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Design Requirements for Acoustic Comfort in Lecture Theatres: A Case Study of Oke-Ogun Polytechnic, Saki, Nigeria

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Abstract— Acoustic comfort in lecture theatres is a critical determinant of speech intelligibility, learning effectiveness, and user satisfaction, yet it remains a frequently overlooked design parameter in many Nigerian tertiary institutions. This study therefore evaluates the design requirements for achieving and acoustic comfort and assessing the facilities at Oke-Ogun Polytechnic, Saki, Nigeria. A mixed-methods approach was employed, combining objective physical audits of eight lecture theatres with subjective assessments from 342 students. Data were collected using structured questionnaires which was analysed with Likert Scale (Mean Weighted Value, MWV) and direct observation. Findings reveal significant acoustic deficiencies. Key design requirements identified include: achieving a reverberation time (RT) suitable for speech (not exceeding 1.0 seconds) by moving away from hard, reflective finishes (terrazzo, plaster, corrugated metal) towards absorptive materials (acoustic tiles, fabric-wrapped panels); implementing a robust building envelope with sound-insulating walls, sealed double-glazed windows, and insulated roofing to mitigate external noise (rain, generators, traffic MWV up to 3.43); adopting fan-shaped or splayed geometries to improve sound distribution and reduce flutter echoes; integrating sound reinforcement systems as a complement to, not a replacement for, good architectural acoustics; and establishing acoustic buffer zones within campus planning. The study concludes that design for acoustic comfort requires a holistic, performance-based strategy, moving beyond a singular focus on durability and capacity. These findings provide an evidence-based framework for designing the proposed Lecture Theatre for the College of Nursing Science, Saki and serve as a reference for similar educational building projects in acoustically challenging tropical contexts.

Keywords— acoustic comfort, lecture theatre design, speech intelligibility, reverberation time, oke-ogun polytechnic, architectural acoustics, nigeria.

I. INTRODUCTION

The quality of the built learning environment directly correlates with educational outcomes. While visual comfort and thermal regulation often dominate design discourse, acoustic performance is equally fundamental, particularly in lecture theatres where oral communication is the primary mode of instruction (Ayinla, Ekpo, Adebisi and Adetunji, 2023), Obisung, (2021). A lecture theatre with poor acoustics imposes a significant cognitive load on students, forcing them to expend mental effort on decoding speech rather than processing content, while also causing vocal fatigue for lecturers. Adeyemi (2022).

In the Nigerian context, many lecture theatres are designed primarily to maximize seating capacity and material durability, with little to no consideration for how sound behaves within the space. This oversight results in common, severe acoustic defects: excessive reverberation times (often >1.5 seconds, versus a recommended <1.0 seconds for speech), high background noise levels from external sources and building services, uneven sound distribution creating dead zones, and intrusive echoes. Ayinla *et al.,* (2023); Oladimeji and Abdulsalam, (2022).

Learning in lecture theatres depends strongly on interaction. There are two principal types of interaction: the lecturer-to-student interaction, in which the lecturer projects speech to the entire audience; and student-to-student interaction, often during group tasks or informal discussions. If these interactions occur in a space with poor acoustic design, conversations among students, echoes, and background noise may mask the main speech signal (Adeyemi, 2022). When these interactions are supported by acoustic design that controls noise and reverberation, occupants experience acoustic comfort, the sense that the sound environment is satisfactory for listening, concentration, and speech intelligibility (Oluwole, 2022).

Many lecture theatres in Nigeria face serious acoustic challenges. One frequent problem is excessive reverberation: in several institutions studied recently, reverberation times were found to be higher than recommended for speech spaces, meaning that spoken words linger and overlap, reducing intelligibility (Ayinla *et al.,* 2023). Background noise is another major issue: external traffic, ambient campus operations, and noise from ventilation systems intrude into lecture theatres, especially where windows, doors or wall junctions are not acoustically sealed (Obisung *et al.,* 2021). Reflective finishes are also common: concrete, uncarpeted floors, bare plastered walls, and high ceilings without acoustic treatment led to echoes and make speech sound harsh or muddled (Nkwocha *et al.,* 2021).

This research gap directly undermines the evidence-based design of future facilities, particularly the proposed Lecture Theatre for the College of Nursing Science, Saki, where absolute speech clarity is paramount for communicating precise medical terminology. Anecdotal evidence and preliminary observation suggested that its lecture theatres suffer from these pervasive acoustic problems. However, no comprehensive, empirical study had been conducted to identify the specific design requirements for acoustic comfort within this unique context of tropical climate, locally available materials, and specific user behaviours.

Study Area

This study was carried out at The Oke-Ogun Polytechnic, Saki (TOPS), located in the Saki West Local Government Area of Oyo State, Southwestern Nigeria.Geographically, the institution is positioned within the tropical derived savanna zone, bounded approximately by the coordinates 8°40’N to 8°41’N latitude and 3°23’E to 3°24’E longitude, a rapidly growing institution in Oyo State, Nigeria. The specific focal point of the spatial and structural evaluation targets the institution's primary lecture theatres and learning spaces, which serve as the foundational dataset for evaluating acoustic performance, environmental comfort

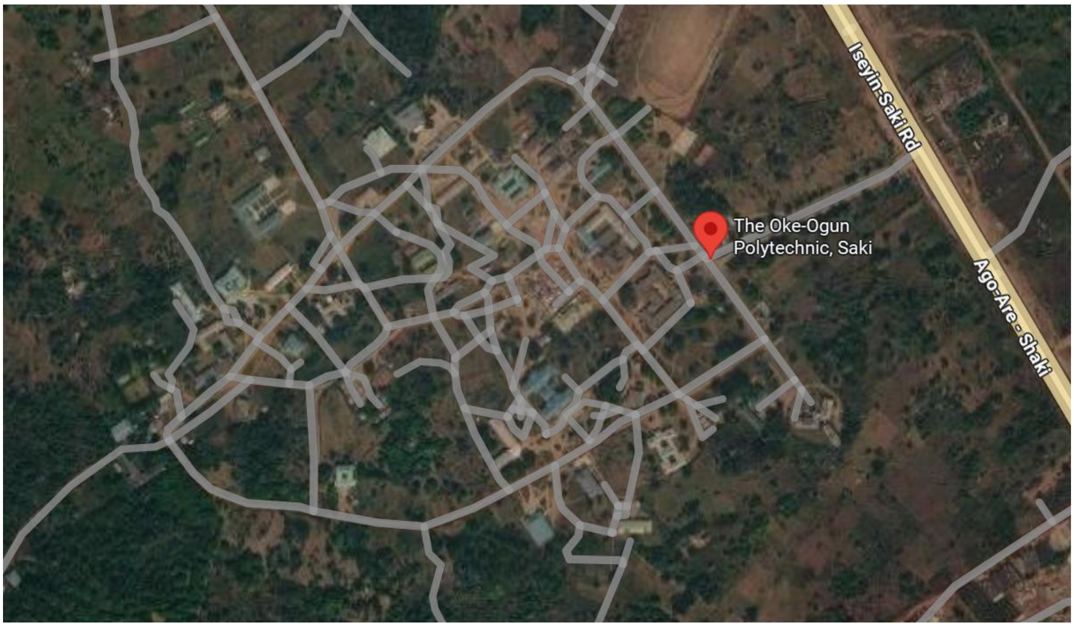

Figure 1: The Oke-Ogun Polytechnic imagery
Source: Google maps, 2026

II. LITERATURE REVIEW

This study is grounded in established principles of architectural acoustics

Key Acoustic Concepts for Lecture Theatres

i. Reverberation Time (RT): This is the single most critical metric. Defined as the time it takes for sound to decay by 60 decibels (dB), RT dictates how "live" or "dead" a room sounds. For lecture theatres, where speech intelligibility is paramount, the optimal RT range is 0.5 to 1.0 seconds Oladimeji and Abdulsalam (2022). Longer RTs cause successive syllables to overlap, blurring speech.
ii. Background Noise Level (BNL): Unwanted sound from external (traffic, generators) or

internal (HVAC, projectors) sources that masks the lecturer's voice. For good intelligibility, a Signal-to-Noise Ratio (SNR) of at least +15 dB is recommended, meaning the lecturer's voice must be 15 dB louder than the background noise Sani and Okoro, (2022).

iii. Sound Absorption and Reflection: Porous materials (acoustic panels, carpet, upholstery) absorb sound energy, reducing RT. Hard, dense surfaces (concrete, plaster, glass, terrazzo) reflect sound, increasing RT and contributing to echoes Okonkwo and Iweka (2021).

Design Requirements from Literature

Synthesized from Nigerian and international studies, the key design requirements for acoustic comfort include:

a. Spatial Geometry: Fan-shaped or slightly splayed wall configurations are preferred over rectangular shoe-box designs as they reduce standing waves and flutter echoes, and improve sound projection to the rear Okonkwo and Iweka, (2021).
b. Material Selection: A strategic combination of absorptive materials (acoustic ceiling tiles, fabric-wrapped wall panels, carpeting) and reflective surfaces (near the lecturer to project sound) is required Yusuf and Adeyemi, (2023).
c. Building Envelope: High-mass walls, sealed double-glazed windows, and insulated roofing are essential to block external noise. Rain noise on corrugated metal roofs is a particularly severe problem in the Nigerian context Ogunode and Babalola (2022).
d. Noise Control: Internal noise from occupants (talking, movement) must be managed through seating design (e.g., upholstered, quiet mechanisms) and circulation planning. External noise is managed through site planning and building orientation Akinwale and Ojo, (2024).
e. Sound Reinforcement: An electronic Public Address (PA) system is a necessary tool to augment natural speech, but it cannot fix poor architectural acoustics; it must be integrated as a complementary system Eze and Mohammed, (2024).

Conceptual Framework

This study is guided by a conceptual framework positing that Acoustic Comfort in a lecture theatre is a function of three interdependent architectural domains:

(1) Spatial Configuration (geometry, volume, seating rake),
(2) Material Performance (absorption, reflection, diffusion properties of finishes),
(3) Environmental Isolation (building envelope's ability to exclude external noise).

Deficiencies in any one domain will compromise overall acoustic comfort, negatively impacting speech intelligibility and user satisfaction. This framework informs the data collection and analysis, which aims to identify the specific, actionable design requirements for the study area.

III. METHODOLOGY

This study employed a mixed-method approach which combined objective physical audits with subjective user surveys to triangulate findings. The study was conducted at The Oke-Ogun Polytechnic, Saki (TOPS), Oyo State, Nigeria. The sampling frame comprised all eight (8) lecture theatres frequently used for instruction. Slovin's formula was used to select 348 students from a total population of 2,500 regular users (put percentage %). A total of 342 questionnaires were returned, representing a 98.3% response rate. The sample included students from all academic levels (ND I to HND II) and all eight lecture theatres: New 500LT, Old 500 LT, SES LT, 250 LT (A1 and A2), SGI LT, Red Block, and SBCS LT.

Data Collection Instruments

Questionnaire: A structured questionnaire was administered to assess users' perceptions across four key acoustic indices: hearing audibility, speech clarity, noise disturbance sources, and overall satisfaction. Responses were recorded on a 5-point Likert scale. The instrument was pilot-tested for reliability (Cronbach's alpha > 0.80).

Physical Audit Checklist: Researchers conducted direct observations and physical measurements to document each theatre's geometry (shape, dimensions, volume), surface finishes (walls, ceiling, floor), seating type, glazing, roofing material, and existing sound systems.

Data Analysis

The quantitative data from the questionnaires were analyzed using descriptive statistical tools (likert

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scales) and physical audit checklist (direct observations and physical measurements). A Mean Weighted Value (MWV) was calculated for each variable to determine the central tendency of user perceptions, where MWV = Σ(fi * xi) / Σfi, with xi representing the Likert scale value (1=Very Poor to 5=Excellent).

IV. FINDINGS AND DISCUSSION

The findings presented here focus on identifying design requirements by analysing existing deficiencies. Results are organized around the key domains of the conceptual framework.

Physical Audit: Existing Design Characteristics

The physical audit revealed a consistent pattern of acoustically poor design across all eight lecture theatres.

Table 1: Physical Audit of Lecture theatres in the Study Area

Feature	Observed Condition	Acoustic Implication
Geometry	Rectangular (6 theatres) / Kite-shaped (2 theatres)	Creates parallel walls, leading to flutter echoes and standing waves.
Wall Finish	Smooth plaster with emulsion paint (all 8 theatres)	Highly reflective, minimal sound absorption (NRC ~0.05).
Floor Finish	Terrazzo or ceramic tile (all 8 theatres)	Highly reflective, amplifies impact noise from footsteps and moving chairs.
Ceiling	Suspended asbestos/PVC grid (present but often damaged)	A potential asset, but damaged panels allow sound to escape into roof plenum.
Seating	Wooden benches / Unupholstered plastic chairs	Reflective, noisy when moved; provides no sound absorption.
Windows	Louvre blades (all 8 theatres)	Extremely poor sound insulation; direct path for external noise.
Roof	Corrugated metal or asbestos sheets (all 8 theatres)	Highly resonant during rain ("drum effect"), generating extreme noise.

Sources: Author’s Compilation 2026

The physical audit results presented in Table 1 reveal a clear and pervasive pattern: all eight lecture theatres exhibit design characteristics that are fundamentally hostile to good acoustics. The combination of rectangular or kite-shaped geometries with smooth plaster walls, terrazzo or ceramic tile floors, and unupholstered wooden or plastic seating creates an environment dominated by hard, highly reflective surfaces with minimal sound absorption (NRC ~0.05). This configuration directly explains the likelihood of flutter echoes, standing waves, and excessive reverberation times, which are known to impair speech intelligibility and increase listener fatigue. Furthermore, the presence of louvre-bladed windows and corrugated metal or asbestos roofing introduces severe vulnerabilities to external and environmental noise particularly the “drum effect” during rain, which can render teaching entirely unintelligible. Collectively, these deficiencies confirm that the existing design fails to support the primary function of a lecture theatre: clear verbal communication.

Despite this largely negative profile, the findings also identify a critical and actionable asset. The presence of a suspended ceiling grid in most theatres even where panels are currently damaged offers a ready-made, cost-effective retrofitting opportunity. Replacing damaged asbestos or PVC panels with high-performance acoustic tiles would directly address the lack of ceiling absorption, one of the most efficient surfaces for reducing reverberation without altering walls or floors. This finding suggests that significant acoustic improvement may be achievable through targeted, low-disruption interventions rather than full structural redesign. Future discussion should therefore prioritize ceiling retrofitting as a first-phase solution, alongside addressing window and roof noise pathways through sealing, double-glazing, or roof insulation strategies.

User Perceptions: Key Design Requirements Identified

Hearing Audibility and Speech Clarity

Respondents rated the clarity of the lecturer's voice as only moderate, with an MWV of 2.91 (where 3.0 is neutral). The ability to hear other students across the hall was notably worse, with the lowest MWV in this section (2.86), indicating poor student-to-student communication (Table 2). The ANOVA test showed no significant difference in these perceptions across the eight theatres (p = 0.824), suggesting a systemic acoustic issue.

Table 2: Hearing Audibility and Speech Clarity

Variable	Mean Weighted Value (MWV)
Clarity and distinctness of lecturer's voice	2.91
Clear hearing of lecturer without difficulty	2.95
Need to strain ears during lectures	2.96
Ability to hear other students across the hall	2.86
Grand Mean (Section)	2.93

Sources: Author's Compilation 2026
Interpretation: MWV < 3.00 = Negative/Inadequate.

The user perception data provide compelling evidence that the acoustic deficiencies identified in the physical audit translate directly into real-world educational barriers. With a section grand mean of 2.93 (below the neutral threshold of 3.00), respondents consistently rated all aspects of hearing and speech clarity as inadequate. The clarity of the lecturer's voice (MWV = 2.91) and the need to strain ears during lectures (MWV = 2.96) indicate that students are actively compensating for poor acoustics, a known contributor to cognitive load and accelerated fatigue. Most concerning is the lowest-rated item the ability to hear other students across the hall (MWV = 2.86) which signals that student-to-student interaction, essential for active learning and discussion-based pedagogies, is severely compromised. This finding extends the problem beyond traditional lecture delivery to collaborative learning environments.

The statistical outcome of the ANOVA test (p = 0.824) is particularly instructive. The absence of significant perceptual differences across the eight theatres confirms that the acoustic problems are not isolated to one or two poorly designed rooms but are systemic across the entire study area. This uniformity strongly suggests that the root causes are fundamental design and material choices such as the consistent use of reflective walls, hard floors, and louvre windows documented in the physical audit rather than variable factors like room size or maintenance history. Practically, this means that piecemeal or theatre-by-theatre solutions would be inefficient. Instead, the findings argue for a standardised acoustic retrofit protocol applied across all theatres, prioritising interventions that improve both lecturer-to-student and student-to-student audibility, such as ceiling absorption, rear-wall diffusion, and the elimination of hard, parallel surfaces.

Identification of Noise Disturbance Sources

This section yielded the most critical findings, identifying both internal and external noise sources that design must mitigate. All MWV values above 3.00 indicate a "disturbing" to "very disturbing" level of interference.

Table 3: Noise Disturbance Sources

Noise Source	Category	Mean Weighted Value (MWV)	Rank
Students talking or whispering	Internal (Occupant)	3.52	1st
Rain noise on roof	External (Environmental)	3.43	2nd
Noise from movement in/out of hall	Internal (Occupant)	3.36	3rd
Noise from generators or power plants	External (Mechanical)	3.27	4th
Noise from chairs, bags, physical movement	Internal (Occupant)	3.25	5th
Noise from adjacent spaces/corridors	Internal (Transmission)	3.16	6th

Traffic noise from nearby roads	External (Urban)	3.13	7th
Noise from ventilation systems	Internal (Mechanical)	2.94	8th

Sources: Author's Compilation 2026

The identification of noise disturbance sources reveals a critical and somewhat counterintuitive hierarchy of acoustic interference. Occupant-generated noise specifically students talking or whispering emerges as the most disturbing factor (MWV = 3.52, ranked 1st), surpassing even the highly intrusive rain-on-roof effect (MWV = 3.43, ranked 2nd). This finding is particularly significant because it shifts the focus from purely environmental noise control to the design's role in managing human behaviour. Poor room acoustics, characterised by long reverberation times and minimal sound absorption, cause normal conversation to propagate across the hall, forcing students to speak louder to be heard, which in turn raises the overall noise floor in a classic Lombard effect spiral. The high ranking of movement-related noises (entry/exit, chairs, bags, footsteps) further reinforces that the physical environment provides no acoustic damping for transient but frequent disruptions. Notably, ventilation system noise (MWV = 2.94) fell below the disturbing threshold, suggesting that mechanical noise, while present, is less problematic than the combined effect of reflective surfaces and occupant activity.

The ranking of external noise sources provides direct validation of the physical audit's observations. Rain noise on corrugated metal or asbestos roofing ranks 2nd overall, confirming that the "drum effect" identified in the audit is not merely a theoretical concern but a regularly experienced and highly disturbing classroom reality. Traffic noise (MWV = 3.13) and generator noise (MWV = 3.27) further indicate that the building envelope particularly the louvre-bladed windows documented earlier offers inadequate insulation from surrounding urban and mechanical activities. The ANOVA result (p = 0.751) again demonstrates systemic consistency across all eight theatres, implying that no single room is acoustically protected from these sources. From a design requirement perspective, these findings demand a dual strategy: first, introducing significant sound absorption (e.g., acoustic ceiling tiles, wall panels, carpeting or resilient flooring) to reduce reverberation and occupant-generated noise; and second, improving roof and window insulation to attenuate environmental noise. Without both interventions, even a perfectly quiet mechanical system will not resolve the dominant disturbances caused by students, rain, and movement.

Occupant-generated noise was the single most disturbing factor (MWV = 3.52). Rain noise on the roof was the most significant environmental factor (MWV = 3.43), directly attributable to the corrugated metal roofing observed in all theatres. The ANOVA test again showed no significant difference across theatres (p = 0.751).

Overall Acoustic Comfort and Satisfaction

Overall satisfaction with acoustic comfort was very low (MWV = 2.85). In contrast, students strongly agreed on the importance of clear hearing for effective learning (MWV = 3.86), revealing a significant "expectation vs. reality" gap. Respondents also agreed that poor sound quality affects concentration (MWV = 3.26) and that lecturers struggle by having to raise their voices (MWV = 3.36). The ANOVA was non-significant (p = 0.695), confirming the acoustic problems are consistent across the polytechnic's lecture theatre stock.

V. CONCLUSION

This study concludes that the existing lecture theatres at Oke-Ogun Polytechnic, Saki, do not meet the fundamental design requirements for acoustic comfort. Their design is characterized by highly reflective materials, an acoustically weak building envelope (particularly louvered windows and resonant metal roofs), problematic geometries, and a neglect of occupant-generated noise. Students experience poor speech intelligibility, high levels of distracting noise, and low overall satisfaction, despite recognizing the critical importance of good acoustics for their learning. These findings provide an evidence-based framework for designing the proposed Lecture Theatre for the College of Nursing Science, Saki and serve as a reference for similar educational building projects in acoustically challenging tropical context.

Limitations of the Study

This study relied primarily on user perception (subjective data) and physical observation. A detailed objective measurement of Reverberation Time using a sound level meter and impulse response was outside the scope of this phase of the research but is recommended for future work to create a quantitative baseline.

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