution applies with particular force to the level-based comparisons themselves. Because department was not captured as a variable and the sample was expanded from Architecture to include Microbiology partway through data collection, the 200-, 300-, and 400-level groups compared here may not be evenly split between the two departments; if one department is disproportionately represented at a given level, the noise difference reported above could reflect a department effect (for example, studio-based teaching in Architecture) as much as, or instead of, a genuine academic-level effect. The apparent rise in noise perception across levels should therefore be treated as a pattern requiring confirmation in future work that records department directly, rather than as clear evidence of a level-based trend.

4.5 Relationships Between Indoor Environmental Quality, Learning Environment Conditions, and Perceived Learning Impact

Spearman's rank-order correlation was used to examine how the five IEQ and learning environment dimensions related to students' perceived learning impact. Table 5 presents the results.

Table 5. Spearman's Rank-Order Correlations Between Indoor Environmental Quality, Learning Environment Dimensions, and Perceived Learning Impact (n = 97)

Construct	ρ (Impact 1: Overall Learning)	p	ρ (Impact 2: Academic Work)	p	95% CI (Impact 1)	95% CI (Impact 2)
Thermal Comfort	.520	<.001	.399	<.001	[.358, .652]	[.217, .554]
Indoor Air Quality	.481	<.001	.450	<.001	[.311, .621]	[.275, .596]
Lighting Conditions	.469	<.001	.420	<.001	[.297, .611]	[.241, .572]
Noise Conditions	.451	<.001	.385	<.001	[.276, .597]	[.201, .543]
Classroom Characteristics	.207	.042	.197	.054	[.008, .390]	[-.003, .381]

Note. ρ = Spearman's rho. Impact 1 = "Overall, classroom conditions affect my learning." Impact 2 = "Classroom conditions affect how well I can do my academic work." 95% CI calculated using Fisher's z-transformation.

Thermal Comfort showed the strongest association with overall perceived learning impact (ρ=.520, 95% CI [.358, .652], p<.001), followed by Indoor Air Quality (ρ=.481, 95% CI [.311, .621]), Lighting Conditions (ρ=.469, 95% CI [.297, .611]), and Noise Conditions (ρ=.451, 95% CI [.276, .597]). A similar pattern held for perceived impact on academic work, with Indoor Air Quality showing the second strongest correlation (ρ=.450, 95% CI [.275, .596]), followed by Lighting Conditions (ρ=.420, 95% CI [.241, .572]) and Noise Conditions (ρ=.385, 95% CI [.201, .543]). All four relationships were positive and statistically significant (p<.001), and in each case the confidence interval excluded zero, which supports how reliable these associations are.

Classroom Characteristics showed a weaker relationship with perceived learning impact: a small but statistically significant correlation for overall learning (ρ=.207, 95% CI [.008, .390], p=.042), and a non-significant relationship with perceived impact on academic work (ρ=.197, 95% CI [-.003, .381], p=.054). The confidence interval for the latter marginally includes zero, which fits its borderline non-significance. Overall, students who reported poorer IEQ and learning environment conditions also reported greater perceived negative impact on their learning and academic work.

A key finding of this study is that students' perceptions of IEQ and classroom conditions were positively linked to how they perceived their own learning. Of the five dimensions assessed, Thermal Comfort had the strongest relationship with perceived learning, followed by Indoor Air Quality, Lighting Conditions, and Noise Conditions. This broadly matches earlier research showing that students' perceptions of their classroom environment relate closely to perceived cognitive performance and learning experience (Brink, Loomans, Mobach, & Kort, 2021).

One notable point is that the dimensions students found most problematic were not necessarily the ones most strongly tied to learning. Classroom Characteristics had the highest composite scores, yet Thermal Comfort showed the strongest relationship with perceived learning. This suggests that visible concerns like overcrowding may shape students' general impression of their learning environment, while thermal conditions more directly affect their ability to concentrate and stay engaged during class.

This strengthens the case for an occupant-centred view when evaluating educational environments. Objective environmental measurements are still essential for assessing building performance, but students' perceptions add complementary evidence of how a learning environment is actually experienced day to day. Understanding this helps universities identify which conditions matter most to learning, and prioritise the interventions that improve both comfort and educational effectiveness. Given the reliability profile reported in Section 3.6, these composite-level findings should be read as indicative of broad patterns in students' perceptions rather than as confirmatory measurement of the underlying constructs.

Overall, the findings support treating indoor environmental quality as a core part of learning environment quality, not just a measure of building performance. For architects, university managers, and facilities planners, this means environmental quality needs to be built into the planning, design, and management of educational spaces from the start, if the goal is a healthier, more comfortable, more supportive learning environment.

4.6 Student-Identified Environmental Improvement Priorities

All 97 respondents answered the open-ended question asking what changes would most improve their classroom environment. Table 6 presents the themes identified through content analysis and how often each appeared.

Table 6: Themes from Content Analysis of Open-Ended Improvement Suggestions (n=97)

Theme	n	%
General improvement of classroom conditions	33	34.0

Theme	n	%
Improved ventilation and airflow	29	29.9
Improved furniture and seating	23	23.7
Better lighting	19	19.6
Reduced overcrowding or larger classrooms	13	13.4
Noise reduction	10	10.3
Cooling systems (fans or air conditioning)	8	8.2
Cleanliness and maintenance	2	2.1

Note. Percentages do not sum to 100% as responses could be coded into more than one theme.

The most frequently cited priority was ventilation and airflow (29.9%), with students naming functional fans, better cross-ventilation, and more fresh air circulation as the changes most needed. Furniture and seating was the second most specific theme (23.7%), with students pointing to broken, insufficient, or uncomfortable chairs and tables as real barriers to engagement. Better lighting was cited by 19.6% of respondents, and 13.4% specifically mentioned reducing overcrowding or moving to larger classrooms. A number of responses raised noise reduction (10.3%), pointing to external traffic noise and noise from nearby activities as particular concerns. Cooling through fans or air conditioning was specifically mentioned by 8.2% of respondents. A further 34.0% of responses gave general calls for improvement without naming a specific dimension, many pointing simply to the need for a healthier, more comfortable, more supportive learning environment.

The qualitative findings closely matched the quantitative results in showing what students consider the most important improvements. Better ventilation and airflow came up most often, reflecting students' continued reliance on open windows and their concerns about air movement in class. Furniture and seating, better lighting, larger classrooms, and noise reduction were also named as priorities.

Interestingly, some conditions with stronger statistical links to perceived learning, thermal comfort in particular, came up less often in the open-ended responses than more visible issues like ventilation and furniture. This suggests students may find it easier to name tangible physical fixes than to identify the underlying conditions actually shaping their learning experience. Even so, the agreement between the quantitative and qualitative findings strengthens confidence in the overall interpretation, and shows the value of pairing structured survey data with students' own recommendations.

4.7 Implications for Theory and Practice

The findings support both theoretical perspectives behind this study. In line with Person-Environment Fit Theory (Lewin, 1936; Edwards et al., 1998), students' perceptions show that learning environment quality depends on how well classroom conditions meet their needs.

Environmental Stress Theory (Evans & Cohen, 1987) helps explain how stressors such as excessive heat, poor ventilation, inadequate lighting, and noise can reduce students' comfort and engagement during learning.

The practical implications of these patterns for architectural design, facilities management, and institutional planning are covered in detail in Section 6.

5. CONCLUSION

This study examined students' perceptions of indoor environmental quality and classroom conditions as indicators of learning environment quality in a naturally ventilated Nigerian public university. The findings show that students experience their learning environment through the combined effect of classroom characteristics, indoor air quality, thermal comfort, lighting, and noise conditions, with thermal comfort showing the strongest relationship with perceived learning. Overcrowding and reliance on natural ventilation were the most prominent concerns, but the results show that improving learning environments needs an integrated approach across several dimensions, not fixes to isolated building deficiencies.

By taking an occupant-centred approach, this study adds to the growing evidence for the value of students' perceptions in evaluating educational environments. The findings show that students' experience is practical evidence for identifying environmental priorities and informing architectural design, facilities management, and institutional planning.

Ultimately, building an effective learning environment is about more than providing classroom space. It requires buildings that actively support students' comfort, health, engagement, and learning. For universities working in resource-constrained settings, building indoor environmental quality into the planning, design, and management of learning spaces is a practical way toward healthier, more supportive, and more effective educational environments.

6. RECOMMENDATIONS

6.1 Implications for Architectural Design and Space Planning

These findings show why learning environment quality needs to be considered early in architectural design, not added on afterward. Students identified overcrowding and reliance on open-window ventilation as the most prominent characteristics of their classrooms, which means passive environmental design should remain a priority in both new educational buildings and the retrofit of existing ones. In naturally ventilated universities like the University of Jos, strategies such as effective cross-ventilation, appropriate building orientation, adequate ceiling heights, better window design, and balanced daylight provision can improve indoor environmental quality while reducing dependence on mechanical systems. Because a learning environment is shaped by several conditions interacting at once, architectural interventions should treat ventilation, occupancy, lighting, and thermal performance as one integrated design problem rather than separate building features (Brink, Loomans, Mobach, & Kort, 2021; Toyinbo, 2023).

The significant differences in noise perception across academic levels also suggest that learning spaces should be designed around their actual function. Studio-based teaching spaces in particular could benefit from better acoustic treatment and spatial planning to reduce noise disruption while still supporting collaborative work.

6.2 Implications for Facilities Management

Several of the concerns students raised can be addressed through routine facilities management without major capital spending. Students consistently pointed to dust, poor furniture, bad lighting, and insufficient ventilation as priorities. Regular classroom maintenance, better cleaning schedules, repair or replacement of damaged furniture, upkeep of windows and ventilation openings, and simple lighting improvements could meaningfully improve learning environments at relatively low cost. These interventions matter most for resource-constrained universities where large-scale infrastructure upgrades are not always immediately feasible.

6.3 Implications for Institutional Planning

The prominence of overcrowding points to a need for institutional planning to match student enrolment to available teaching space. Measures such as reducing class sizes where possible, scheduling parallel teaching sessions, and allocating spaces according to their environmental characteristics could improve students' experience while easing pressure on existing facilities. The variation in perceived noise across academic levels also suggests that space allocation should account for the different environmental needs of lecture-based and studio-based teaching.

6.4 Implications for Occupant-Centred Evaluation

These findings show the value of building students' perceptions into how university learning environments are evaluated. Classroom Characteristics was the most visible concern, yet Thermal Comfort had the strongest relationship with perceived learning, which means the most noticeable environmental problems are not always the ones with the greatest effect on students' education. Institutions should therefore pair routine building inspections with regular occupant-centred assessments that look at both environmental conditions and their perceived effect on learning. This gives a practical, low-cost basis for prioritising improvements and supporting evidence-based decisions in educational building design, facilities management, and institutional planning.

6.5 A Prioritized Framework for Action

Sections 5.1 to 5.4 outline the range of interventions available to architects, facilities managers, and institutional planners. Translating these into a workable framework, however, requires combining two forms of evidence already reported in this study: the strength of each dimension's statistical relationship with perceived learning (Table 5) and the frequency with which students themselves named each concern (Table 6). This section arranges the interventions discussed above by resource tier and evidence basis, so that institutions with limited budgets can act on the strongest available evidence rather than on visibility alone.

As established in Section 4.5, the correlation results reported in Table 5 provide a clear prioritization signal: Thermal Comfort (ρ=.520) and Indoor Air Quality (ρ=.481) show a substantially stronger relationship with perceived learning than Classroom Characteristics (ρ=.207), even though the latter is both the highest-rated concern and the condition most frequently named in student open-ended responses (Table 6; Section 4.6). Rather than restate that contrast, this section builds on it directly: where resources are constrained, institutions should not default to addressing the most visible or most frequently reported condition first; thermal comfort and indoor air quality warrant priority attention because of their stronger demonstrated link to students' learning, even though overcrowding and ventilation practice are what students notice and report most readily.

Table 7: Prioritized Improvement Actions by Resource Tier

Tier	Illustrative Actions	Primary Dimension(s) Addressed	Evidence Basis
Tier 1 — Immediate, low-cost	Routine dust removal, improved cleaning schedules, and upkeep of window and door openings	Indoor Air Quality	Dust rated among the highest IAQ concerns (M=3.66); addressable through routine facilities management (Section 5.2)
Tier 1 — Immediate, low-cost	Repair or replacement of damaged furniture and seating	Classroom Characteristics	Second most-cited student priority (23.7%, Table 6)
Tier 1 — Immediate, low-cost	Basic glare control (blinds, seating repositioning) and bulb replacement	Lighting Conditions	Cited by 19.6% of respondents; low-cost per Section 5.2
Tier 2 — Medium-term, moderate cost	Provision and maintenance of ceiling or standing fans	Thermal Comfort	Cooling cited by 8.2% of respondents; addresses the dimension with the strongest correlation with perceived learning (ρ=.520, Table 5)
Tier 2 — Medium-term, moderate cost	Acoustic treatment (sound-absorbing panels, partitions) in studio-based teaching spaces	Noise Conditions	Significant rise in noise perception from 200-level to 400-level (Section 4.4); studio-based teaching implicated (Section 5.3)
Tier 2 — Medium-term, moderate cost	Scheduling adjustments to reduce peak-time class sizes	Classroom Characteristics	Reduces overcrowding without new construction (Section 5.3)
Tier 3 — Long-term, capital-intensive	Building retrofits: improved cross-ventilation design, window enlargement, ceiling height adjustment	Thermal Comfort; Indoor Air Quality	Addresses the root causes of heat and stuffiness concerns (Section 5.1); aligns with the two strongest learning correlations in Table 5

Tier	Illustrative Actions	Primary Dimension(s) Addressed	Evidence Basis
Tier 3 — Long-term, capital-intensive	New classroom construction sized to current enrolment	Classroom Characteristics	Addresses overcrowding at its source (Section 5.3)
Tier 3 — Long-term, capital-intensive	Integration of daylighting design in future buildings	Lighting Conditions	Reduces long-term reliance on retrofit lighting fixes

Note. Tiers reflect relative cost and implementation timeframe, not sequence of necessity; Tier 1 actions can be pursued immediately and in parallel with planning for Tiers 2 and 3. The evidence basis draws on the correlation strengths reported in Table 5 and the thematic frequencies reported in Table 6.

This tiered framework is intended as a starting point for institutional decision-making rather than a fixed sequence. Its main contribution is practical rather than empirical: it translates the visibility-versus-consequence contrast discussed in Sections 4.5 and 4.6 into a concrete sequence of actions that resource-constrained institutions can follow, so that Thermal Comfort and Indoor Air Quality are not deprioritised simply because they are less visibly reported.

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