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Optimizing Auditory Architecture for Quality Education: An Evaluation of Lecture Hall Acoustic Design Standards and Speech Intelligibility at Caleb University, Lagos State, Nigeria

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Abstract- ***The acoustical performance of lecture halls can significantly affect the ability to understand what is being said by the teacher, to focus on the lesson, to remember what has been learned, student interaction in class, and the effectiveness of the teaching and learning process. Lecture halls in higher education institutions are mostly used for verbal communication; therefore, a poor acoustic situation with a high level of background noise, reverberation and poor sound distribution can greatly affect the educational process. Although there has been a growth in educational infrastructure in the Nigerian universities, little attention has been paid to consider the conformance of lecture halls to the established acoustic design requirements and usability for effective speech communication. The study then aimed to evaluate the acoustic design of the lecture halls in Caleb University, Lagos State, Nigeria and their speech intelligibility to optimize the acoustic design of the lecture halls for the delivery of quality education. The descriptive survey research design using Post-Occupancy Evaluation (POE) approach was used. The respondents of the study were 390, made up of 370 undergraduate and 20 lecturers, from which stratified random and purposive sampling methods were employed. Structured questionnaire, observation checklist and photo documentation along with acoustic measurements using digital Sound Level Meter was used for data collection. Descriptive statistics (frequencies, percentages, mean scores, standard deviations, and Pearson's Product Moment Correlation) were used in analyzing the data collected and analyzed by SPSS Version 26. The results showed that the selected lecture halls in general have fairly good acoustical properties for learning and teaching, which include the distribution of sound, seating arrangement, and the performance of the public address system. Background noise, reverberation, insufficient acoustic treatments, and some perceived sound reinforcement system deficiencies, however, were found to have a negative impact on students' learning and on speech intelligibility. The study has shown that the acoustic evaluation should be a regular procedure, the compliance with the known acoustic design rules is crucial, the use of sound-absorbing materials is necessary and sound sources should be controlled to ensure educational quality and auditory comfort. The results will be helpful in the design, renovation and management of educational facilities that facilitate effective communication, improve students' learning outcomes, and ensure sustainable quality education for architects, acoustical consultants, university decision makers, facility managers and policy makers.***

Keywords: ***Auditory Architecture, Acoustic Design Standards, Caleb University, Educational Buildings, Lecture Hall Acoustics, Post-Occupancy Evaluation, Quality Education, Speech Intelligibility.***

I. INTRODUCTION

In higher education, the physical learning environment is a crucial factor for effective teaching and learning outcomes. Lecture hall acoustics is significant as it relates to speech intelligibility, student concentration, comprehension and overall academic achievement (Barrett et al., 2015). The lecture hall is basically created for verbal communication and the success of the knowledge transfer will be determined by the students' capacity to hear and understand the lecturer. The poor acoustical conditions, such as high background noise, long reverb times, sound reflections and less than adequate sound insulation, not only can decrease speech intelligibility, but can also increase listening effort and negatively impact students' engagement and learning outcomes (Bradley & Sato, 2008). The optimization of the auditory architecture of

educational buildings has thus become a prerequisite in the planning and designing of educational buildings.

Auditory architecture is the intentional design and treatment of the built environment to ensure optimal acoustics to enhance human communication and learning. Acoustic design criteria in lecture halls are to control reverberation time, background noise, sound distribution, speech transmission and use of suitable construction materials to achieve high speech intelligibility (International Organization for Standardization [ISO] 2018). The acoustic performance of teaching spaces can be evaluated by using measurable parameters that are codified in International standards like the ISO 3382-1 and recommendations from educational building guidelines. Following these requirements will ensure that the learning environment promotes effective communication between lecturer and learner, and reduce the chances of interruption which can affect learning or understanding (Long, 2014).

In recent years, universities have come to understand that the quality of the learning environment is an important factor in education, in addition to curriculum and teaching quality. Research has shown that poor classroom acoustics have been linked to decreased attention, decreased information retention, increased fatigue, and decreased academic achievements, specifically in large lecture facilities where speech needs to be communicated at a distance from the lecturer (Shield & Dockrell, 2008). Acoustic design is part of inclusive and equitable education, especially for students with hearing loss, who are non-native language speakers, and are sitting at the back of the lecture room, among whom are most vulnerable to the detrimental impact of poor speech intelligibility (World Health Organization [WHO], 2021).

While many Nigerian universities have committed greatly to the enhancement of lecture halls to cater for the increased population of students, relatively less attention has been directed towards assessing the compliance of lecture halls to the accepted acoustic design standards. The studies carried out in existing literature in Nigeria have been mainly thermal comfort, illumination, ventilation and building performance with a less attention on auditory architecture and speech intelligibility in higher education learning environments. However, empirical data on the acoustic performance of lecture halls in private universities such as Caleb University, Lagos state, is lacking.

With the rising enrollment and the need to enhance the teaching and learning environment, Caleb University has seen significant infrastructural growth. But the acoustical quality of its lecture halls, in terms of how well they offer to enable effective communication and learning has not been thoroughly assessed. Therefore, it is important to evaluate these rooms acoustically both objectively by design standards and subjectively by users' perception in order to identify any deficiencies and give recommendations for practical improvements. In view of the above, the study is an evaluation of the lecture hall acoustic design standards and speech intelligibility of Caleb University in Lagos State, Nigeria with a view to optimizing the acoustic design of the lecture halls in order to enhance quality education. The results will be used to benefit architects, acoustical consultants, university administrators and facility managers in creating and managing learning environments that will improve communication, student experience, and educational quality.

1.1 Aim and Objectives

The aim of this study is to evaluate the acoustic design standards and speech intelligibility of lecture halls at Caleb University, Lagos State, Nigeria, in order to optimize auditory architecture for quality education.

Objectives of the Study

The specific objectives of the study are to:

i. Assess the acoustic design characteristics of selected lecture halls at Caleb University, Lagos State, Nigeria.
ii. Evaluate the level of speech intelligibility in the selected lecture halls during teaching and learning activities.

iii. Examine students' and lecturers' perceptions of the acoustic quality and speech clarity within the lecture halls.
iv. Determine the relationship between lecture hall acoustic conditions and effective teaching and learning at Caleb University.
v. Recommend strategies for improving lecture hall acoustic performance in line with established acoustic design standards to enhance speech intelligibility and educational outcomes.

1.2 Problem Statement

The quality of lecture hall acoustics is a critical factor in achieving effective teaching and learning in higher education institutions. Lecture halls are primarily designed to facilitate verbal communication between lecturers and students, making clear speech transmission essential for comprehension, concentration, and academic performance. However, poor acoustic conditions, such as excessive background noise, prolonged reverberation time, inadequate sound insulation, and uneven sound distribution, can reduce speech intelligibility, increase listening effort, and negatively affect students' ability to understand lectures (Bradley & Sato, 2008). These acoustic deficiencies are particularly problematic in large lecture halls where students seated farther from the lecturer often experience greater difficulty in hearing and interpreting spoken information.

Research has consistently shown that poor acoustic environments can impair students' learning outcomes by reducing attention, increasing fatigue, and lowering information retention. Students who are non-native speakers, those with hearing difficulties, and those learning in overcrowded lecture halls are especially vulnerable to the effects of poor speech intelligibility (Shield & Dockrell, 2008). Despite the growing recognition of acoustics as an essential component of educational building performance, many higher education institutions continue to prioritize seating capacity and architectural aesthetics over acoustic quality during the design and construction of lecture halls (Long, 2014).

In Nigeria, rapid growth in student enrolment has resulted in increased pressure on university learning facilities, leading to the construction and expansion of lecture halls without comprehensive evaluation of their acoustic performance. Although considerable attention has been given to indoor environmental quality factors such as lighting, thermal comfort, and ventilation, limited empirical research has examined lecture hall acoustics and speech intelligibility within Nigerian universities. Consequently, there is inadequate evidence regarding the extent to which existing lecture halls comply with recognized acoustic design standards and effectively support communication between lecturers and students.

At Caleb University, Lagos State, continuous investment has been made in educational infrastructure to improve the learning environment. However, there is limited information on whether the acoustic design of the university's lecture halls provides adequate speech intelligibility for effective teaching and learning. Without such evaluation, deficiencies in acoustic performance may remain undetected, thereby reducing instructional effectiveness and students' academic experiences. This study therefore seeks to evaluate the acoustic design standards and speech intelligibility of selected lecture halls at Caleb University with a view to identifying existing challenges and providing recommendations for optimizing auditory architecture to support quality education.

II. LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature that is relevant to the study of the architecture for an auditory space, acoustics in lecture halls, standards for acoustics, speech intelligibility, and the effect of these on quality education. It also reviews the theoretical and empirical research on the acoustic performance of lecture halls and highlights the knowledge gap that would require this study.

2.2 Concept of Auditory Architecture

Auditory architecture is a new term for the conscious design and organization of buildings which are optimized in terms of acoustics to ensure maximum

acoustic comfort for listening, best speech communication and highest users' comfort. While other building performance attributes are concerned with visual and thermal comfort, auditory architecture is concerned with manipulating sound by means of suitable room geometry, material choice, sound absorption, insulation and diffusion. In educational facilities, an effective acoustic design helps the lecturer's voice be heard clearly by the pupils, and it helps to reduce unwanted background noise and reverberation (Long 2014). Studies indicate that lecture halls that are acoustically designed enhance students' learning outcomes, attention and speech intelligibility (Bradley & Sato 2008).

The standards for acoustic design in lecture halls are outlined in 2.3 Lecture Hall Acoustic Design Standards.

Acoustic design standards are measurable codes that are used to design lecture halls that facilitate effective verbal communication. The parameters that are important are reverberation time (RT), background noise level, speech transmission index (STI), sound insulation and room geometry. Standards like ISO 3382-1 suggest the appropriate reverberation time values for educational environments to guarantee good speech intelligibility and reduce sound distortion. Too many reverberations or background noises lead to speech intelligibility problems and put extra strain on students to listen to what is being said, which leads to less concentration and thus less academic performance (ISO, 2018; Long, 2014). Other factors also play a significant role in the acoustical characteristics of lecture rooms, such as the choice of sound absorbing materials, ceiling finishes, wall finishes and seating arrangements.

2.4 Speech Intelligibility and Quality Education

Speech Intelligibility refers to how clearly the word is understood and heard by the listener. Because teaching relies mainly on verbal communication, it is one of the most important factors in assessing acoustic performance in an educational environment. Poor speech intelligibility due to noise, echoes or poor room acoustics has been shown to impact students' comprehension, memory, participation in the classroom and academic performance (Shield & Dockrell, 2008). Insufficient acoustics conditions are particularly impacting to students who are seated towards the back of lecture halls, or those who have additional hearing impairments. Thus, enhancement of speech intelligibility is directly related to inclusive education and increased teaching effectiveness.

2.5 Indoor Environmental Quality and Acoustic Comfort

Thermal comfort together with lighting, ventilation and indoor air quality is one of the main contributors to the Indoor Environmental Quality (IEQ) as far as acoustic comfort is concerned. Asaju, Alagbe and Adetona (2023) conducted studies that showed that indoor environmental quality (IEQ) is an important factor that can affect the comfort of students and their academic performance in tertiary institutions and therefore it should be given the same importance as other environmental factors. Likewise, Asaju et al. have found that IEQ in education buildings impacts on user satisfaction and overall learning activity, while acoustics is one of the key parameters that needs to be evaluated in the building.

2.6 Theoretical Review

The Building Performance Theory developed by Preiser and Vischer (2005) forms the basis of this study. The theory suggests that the effectiveness of a building needs to be assessed from a users' functional, environmental and psychological perspective once it has been occupied. In the field of education, the theory contributes to the evaluation of lecture hall acoustic performance, which involves considering the perceptions of users in addition to acoustic criteria. Hence it can serve as an appropriate tool for assessing the intelligibility of speech and for determining areas of need for optimum auditory architecture.

2.7 Empirical Review

A number of empirical research studies have shown that the acoustics in lecture halls have a significant impact on the student's learning experience. Bradley and Sato (2008) showed that better classroom acoustics has resulted in better speech intelligibility and learning performance among students. In a similar context, Shield and Dockrell (2008) found that too much noise in the classroom had a negative

impact on students' concentration and academic performance.

In Nigeria, Asaju, Alagbe and Adetona (2023) studied the IEQ of lecture rooms and found that acoustic IEQ in addition to thermal comfort and lighting has a significant effect on the comfort and satisfaction of the students. Similar to the findings of the above studies, Asaju et al. (2026) also stressed the significance of acoustic conditions in the indoor environmental quality of naturally ventilated university lecture halls and proposed its inclusion in the evaluation of the educational building. Further, recent studies on the problem of auditoria in Nigerian universities have made reverberation and background noise of the auditoria to be identified as one of the major problems, with recommendations for incorporating acoustic design principles at the design stage.

2.8 Literature Gap

While there are several studies on IES in schools and students' comfort in school buildings, the acoustic design standards for lecture halls and speech intelligibility in private universities in Nigeria have not been studied in detail. Most of the current studies in Nigeria on the subject matter have been focused on thermal comfort, lighting, ventilation and overall indoor environmental quality, and minimal attention has been paid to the objective evaluation of auditory architecture. In addition, there is a lack of published data to evaluate if the lecture halls of the Caleb University in Lagos State are designed to meet the recommended acoustic design criteria and to offer adequate speech intelligibility for efficient teaching and learning. This study therefore aims at closing this gap, by evaluating the acoustic performance of selected lecture halls both on the basis of user perception and acoustic design standards, in order to make recommendations for enhancing the educational quality.

III. RESEARCH METHODOLOGY

3.1 Research Design

The design of this study was descriptive survey research design and the method of this study was Post-Occupancy Evaluation (POE) that was used to evaluate the acoustic performance of the lecture halls in Caleb University, Lagos State, Nigeria. According to Creswell and Creswell (2018), the descriptive survey design is suitable for this study as it allows data to be gathered from students and lecturers regarding their perceptions on lecture hall acoustics, speech intelligibility and overall suitability of the learning environment without manipulating the study variables. The POE approach offers a methodical way to assess the performance of an occupied building by analysing the extent to which it meets users' functional and environmental requirements after occupation (Preiser & Vischer, 2005).

The study also includes physical observation of lecture halls, taking into account the previously mentioned acoustic design aspects, such as room configuration, ceiling and wall finishes, sound-absorbing materials, seating arrangement and possible sources of internal and external noise, to complement the user's perception. This combined method allows to evaluate the acoustical properties of the chosen lecture halls from both a subjective and objective point of view.

It is the best research design for this study due to the study by Asaju, Alagbe and Adetona (2023) which used the Post-Occupant Evaluation framework to evaluate the indoor environmental quality of university learning environment. Their research showed that user perspectives of the building are a reliable source of data that can be used to improve performance of the building and the learning experience of the students in occupied educational buildings. Thus, descriptive survey and POE approach is found to be appropriate for this evaluation because of the standards of the acoustic design of the lecture hall at Caleb University and the intelligibility of speech.

3.2 Study Area

The study was carried out at Caleb University, Imota, Lagos State, Nigeria. Caleb University is an authorized private faith-based institution founded in the year 2007 by the National Universities Commission (NUC). The university has undergraduate and post-graduate courses in different colleges such as Environmental Sciences, Pure and

Applied Sciences, Arts, Social and Management Sciences and Education. The campus includes specially designed educational buildings like lecture halls, classrooms, laboratories, libraries, studios and seminar rooms, which serve educational, learning and research purposes.

The university has been continuously developing its infrastructures to meet the demands of its ever increasing student population and enhance the quality of education. These include lecture halls of different capacities, where lectures, seminars and academic discussions take place. The architectural design, seating layout, construction material, ventilation systems and acoustical properties of these lecture halls vary, allowing them to be used to test acoustic performance and speech intelligibility.

The study area was chosen as the Caleb University because of its efforts to create an ideal learning atmosphere and continuous investment in its educational facilities. In addition, the university offers a suitable environment to evaluate the degree of conformity with the recommended values of acoustic design for lecture halls, and the effectiveness of the verbal communication in the process of teaching and learning in the lecture halls. The study results are anticipated to give practical suggestions on the enhancement of the auditory architecture and the quality of education in the university and other higher education institutions in Nigeria.

3.3 Population and Sampling

The population of this study consists of all the undergraduate students and lecturers who use the selected lecture halls on regular basis at Caleb University, Lagos State Nigeria. It is estimated that the university has 5000 undergraduate students, who are the main users of the lecture halls and are the best ones to assess the intelligibility and acoustic conditions at lecture. Lecturers who are regular users of the selected lecture halls are also taken into account as they have a first-hand experience of the acoustic environment from the perspective of speech delivery.

The Yamane (1967) formula was used to determine a sample size of 370 undergraduate students at 95% confidence level with a 5% margin of error for a finite population. Besides, 20 lecturers were purposively selected who regularly use the selected lecture halls, making the sample of 390. In order to ensure adequate representation of students in the various colleges and levels of study, the stratified random sampling method was used, and the purposive sampling method was used for lecturers as a result of their direct teaching experience in the selected lecture halls. This mix of sampling methods will provide data from respondents with sufficient knowledge and experience of the acoustic conditions in the university's lecture rooms.

3.4 Instruments for data collection

The following research instruments were used in collecting data:

i. Structured Questionnaire: The main instrument used for data collection was structured questionnaire. It was given to students and lecturers to gather information about their perceptions of the acoustic quality of lecture halls, speech intelligibility, background noise, reverberation and overall satisfaction of the acoustic environment. The questionnaire adopted a five-point Likert scale for quantitative analysis of the opinions of the respondents (Creswell & Creswell, 2018).

ii. Assessment of the physical and acoustic characteristics of the lecture halls selected: An observation checklist was applied to the assessment of the physical and acoustic characteristics of the selected lecture halls. The checklist was limited to the features including room sizes, seating arrangement, ceiling height, wall and floor finishes, sound-absorbing materials, ventilation systems, public address systems, windows and doors, and internal/external sources of noise. This instrument gave objective data and information about the level of compliance of the lecture halls with the recommended acoustic design criteria.

iii. Acoustic Measurement Instrument (Sound Level Meter): The ambient sound level within the selected lecture halls was measured at lecture time with the instrument known as Sound Level Meter (SLM). Objective sound pressure level (dB) assessment of background noise and speech

intelligibility was achieved with the instrument. A wide range of recommendations exist for the use of sound level meters in the evaluation of the acoustic performance of educational spaces in architectural acoustic studies (Long, 2014).

iv. Photographic Documentation: Photographs of the chosen lecture halls were captured to document the architectural features, seating configurations, acoustic treatments and overall physical condition of the lecture halls. The photographs helped to support the observation findings and to support the evaluation of the lecture halls.

Using these instruments, both subjective (users' perception) and objective (physical observations and acoustic measurements) data was obtained, thus providing a full evaluation of the acoustic performance and speech intelligibility of the lecture hall.

3.5 Validity and Reliability

Validity

Some of the research instruments were validated by experts. The project supervisor and experts on research methodology, Architecture and Building Science, reviewed the questionnaire, observation checklist, and acoustic measurement procedures to assure that the instruments were appropriate for measuring lecture hall acoustic quality, speech intelligibility and compliance with acoustic design standards. Their observations and recommendations were used for the clarity, relevance and content validity of the instruments prior to data collection (Creswell & Creswell, 2018).

Reliability

To ensure reliability, a pilot study was carried out using a small sample of students and lecturers from a university that were not part of the study but had similar characteristics to that of Caleb University. The Cronbach's Alpha was used to analyze the responses that were obtained from the questions to establish the internal consistency of the instrument. The reliability coefficient of 0.70 or higher was deemed acceptable, thus the questionnaire was reliable for the main study (Taber, 2018). In addition, the Sound Level Meter was calibrated according to the manufacturer's specifications before use to ensure the accuracy and consistency of the acoustic measurements.

3.6 Method of Data Analysis

The collected data from the questionnaires, observation checklist and acoustic measurements were analyzed by using descriptive and inferential statistical techniques using the aid of the Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive data such as frequencies, percentages, mean scores and standard deviation scores were used to describe the demographic information of the respondents and to analyse their perception of acoustic quality of the lecture hall and their speech intelligibility. The level of agreement on each questionnaire item was determined by their mean scores, and the acoustic measurements taken by the Sound Level Meter were compared with the recommended acoustic design standards to evaluate the performance of the selected lecture halls (Long, 2014).

Pearson Coefficient Product Moment Correlation (PPMC) was used to find the correlation between lecture hall acoustic conditions and effective teaching and learning at 0.05 level of significance (α). The subjective responses and objective acoustic measurements were combined to give a complete picture of the acoustic performance of the lecture halls, as is recommended in the Post-Occupancy Evaluation (POE) of educational buildings (Preiser & Vischer, 2005). As in other studies, Asaju et al. (2023), Alagbe and Adetona (2023) use an analytical approach to assess the indoor environment in a university learning environment.

3.7 Ethical Considerations

Great care was taken to adhere to ethical standards throughout the research process, proactively protecting the rights of the subjects and the integrity of the research. Before collecting the data the permission letter was secured from the relevant authorities of Caleb University. Furthermore, all participants were told about the aim of the study and their informed consent was requested prior to the administration of questionnaires and the observations. The participation was voluntary, and the respondents were given details on their right to

withdraw at any time without any repercussions (Creswell & Creswell, 2018).

All information gathered was anonymous and confidential, and respondents did not have to provide their names or any personal identifiers, and was only used for academic purposes. All information gathered was kept confidential and reported in a summary, so as to avoid identification of any participant. Besides, ethical guidelines were followed for educational research, as the acoustic measurements and observation were conducted without interfering with the normal teaching and learning activities. Following these ethical values helped the study results to be credible, reliable and acceptable (Resnik, 2020).

IV. RESULTS AND DISCUSSION

4.1 Demographic profile of respondents

This chapter presents the analysis of data collected for the study titled "Optimizing Auditory Architecture for Quality Education: An Evaluation of Lecture Hall Acoustic Design Standards and Speech Intelligibility at Caleb University, Lagos State, Nigeria." A total of 390 questionnaires were administered and successfully retrieved, representing a 100% response rate. The data were analyzed using frequencies, percentages, mean scores, standard deviations, and rankings in line with the study objectives.

4.2 Demographic Characteristics of Respondents

Table 4.1 Gender Distribution (N = 390)

Gender	Frequency	Percentage (%)
Male	214	54.9
Female	176	45.1
Total	390	100.0

Discussion

Table 4.1 shows that 214 respondents (54.9%) were male, while 176 respondents (45.1%) were female. The result indicates that both genders were adequately represented, with a slight predominance of male respondents.

Table 4.2 Age Distribution

Age	Frequency	Percentage (%)
Below 18 years	16	4.1
18–20 years	119	30.5
21–25 years	201	51.5
Above 25 years	54	13.9
Total	390	100.0

Discussion

The majority of respondents (201; 51.5%) were between 21 and 25 years, followed by 119 respondents (30.5%) aged 18–20 years. Only 16 respondents (4.1%) were below 18 years, while 54 respondents (13.9%) were above 25 years. This indicates that most respondents were within the active undergraduate age bracket.

Table 4.3 Status of Respondents

Status	Frequency	Percentage (%)
Student	370	94.9
Lecturer	20	5.1
Total	390	100.0

Discussion

Table 4.3 indicates that the majority of respondents (370; 94.9%) were students, while 20 respondents (5.1%) were lecturers. This distribution is appropriate because students are the primary users of lecture halls, while lecturers provide valuable insights based on their teaching experience.

Table 4.4 College Distribution

College	Frequency	Percentage (%)
Environmental Sciences	78	20.0
Arts, Social & Management Sciences	145	37.2
Pure & Applied Sciences	98	25.1
Education	46	11.8

College	Frequency	Percentage (%)
Others	23	5.9
Total	390	100.0

Discussion

Respondents were drawn from different colleges across the university. The highest proportion (145; 37.2%) belonged to the College of Arts, Social and Management Sciences, followed by the College of Pure and Applied Sciences (98; 25.1%). The distribution demonstrates that the study captured opinions from diverse academic disciplines.

Table 4.5 Level of Study (Students Only)

Level	Frequency	Percentage (%)
100 Level	74	20.0
200 Level	94	25.4
300 Level	91	24.6
400 Level	74	20.0
500 Level	37	10.0
Total	370	100.0

Discussion

Among the student respondents, 200 Level students (25.4%) constituted the largest group, closely followed by 300 Level students (24.6%). Students from all academic levels participated, ensuring that opinions were obtained from users with varying degrees of experience using the university's lecture halls.

Table 4.6 Frequency of Lecture Hall Usage

Frequency of Use	Frequency	Percentage (%)
Daily	229	58.7
Several times weekly	101	25.9
Once weekly	39	10.0
Occasionally	21	5.4
Total	390	100.0

Discussion

The majority of respondents (229; 58.7%) reported using lecture halls daily, while 101 respondents (25.9%) used them several times each week. This indicates that most respondents had regular exposure to the acoustic conditions of the lecture halls, making their responses reliable.

Table 4.7 Most Frequently Used Lecture Hall

Lecture Hall	Frequency	Percentage (%)
Main Lecture Theatre	153	39.2
College Lecture Hall	122	31.3
Studio/Laboratory Lecture Hall	49	12.6
Seminar Room	41	10.5
Others	25	6.4
Total	390	100.0

Discussion

The findings show that the Main Lecture Theatre was the most frequently used learning space (39.2%), followed by College Lecture Halls (31.3%). This reflects the heavy use of large lecture halls for general courses and university-wide academic activities.

Demographic Characteristics Summary

The demographic results show that the respondents were mostly undergraduate students and some lecturers were also included. The number of respondents was larger for males, but the numbers were approximately equal for male and female respondents. The majority of the respondents (76.9%) were aged between 21 and 25 years, which is the age group of the active university population. The respondents were taken from various colleges and various levels of study with the largest group consisting of 200 and 300 level students. In addition, most of the respondents were using the lecture halls on a daily basis and most often, Main Lecture Theatre and College Lecture Halls were the ones that were being used the most. This is a diverse and experienced sample that helps to add weight to the results and offers a solid foundation for determining lecture hall acoustic design standards and speech intelligibility at Caleb University.

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Even with these positive results, some of the respondents felt that the main acoustic problems encountered were background noise, reverberations and public address system limitations. Thus, they suggested that measures should be taken to enhance sound absorption materials, upgrade audio systems, reduce external noise, and periodically evaluate the acoustics.

Finally, the chapter confirms that by using the best acoustic design standards and good facility management practice, the speech intelligibility of the Caleb University auditory architecture can be optimized, which will lead to better students' learning experience and better quality of education.

4.3 Assessment of Lecture Hall Acoustic Design (Objective One)

This section presents the respondents' assessment of the acoustic design characteristics of the selected lecture halls at Caleb University, Lagos State, Nigeria. The responses were measured using a 5-point Likert scale,

where:
5 = Strongly Agree (SA)
4 = Agree (A)
3 = Neutral (N)
2 = Disagree (D)
1 = Strongly Disagree (SD)

A mean score of 3.00 and above indicates agreement that the lecture hall possesses satisfactory acoustic design characteristics, while a mean score below 3.00 indicates dissatisfaction.

Table 4.8 Assessment of Lecture Hall Acoustic Design (N = 390)

S/N	Statement	SA	A	N	D	SD	Mean	SD	Decision
8	The lecture halls have adequate sound distribution.	122	156	47	38	27	3.79	1.02	Agree
9	The lecture halls have appropriate room size and shape for good acoustics.	114	149	56	43	28	3.71	1.05	Agree
10	The seating arrangement allows me to hear the lecturer clearly.	126	151	45	40	28	3.79	1.03	Agree
11	The wall and ceiling finishes help reduce echoes.	89	148	62	58	33	3.52	1.11	Agree
12	Background noise from outside rarely affects lectures.	82	135	61	71	41	3.37	1.18	Agree
13	Public address systems function effectively during lectures.	118	146	52	45	29	3.72	1.04	Agree
14	The lecture halls provide an acoustically comfortable learning environment.	121	150	49	42	28	3.75	1.02	Agree

Table 4.9 Ranking of Lecture Hall Acoustic Design Attributes

Rank	Acoustic Design Attribute	Mean
1	Adequate sound distribution	3.79
1	Seating arrangement enhances hearing	3.79
3	Acoustically comfortable learning environment	3.75
4	Effective public address system	3.72
5	Appropriate room size and shape	3.71
6	Wall and ceiling finishes reduce echoes	3.52
7	Background noise rarely affects lectures	3.37

Discussion of Findings

Table 4.8 presents the results with the general outlook being favourable in terms of the acoustic design of the selected lecture halls at Caleb University with all the variables tested having their mean scores exceeding the benchmark value of 3.00.

Both sound distribution and the seating arrangement that provides students good opportunity to hear the lecturer were rated highly with a mean score of 3.79 for each. This indicates that the architecture for the lecture halls and the distribution of sound in general are suitable for effective verbal communication in lectures. Sitting arrangements and sound distribution are crucial to allow students to hear the lecture irrespective of their position in the lecture hall.

The respondents also concurred that the lecture halls are acoustically comfortable for learning (Mean = 3.75) and the public address systems are effective during lectures (Mean = 3.72). The results reveal that the current sound reinforcement systems can generally provide acceptable speech transmission in the larger lecture halls, particularly those with a large number of attendees and where sound amplification is required.

The mean score for the statement regarding the size and shape of the room for good acoustics was also favourable (3.71), suggesting that the respondents felt that the architectural set up of the lecture halls was reasonably good for speech communication.

However, somewhat lower ratings were given for wall and ceiling finishes that minimise echoes (Mean = 3.52) and the statement that the outside background noise rarely affects lectures (Mean = 3.37). Based on these results, it is concluded that the acoustic conditions in the lecture halls are satisfactory in general, but there are still acoustic problems that may arise such as the intrusion of external noise and inadequate acoustic finishes in some of the lecture halls. This can make speech less intelligible and can make it harder to hear, especially during the peak hour and when outdoors.

In general, the results show that the lecture halls have a good acoustic design property, which support teaching and learning. However, acoustic improvement, noise control, and other treatment and control measures would further enhance the speech intelligibility and make the auditory learning environment more favorable.

Summary of Objective One

The first aim of the study was to determine the acoustic design features of the selected lecture halls of the Caleb University.

The results showed that:
Most of the respondents agreed that the lecture halls have satisfactory acoustic design characteristics.

The top rated acoustic attributes were sound distribution and seating arrangement.

The acoustics (P.A. systems) and acoustics comfort were also favorably assessed.

Wall and ceiling finishes for background noise control and echo reduction were rated relatively low and were identified as an area that needs improvement.

The mean scores for all assessed variables were above 3.00, showing that the acoustic surroundings in the lecture halls is generally suitable for teaching and learning.

The results indicate that the lecture halls are acoustically functional, but can be further optimized in terms of sound insulation, acoustical finishes and external noise control, which will enable better performance and speech intelligibility for lecturers and students.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study tested the acoustic design criteria as well as speech intelligibility of the lecture halls in Caleb University, Lagos State, Nigeria for optimum acoustic design for enhanced speech intelligibility in the quest for quality education. The results indicated that the acoustical characteristics in the selected lecture halls are generally satisfactory to facilitate teaching and learning. The sound distribution, seating arrangement, the room configuration and sound systems were found to be positively perceived by the respondents thus facilitating satisfactory speech communication during lecture.

The study also determined that students' learning experiences and learning engagement were greatly influenced by speech intelligibility. It was observed that when speech was clear, concentration was better, classroom interaction, comprehension and overall teaching effectiveness were better. The results also indicated problems of background noise, reverberation, insufficient acoustic treatments and sometimes the inefficiency of the sound reinforcement system, which resulted in a poor level of speech clarity and consequently impaired learning, especially in large lecture rooms or rooms with poor acoustical characteristics.

The study also revealed that other acoustic parameters, such as background noise level, room acoustics and the number of people in the lecture hall, the acoustic properties of the walls and ceilings, the room geometry, and the performance of the public address system, have a significant effect on the acoustics of lecture halls. The results highlight the need to bring acoustic design considerations into play as a key part of the design, construction, and operation of educational built environments rather than as an adjunct.

The study thus concludes that the overall ambience of the lecture halls of Caleb University is conducive to teaching and learning in the general sense, but there is need for continuous improvement in matters of acoustic design and maintenance of the facilities in order to achieve the best speech intelligibility. Through regular acoustic evaluations, the installation of sound absorption materials, the improvement of audio systems, the effective control of external noise and the application of recognized acoustic design specifications, the acoustic comfort and educational value will be greatly improved. These measures will enhance the learning experiences of students and help to promote effective knowledge delivery across all HEIs, while also contributing to the creation of more functional and sustainable learning environments.

5.2 Recommendation

Based on the results of this study, the following recommendations are made to enhance the acoustic performance and intelligibility of speech in lecture halls at Caleb University, Lagos State, Nigeria:

1. Periodic Post-Occupancy Evaluations (POE) of the lecture halls should be held by the university management to detect the acoustic deficiencies of the lecture halls and to take the necessary corrective measures at the earliest opportunity.
2. Acoustic ceiling panels, wall absorbers, acoustic curtains, carpets and other sound-absorbing materials should be added to existing and new lecture halls to minimize reverberation and enhance speech intelligibility.
3. The public address and sound reinforcement systems should be upgraded and periodically serviced to provide even sound coverage and intelligible speech communication, especially in large lecture theatres.
4. The external and internal noise sources shall be effectively controlled by adopting the appropriate building materials, sound insulation measures such as acoustic doors, double glazed windows and minimizing activities that create excessive noise around lecture halls during lectures.
5. Ideal acoustic design requirements, such as recommended reverberation times, background noise limits, and speech intelligibility requirements, should be incorporated into the design of new educational buildings, and should be ones commonly used by architects and building professionals throughout the world.
6. The number of students in the lecture hall must be controlled to ensure that it is not too large, and that it does not lead to a deterioration in the quality of speeches heard or in listening comfort for the students. Increase size of lecture areas as necessary to meet rising enrollment.
7. Lecture halls should have a regular maintenance schedule set up by the University facility managers to keep acoustic finishes, sound systems, doors, windows, and ventilation systems working properly and effective for good communication.

8. The awareness programs should be arranged for lecturers and students about the importance of establishing a conducive acoustic environment: limiting unnecessary conversations and noises during lectures.
9. Educational building projects planned, designed and constructed in Caleb University should go by the auditory architecture principle, which means the inclusion of acoustic consultants in the planning, design and construction process in order to secure the compliance of the building project to the accepted standards for acoustic performance.
10. More research work is needed in other Universities in Nigeria with objective acoustic parameters (reverberation time, Speech Transmission Index (STI), Background noise level assessments) to give a wider evidence of how to improve learning environments in Higher education Acoustics.

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