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ARCHITECTURAL DESIGN ELEMENTS AND SECONDARY SCHOOL STUDENTS' ACADEMIC PERFORMANCE IN AKWA IBOM STATE

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ABSTRACT

Purpose: This study examines how architectural design elements influence students' academic performance in public and private secondary schools in Akwa Ibom State, Nigeria. It focuses on three domains: physical learning environment, spatial organisation, and technology integration.

Methodology: A mixed-methods concurrent embedded design was used, with an ex post facto descriptive-correlational quantitative strand. Data came from structured questionnaires administered to 1,816 SS3 students in 227 schools selected through multi-stage sampling, supported by observation checklists, photographs, and six years of WASSCE records (2019–2024). Data were presented using descripted statistical methods and analysed using ANOVA, Pearson correlation, and multiple and moderated regression.

Findings: Natural lighting and openable windows were universal, but private schools had significantly better provision of ICT infrastructure, collaborative spaces, and recreational areas. Private schools also achieved higher WASSCE performance (81.30% vs. 75.30%). The regression model explained 57.9% of the variance in performance, with recreational areas, smart-boards, collaborative learning spaces, reliable Wi-Fi, and sufficient classroom space as significant predictors. School type remained significant factor determining how architectural design elements influenced student academic performance.

Research Limitations/Implication: The cross-sectional design showed clearly, associations between architectural design elements and academic performance, but not causal effects or changes over time.

Practical Implication: Planners should prioritise high-impact elements, upgrade ICT and collaborative facilities in public schools, and adopt climate-responsive design standards with regular audits.

Originality: The study integrates physical, spatial, and technological design domains in a single public–private comparison in Akwa Ibom State, a region underrepresented in school design research.

Keywords: School architecture; academic performance; technology integration; public–private schools; Nigeria.

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1. INTRODUCTION

Education underpins individual development and societal advancement by equipping learners with the knowledge, skills, and attitudes needed for personal growth and national progress (Barrett *et al*., 2018) and the global discourse has shifted from access to schooling toward the quality of learning outcomes (Omolo *et al*., 2020). This shift is captured in the Sustainable Development Goal 4, which calls for inclusive and equitable quality education and lifelong learning for all (UNESCO, 2021; United Nations, 2015). Even so, educational deprivation persists, particularly in low- and middle-income countries. In countries such as Nigeria, over 50% of 10-year-old children cannot read and comprehend a simple text (UNICEF, 2020), revealing a gap between schooling and actual learning. This "learning crisis" is worsened by inadequate infrastructure and poor learning environments.

The problem is acute in Nigeria. The World Bank's (2022) Service Delivery Indicators report shows that private secondary school students outperform their public school peers by as much as 20 percentage points in basic literacy and numeracy. The gap is linked to teacher attendance (about 87% in private schools versus 58% in public schools) and to differences in classroom conditions and infrastructure quality. These findings suggest that, beyond pedagogy, the quality of the built environment may play a critical role in academic performance.

Governments and stakeholders are therefore responsible for providing conducive, well-equipped learning environments. The Nigerian Constitution (Section 18, 1999) requires equal and adequate educational opportunities at all levels, and the World Health Organization (2021) affirms that improving the physical school environment, for example, through green spaces and structured physical activity, enhances cognitive outcomes, reduces absenteeism, and improves achievement. Creating high-quality educational infrastructure is thus a shared responsibility of policymakers, architects, educationists, and researchers (Barrett *et al*., 2019). Barrett *et al*. (2019) stress that school design should prioritise accessibility and functionality, and that improving ventilation, lighting, acoustics, and outdoor space is a strategic investment in learning outcomes and equity.

Education in Nigeria is delivered through formal and informal systems, with formal schooling in public or private institutions across primary, secondary, and tertiary levels (Nwankwo and Godwin, 2021). Public schools are established, funded, and managed by government, whereas private schools are funded mainly by their proprietors (Chigbo, 2022). This study focuses on secondary education, a pivotal phase that prepares students for tertiary education or employment (Emordi, 2024), and compares public and private secondary schools in Akwa Ibom State. Akwa Ibom reflects the national picture: despite government efforts, public secondary schools remain under-resourced (Ojo, 2023; Terhemba *et al*., 2021). Public schools in many parts of Nigeria suffer from aging infrastructure, overcrowded classrooms, inadequate maintenance, and poor access to modern teaching technologies (Ogunode, 2021; Bashar and Yasin, 2020). These shortcomings are widely believed to create suboptimal learning conditions, widen educational inequalities, and erode public confidence in state-funded infrastructure (Ehigiamusoe, 2012; Udoudo and Akpanobong, 2020). Private schools, by contrast, generally appear to offer better physical facilities, smaller classes, and greater access to technology, which increases their appeal to parents (Chigbo, 2022; Ogunode, 2021).

Students spend nearly one-third of their day in school (Ma'bdeh and Al-Khatatbeh, 2019; Ukpong *et al*., 2022), so the physical and spatial characteristics of schools cannot be treated as peripheral. Classrooms are the primary instructional "cells" and the focal point for judging how built form supports or hinders cognitive processes. School design must therefore be approached as "Pedagogical Architecture", a specialised field whose requirements exceed those of conventional residential or commercial buildings. Schools are complex socio-technical ecosystems that shape students' well-being and social development, so their design influences both academic achievement and holistic growth.

This calls for collaboration among architects, educators, and policymakers to create fluid learning spaces. Architectural elements, from the passive physical characteristics of the building (Barrett *et al*., 2019) to flexible learning spaces and integrated digital affordances (Manca *et al*., 2020; Makeremi *et al.*, 2024), are critical determinants of school climate. Treating technology as an inherent architectural element rather than an add-on allows design to better shape the cognitive and social atmosphere of the school.

The study draws on a synthesis of contemporary literature. Baafi (2020) argued that the quality of the school physical environment is a core determinant of academic engagement. Barrett *et al*. (2019), in a large-scale empirical study, showed that "naturalness" factors such as lighting, air quality, and spatial organisation account for a significant share of variation in students' academic progress. Manca *et al*. (2020) highlighted the convergence of spatial design and digital infrastructure and the need for flexible, technology-responsive environments. In a developing context, Onwuka and Nwogu (2024) identified persistent infrastructural inequalities between public and private schools that shape learning conditions and outcomes. Makeremi *et al*. (2024) called for context-sensitive frameworks that integrate environmental quality, spatial configuration, and digital affordances, particularly in the global South.

Building on these studies, the current study organised architectural design elements into three interrelated domains. The physical learning environment covers sensory factors such as lighting, thermal comfort, ventilation, and acoustics, which affect comfort, concentration, and engagement (Baafi, 2020; Barrett *et al*., 2019). Spatial Organisation refers to the configuration and connectivity of classrooms, shared areas, and outdoor spaces, which influences movement, interaction, and usability (Barrett *et al*., 2019). Technology Integration concerns the presence and use of digital infrastructure, which improves access to information, supports interactive learning, and accommodates diverse instructional approaches (Mdhlalose and Mlambo, 2023).

Academic performance, typically assessed through standardised examinations and continuous assessment (Liem, 2019; Romuald, 2023), has been widely linked to environmental quality. Barrett *et al*. (2019) reported that optimal conditions, particularly daylighting and thermal comfort, can improve academic progress by up to 16%. Imms and Cleveland (2020) found that flexible spatial arrangements promote collaboration and peer engagement. Studies by ASHRAE (2023), Figueiro *et al*. (2021), Herman (2015), and Oruikor (2023) reinforce the importance of acoustics, ventilation, and layout, while Mdhlalose and Mlambo (2023) and Oruikor (2023) show that digital infrastructure aligned with instructional goals, enhances engagement and performance.

Despite this recognition, gaps remain in understanding how specific architectural features affect student performance in Nigeria. Bashar and Yasin (2020) documented serious deficiencies in public secondary school facilities and noted that private schools generally have stronger, better-maintained infrastructure. Chigbo (2022) linked the private-school advantage to superior architectural quality. However, these studies examine infrastructural disparities in general terms and offer limited insight into how specific elements, such as spatial configuration and technology integration, drive differences in performance. Evidence from Akwa Ibom State is also scarce, and rigorous comparative analysis is lacking. Therefore, a context-specific, disaggregated study is needed to guide evidence-based interventions.

Concerns about the quality of Nigerian secondary education have serious implications for individual and national development. Research has examined teacher effectiveness, curriculum implementation, and administrative practices, but far less attention has gone to architectural design elements, even though global evidence suggests well-designed environments are core determinants of engagement, focus, and cognitive achievement (Barrett *et al.*, 2019). In Nigerian literature, built environment factors are often treated as secondary variables, and where they are studied, it is usually in isolation, such as lighting or ventilation alone. The combined influence of the physical learning environment, spatial organisation, and technology integration is rarely considered. This fragmented approach obscures how the built environment holistically shapes the student

experience and lacks the design-specific depth needed to examine pedagogical architecture.

There is also a widespread perception that private secondary schools inherently offer better infrastructure and therefore better outcomes (Bashar and Yasin, 2020; Chigbo, 2022). The perception drives parental preference and private investment, but its validity in Akwa Ibom State is uncertain, as local observation suggests some private schools lack facilities found in established public institutions. Moreover, no locally grounded studies assess how the architectural domains collectively influence performance in high-stakes examinations such as West African Senior School Certificate Examination (WASSCE) and Unified Tertiary Matriculation Examination (UTME). This lack of data weakens educational planning, resource allocation, and policy, and may cause infrastructure efforts to be misdirected and inequalities between public and private schools to deepen.

This study therefore investigates how specific architectural design elements influence students' academic performance in public and private secondary schools in Akwa Ibom State. Using a structured, comparative approach, it aims to generate context-specific evidence to inform policy, guide targeted architectural interventions, and promote more equitable and effective learning environments.

1.1. Research Hypotheses

The following null hypotheses were formulated:

i. H_{01}: There is no significant difference in the availability of architectural design elements between public and private secondary schools in Akwa Ibom State.

ii. H_{02}: There is no significant relationship between architectural design elements and students' academic performance.

iii. H_{03}: Architectural design elements make no significant contribution to the performance disparities between public and private secondary schools.

1.2. Significance and delimitation of the study

The study addresses three gaps in the literature: the limited treatment of architectural design elements as independent determinants of academic performance, the fragmented analysis of these elements in isolation rather than as an integrated system, and the lack of context-specific empirical evidence comparing public and private secondary schools in Akwa Ibom State. Although international research increasingly highlights the influence of the physical learning environment on outcomes, evidence from the current study area remains scarce. By examining this underexplored relationship, the study offers a more nuanced understanding of architectural design as a determinant of academic achievement.

The study also has practical relevance for educational planning and infrastructure development. By identifying the elements that most strongly influence performance, its findings provide an evidence base for designing, constructing, and upgrading secondary school facilities, which matters where infrastructure disparities between public and private institutions persist and affect quality and equity.

Theoretically, the study advances discourse at the intersection of architecture and education. Situating the analysis within the socio-cultural and economic context of Akwa Ibom State yields context-sensitive insights that may refine existing frameworks on the built environment and learning outcomes, and the comparative dimension shows how variations in design provision relate to differences in performance across school types.

The study examines the relationship between architectural design elements and academic performance in public and private secondary schools in Akwa Ibom State, focusing on SS3 classes and drawing on a representative sample of senior secondary schools. The design elements examined are the physical environment, spatial organisation, and technology integration. Academic performance is assessed using WASSCE results, giving a contemporary view of achievement trends. Data sources include student surveys, evaluations of school design features, and academic records,

covering qualitative and quantitative variables such as architectural indices, survey responses, and performance metrics.

Although performance is shaped by many factors, including teacher quality, socioeconomic status, and access to learning resources, the study deliberately focuses on the architectural and environmental dimensions of school design to give targeted insight into how spatial and infrastructural qualities affect outcomes. It adopts a descriptive and comparative design using cross-sectional data from multiple schools at a single point in time. No experimental manipulation was involved, so conditions were observed ethically and without disruption. Descriptive and correlational techniques were used, focusing on patterns and associations rather than causality.

2. LITERATURE REVIEW

2.1. Overview of Architectural Design Elements in Secondary Schools

School design shapes the quality of the learning environment and influences student outcomes and teacher satisfaction (Marquez, 2019). Once regarded as mainly an aesthetic or structural matter, it is now recognised as functionally important for effective learning, collaboration, and well-being (Ariani and Mirdad, 2016; Keiser, 2024; Makaremi *et al*., 2024). Specific elements shown to matter include natural light (Heschong Mahone Group, 1999), flexible layouts and movable furniture (Higgins *et al*., 2005), supportive technology (Oruikor *et al*., 2023; Li and Ma, 2019), functional common areas and outdoor spaces (Barrett *et al*., 2018), and accessible resource centres such as libraries and ICT centres (Ikegbusi *et al*., 2022).

Drawing on literature from 1999 to 2024, the study classifies architectural design elements into three categories: physical learning environment, spatial organisation, and technology integration. Brown *et al*. (2020) stress the need to integrate digital and physical dimensions, and Onwuka and Nwogu (2024) support the framework's relevance in Nigeria, where infrastructural disparities between public and private schools (Bashar and Yasin, 2020) call for a multi-dimensional rather than fragmented approach.

2.1.1 The physical environment

This covers lighting, thermal comfort, ventilation, air quality, and acoustics (Baafi, 2020; Barrett *et al*., 2018), which shape the sensory experience of students and teachers. For lighting, high-performance glazing, clerestories, and bilateral windows deliver visual comfort and remove dark zones (Barrett *et al*., 2019; Pellegrino *et al*., 2022). A window-to-floor ratio of at least 20% supports well-being (Annesi-Maesano and Annesi-Maesano, 2016), while a Window-to-Wall Ratio above 40–45% risks thermal stress and glare (De Luca, 2020), so external shading is needed. In tropical climates like Akwa Ibom, passive cooling through clerestory extraction, perforated walls, reflective roofing, and shaded corridors reduces stagnant air, a cause of fatigue and inattention (Makaremi *et al*., 2024; Alozie, 2020; Baafi, 2020). Acoustic design relies on sound-absorbing materials, partitions, and siting classrooms away from noise sources, with buffers such as walls or vegetation (ICC, 2017; Agaja and Akande, 2024).

2.1.2 Spatial organisation.

This is the deliberate arrangement of indoor and outdoor spaces to support teaching, movement, and interaction (Barrett *et al*., 2018; Cheryan *et al*., 2014). Effective classrooms offer movable furniture, enough space to avoid overcrowding, and adequate storage (Higgins *et al*., 2005; Oruikor *et al*., 2023), while good circulation reduces congestion (Ghazvini and Khajehpour, 2011). Communal zones such as libraries, dining areas, and halls act as nodes in a collaborative learning ecosystem (Tondeur *et al*., 2017; Lennertz, 2018; Marchand *et al*., 2023). Outdoor spaces are dynamic learning zones that support physical, mental, and cognitive development (Mygind *et al*., 2019; Reuben *et al*., 2020).

2.1.3 Technology integration.

Digital tools and smart infrastructure are now embedded in the learning environment, forming a "learning ecosystem" in which physical and digital space work as one (Brown *et al*., 2020). Key components include computer labs, interactive displays, and reliable Wi-Fi, together with architectural planning such as flexible layouts and dedicated technology zones (Tondeur *et al*., 2017; Keiser, 2024; Li and Ma, 2019; Makaremi *et al*., 2024).

2.2. Academic Performance in Public and Private Schools

Academic performance is a multidimensional construct measured through standardised scores, Grade Point Averages (GPA), attendance, and completion rates (Ma *et al*., 2024), and it reflects the interaction between learner engagement and educational inputs, including the school's architectural characteristics (Makaremi *et al*., 2024; Oruikor *et al*., 2023). It differs from academic success, which is broader and longer term (Adewale *et al*., 2021; Kumar *et al*., 2021). Functional facilities predict achievement on standardised tests (Odeajo and Odefadehan, 2022), GPAs are sensitive to school climate (OECD, 2020; Uline and Woolner, 2021), and daylighting, ventilation, acoustics, and technology reduce health-related absenteeism (Uline and Woolner, 2021). In Nigerian public schools, absenteeism often reflects classroom heat and noise (Okolie *et al*., 2024), and modern facilities improve completion rates (Santika, 2021; Uline and Moran, 2018).

Private schools are widely associated with better outcomes because of lower student-teacher ratios and better infrastructure (UNICEF, 2020; World Bank, 2022), but school type is not the only factor. Governance, teacher quality, and parental involvement mediate the relationship (Apeh and Nteh, 2023; Ogunode and Yusuf, 2025), and well-resourced public schools, often aided by the Universal Basic Education Commission (UBEC), can match private performance (Nnamani and Ugoji, 2020; Okolie and Eze, 2019). Teacher quality (García and Weiss, 2020; Hattie, 2023) and socioeconomic status (Reardon, 2021; UNESCO, 2024) are major influences. The study therefore set as controls, gender, school location, school size, school age, and boarding status to isolate the effect of design. Gender affects sensitivity to heat and noise (Manca *et al*., 2020); location captures infrastructure and maintenance advantages (Ashameri, 2021; Okolie *et al*., 2024); size and age affect crowding and design relevance (Barrett *et al*., 2019; Leander and Bolden, 2020); and boarding status determines the "environmental dosage" of exposure to school facilities (Uline and Woolner, 2021).

Comparative studies attribute the public-private gap to resource allocation, management, and physical environment quality (Onwuka and Nwogu, 2024; World Bank, 2022; Ma *et al*., 2024). Private schools, with more flexible funding, can invest in thermal comfort, acoustics, and digital infrastructure (Makaremi *et al*., 2024), while public schools face deteriorating conditions that reduce concentration and performance (Iqbal and Khan, 2012; Okolie *et al*., 2024; Odeajo and Odefadehan, 2022). The evidence is contested. Lubienski and Lubienski (2006) found a private advantage among over 60,000 US students, but Larsen *et al.* (2022) and Ma *et al.* (2024) found it disappears once socioeconomic status and prior achievement are controlled. Onwuka and Nwogu (2024) argue the Nigerian gap reflects uneven distribution of inputs such as technology-integrated spaces rather than ownership. Longitudinally, Jeynes (2003) and Shakeel and Wolf (2021) reported higher private graduation rates, increasingly linked to positive school climate (Lobo, 2023; Makaremi *et al*., 2024). In Nigeria, private schools gain a "double advantage" by using better environments to attract teachers (Ehigiamusoe, 2012; Owoeye and Yara, 2011), and in Akwa Ibom private students outperform public peers (Akpan, 2015; Udo, 2018). This study goes further by isolating specific design elements as determinants of the gap.

2.3. Relationship between Design Elements and Academic Performance

School buildings actively mediate learning through their physical features, spatial organisation, and technology (Parmalee, 2024; Blackwell and Yaneva, 2024; Giron, 2025). Good design reduces cognitive load through visual and thermal comfort (Kükrer

and Eskin, 2021), limits distraction through acoustic control (Fretes and Palau, 2025; Shield and Dockrell, 2003), and fosters belonging (Mygind *et al.*, 2019), whereas poor design causes stress, fatigue, and disengagement (Edene and Eghomwanre, 2023; Ma *et al*., 2021). In Akwa Ibom, heat, humidity, glare, and unequal access to technology (Adedayo and Akinyemi, 2020; Adewale and Akinola, 2020) amplify the effect of design decisions.

Physically, daylight improves mood and alertness. Thermal comfort in the 20–25°C range supports focus (Okafor *et al*., 2025; Ahmadi *et al*., 2023), good ventilation reduces CO_2 and respiratory problems (Sadrizadeh *et al*., 2022), and noise impairs comprehension, while acoustic treatment improves speech intelligibility (Gislason, 2010). Spatially, well-planned layouts, modular classrooms, accessible resource centres, and clustered or circular seating promote interaction and collaboration (Barrett *et al*., 2019; Higgins *et al*., 2005; Fisher *et al*., 2021; Oruikor *et al*., 2023), whereas overcrowding limits mobility and engagement (Ikegbusi *et al*., 2022). Libraries (Fakunle, 2023; Wang and Wu, 2023) and green outdoor spaces (Reuben *et al*., 2020; Mygind *et al*., 2019) further support independent learning and cognitive function. Technologically, smart classrooms, computer labs, e-learning hubs, and STEM laboratories improve engagement and outcomes (Keiser, 2024; Tondeur *et al*., 2017; Evans, 2024; Cóndor-Herrera *et al*., 2021), but a digital divide between public and private schools persists.

2.4. Influence of Specific Design Elements on Academic Performance

2.4.1 Physical environment.

The Heschong Mahone Group (1999) studied over 21,000 students and found that those in the most day-lit classrooms progressed 20% faster in mathematics and 26% faster in reading in one district, with 7–18% advantages elsewhere. Diffusing skylights were linked to 19–20% better learning rates and operable windows to 7–8% higher performance. Annesi-Maesano and Annesi-Maesano (2016) found a window-to-floor ratio of at least 20% significantly improved learning across 148 classrooms in 23 European countries, and Herman (2015) reported a moderately positive correlation between natural light and performance (r = 0.35). Barrett *et al*. (2018) linked daylight to higher achievement and fewer disruptions. Artificial lighting matters where daylight is limited: extremes of brightness cause strain and fatigue, while light of 4000K to 6500K supports alertness and reading (Winterbottom and Wilkins, 2009), and daylight-responsive systems are increasingly favoured (Barrett *et al*., 2019).

2.4.2 Thermal comfort and noise

Chong *et al*. (2023) found in a naturally ventilated Malaysian classroom, that performance was best when students felt "slightly cool" and air velocity exceeded 0.95 m/s, which is highly relevant to Akwa Ibom's climate. Barrett *et al*. (2019) identified 20–23°C as optimal, Ma *et al*. (2021) linked poor thermal comfort and air quality to health symptoms and absenteeism, and Kükrer and Eskin (2021) reported a 47.4% gain in typing efficiency and 32.6% in cognitive processing after thermal improvements. On acoustics, a meta-analysis by Fretes and Palau (2025) showed noise impairs attention, working memory, and reading comprehension. Studies covering Lagos and Edo reported classroom noise well above international standards (Adesanya *et al*., 2024; Edene and Eghomwanre, 2023).

2.4.3 Spatial organisation.

The HEAD Project found "individualisation," the capacity to accommodate shifting learning modes, was central to progress (Barrett *et al*., 2019). Flexible and open-plan environments increase peer engagement (Higgins *et al*., 2005; Fisher *et al*., 2021), reconfigurable seating builds belonging (Cheryan *et al*., 2014), and clustered seating raises engagement more than rows (Gao *et al*., 2021; Wannarka and Ruhl, 2008). Ikegbusi *et al*. (2022) found overcrowded Lagos classrooms limited mobility and engagement. Common areas support collaboration and school culture (Lennertz, 2006), library placement correlates with better study habits (Ikegbusi *et al*., 2022; Fakunle, 2023), and green outdoor spaces reduce stress and improve attention and memory (Mygind *et al*.,

2019; Reuben *et al*., 2020; Kuo *et al*., 2019). The World Health Organisation, WHO (2021) recommends at least 60 minutes of daily moderate-to-vigorous activity. Shading, permeable surfaces, and interactive landscapes could enhance outdoor spaces in Akwa Ibom's tropical climate.

2.4.4 Technology integration.

Technology works best as a "learning ecosystem" (Brown *et al*., 2020). Access to equipped facilities improves engagement and achievement (Knezek, 2009; Knezek and Christensen, 2020; Ma *et al*., 2024; Ogungweru, 2023), and interactive whiteboards improve comprehension and retention (Cóndor-Herrera *et al*., 2021), though effectiveness depends on pedagogical alignment (Scherer *et al*., 2021). Reliable internet is essential, and poor implementation can undermine benefits (Aslam *et al*., 2024). Barrett *et al*. (2015, 2018) found that individualised classrooms with embedded digital infrastructure explained much of the 16% variation in pupil progress, and Li and Ma (2019) stress electrical capacity and spatial flexibility. In Nigeria, public schools face poor connectivity, outdated computers, and unreliable electricity, whereas private schools are better resourced (Adedayo and Akinyemi, 2020; Adewale and Akinola, 2020). Akwa Ibom likely shows similar disparities, though technology succeeds only when embedded in pedagogy (Onwuka and Nwogu, 2024; ISTE, 2019).

2.5. Comparative Analysis of Public and Private Schools by Design Elements

Variation in physical infrastructure helps explain the performance gap (Nalongo, 2024; Barrett *et al*., 2019; UNICEF, 2020; World Bank, 2022; WHO, 2021). *Physically*, Statistics Canada (2020) linked better lighting and temperature control in private schools to PISA scores 5.9 – 6.7% higher, and Akinnubi *et al.* (2024) found lighting and ventilation improved outcomes in Ogun State private schools. UNICEF (2020) tied poor lighting and ventilation in public schools to absenteeism and reduced focus, and in Akwa Ibom, Abasiubong and Umoh (2023) found significant negative correlations between inadequate lighting and ventilation and achievement in Ukanafun public schools. The World Bank (2022) credited Nigerian private schools with better climate control and acoustics, and noise control, linking these to cognitive and mathematics performances (Duval and Moliner, 2020; Elujekwute et al., 2021).

Spatially, private schools benefit from reduced overcrowding (World Bank, 2022; Uline and Woolner, 2021), more flexible layouts and ergonomic furniture (Higgins *et al*., 2005; Akinnubi *et al*., 2024), better libraries, halls, and communal spaces (UNICEF, 2020), and better-maintained grounds (Akande *et al.*, 2023; Bauer, 2023). Many public schools have rigid layouts and neglected outdoor areas. *Technologically*, private schools have labs, Wi-Fi, and smart boards, while public schools suffer a "digital divide" (Azeez *et al*., 2022). Adedayo and Akinyemi (2020) and Adewale and Akinola (2021) found higher ICT use in private schools correlated with better performance. Overall, spatial and technological advantages consistently favour private schools.

2.6. Empirical Studies on Architectural Design Elements and Academic Performance

Barrett *et al.* (2019), the foundational benchmark, studied 3,766 pupils in 153 UK classrooms and found classroom design alone explained 16% of variation in academic progress, with "naturalness" factors (light, temperature, air quality) most influential. However, it covered primary schools in a temperate climate, leaving a gap for tropical secondary schools. Herman (2015) found a positive link between natural light and performance ($r = 0.35$) and a negative one for poor acoustics ($r = -0.22$). Lehmann and Seitz (2021) found sustainable features in 850 Bavarian secondary students' schools improved scores and well-being but did not isolate features or school ownership. Duval and Moliner (2020) found noise negatively correlated with cognition ($r = -0.30$) but studied acoustics alone, and Martins and Gomes (2019) found daylight improved performance in Portugal without considering other variables.

On spatial design, Jin and Peng (2022) found flexible layouts improved satisfaction and perceived learning support among Chinese undergraduates. Jensen and Pedersen

(2018) in Denmark and Lopez and Silva (2021) in Brazil found flexible layouts promoted collaboration and modestly improved performance, though with small samples, weak metrics, and poor control of pedagogy and socioeconomic factors. Tanner (2009) linked spatial geometry, daylight, and outdoor areas to higher mathematics and reading proficiency across 71 US schools, but did not differentiate by school type. Schneider (2017) found a 4% gain in test scores after facility upgrades among 5,000 Californian students without examining specific features. Cohen and Fisher (2019) linked technology-integrated classrooms to STEM performance but conflated technological and spatial factors. Ramirez and Santos (2020) in Colombia, Boys (2017) and Woolner and Hall (2018) in Australia, and Osei and Agyeman (2021) in urban Ghana all linked better facilities to performance, but with limitations in isolating design from socioeconomic effects, omitting retrofitted schools, small samples, and ignoring the public-private gap.

Nigerian studies show similar patterns. In Uyo Senatorial District, Iroegbu and Maxwell (2017) found students in adequately equipped schools scored higher (M = 59.45 versus 36.35), with classes under 45 doing best, and Adeleke *et al.* (2024) found deteriorating facilities and overcrowding in Ukanafun public schools. Abasiubong and Umoh (2023) found significant correlations for classroom condition (r = 0.62), lighting and ventilation (r = 0.59), and infrastructure (r = 0.65), but only in one LGA and only public schools. Adewale and Lawal (2022) found the physical environment predicted goal achievement (β = 0.31) in south-western public schools, but treated it as a composite variable. Akpusugh (2022) found a positive relationship (r = 0.58) in Makurdi public schools without private comparison. Elujekwute *et al.* (2021) found school environment correlated with mathematics achievement (r = 0.61) but studied one subject only. Akinnubi *et al.* (2024) studied only faith-based private schools without standardised evaluation frameworks, and Adewale *et al.* (2021) found comfort and satisfaction, rather than physical features directly, linked to performance (r = 0.48) among university architecture students.

2.7. Research gaps

This study addresses key gaps in the literature on architectural design elements and students' academic performance. Although the built environment's role in education is receiving growing attention, existing research remains limited in cross-sector comparison, integrated analysis of design components, and representation of under-studied contexts such as Akwa Ibom State, Nigeria. First, much of the literature originates from developed countries, creating a contextual mismatch when applied to developing settings like Nigeria. This study responds with a context-specific investigation of school environments within a distinct socio-educational setting. Second, Nigerian empirical studies often examine public or private schools in isolation, limiting comparative insight. This study adopts a dual-sector approach to examine how architectural variations between public and private secondary schools relate to academic performance.

Thirdly, lighting, acoustics, and spatial arrangement are usually studied separately or merged into aggregated measures of environmental quality, which prevents an integrated understanding of their collective influence on learning outcomes. Fourthly, existing studies rely heavily on subjective assessments, with insufficient observational or visual evidence to support contextual interpretation and validation. Fifth, technology integration has received little attention as a spatial-architectural component of school design. Rather than treating ICT as peripheral, this study examines how technological infrastructure embedded in the learning environment influences learning outcomes. Finally, Nigerian educational research is regionally imbalanced, concentrated in the Southwest and North-Central. This study contributes empirical evidence from Akwa Ibom State in the South-South region of Nigeria, which is one with distinct socio-environmental characteristics.

2.8. THE STUDY AREA

2.8.1 Location and climate:

Akwa Ibom State lies in Nigeria's South-South zone, between latitudes 4°30' and 5°32' N and longitudes 7°25' and 8°30' E, with the Atlantic Ocean to its south (Figures 1

and 2). Created in 1987 from the former Cross River State, it covers 8,412 km² and has 31 Local Government Areas, with Uyo as its capital. Its three senatorial districts (Uyo, Ikot Ekpene, and Eket) together host 285 public and 268 private senior secondary schools, which provide the public-private comparison at the heart of the study title.

The state's latitude and proximity to the Atlantic shape humidity, airflow, and the angle of sunlight. These directly affect natural ventilation, daylighting, and building orientation in schools, which are core architectural design elements. The location therefore provides the basis for judging which ventilation and comfort strategies suit the region and how they may support academic performance.

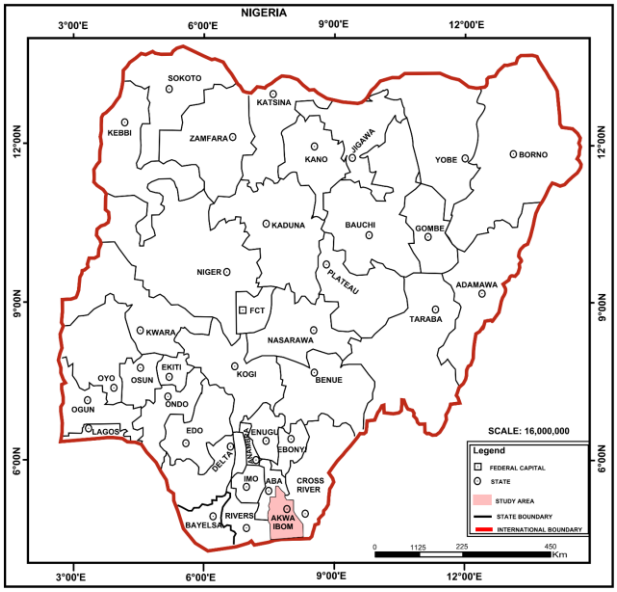


Figure 1: Location of Akwa Ibom state in Nigeria

Source: Udoenang (2026)



Figure 2: Distribution of local governments and senatorial districts in Akwa Ibom State

Source: Udoenang (2026)

2.8.2 Physical setting: The tropical monsoon climate has a wet season from March to October, with rainfall peaking at 494 mm in July. Temperatures average about 27°C but

reach 41°C, humidity climbs to 92%, and the state receives about 2,500 sunshine hours a year with a UV index of 9 to 14. School buildings therefore need effective drainage, leak-proof roofing, shading devices, cross-ventilation, suitable window placement, and glare control. Heat stress and humidity reduce productivity and impair cognition (Chong *et al*., 2023), so poorly adapted classrooms can mean weaker concentration, greater fatigue, and lower academic outcomes. Local mangroves and rainforests also offer chances to cool school microclimates through shade and vegetation.

2.8.3 Demographic setting: The population rose 38% between 2006 and 2023 to 5,482,177, and Uyo alone has about 1,329,000 residents. Urban migration has increased classroom density and depleted instructional resources in both public and private schools. This ties the study area to spatial organisation, designs must remain ventilated and flexible enough to accommodate larger cohorts without harming learning.

2.8.4 Socio-economic and cultural setting: The state's oil and gas wealth shapes its ability to fund public school infrastructure (Ojo, 2023), while socio-economic stratification influences private school patronage and facility quality. Corporate and non-governmental actors, including ExxonMobil, Oriental Energy, Savannah Energy, Frontier Oil, EATECH, the Maritime Academy of Nigeria, and the Global Partnership for Education, have funded laboratories, ICT facilities, furniture, and infrastructure. These interventions may narrow or widen gaps between public and private schools, especially in technology integration, and must be considered when assessing design effects on performance.

2.8.5 Relevance to the title: The study area supplies the context linking the title's variables. Its climate makes the physical learning environment (lighting, ventilation, thermal comfort) especially consequential. Its rapid urbanisation makes spatial organisation a pressing concern. Its uneven funding and external interventions make technology integration a likely source of public-private disparity. Its district structure also allows representative comparison of public and private schools across the state.

3. METHODOLOGY

3.1. Research Design

The study used a mixed-methods concurrent embedded (Nested) design to examine how architectural design elements influence students' academic performance in public and private secondary schools in Akwa Ibom State. The quantitative strand was dominant, with qualitative observational data embedded to validate and enrich the findings through triangulation (Creswell and Creswell, 2022). The quantitative component was an Ex Post Facto descriptive-correlational design, since both the design elements and the academic outcomes already existed and could not be manipulated. It therefore examined differences, relationships, and predictive patterns rather than experimental causality (Kerlinger and Lee, 2000; Cohen *et al*., 2018).

3.2. Data Instruments

The units of data were schools and students: 1,816 SS3 students from 227 schools (79 in Uyo, 87 in Ikot Ekpene, and 61 in Eket districts). SS3 students were chosen for their sustained exposure to school facilities. Four sources of data were used:

- Questionnaire: A structured five-point Likert questionnaire measured the physical learning environment, spatial organisation, and technology integration, inaddition to demographic details. Composite scores were computed for each domain.
- Observation checklist: Structured observations across the same three domains verified questionnaire responses.
- Photographs: Classrooms, circulation areas, and architectural features were photographed with consent.

- WASSCE records: The Performance Index (PI) was the proportion of students obtaining at least five credits, including English Language and Mathematics, from 2019 to 2024.

3.3. Validity and Reliability

Experts in architecture and educational research methodology reviewed the instruments for content validity (Hardesty and Bearden, 2004), and triangulation strengthened validity further. Cronbach's Alpha ranged from 0.76 to 0.88, indicating acceptable to high consistency. A pilot with 30 SS3 students from non-sampled schools showed that some technical terms were unclear, so the instruments were revised (Saunders *et al*., 2019).

3.4. Population and Sampling

The population was 553 senior secondary schools (285 public, 268 private) and 67,723 SS3 students, based on Akwa Ibom State Ministry of Education (2024) figures. A multi-stage procedure was used: stratification by senatorial district, classification by school type, proportionate allocation, purposive selection of schools with complete 2019 to 2024 WASSCE records, and simple random selection of students. The Finite Population Correction formula (Cochran, 1977; Thompson, 2012) gave 227 schools (118 public, 109 private) and a minimum of 382 students. Because design features were assessed at school level, eight students were randomly selected per school, giving 1,816 students (944 public, 872 private). These are as shown in Table 1. Access was secured through the University of Uyo's Department of Architecture and the Commissioner for Education.

Table 1: Adjusted Distribution of Sampled SS3 Students

Senatorial District	Total	Public	Private
Uyo (North-East)	632	320	312
Ikot Ekpene (North-West)	696	360	336
Eket (South)	488	264	224
Total	1,816	944	872

3.5. Research Variables

The dependent variable was academic performance (PI). The independent variables were physical environment, spatial organisation, and technology integration. School type was a moderating variable, and student perception was the intervening variable. Controls were gender, age, school location, size, age, and boarding status (Hünermund and Louw, 2023).

3.6. Data Analysis

Parametric techniques were justified by the large sample and the treatment of composite Likert scores as approximately continuous. Descriptive statistics summarised availability of design elements. One-Way ANOVA tested differences in the availability of architectural design elements between school types (H_{01}), Pearson correlation tested relationships with performance (H_{02}), Multiple Linear Regression identified the strongest predictors, and regression including school type assessed how far design explains the performance gap (H_{03}). Analysis used IBM SPSS at a 0.05 significance level (Cohen, 1992).

3.7. Ethical Issues

Informed consent was obtained, participants could withdraw freely, and disruption was minimised. Confidentiality was protected through anonymisation, coded identifiers, and secure storage, and all participants were treated equitably.

4. PRESENTATION AND DICUSSION OF RESULTS

4.1. Assessment of Key Architectural School Design Elements in Public and Private Secondary Schools of Akwa Ibom State

All 1,816 questionnaires administered to Senior Secondary Three (SS3) students in the 227 sampled schools were completed and returned (100% response rate). Data were analysed in IBM SPSS and triangulated with structured field observations and photographs. Availability scores range from 0 to 1. The comparative results for the physical learning environment variables are presented in Figure 3.

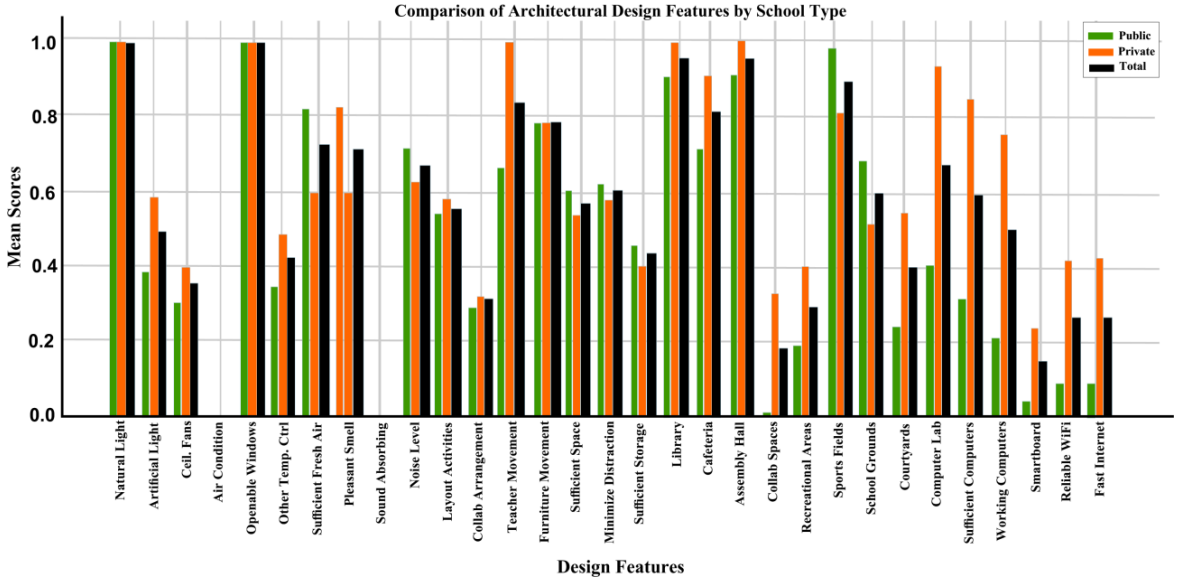


Figure 3: Comparison of Architectural School Design Elements by School Type

4.1.1 Physical learning environment

Natural lighting and openable windows scored 1.00 in both school types, whereas no school had air conditioning or sound-absorbing materials. Private schools had more artificial lighting (M = .58 vs. .39), ceiling fans (.40 vs. .30), and other temperature-control measures (.48 vs. .35). Public schools scored better on both fresh air and pleasant indoor smell (M = .83 vs. .60) and public schools scored slightly higher on noise comfort (.72 vs. .63).

4.1.2. Spatial organisation

Private schools led on teacher ease of movement (1.00 vs. .66), collaborative learning spaces (.33 vs. .02), assembly halls (.85 vs. .53), cafeterias (.73 vs. .45), attractive courtyards (.54 vs. .24), and recreational areas (.40 vs. .19). Public schools led on sports fields (.98 vs. .81), classroom space (.60 vs. .53), distraction minimisation (.62 vs. .58), and storage (.46 vs. .41). Furniture flexibility (.60 vs. .59) and provision for varied learning activities (.54 vs. .58) were similar across sectors, and libraries were widely available (public M = .91; private M = 1.00).

4.1.3. Technology integration

This domain showed the widest gap. Private schools recorded higher availability of computer laboratories (.93 vs. .40), computers (.85 vs. .31), functional computers (.75 vs. .21), and Wi-Fi (.42 vs. .09).

4.1.4 Field observations

Many pre-1970 missionary-founded schools (now public or private) and some government model schools built around 2000 had spacious classrooms, high ceilings, large operable windows, clerestory openings, verandas, and wide corridors. Several

recently built private schools had compact layouts, small windows, limited circulation space, and rigid classroom configurations as shown in Figure 4.

(a)  (b) 

Figure 5.4: Classroom Spatial Conditions in Selected Secondary Schools; (a) Organized and Well-Spaced Classroom Environment, (b) Overcrowded Classroom with Limited Spatial Flexibility.

4.1.5. Statistical test

One-way ANOVA showed significant differences ($p < .05$) for most design elements, between private and public schools. The largest being for ICT items (Table 1). Therefore, for the elements: artificial lighting, teacher ease of movement, collaborative learning spaces, cafeteria, assembly hall, recreational areas, sports fields, computer laboratory, sufficient computers, smart-boards and reliable Wi-Fi, the null hypothesis one (H_{01}) was rejected. For the elements: natural light, openable windows, air conditioning, acoustics, furniture mobility, space, and storage, there were no significant differences. The null hypothesis (H_{01}) was accepted for this elements.

Table 1: Selected Availability Scores by School Type and One-Way ANOVA Results

Design element	Public (M)	Private (M)	F	p
Artificial lighting	.39	.58	9.31	.003
Teacher ease of movement	.66	1.00	60.11	< .001
Collaborative learning spaces	.02	.33	44.25	< .001
Cafeteria	.45	.73	15.71	< .001
Assembly hall	.53	.85	11.81	.001
Recreational areas	.19	.40	11.92	.001
Sports fields	.98	.81	18.14	< .001
Computer laboratory	.40	.93	105.69	< .001
Sufficient computers	.31	.85	94.60	< .001
Smart-boards	.05	.24	17.88	< .001
Reliable Wi-Fi	.09	.42	35.36	< .001

Note: Public schools, n = 118; private schools, n = 109. Only elements with significant differences are shown.

4.2. Assessment of Student Academic Performance in Public and Private Schools in Akwa Ibom State

Students' academic performance was measured as the average percentage of students obtaining at least five credits, including English Language and Mathematics, in the West African Senior School Certificate Examination (WASSCE) from 2019 to 2024). Table 2 presents students' WASSCE score by school type and Table 3 presents students' WASSCE score by senatorial district.

The 5.99 points gap is both statistically significant and educationally meaningful, since the benchmark is the credit-level requirement for progression to tertiary education.

The wider spread among public schools shows that some government schools, particularly urban ones or those assisted by government or non-governmental interventions, performed competitively or even surpassed private schools. The standard deviation also suggests the influence of other determinants of students' academic performance. School type is therefore an important but not exclusive determinant. Leadership, teacher qualifications, and socio-economic contexts also matter.

Table 2: WASSCE score by school type

School type	Mean	N	Std. Deviation
public	75.3031	118	18.74835
private	81.2954	109	12.91248
Total	78.4181	227	16.22631

Table 3: WASSCE score by senatorial district

Senatorial district	Mean	N	Std. Deviation
Uyo	75.5904	79	18.22400
Ikot Ekpene	80.3495	87	15.41358
Eket	79.3254	61	14.23678
Total	78.4181	227	16.22631

4.3. Examining the Relationship between Architectural School Design Elements and Student Academic Performance

A correlational analysis was conducted to examine the relationship between selected architectural school design elements and students' academic performance across public and private secondary schools in Akwa Ibom State. This analysis utilized Pearson's product-moment correlation coefficients, focusing on the association between architectural elements and West African Senior School Certificate Examination (WASSCE) performance.

Table 4 showed that Pearson's Product-Moment correlation gave positive association between WASSCE performance and several architectural design elements. With elements grouped to three domains: physical, spatial and technology. Under physical environment, sufficient fresh air gave a Pearson correlation coefficient, r, of .198 and a statistical significance, *p, less than 0*.01; pleasant smell (r = .152, p < .05); and artificial lighting (r = .005, p = .936). Artificial lighting was the only physical environment element not significantly correlated with student academic performance. Students' responses noted that artificial lighting quality affected concentration and caused eye fatigue.

The spatial organisation domain showed sufficient classroom space (r = .185), layout flexibility (r = .159), collaborative arrangements (r = .157), libraries (r = .198), and collaborative learning areas (r = .277) were all significantly correlated with students' academic performance (Table 4). Students noted that well-equipped common areas encouraged study.

Technology integration domain showed computer labs (r = .205), smart-boards (r = .259), and reliable internet (r = .267), were all significantly correlated (p < .01) with students' academic performance. Students opined that computers and interactive whiteboards made lessons more engaging.

These associations were supported by the qualitative strand. Students reported that well-lit classrooms aided concentration but that poorly calibrated artificial lighting caused eye fatigue. This helps explain why the mere presence of artificial lighting was unrelated to performance. Its quality, not its availability, appeared to matter. Likewise, students linked libraries and other common areas to more frequent study habits and a more positive school experience. They described computers and interactive whiteboards as making lessons more engaging. The combination of statistical and perceptual evidence suggests that design elements influence performance largely through comfort, engagement, and access to learning resources. Therefore, the null hypothesis two, H_{02}, was rejected.

Table 4: Pearson Correlations between selected design elements and WASSCE performance

Design element	Domain	r	p
Sufficient fresh air	Physical	.198	< .01
Pleasant indoor smell	Physical	.152	< .05
Artificial lighting	Physical	.005	.936
Sufficient classroom space	Spatial	.185	< .01
Layout flexibility	Spatial	.159	< .05
Collaborative arrangements	Spatial	.157	< .05
Library	Spatial	.198	< .01
Collaborative learning areas	Spatial	.277	< .001
Computer laboratory	Technology	.205	< .01
Smart-boards	Technology	.259	< .01
Reliable internet	Technology	.267	< .01

By school type, public schools had more of the passive environmental features (daylight, fresh air, pleasant smell) that correlated positively with performance, while private schools had more digital infrastructure and flexible spatial arrangements, which also correlated positively with performance.

4.4. Determination of Architectural Design Elements with the Most Significant Influence on Students' Academic Performance in Public and Private Secondary Schools in Akwa Ibom State

To identify the architectural design elements with the most significant influence on students' academic performance in public and private secondary schools across Akwa Ibom State, a multiple linear regression analysis was conducted. Results of multiple linear regression analysis are as shown in Tables 5 and 6. This statistical model assessed how specific architectural features predicted student academic performance, as measured by West African Senior School Certificate Examination (WASSCE) results.

Table 5: Model summary for regression analysis of architectural school design elements predicting students' academic performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F-value	df	p-value
1	0.761a	0.579	0.522	11.10034	34.932	(10, 254)	p < 0.001

a. Predictors: (Constant), fast_internet, suff_freshair, School_grounds, Ceiling_fans, pleasant_smell, Recreational_areas, distraction_minimization, Teacher_ease_of_movement, Assembly_Hall, Sufficient_space, smartboard, Attractive_courtyards, comp_in_workble_condition, Cafeteria, comfortable_noise_level, Sufficient_storage, Other_temp, Library, Reliable_wifi, computer_lab, sports_fields, collaborative_learning_spaces, Furniture_easy_movement, classroom_arrangement_collaboration, classroom_layout_diff_activities, Artificial_light, sufficient_comp

The regression model was strong and significant, $R = .761$, $R^2 = .579$, adjusted $R^2 = .522$, $F(10, 254) = 34.93$, $p < .001$. Recreational areas was the strongest predictor, followed by smart-boards, collaborative learning spaces, reliable Wi-Fi, and sufficient classroom space. Students said time to play and unwind helped them focus afterwards, and that smart-boards and reliable internet made lessons easier to follow and supported access to notes and learning platforms. Sufficient computers, computer condition, and fast internet were not significant, suggesting that the quality and effective use of technology matter more than availability alone.

Table 6: Significant Predictors of WASSCE Performance in the Multiple Regression Model

Predictor	B	SE	β	t	p
Recreational areas	28.99	3.59	.405	8.08	< .001
Smart-boards	8.53	2.25	.258	3.79	< .001
Collaborative learning spaces	11.22	5.18	.219	2.17	.031
Reliable Wi-Fi	6.51	2.41	.189	2.70	.007
Sufficient classroom space	3.92	1.92	.119	2.04	.043

Note. Full model included 27 design elements; only significant predictors are shown. Dependent variable: WASSCE score.

Collaborative spaces were consistent with active, peer-based learning, and adequate classroom space was associated with greater comfort, fewer distractions, and clearer visibility and audibility during lessons. The negative, non-significant coefficient for the number of computers should be interpreted cautiously, because computer availability, condition, and connectivity are closely related in the model.

4.5. Contribution of Architectural Design Elements to Performance Disparities between Public and Private Secondary Schools in Akwa Ibom State

To explore the nuanced role of school type in moderating the impact of these design features, a moderated multiple regression analysis was conducted. This analysis specifically examined whether the effect of certain design features on academic performance was moderated by school type (public vs. private). The results of this moderated regression are detailed in Table 7. The moderated regression showed that school type had its own significant effect, so private schools outperform even after accounting for design. The benefits of recreational areas and Wi-Fi were significantly stronger in private schools, whereas the effects of smart-boards, collaborative spaces, and classroom space were similar across both sectors. H_{03} was rejected: architectural design elements contribute significantly to the performance gap between public and private secondary schools.

Public schools' larger classrooms and sports fields did not translate into higher performance. Large room footprints are often offset by enrolment above the 45-student threshold, and many outdoor facilities in public schools are in poor condition, so their spatial advantage is not matched by the digital and collaborative provisions that predicted performance in the model. Null hypothesis three, H_{03}, is therefore rejected.

Table 7: Moderated Regression of Design Elements and School Type on WASSCE Performance

Predictor	B	SE	p	Interaction p
Recreational areas	28.99	6.75	< .001	.009
Smart-boards	8.53	2.43	< .001	.122
Reliable Wi-Fi	6.51	2.38	.007	.031
Collaborative learning spaces	5.00	2.08	.014	.285
Sufficient classroom space	3.46	1.62	.021	.198
School type (public = 0, private = 1)	12.35	3.45	< .001	—

Note. Interaction p refers to the predictor × school type term.

4.6. Discussion of results

The universal provision of natural lighting and openable windows suggests that passive environmental design is a basic feature of school buildings in the state regardless of ownership. This is consistent with recommendations on daylighting and natural ventilation in tropical climates (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE], 2019; Illuminating Engineering Society [IES], 2023)

and with evidence that daylight supports concentration, comfort, and achievement (Barrett *et al.,* 2019). It likely reflects a regional tradition of climate-responsive design that limits reliance on mechanical cooling.

The field observations point to a historical pattern beyond the public–private divide. Pre-1970 missionary schools and some government model schools of around 2000 display learner-centred, climate-responsive features, whereas many recent private schools prioritise site maximisation over environmental quality. Design philosophy at the time of construction may therefore matter as much as current ownership.

Private schools' greater provision of artificial lighting, fans, and temperature control suggests that proprietors invest in supplementary building services, in line with Barrett *et al*. (2019) and Uline and Woolner (2021). Public schools' better fresh-air and smell scores probably reflect larger sites and wider spacing between blocks, which allow cross-ventilation, whereas constrained urban private sites restrict airflow. This fits environmental psychology, which holds that environmental conditions shape comfort, behaviour, and cognition (Marchand *et al*., 2023). Acoustic design was neglected in both sectors, a notable gap given evidence that poor acoustics reduce speech intelligibility and increase cognitive effort (Fretes & Palau, 2025; Shield & Dockrell, 2003).

Private schools' stronger collaborative layouts, cafeterias, assembly halls, and collaborative spaces fit Constructivist Learning Theory, which favours environments that encourage interaction and active participation (Bada, 2015). Public schools' advantage in space and sports fields reflects the larger land holdings of older government schools, consistent with Educational Facilities Planning Theory. The greatest disparity was in technology integration, supporting Lackney's (2004) view of technology as integral to modern facilities and Perna and Thomas's (2008) view that institutional resources contribute to achievement. Improving design standards, particularly in public schools and in new schools of any ownership, is therefore essential for equitable learning environments.

The relationship between thermal comfort and performance can be read through the stimulus–organism–response model: well-ventilated, daylit classrooms act as positive stimuli that lower the environmental load on students, freeing cognitive resources for higher-order processing. This is consistent with Barrett et al. (2019), who found that classroom design explained 16% of variation in pupils' academic progress, although their study was set in a temperate climate. In the warm-humid tropical setting of Akwa Ibom, passive cooling features are likely to matter even more, which strengthens the case for preserving and replicating the climate-responsive features of older school buildings.

The technology gap has clear educational implications. Contemporary learning depends on digital tools for information access, collaboration, and skills acquisition, so inadequate ICT infrastructure in public schools limits technology-enhanced learning and students' preparedness for a digitally driven environment. In summary, both sectors are strong in passive environmental design, but marked disparities exist in technology integration, indoor environmental support systems, collaborative spaces, and supporting facilities.

The model's explanation of about 58% of the variance supports Herman (2015) and Barrett *et al*. (2015), who treat the physical environment as a core determinant of achievement rather than a background factor. The findings are interpreted through the Integrated Conceptual Model of Student Success (Perna & Thomas, 2008), environmental psychology, Constructivist Learning Theory, and Educational Facilities Planning Theory, which together hold that adaptable, interactive, student-centred environments support engagement, well-being, and cognition.

Recreational areas. As the strongest predictor, these spaces offer "environmental decompression" in high-density classrooms, consistent with evidence that outdoor environments and physical activity reduce stress and improve executive function, memory, and attention (Falk *et al*., 2021; Mygind *et al.,* 2019; World Health Organization [WHO], 2021). In Akwa Ibom's climate, shaded areas also provide thermal relief.

Smart-boards. They act as "informational affordances" that support multimodal instruction and link abstract concepts to visual understanding (Kim *et al*., 2013), although their effect depends on teacher competence (Lackney, 2004). Their absence from public schools creates a "pedagogical ceiling," while in private schools they support active knowledge construction.

Reliable Wi-Fi. It connects the classroom to wider knowledge resources and functions as institutional support (Perna & Thomas, 2008). Unequal access reflects a structural divide in academic equity (Organisation for Economic Co-operation and Development [OECD], 2020; Warschauer & Matuchniak, 2010).

Digital infrastructure in context. Students with robust connectivity can pursue autonomous, inquiry-based learning and are less dependent on outdated physical libraries, whereas the lack of reliable connectivity in many public schools restricts them to a teacher-centred model and widens the gap in the digital literacy needed for twenty-first-century competitiveness (OECD, 2020). The non-significance of computer numbers and internet speed, alongside the significance of smart-boards and Wi-Fi, suggests that reliable, pedagogically integrated technology matters more than raw equipment counts.

Collaborative learning spaces. They enable peer engagement and cooperative problem-solving. Clustered seating raises engagement relative to rows (Gao *et al*., 2021; Wannarka & Ruhl, 2008), so reconfiguring seating for group work is a practical improvement even in resource-constrained schools.

Sufficient classroom space. Its effect was modest and depends on occupancy density. Iroegbu and Maxwell (2017) found that cohorts below 45 students achieved better results in the Uyo Senatorial District, and large public classrooms often lose their advantage once enrolment exceeds that threshold, a "density paradox." Overall, no single element works in isolation: performance reflects a combination of technological, spatial, and environmental factors.

Interpretation across predictors. Public schools' foundational environmental quality acts as a physiological buffer, but this advantage plateaus at basic comfort. Private schools' stronger institutional affordances, namely digital infrastructure, recreational areas, and flexible collaborative spaces, coincide with the elements that most strongly predicted performance. This is consistent with the view that the achievement gap is partly a design gap: the significant school-type effect and the stronger private-school benefits of recreational areas and Wi-Fi suggest that these elements are better integrated into the wider system of institutional support in private schools, whereas their absence or instability in public schools acts as a barrier to academic equity (Uline & Woolner, 2021).

2. CONCLUSION AND RECOMMENDATIONS

This study examined how architectural design elements influence students' academic performance in public and private secondary schools in Akwa Ibom State. Passive environmental features, notably natural lighting and openable windows, were present in both sectors. Private schools, however, were better provided with artificial lighting, collaborative learning spaces, recreational areas, and especially ICT infrastructure, with significant differences for most of these elements. Private schools also recorded higher WASSCE performance (81.30% vs. 75.30%), although the wider spread among public schools shows that some government schools perform competitively.

Design elements were positively associated with performance. The regression model explained 57.9% of the variance in WASSCE outcomes, with recreational areas, smart-boards, collaborative learning spaces, reliable Wi-Fi, and sufficient classroom space as the significant predictors. Public schools retained advantages in basic environmental quality and space, but these did not offset their shortage of the digital and collaborative provisions that predicted performance. School type remained significant after design was controlled, and the benefits of recreational areas and Wi-Fi were stronger in private

schools, so design contributes substantially to, but does not fully explain, the performance gap.

Architecture is therefore an active participant in learning rather than a passive container, and the achievement gap is partly a design gap. The state's warm-humid climate and growing enrolment make ventilation, thermal comfort, and spatial flexibility especially consequential.

From the findings of the study, it is recommended that;

i. High-impact elements should be prioritised. Planners should give budget, renovation, and new-construction priority to recreational areas, interactive technology, reliable internet, collaborative spaces, and adequate classroom space. Shaded outdoor recreational spaces suit the tropical climate.

ii. Design divide in public schools should be closed. Government should upgrade public schools, particularly in the areas of ICT infrastructure, flexible collaborative classrooms, recreational facilities, and environmental quality, with reliable power and maintenance so that equipment stays functional and is used in teaching.

iii. Climate-responsive standards should be adopted. The Ministry of Education, with architectural and planning bodies, should enforce minimum standards for lighting, cross-ventilation, thermal comfort, acoustic treatment, space per pupil, and ICT provision. This should be supported by regular facility audits.

iv. Current designers should learn from older school designs. New schools of any ownership, especially private schools on constrained sites, should retain adequate site area, window size, and cross-ventilation, following the learner-centred features of pre-1970 missionary and government model schools.

v. Student enrolment should be effectively managed. Class sizes should stay near the 45-student threshold so that spacious classrooms deliver their benefit, with additional classrooms built where enrolment exceeds capacity.

vi. Extend the research. Future studies should use longitudinal and multilevel designs, include teachers and administrators, and examine security, landscaping, and building orientation.

3. LIMITATION OF THE STUDY

The cross-sectional study collected data from many sc$_{ho}$ols at a single point in time. It therefore showed associations between architectural design elements and academic performance, but not causal effects or changes over time.

Design elements were assessed largely through SS3 students' perceptions. These may be shaped by personal preferences and prior schooling experience, which introduces subjectivity. Structured questionnaires on observable features, observation checklists, and photographs were used to triangulate the data, but they did not remove this limitation.

Access to detailed architectural documentation such as building plans was limited. Physical conditions were therefore judged through direct observation and checklists rather than measured values such as illuminance, air velocity, temperature, or noise levels. Many elements were scored by availability, which captures presence more readily than quality or condition.

Academic performance is also shaped by teacher quality, socio-economic background, school leadership, and learning resources. The study focused on architectural and environmental dimensions. It controlled only gender, age, location, school size, school age, and boarding status. The influence of unmeasured factors cannot be ruled out.

Finally, the scope was limited to senior secondary schools in one state and to three design domains: physical environment, spatial organisation, and technology integration. Elements such as security, landscaping, and building orientation were not examined, and the findings may not generalise to other regions or educational levels.

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