

Exploring Students Awareness, Access and Utilization of Artificial Intelligence (AI) in Architectural Design: A Study of Selected Tertiary Institutions in Southeast Nigeria

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Abstract

Artificial intelligence has become a trending topic in the last decade and has permeated all spheres of life and profession and Architecture is no exception. The use of artificial intelligence in architecture is still in its infancy as more research is still being carried out in the application of artificial intelligence in architecture to solve problems ranging from intelligent material design to architectural plan solutions. This study aimed at examining students' levels of awareness, access and the use of artificial intelligence in architectural design in selected tertiary institutions in Southeast Nigeria. The three tertiary institutions selected are; The Department of Architectural Technology, Akanu Ibiam Federal Polytechnic Unwana, The Department of Architectural Technology Abia State polytechnic, Aba and The Department of Architecture, Abia State University, Uturu. The main objective is to carry out a survey to investigate the awareness, access, and utilization of artificial intelligence (AI) in architectural design among students in selected tertiary institutions in Southeast Nigeria. This study adopted a descriptive research design of the survey method and employed a three-sectioned questionnaire to elicit information from the respondents. The sample size included a multistage sample of 300 undergraduates across three tertiary institutions in Ebonyi State and Abia State. The findings of the study were that the majority of the students are not aware of Artificial intelligence and will use AI if they are aware and have access to it for their Architectural design. Therefore, there is a need for integrating AI related courses and workshop into Architectural curriculum which can lead to better prepared graduates who are proficient in using advanced design tools, potentially increasing their employability and innovation in the field. This study concluded that students' ability to explore digital resources such as AI for Architectural design is dependent on their awareness and access to digital technologies. A lack of these will result in a lack of use and lack of skill to use them.

Keywords: Artificial Intelligence, Awareness, Access, Architectural Design, Tertiary Institutions, Nigeria, Digital Technology.

Introduction

The increasing digitization and automation process in daily life through the use of Artificial Intelligence (AI) pose great challenge for society and education (Kandlhofer, Weixelbraun,

Manuel, Steinbauerm-wagner, & Agoston, 2023). Artificial intelligence in Education (AIEd) is an evolving interdisciplinary arena incorporating AI technologies to renovate and enhance teaching and learning environments (Firas, 2024). In the integration of artificial intelligence it is imperative to move beyond the perspective of researchers and integrate the perspective of students (Christelle, Lianne-blue, Victoria, Laurent, & Margarida, 2024). The use of emerging technology in Nigerian tertiary institutions is an awareness that has become part of this digital society, which characterized science, teaching, and learning in the twenty-first century (Adebayo, et al 2021). Nigeria Computer Society (NCS) claimed that emerging technology is a fundamental part of information and communication technology (ICT) that is capable of encouraging, stimulating, and engaging students in education (Nigeria Computer Society, 2014). According to the minister of communication Nigeria as at 2013, thirty-two million, five hundred and thirteen thousand, two hundred and sixty-one Nigerians access the Internet through telecommunications networks, a larger percentage of which are young people (Oisanwo, Ajaegbu, & Akande, 2014). The introduction of AI into education marks a significant departure from conventional teaching methods. (Yoshija, 2024) Access to Artificial Intelligence (AI) among students is one of the long-term consequences of increasing the emergence of AI technological devices for architectural design purposes, is perhaps the evolution of what is termed Architectural intelligence.

The practice of Architecture, its approaches, backgrounds, and know-how are today at the center of passionate debates challenged by outsiders, arriving with new practices, and questioned within, as practitioners doubt of its current state, Architecture is undergoing a truly profound advancement (Chaillou, 2019). Among the elements that will leave a long-term effect on our discipline, technology certainly is one of the main courses at play. The development of drawing tools has gotten more and more advanced since the introduction of digital tools like CAD and CAAD in the early 1960s, (Carpo, 2017) and the emergence of highly technological advancements such as Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and digital twins have made significant changes and improvements in the way we work and interact with each other and drawing digitally has been widely practiced by architects, Thus digital image files showing plan drawings have become the most popular format to communicate between architects and clients. These advancements have enabled the consumption and analysis of large volumes of data in a shorter time than any human ever would be able to do. (Carl, 2022). The conception of buildings has already started a slow alteration: first by leveraging new construction techniques, then by developing acceptable software, and eventually today by introducing statistical computing capabilities (including Data Science & AI). An architect can draw an architectural plan without thinking of any cognitive aspects of the design. However, behind the drawing action, a highly meticulous and sophisticated method is unfolding in the mind. Arguments abound that formally describing these design processes to train an algorithm would not be possible or efficient. This falls into the artificial intelligence (AI) problem space. Goodfellow, Bengio, & Courville, (2016) states that the real challenge for AI is being

able to solve tasks that people can do easily but formally have difficulty explaining. Human beings solve such problems intuitively. It is quite challenging to formally define the act of designing in architecture, too. For autonomous drawing processes, instead of trying to formally explain the design, an algorithm can derive meaningful solutions through drawing datasets. Today, with the concept of big data, algorithms can evaluate data, and deep learning algorithms can be trained without needing to formally describe processes. Despite the recognized benefits of AI in Architecture and Architectural Education, there remains a gap in understanding how Architectural students in specific regions, such as south- East of Nigeria, are engaging with these technologies. This study aims to explore, the awareness, access and utilization of AI tools among architectural students in selected tertiary institution in this region. For guiding the conduct of this study, the following research questions are generated:

- i. Are universities students familiar with the use of artificial intelligence for architectural design?
- ii. Do university students have access to Artificial intelligence for architectural design?
- iii. What is the level of students' competency in the use of artificial intelligence for architectural design?

Literature Review

Historical Overview

In the mid-20th century scholars in the United Kingdom conducted research for many years on the possibility of building machine intelligence and then founded the artificial intelligence field in 1956. Although the first use of the term artificial intelligence, was first coined by John McCarthy in 1956 when he held the first academic conference on the subject (Smith, et al, 2006). This field of artificial intelligence was started by the members of the Ratio Club, a group of researchers including Alan Turing. The first extensive work in the field of artificial intelligence was done in the mid-20th century by the British logician and computer pioneer Alan Mathison Turing (Encyclopeadia Britannica, 2007). He is also regarded as the father of Modern computer science. Born in 1911, he showed great proficiency with mathematics and after progressing from college he put out a paper "On Computable Numbers, with an Application to the Entscheidungs problem" in which he projected what would later be known as a Turing Machine – a computer with the ability of computing any computable function. This publication itself was built on concepts proposed by Kurt Godel that there are statements about computing numbers that are true, but that can't be proven (Enslow, 1989). Alan Turing worked on the problem and was determined to help define a system for ascertaining which statements could be proven. In the process, he proposed the Turing Machine. The paper defines a "computing machine" with the capacity to read and write symbols to a tape using those symbols to execute an algorithm (Martins, 1984.) This paper and the Turing machine provided that base for the model of computation. While Alan Turing was engrossed primarily in mathematics and the theory of what would become computer science throughout and immediately after college, soon World War 2

came and he became interested in more hands-on matters. The use of cryptography by the Axis gave him a spur to focus on building a machine capable of breaking ciphers. Before this potential use presented itself, Alan Turing likely hadn't been too concerned that the Turing machine he'd proposed in his earlier work was not feasible to build. In 1939 he was requested to join the Government Code and Cipher school as a cryptanalyst (Singh, 1999) and it became clear that he needed to build a machine capable of breaking codes like Enigma which was used by the Germans. He designed in a few weeks and received funding for the construction of electromechanical machines called 'bombes' which would be used to break Enigma codes and read German messages by automating the processing of 12 electrically linked Enigma scramblers. It wasn't the Turing machine, but the idea of generating cipher text from plaintext via a distinct algorithm fit with the Turing machine notion. After the war, Turing returned to academia and became engrossed in the more philosophical problem of what it meant to be sentient, which led him down the path to the Turing test. The ground-breaking work of Alan Turing after WWII established the grounds for the concept of computer intelligence. It is also important to note that Bush's seminal work "As We May Think" (Bush, 1945) where he proposed a system that amplifies people's knowledge and understanding was written five years before Alan Turing's paper on the notion of machines being able to simulate human beings and the ability to do intelligent things, such as play Chess. (Turing, 1950). In his work, Alan Turing examined *the question of whether or not machinery can show intelligent behavior*. To resolve the problem, Turing proposed a first experiment involving three subjects: A, B, and C. Then, in his paper *Computing Machinery and Intelligence*, "which to this day is still considered the benchmark for identifying the intelligence of an artificial system (Haenlein & Kaplan, 2019). Alan Turing in reasoning about the question 'Can machines think?' proposed to reformulate the proposition as: *Can machines do what we (as thinking entities) can do?* Then, he proposed a test known as the "imitation game" also called the "Turing test". In this test, a man and a woman go into separate rooms, and guests try to tell them apart by writing a series of questions and reading the typewritten answers sent back. Both the man and the woman have the goal of convincing the players that they are the other. Turing modified the game by exchanging one of the two players (man or woman) with a machine. This enabled Turing to formulate the following question: "Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman?" This test, or "Imitation Game" as it was called in the paper, was put out as a modest test that could be used to substantiate that machines could think.

Without a vision of what AI could achieve, the field itself might never have formed or simply remained a branch of math or philosophy. The fact that the Turing test is still being discussed and researchers attempt to produce software capable of passing it are indications that Alan Turing and the proposed test provided a strong and useful vision to the field of AI. Its relevance to this day seems to indicate that it will be a goal for the field for many years to come and a necessary marker in tracking the progress of the AI field as a whole.

AI in Education

Artificial Intelligence (AI) has been gradually incorporated into the field of education, transforming various aspects of teaching and learning (Almasri, 2024). AI has significantly influenced instructional practices, assessment strategies, and organizational processes. It has enabled tailored learning experiences, adaptive learning systems, and intelligent tutoring systems that cater to individual student needs. For instance, AI-driven platforms can analyze student performance data to provide customized feedback and learning paths (Verdu, Regueras, Gal, Castro, Verdu, & Kohen-Vacs, 2016). The integration of AI in education offers numerous advantages, including enhanced student engagement, enhanced learning outcomes, and effective administrative operations. AI-powered tools can automate routine tasks, allowing educators to focus more on teaching and less on administrative duties. Additionally, AI can provide real-time insights into student progress, helping teachers identify areas where students may need additional support. Despite its prospects, AI in education also presents several challenges. These include ethical concerns, data privacy issues, and the digital divide. Ensuring that AI systems are transparent, fair, and unbiased is crucial to maintaining trust in educational institutions. Moreover, there is a need to address the digital divide to ensure that all students have access to AI-powered educational resources. The future of AI in education looks promising, with ongoing research and development aimed at addressing current challenges and exploring new opportunities. Future studies should focus on developing ethical guidelines for AI use in education, enhancing digital literacy among educators and students, and promoting equitable access to AI technologies.

AI Adoption in Nigeria's Education System

Artificial Intelligence (AI) has the potential to revolutionize education by providing personalized learning experiences, enhancing administrative efficiency, and fostering innovative teaching methods. In Nigeria, the adoption of AI in education is gaining momentum, driven by the need to address various challenges in the education sector and improve learning outcomes. Nigeria has been making significant strides in integrating AI into its education system (Tribune, 2024).

The Federal Ministry of Education has developed a National Digital Learning Policy aimed at leveraging digital technology to enrich teaching and learning (Federal Ministry of Education, 2023). This policy focuses on mitigating the impact of disruptions to learning systems and promoting the adoption of innovative educational technology tools.

AI adoption in Nigerian education offers several benefits, including personalized learning experiences, improved student engagement, and enhanced administrative efficiency (Sule, 2024).

AI-powered tools can analyze student performance data to provide customized feedback and learning paths, helping teachers identify areas where students need additional support. Additionally, AI can automate routine administrative tasks, allowing educators to focus more on teaching. Despite the potential benefits, AI adoption in Nigeria's education system

faces several challenges, such as inadequate infrastructure, lack of qualified teachers, and inconsistent access to learning resources. Addressing these challenges requires significant investment in AI infrastructure, training for educators, and policies to ensure equitable access to AI technologies

AI in Architecture-Background

According to Chaillou, (2019), the application of AI into the architectural realm didn't happen as a sudden disruption, but rather as a natural progression and accumulation of preceding concepts that used related technologies. One of the early examples of utilizing digital technology to serve the architectural design imagination was Frank Gehry's design for the Guggenheim Bilbao Museum. The building's distinctive curved surfaces and flowing lines are a signature feature of Gehry's architecture, and they posed a significant challenge for traditional architectural design methods. To overcome this challenge, Gehry turned to digital technology. He used a computer-aided design (CAD) program called CATIA, which was originally developed for the aerospace industry to design fighter jets. Using CATIA, Gehry was able to visualize and materialize the complex curved surfaces of his design, creating a 3D model that could be used to guide the construction of the building (Fig. 2). The steel frame for the Guggenheim Bilbao Museum is composed of hundreds of individual steel members, each of which was designed using CATIA, which allowed to precisely control the shape, size, and location of each member, ensuring that the frame well before the construction process. This early adoption of digital technology allowed Gehry to achieve his ambitious design for the Guggenheim Bilbao Museum, pushing the boundaries of architectural design and creating a truly iconic building.

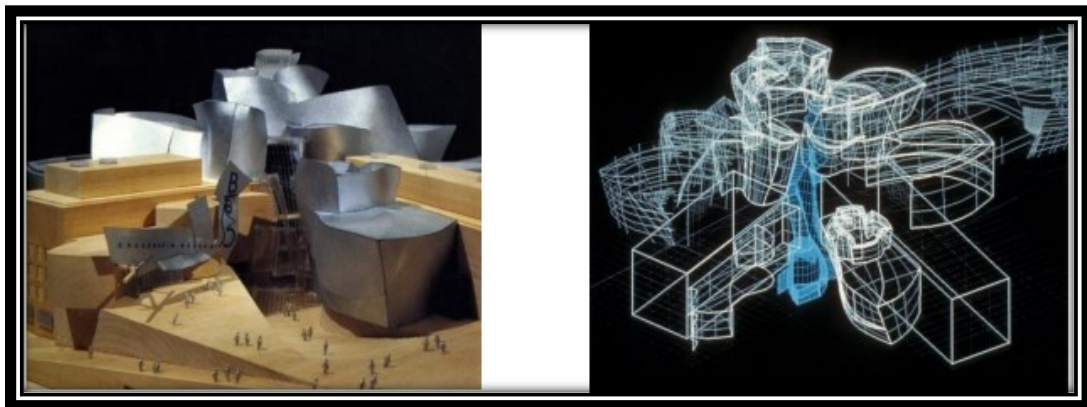


Plate 1: The free-form scale model of Guggenheim Bilbao Museum (Right) Vector representation of the museum's form in CATIA (Marcos, 2017)

This historical evolution of using AI in architecture can be divided into four main steps: modularity, computational design, parametric design, and AI Modularity involves using standardized, interchangeable parts in design to allow for flexibility and adaptability in construction. Computational design uses computers to assist in the design process,

allowing for more precise and complex designs. Parametric design uses algorithms and variables to generate design options based on specific criteria. AI takes these concepts even further by using advanced machine learning algorithms to assist in the design process and create even more complex and optimized designs. (Hegazy & Saleh, 2023)

Artificial Intelligence Algorithms used in Architecture

Generative Adversarial Networks (GANs)

GAN is an acronym for generative adversarial networks. GAN is a class of deep neural nets that is a generative model (Uzun, Birgül Çolakoglu, & İncöglü, 2020). GAN algorithms are used as a generative system. Generative Adversarial Networks (GANs) is an offspring of the evolution that Artificial Intelligence (AI), Machine Learning (ML), and Neural Networks (ANNs) have been processing through in the last century (Schmidt, 2020). Architectural plans are a subclass of architectural drawings. Architects draw plans centered on spatial organization decisions, such as the location of the building, the size of the space, the relation between the spaces, etc. Plan production is a repetitive drawing process where spatial organization decisions are made. The repetitive process in the designing and drawing of architectural plans can be produced autonomously using the GAN model, a deep learning algorithm. An example of studies carried out using a GAN network is the study by Huang & Zheng, (2018) were able to design plans using GAN networks. GAN networks are strong enough to generate visual data. The GAN system that Huang and Zheng used was a specialized GAN network called Pix2pixHD. This network can derive visual information from labels. For example, if the label is the kitchen label, drawings of the kitchen plan are generated on that label. In the dataset used by Huang and Zheng, features (furnishing, walls, and bearing systems) are produced autonomously on plan drawings using the GAN network. Chaillou, (2019) work is another study on plan generation with GAN networks. In this study, GAN networks generate plans in three steps. In the first step, the total shape of the plan is generated. In the second step, GAN produces interior partitioning and spatial arrangement. The third step ends with furnishing and plan production. This study reveals the power of GAN networks in autonomous plan generation. In Chaillou's work, the resulting plans are very clear, right down to the details of the plan, the openings in the walls, and the spatial organization.



Fig 1: Training sequence key (source: Chaillou, 2019)

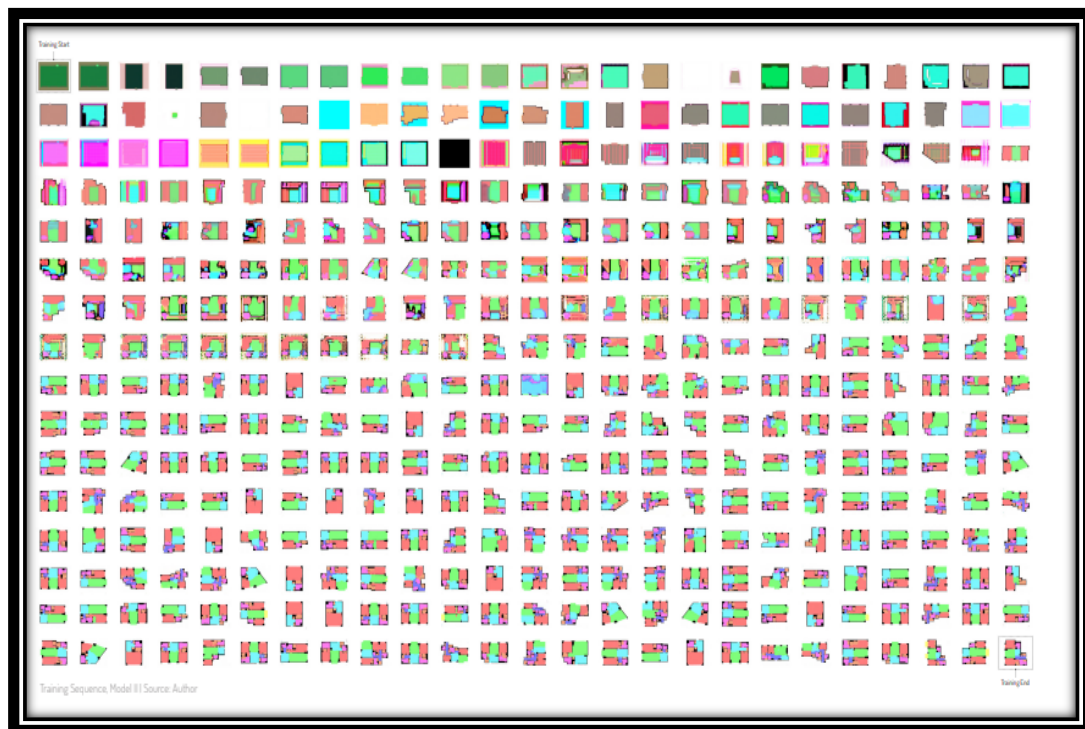


Fig 2: Training sequence model (source: Chaillou, 2019).

Artificial Intelligence and Conceptual Designs in Architecture

An instance of using AI factually in architectural design could be found in the study conducted by As, Pal, & Basu, (2018) where they presented a deep neural network (DNN) approach using graphs to generate conceptual designs in architecture. They showed that their system can evaluate and score designs, decompose them into essential building blocks, and recombine them into novel compositions (Fig.1). The authors also demonstrated how to use generative adversarial networks (GANs) to generate new designs

not seen in the training set. The study showed how DNNs can be used to discover interesting building blocks in design data, merge them in a mathematically principled manner to yield new compositions, and generate interesting design variations using GANs. The preliminary results were promising, but the authors noted limitations and constraints in the scope of the designs, the limited number of design samples, and the lack of evaluation of the generated designs.

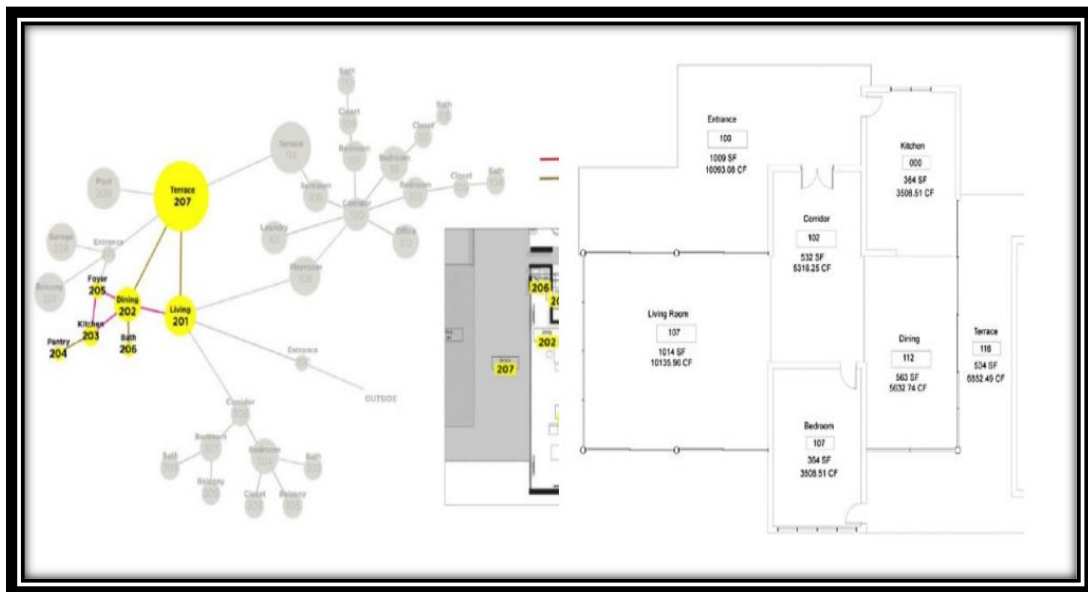


Fig 3: (Left) DNN concluding zoning relationships from the dataset provided (Right) a floor plan generated by AI using the concluded zoning rules (As, Pal, & Basu, 2018)

Artificial intelligence: Virtual Reality Used in Architecture

Virtual media is a bridge to fill a physical space. In the last decade, a tool called Virtual Reality became widely known in the gaming industry. Virtual reality is defined as follows: "A computer simulation of a real or imaginary system that enables a user to perform operations on the simulated system and shows the effects in real-time." (The American Heritage Dictionary, 2020) Examples of this technology are the virtual reality glass HTC Vive and the Oculus Rift. Google has made a cheaper alternative called Google Cardboard where, unlike the Vive and the Rift which rely on an external processing unit, the phone becomes the processing unit that projects the virtual world surrounding the user. The aim is then to merge the simulation with the in a real space. A virtual-physical space, also called Augmented Reality. This optimum tool set has the potential for the user to interact with virtual objects surrounding him. An example of this technology is the Microsoft Hololense, which is already capable of rendering objects in real-time.

Artificial Intelligence: Smart Buildings and Cities

AI plays a crucial role in the development of smart buildings and cities, where sensors and systems can dynamically respond to changing environmental conditions. Building

management systems powered by AI can optimize energy usage, control lighting, and HVAC systems, and enhance overall efficiency. A good example of a smart building is The HSB Living Lab is a residential building that is occupied by students and guest teachers, located at the Joannesberg Science Park in Gothenburg, Sweden is a collaboration project between Chalmers University of Technology and HSB, a Swedish housing association who aim is to research more sustainable living methods and create sustainable housing for the future. The building is made out of pre-fabricated housing units that are composed together to inhabit 33 people who reside in the building continuously. To research construction technologies of future use, the building features interior facades that can be swapped out and upgraded. To achieve the goal of researching sustainable living methods, the project uses smart technologies and therefore also relates to the term Smart Architecture. These technologies track the students' behavior and indoor qualities such as the emissions of each user, and the concentration of carbon dioxide in each space unit but also detect the social behavior of the inhabitants.



Plate 2: The HSB Living Lab (Schmidt, 2020)

AI-Image Generation for Design Consideration: Case Studies

One of the principal prospective uses for AI image generation is the knack to easily imagine radical, futuristic, and highly abstract forms. This allows for the generation of images that feature rare and abstract designs, often with a highly aesthetic configuration and impression. These results are done by creating a text prompt in the form of instruction that mixes various concepts, and architectural styles, and emphasizes terms such as "sci-fi" and "futuristic" elements within the prompt. For instance, Tim Fu, a designer at Zaha Hadid

Architects, has demonstrated a variety of design explorations that mix organic forms and naturally inspired patterns in aesthetic architectural representations that reflect futuristic concepts and materials (Tim, 2022). These designs showcase the potential of AI image generation to create highly imaginative and abstract forms that can be used in the exploration of new architectural concepts and styles (Plate 3).

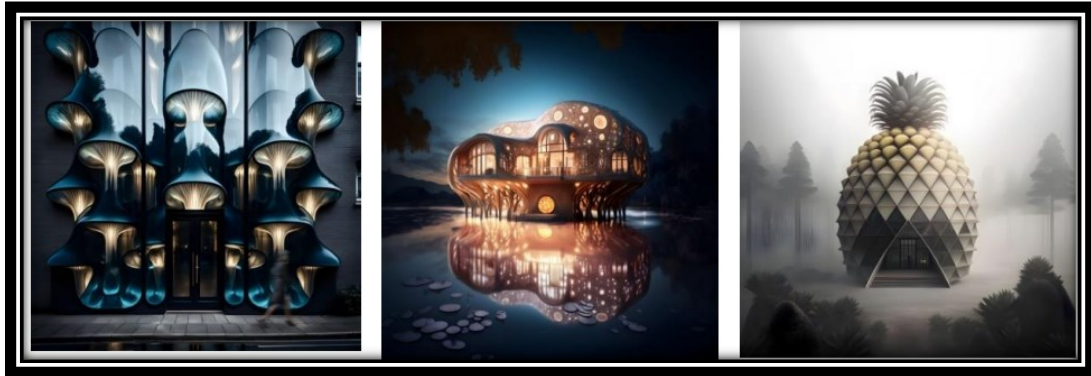


Plate 3: A variety of designs generated by Midjourney showing nature-oriented and futuristic concepts (Source: Tim, 2022)

Artificial Intelligence and Biomimicry Architecture

AI image generation can be used to generate designs that mimic the forms, functions, and behaviors of natural systems, due to its ability to abstract elements and mix styles consistently. For example, a building designed using biomimicry principles might use materials and structures inspired by the shells of mollusks (snails) or the leaves of plants, allowing it to blend seamlessly into its environments and function more efficiently. In this context, El Sayary, (2022) used Midjourney to generate a variety of imaginative forms that directly depict structures inspired by natural phenomena, such as ant colonies (Plate 4) and forests (plate 5). The author argued that the generated designs not only reflect nature but also the identity of the place, by using natural local materials in the forms as well. Midjourney was able to generate highly detailed, fluid forms with relatively convincing structural and aesthetic orders.



Plate 4: Design generated by midjourney inspired by ant colonies in terms of structure, forms, and materials (source: El Sayary, (2022))



Plate 5: Tree-like design inspired by African foliage nature (Source: El Sayary, (2022))

Artificial Intelligence Used in Architectural Sketches

AI image generation also showed a potential use for enhancing architectural sketches and thoughts in several ways, where an AI image generation system could be taught to complete incomplete sketches or to create new variations of a design built on a set of input sketches. This could be useful for quickly generating a range of design options for architects to choose from, or for helping architects explore different design concepts more easily without the need to further envision each idea (e.g., using 3D modeling and rendering tools). A good example of this could be seen in the exploitation of img2img- an implementation of Stable Diffusion- by AbdelShakour, (2022) to generate façade design visualizations based on students' simple sketches. The generated images were reported as

closely aligned with the original sketches in terms of camera angles, building masses, and heights (Plate 6). The author also notes that while the generation time for these images is relatively fast, they do require a high level of GPU computing to be generated quickly.

Statement of Research Problem

The specific problem addressed in this study is the potential disparity in Architectural AI education and resource availability among architectural students in South-East of Nigeria. By investigating students' awareness, access, and utilization of AI, this research seeks to identify barriers and opportunities for enhancing AI integration in Architectural Education.

Methodology

A descriptive research survey was employed for this study. This method was considered the most appropriate design for this research because it entails selecting a chosen sample from a large population. The population for the study consists of students in three (3) tertiary institutions in Abia State and Ebonyi State, The Akanu Ibiam Federal Polytechnic, Unwana, The Abia State Polytechnic in Aba, and the Abia State University, Uturu, Abia State. A multi-stage sampling technique was adopted for this study. Proportional sampling techniques were used to draw the precise number of participants from each institution after which a simple random sample technique was used to select 200 respondents out of the total population of 833 students in the three tertiary institutions. The sample size for the study consists of 200 undergraduate students. This study employs a questionnaire to elicit information from the respondents and the categories of variables were independent variables of awareness, access, and competence use of the dependent variable.

First year: 250 students

Second year: 200 students

Third year: 180 students

Final Year: 203 students

Total population (**N**) = 833 students

Proportion

First year: $P_{\text{first year}} = 250/833 = 0.300$

Second year: $P_{\text{second year}} = 200/833 = 0.240$

Third year: $P_{\text{third year}} = 180/833 = 0.216$

Final Year: $P_{\text{Final year}} = 203/833 = 0.244$

Multiplying, the total sample size by the proportion of each stratum to determine the sample size for each stratum.

Sample Size

First year: $200 * 0.300 = 60$

Second year: $200 * 0.240 = 48$

Third year: $200 \times 0.216 = 43$

Final year: $200 \times 0.244 = 49$

Sample size = 200 Total population = 833.

Research Instruments

The instrument used for this research is a structured questionnaire titled "Student's Awareness of, Access to, and the Use of Artificial Intelligence for Architectural Design in Tertiary Institutions". The questionnaire is a close-ended type, which contains a set of pre-determined options for the items presented. The questionnaire contains three sections. Section A requires the demographic information of the respondents. Section B asked questions to assess students' awareness and accessibility of artificial intelligence while Section C, asked questions on students' competence in the use of artificial intelligence architectural design. Section B was structured using a Nominal Scale of Aware, Not Aware and Accessible, Not Accessible questions while Section C Scale was structured using Likert scale responses modes of Highly Competent (HC), Moderately Competent (MC), and Not Skilled (NS). These were presented using three (3) point ratings ranging from Highly Competent (1) to Not Skilled (3) using the mean score benchmark of 2.5 for the correspondent's competency.

Validation of the Research Instrument

The instrument was validated by three experts from the Education Department at the Abia State University Uturu Nigeria, faculty Lecturers of Environmental science and Lecturers of the department of computer Science that specialize in AI. Fallout from the suggestion made by the experts was noted and the modifications were made to the questionnaires accordingly. All the articles in the questionnaire were judged to be important to what is being measured thereby guaranteeing adequate content and face validity of the instrument.

Procedure for Data Collection

The researchers obtained a letter of introduction from the Head of the Department of Architectural Technology, Akanu Ibiam Federal Polytechnic, to seek consent from the suitable authorities within the sampled schools to enable easy administration of the questionnaires. The survey was carried out between February 12th, 2024 to April 16th 2024, the length of time was as a result of difference in resumption of student in Various Campuses across the three Tertiary institution been studied. The researchers read and clarified the aim of the study to the participants. The respondents had adequate time to react to the questionnaire. After this, the researcher personally collected the answered questionnaire and reviewed the qualified and sufficiently completed questionnaire. Inadequate information or a doubtful answer like showing observable patterns was removed for those particular items only. Decent consideration was maintained throughout data collection. The researcher ensured that respondents were not compelled to fill out the

questionnaire and respondents were allowed to participate voluntarily. Also, the utmost confidentiality and secrecy of the respondents were maintained during the administration, collation, and report of research findings. Through the assistance of a statistical analyst, the researchers tabulated the data collected from the participants using ANOVA (Analysis of Variance) which was employed to analyze the data and test the hypotheses related to the level of access and awareness of AI in architectural design among students of different academic levels. Ethical considerations were maintained throughout the data collection period. The researchers ensured that respondents participated voluntarily and were not coerced into filling out the questionnaire. Additionally, utmost confidentiality and anonymity of the respondents were preserved during the administration, collation, and reporting of the research findings.

Data Analysis Techniques

The data collected and examined in this section embodies the variables of focus for the study and background information of undergraduate students who were actively involved in the study. The demographic information in which data were collected and analyzed is presented in Table 1 revealing the demographic information of the participants in this research. As indicated, the gender difference rate of 60% was observed, indicating that there was a remarkable difference in the proportion of participants in the study: female respondents (20%) were less than male respondents (80%). Correspondingly, more students from polytechnics 60% formed a larger proportion of the sample size, while 40% were from the universities.

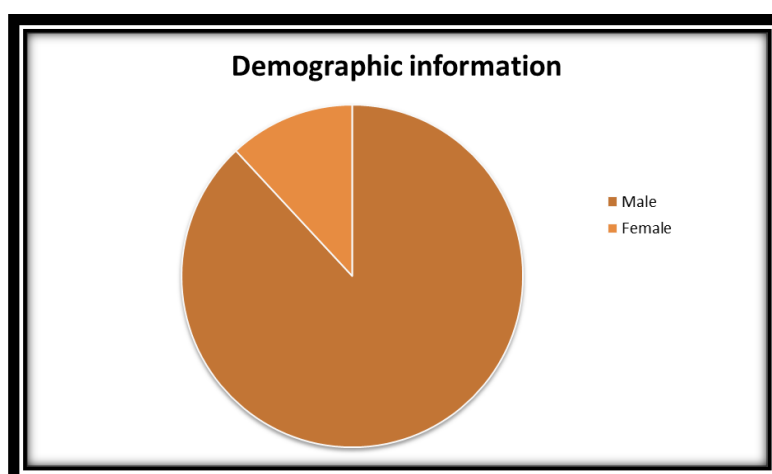


Fig 4: Pie chart shows the percentage of respondents' for Male students and Female students

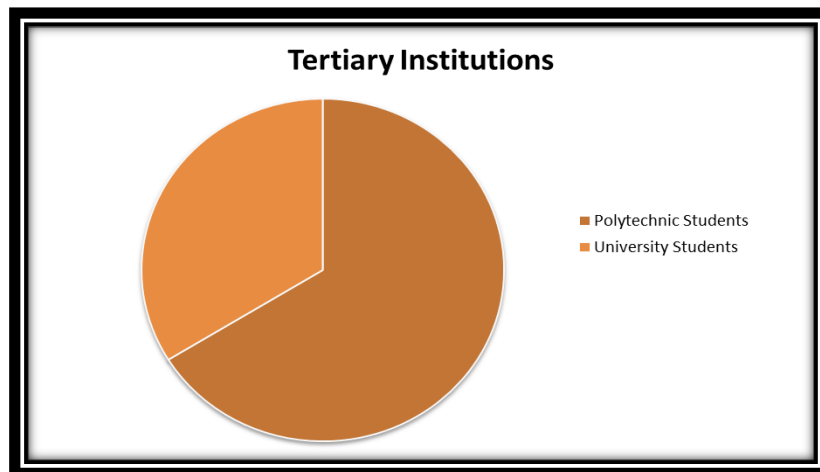


Fig 5: Pie chart shows the percentage of respondents for Polytechnic students and University students

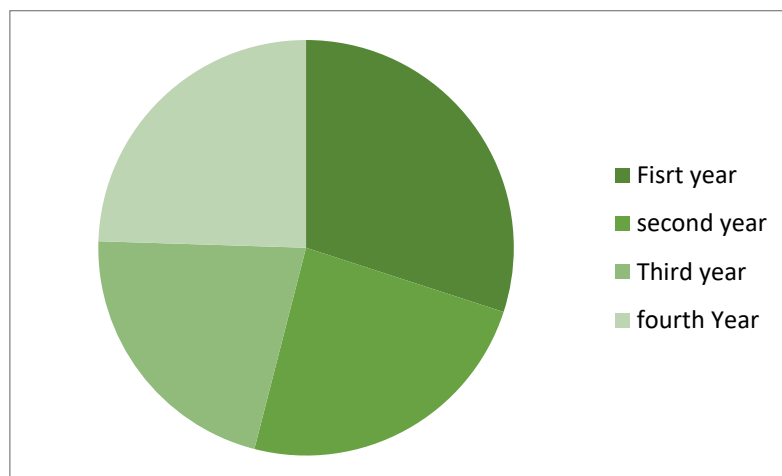


Fig 6: Percentage distribution of sample size

Results and Discussion

Research Question One: Are students in the Architecture department in Tertiary institutions aware of the use of artificial intelligence in Architectural Design?

To examine the university student's awareness of Artificial intelligence for architectural design, a data modification was done and only 75 (225) of the sample size successfully responded to the questionnaire satisfactorily. Then, a percentage point scale of 50.0% was adopted. Data collected were analyzed using frequency counts and percentages. As indicated in Table 2, higher parts of the responses were skewed towards the "not aware" response, implying that the majority of the students in tertiary institutions studied are not aware of Artificial intelligence used in Architectural design. However, DALL-E, Maket AI, and Midjourney seem to be known among both university students and polytechnic students. Perhaps, in general, the cumulative total percentage point scale of 70.5% which

is greater than the benchmark of 50.0% indicated that the majority of university students are not aware of Artificial intelligence for Architectural design.

Research Question Two: Do students in Architecture departments have access to Artificial intelligence for Architectural design?

In examining student's access to Artificial intelligence for Architectural design, a percentage point scale of 50.0% was adopted. Data collected were analyzed using frequency counts and percentages. As indicated in Table 3, higher parts of the responses were tilted towards the "not accessible" response, implying that the majority of the students in tertiary institutions examined do not have access to Artificial intelligence for Architectural design. Perhaps, in general, the cumulative total percentage point scale of 80.3% which is greater than the benchmark of 50.0% indicated that the majority of students do not have access to Artificial intelligence for Architectural design.

Research Question Three: What is the level of students' competency in the use of artificial intelligence for Architectural Design?

In evaluating the competency of university students in the use of Artificial intelligence for Architectural design, a percentage point scale of 30% was adopted. Data collected were analyzed using frequency counts and percentages. As indicated in Table 4, higher parts of the responses were tilted towards the "not skilled" response. However, few of the participants still indicated that they were moderately competent in using Artificial intelligence for Architectural Design. These include: using Mid journey to convert text to image; using Maket AI to generate multiply editable floor plans for design options; using Autodesk Forma (formerly Space Maker) for conceptual design options using Get floor plan to convert an idea into a 3D model that can be modified and explored; using interior AI for creativity in realm interior design. Cumulatively, the summary total percentage point scale of 42.7% which is the greatest among the percentage values and greater than the benchmark of 30% indicated that the majority of the students are not skilled and incompetent in the use of artificial intelligence for Architectural Design.

Hypothesis Testing

Hypothesis One: There is no significant difference in the level of awareness of AI in architectural design among students of different academic levels (first year, second year, third year and final year) in selected tertiary institutions in Southeast Nigeria. This is reflected in the findings of the hypothesis tested ($df_{\text{between}} = 3$, $df_{\text{within}} = 196$, $F = 2.35$, $p > 0.05 = 0.074$). Thus, the hypothesis which states that there is no significant difference in the level of awareness of AI in architectural design among student of different academic levels (first year, second year, third year and final year) in selected tertiary institutions in Southeast Nigeria is accepted.

Table 1: Demographic information of respondents

Demographic Data	Frequency	percentage
Gender		
Male	240	80
Female	60	20
Total	300	100
Institution Type		
Abia State University, Uturu	120	40
Akanu Ibiam Federal Polytechnic, Unwana	100	33.3
Abia State Polytechnic, Aba.	80	26.7
Total	300	100

Table 2: Awareness of the use of artificial intelligence for Architectural Design

S/No.	Architectural Design AI	Awareness Frequency (%)	Not Aware Frequency (%)
1	Midjourney	41 (18.2)	184 (81.8)
2	Ark Design	28 (12.4)	197 (87.6)
3	Maket AI	43 (19.1)	182 (80.9)
4	Architect gpt	25 (11.1)	200 (88.9)
5	Get floor Plan	27 (12)	198 (88)
6	ARCHITEChTURE	19 (8.4)	206 (91.6)
7	DALL-E	41 (18.2)	184 (81.8)
8	Autodesk Forma	20 (8.9)	205 (91.9)
9	Click Up	29 (12.9)	196 (87.1)
10	Adobe Firefly	24 (10.7)	201 (89.3)
11	Luma AI	19 (8.4)	206 (91.6)
12	Sidewalk Labs	22 (9.8)	203 (90.2)
13	Finch	12 (5.3)	213 (94.7)
14	Archi Star	15 (6.7)	210 (93.3)
15	Test Fit	19 (8.4)	206 (91.6)
16	Interior AI	22 (9.8)	203 (90.2)
17	Digital Blue Foam	14 (6.2)	211 (93.8)
18	Hypar	10 (4.4)	215 (95.6)
19	Cove Tool	14 (6.2)	211 (93.8)
	Cumulative Total	444 (10.4)	3,831(89.6)

Table 3: Awareness of the use of artificial intelligence for Interior Design

S/No.	Interior Design AI	Awareness Frequency (%)	Not Aware Frequency (%)
1	Planner 5D	27 (12)	198 (88)
2	Home Styler	19 (8.4)	206 (91.6)
3	Smart Draw	19 (8.4)	206 (91.6)
4	Home by me	12 (5.3)	213 (94.7)
5	Havenly	14 (6.2)	211 (93.8)
6	Hutch	10 (4.4)	215 (95.6)
7	Room gpt	10 (4.4)	215 (95.6)
8	Leaperr	15 (6.7)	210 (93.3)
9	Ikea Place	19 (8.4)	206 (91.6)
10	Lex set Ai	19 (8.4)	206 (91.6)
	Cumulative Total	164 (7.26)	2,086(92.74)

Table 4: Awareness of the use of 3D modeling AI tool

S/No	3D Modeling AI Tool	Awareness Frequency (%)	Not Aware Frequency (%)
1	Kaedim	10 (4.4)	215 (95.6)
2	Texture Lab.	12 (5.3)	213(94.7)
3	Luma Lab	12 (5.3)	213 (94.7)
4	Plask	10 (4.4)	215 (95.6)
	Cumulative Total	44 (4.85)	856(95.15)

Table 5: Students' access to the listed artificial intelligence items for Architectural Design

S/No.	Architectural Design AI	Accessible Frequency (%)	Not Accessible Frequency (%)
1	Midjourney	20 (8.9)	205 (91.1)
2	Ark Design	15 (6.7)	210 (93.3)
3	Maket AI	19 (8.4)	206 (91.6)
4	Architect gpt	13 (5.8)	212 (94.2)
5	Get floor Plan	18 (8)	207 (92)
6	ARCHITEChTURE	10 (4.4)	215 (95.6)
7	DALL-E	8 (3.6)	217 (96.4)
8	Autodesk Forma	10 (4.4)	215 (95.6)
9	Click Up	9 (4)	216 (96)
10	Adobe Firefly	14 (6.2)	211 (93.8)
11	Luma AI	11 (4.9)	214 (95.1)
12	Sidewalk Labs	8 (3.6)	217 (96.4)
13	Finch	8 (3.6)	217 (96.4)
14	Archi Star	22 (9.8)	203 (90.2)

15	Test Fit	19 (8.4)	206 (91.6)
16	Interior AI	12 (5.3)	213 (94.7)
17	Digital Blue Foam	7 (3.1)	218 (96.9)
18	Hypar	7 (3.1)	218 (96.9)
19	Cove Tool	7 (3.1)	218 (96.9)
	Cumulative Total	237 (5.5)	4,038(94.5)

Table 6: Students' access to the listed artificial intelligence items for interior design

S/No.	Interior Design AI	Accessible Frequency (%)	Not Accessible Frequency (%)
1	Planner 5D	12 (5.3)	213 (94.7)
2	Home Styler	10 (4.4)	215 (95.6)
3	Smart Draw	9 (4)	216 (96)
4	Home by me	7 (3.1)	218 (96.9)
5	Havenly	12 (5.3)	213 (94.7)
6	Hutch	13 (5.8)	212 (94.2)
7	Room gpt	5 (2.2)	220 (97.8)
8	Leaperr	8 (3.6)	217 (96.4)
9	Ikea Place	6 (2.7)	219 (97.3)
10	Lex set Ai	9 (4)	216 (96)
	Cumulative Total	91 (4.04)	2,159(95.96)

Table 7: Students' access to the listed artificial intelligence items for 3D modeling

S/No	3D Modeling AI Tool	Accessibility Frequency (%)	Not Accessible Frequency (%)
1	Kaedim	9 (4)	216 (96)
2	Texture Lab.	7 (3.1)	218(96.9)
3	Luma Lab	8 (3.6)	217 (96.4)
4	Plask	12 (5.3)	213 (94.7)
	Cumulative Total	36 (4)	864(96)

Table 8: Level of students' competency in the use of artificial Intelligence for Architectural Design

S/ No.	Items	Highly Competent Frequency (%)	Moderately competent Frequency (%)	Not Skilled Frequency (%)
1	I can use mid-journey to convert architectural text to image	32 (14.2)	25 (11.1)	168(74.7)
2	I can use mid-journey to convert architectural text to images to generate building sections	12 (5.3)	15 (6.7)	198(88)
3	I can use maket AI to generate multiple design options for a given project	31 (13.8)	23 (10.2)	171(76)
4	I can use maket AI to generate and edit multiple floor plans for a given project	17 (7.6)	14 (6.2)	194 (86.2)
5	I can use Get Floor Plan to convert a 3D model that can be modified and explored	28 (12.4)	15 (6.7)	182 (80.9)
6	I can use ARCHITEChTURE for Site Planning	14 (6.2)	12 (5.3)	199(88.4)
7	I can use DALL-E to generate architectural prompts from text to image	22 (9.7)	17 (7.6)	186(82.7)
8	I can use DALL-E to generate prompts for Building sections.	7 (3.1)	9 (4)	209(92.9)
9	I can use Click Up to track deadlines for design assignments and collective design tasks.	8 (3.6)	4 (1.7)	213(94.7)
10	I can use Adobe Firefly to create architectural Visual and textual effects.	17 (7.5)	15 (6.7)	193(85.8)
11	I can use Luma AI to optimize the 3D modeling process	10 (4.4)	11 (4.9)	204(90.7)
12	I can use Sidewalk Labs for Urban Planning.	12 (5.4)	14 (6.2)	199(88.4)
13	I can use Archistar for site planning	12 (5.4)	13 (5.8)	200(88.8)
14	I can use Archi Star for aerial perspective.	14 (6.3)	12 (5.3)	199(88.4)
15	I can use Test Fit to generate architectural concept variation.	8 (3.6)	7 (3.1)	210(93.3)
16	I can use Hypar to generate a complete floor Plan.	7 (3.1)	6 (2.7)	212(94.2)
17	I can use Hypar to import Architectural data in DXF or Revit	5(2.2)	5 (2.2)	215(95.6)
18	I can use the cove tool for Plug-ins for popular programs like Sketch-up, and Revit.	12 (5.3)	11(4.9)	202(89.8)
19	I can use Cove Tool to create models	15 (6.7)	5 (2.2)	205(91.1)
	Cumulative Total	283(6.6)	233(5.5)	3759(87.9)

Hypothesis Two: There is no significant difference in the level of access to AI in architectural design among students of different academic levels (first year, second year, third year, and final year) in selected tertiary institutions in Southeast Nigeria. This is reflected in the findings of the hypothesis tested (df between = 3, df within = 196, $F = 1.02$, $p > 0.05 = 0.39$). Thus, the hypothesis which states that there is no significant difference in the level of access to AI in architectural design among students of different academic levels

(first year, second year, third year, and final year) in selected tertiary institutions in Southeast Nigeria is accepted.

Discussion of Findings

This research found that the bulk of students in tertiary institutions are not aware of, and do not have access to the use of AI for Architectural design. This finding could be premised on the fact that AI is relatively new to the Nigerian Architectural community. The application of AI in architectural design is largely credited to the developed countries where most of the students are aware and have the resources to access them (Lazarus, Thurlow, Lail, & Christensen, 2009) Research has highlighted that the growth and acceptance of new technologies in Architectural design and Architecture have grown steadily over the past 20 years, but the acceptance in developing countries is relatively low. The researchers stressed that perhaps AI holds the solution to most local architectural problems and a departure from the traditional hand-drawn architectural design can expose the students early and give them the adequate knowledge to provide solutions to future architectural problems and also place them at par with their foreign counterparts. However, it is largely technologically dependent, with greater emphasis on large integration of resources which could be relatively unavailable to the students. The finding of this study shows that the majority of the students are not skilled and incompetent in the use of AI for learning. This finding corroborates the earlier findings of lack of awareness and access. It is believed that competency in technological innovation is dependent on the knowledge of, availability, and access to the technological innovations. This finding supports the finding of Popenici & Kerr, (2017) who opined that the realm of learning in higher education presents a very different set of challenges for students, especially as the ability to explore AI solutions will potentially restructure the learning process for students. The researchers emphasized that the capability to explore AI skillfully and gain substantive knowledge through its use is wide and requires lots of technical skills which might be unavailable to many students at this time. In light of this, this study found out that as a majority of students are not aware of, lack access to, and do not have the skills to explore or use AI, their level of competence may not be high.

Recommendations

1. Incorporate AI-focused modules into architectural curricula:

Develop Specialized Courses: Create dedicated courses that cover the fundamentals and advanced applications of AI in architecture. These courses should include topics such as machine learning, neural networks, and AI-driven design tools.

Integrate AI into Existing Courses: Embed AI-related content into current architectural design and technology courses. This integration ensures that all students, regardless of their specialization, gain exposure to AI concepts and tools.

Curriculum Updates: Regularly update the curriculum to reflect the latest advancements in AI and its applications in architecture. This ensures that students are learning the most current and relevant information.

2. Provide training workshops for both students and faculty members on AI tools for architectural design:

Hands-on Workshops: Organize practical workshops where students and faculty can learn to use AI tools and software. These workshops should include real-world projects to provide practical experience.

Seminars and Webinars: Host seminars and webinars featuring AI experts and industry professionals. These sessions can cover a range of topics from basic AI concepts to advanced applications in architectural design.

Continuous Professional Development: Encourage continuous learning by offering regular training sessions and refresher courses. This helps both students and faculty stay updated with the latest AI tools and techniques.

3. Increase investment in AI infrastructure in tertiary institutions to improve access for students:

Funding for AI Labs: Secure funding to establish AI laboratories, equipped with the latest hardware and software. These labs should be accessible to all students for their coursework and research projects.

High-Performance Computing Resources: Invest in high-performance computing resources to support AI research and applications. This includes powerful servers, GPUs, and cloud computing services.

Software Licenses: Provide access to essential AI software and tools by securing institutional licenses. This ensures that all students can use these tools without financial barriers.

4. Encourage collaboration between industry and academia to facilitate AI-driven projects and internships for architectural students:

Partnerships with Firms and Tech Companies: Establish partnerships with leading architectural firms and technology companies. These partnerships can provide students with opportunities to work on real-world AI-driven projects.

Joint Research Projects: Promote collaborative research projects between students, faculty, and industry professionals. These projects can focus on innovative applications of AI in architecture.

Internship Programs: Develop internship programs that place students in industry settings where they can apply their AI knowledge. These internships provide valuable hands-on experience and help bridge the gap between academia and industry.

Conclusion

Students' awareness and access to architectural intelligence for design and collaboration depends largely on the standard of ICT labs in various tertiary institutions and the availability and affordability of internet services and power, and also the recruitment of qualified staff, which at the very moment, is very low. Despite the willingness of students to learn these technical skills in AI for architectural design, the absence of these factors has made it almost impossible. The Nigerian government on its own has suggested that a regional fiber optic backbone network should be built to ensure high bandwidth availability, universal funding, and programs for access to emerging digital technologies such as AI. Sadly, the efforts have shown very little or no result. AI has shown abilities to offer exceptional information and skills that are essential to living in the fourth evolution era by providing ways to vigorously discover and represent information. This study has indicated that students' ability to explore digital resources such as AI is dependent on their awareness and access to digital technologies. A lack of these will result in a lack of use and lack of skill to use them.

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