GENERATIVE ARTIFICIAL INTELLIGENCES AND THE PROMOTION OF SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT GOALS (SDG)4 ON EDUCATION IN NIGERIAN UNIVERSITIES

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BEING A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ACCOUNTING, FACULTY OF MANAGEMENT SCIENCES, UNIVERSITY OF BENIN ,BENIN CITY. IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF SCIENCE (B.SC) DEGREE IN ACCOUNTING

NOVEMBER, 2025.

DECLARATION

EDOSA EMMANUEL OSATOHAMWEN declare that,

i. This study is based on a study undertaken by me in the Department of Accounting, Faculty of Management Sciences, University of Benin, Benin City, under the supervision of **Prof. James Odia** of the Department of Accounting, Management Sciences, University of Benin, Benin City, Nigeria.
ii. This work has not been submitted for the award of degree elsewhere.
iii. Ideas and views are product of my personal research and where the view of others has been expressed, they have been duly acknowledged.
iv. Any liability arising from this work is to be wholly borne by me alone

_____ _____

EDOSA EMMANUEL OSATOHAMWEN **DATE**

MGS2104532

CERTIFICATION

We, certify that this research project was carried out by **Edosa Emmanuel Osatohamwen** in the Department of Accounting, Faculty of Management Sciences, University of Benin, Benin City, Nigeria. It is adequate in scope and quality in partial fulfilment of the requirements for the award of Bachelor of Science (BSc.) degree in Accounting.

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Prof James Odia **Date**

(Project Supervisor)

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Prof Osasu Obaretin **Date**

(Head of Department)

DEDICATION

This project work is dedicated to God Almighty for His abundant grace in my life and for seeing me through my academic pursuit and aspirations. He has been my source of strength and on his wings only I have soared.

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Abstract

This study investigates the adoption, usage, and application of Generative Artificial Intelligence (GAI) in promoting sustainability and achieving the Sustainable Development Goal 4 (Quality Education) in Nigerian universities. A descriptive survey research design was employed, targeting 222 professionals, policymakers, academic staff, development officers, environmental experts, and IT personnel involved in sustainability initiatives. Data were collected through googled constructed online questionnaires, with 200 valid responses received, representing a 90% response rate. Descriptive and inferential statistical techniques, including frequency distributions, percentages, mean, standard deviation, and multiple regression analysis, were used to analyze the data. The findings revealed that GAI adoption, usage, and application have a significant positive impact on sustainability and the promotion of quality education, enhancing access to learning resources, personalizing learning experiences, improving academic performance, and reducing educational inequalities. The study also identified challenges, including limited infrastructure, high costs, lack of technical expertise, and resistance to change, which may hinder effective GAI implementation. The research concludes that strategic policy development, adequate resourcing, continuous capacity building, and ethical AI practices are critical for maximizing the benefits of GAI in Nigerian universities. The study contributes to the growing body of knowledge on AI-driven sustainability and education and provides practical recommendations for policymakers, educators, and institutional administrators.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The global demand for sustainable development has intensified over the past few decades as countries continue to face interconnected challenges such as environmental degradation, widening social inequalities, and economic volatility. According to the United Nations (2023), over 1.6 billion people are currently impacted by environmental crises, while more than 700 million people remain trapped in extreme poverty despite years of developmental interventions. In response to these persistent global issues, the United Nations adopted the Sustainable Development Goals (SDGs) in 2015, a framework of 17 integrated goals and 169 targets designed to advance global prosperity, equity, and environmental stewardship by the year 2030 (UNDP, 2023).

Despite this global framework, progress towards achieving the SDGs has been uneven and is increasingly impeded by disruptive forces such as climate change, economic shocks, geopolitical instability, and the long-term consequences of the COVID-19 pandemic. The 2023 SDG Progress Report shows that only 15% of SDG targets are currently on track, 48% are experiencing slow or moderate progress, and

37% are either stagnating or regressing (United Nations, 2023). These sobering realities underscore the urgent need for innovative solutions, scalable technologies, and transformative tools that can accelerate development outcomes and drive systemic change.

Digital transformation, particularly through the integration of emerging technologies, has become an indispensable component of sustainable development. Among the forefront of these innovations is Generative Artificial Intelligence (GAI), a subset of AI designed to autonomously produce new and creative content such as text, code, simulations, images, and even scientific insights. Unlike traditional AI systems that perform specific tasks based on programmed rules, GAI employs deep learning techniques and large language models (LLMs), such as OpenAI's GPT-4 and Google's Gemini, to generate data-driven solutions across multiple domains (Dwivedi et al., 2023; Zhang et al., 2023).

The practical applications of GAI span a wide range of sectors with significant implications for sustainable development. In healthcare, GAI supports drug discovery, diagnostic accuracy, and patient outcome predictions, thereby lowering treatment costs and improving service delivery (Topol, 2023). In agriculture, AI-driven tools enhance food security by forecasting crop yields, managing supply chains, and

responding to the impacts of climate change (FAO, 2022). In environmental conservation, GAI is being used to simulate climate models, monitor carbon emissions, optimize renewable energy use, and track deforestation (Rolnick et al., 2022).

Despite its immense potential, the use of generative AI in advancing the SDGs remains limited, especially in low- and middle-income countries. Barriers such as inadequate digital infrastructure, lack of skilled AI professionals, limited access to high-quality data, and weak institutional support have slowed down the adoption of GAI in regions where its impact could be most transformative (World Bank, 2023). Additionally, ethical dilemmas, regulatory ambiguity, and concerns surrounding data privacy and algorithmic fairness continue to pose significant challenges to its mainstream application (Floridi & Chiriatti, 2023).

In the context of Nigeria, universities play a crucial role in driving technological advancement and fostering research that aligns with sustainable development goals. Nigerian universities serve as centers for innovation, capacity building, and the development of skilled professionals who can bridge the gap between emerging technologies and sustainable practices. However, many institutions still face challenges such as inadequate funding for research, limited access to cutting-edge

digital infrastructure, and insufficient collaboration with technology companies and policymakers (Adeleke & Yusuf, 2023). As the adoption of Generative AI grows globally, Nigerian universities have the potential to leverage this technology for academic research, environmental monitoring, digital learning, and entrepreneurial innovation, thereby contributing to national and global SDG targets. Integrating GAI into teaching, research, and administrative operations could also enhance the quality of education, improve decision-making processes, and promote a culture of sustainability among students and faculty members.

Given these realities, there is a growing need for empirical research to assess how generative AI is currently being adopted, the extent of its usage, and the sectors in which it is being strategically applied to solve real-world sustainability issues. Understanding these dynamics is critical for unlocking the full potential of GAI as a driver of sustainable innovation. Therefore, this study aims to critically examine the role of Generative Artificial Intelligence in promoting sustainability and contributing meaningfully to the achievement of the SDGs. By exploring three core variables adoption, usage, and application the research seeks to provide valuable insights into how GAI is transforming operational models, influencing decision-making, and advancing sustainable practices across critical sectors. The findings of this study are

expected to inform policymakers, development practitioners, technology experts, universities, and other stakeholders on the strategic integration of GAI as a catalyst for inclusive and resilient development.

1.2 Statement of the Research Problem

Sustainable development requires innovative and transformative approaches capable of addressing multifaceted global crises such as poverty, climate change, food insecurity, and unequal access to quality education. While digital technologies including artificial intelligence have demonstrated their potential to drive progress across sectors, the specific contribution of Generative Artificial Intelligence (GAI) to achieving sustainability goals remains significantly underexplored and underutilized.

Scholars such as Dwivedi et al. (2023) argue that although AI technologies have the potential to revolutionize decision-making processes and improve efficiency in sustainability efforts, most studies have focused broadly on predictive and analytical AI, leaving generative models relatively understudied in terms of their direct application to sustainability objectives. This implies a critical knowledge gap regarding how generative systems such as large language models (LLMs) and generative adversarial networks (GANs) are contributing specifically to the Sustainable Development Goals (SDGs).

In a similar vein, Rolnick et al. (2022) highlighted that while machine learning has made substantial strides in environmental monitoring, disaster response, and energy optimization, most applications are concentrated in developed economies with strong data ecosystems. They emphasized that the accessibility and implementation of advanced AI models like GAI in low-resource environments remain limited, which raises equity concerns and reinforces a digital divide that hinders global SDG progress.

Furthermore, Zhang et al. (2023) examined the potential of generative AI for urban sustainability planning and found that while simulations and content generation can accelerate policy design and citizen engagement, there is little empirical data on how often these technologies are adopted in practice and whether they yield measurable sustainability outcomes. They concluded that more empirical studies are needed to evaluate the real-world impact of generative AI applications on sustainability indicators.

From these scholarly perspectives, a clear research gap emerges: There is a lack of empirical evidence that evaluates the adoption, usage, and practical application of generative AI for sustainability, especially in diverse regional and institutional contexts. Existing literature tends to focus either on theoretical potentials or on general AI applications, without systematically assessing how generative AI tools are

currently deployed, who is using them, and whether they are producing tangible results aligned with SDG targets.

This study seeks to fill that gap by conducting a focused empirical investigation into the adoption, usage, and application of Generative Artificial Intelligence in promoting sustainability and achieving the Sustainable Development Goals. By doing so, it will contribute original data and insights that can inform policy, guide institutional investments, and promote a more inclusive and strategic use of emerging technologies for sustainable development worldwide.

1.3 Research Questions

The following research will be answered by the study

1. What is the level of adoption of generative artificial intelligence in sustainability related effort
2. To what extent is generative artificial intelligence used to support sustainability initiatives?
3. How is generative artificial intelligence applied in promoting the Sustainable Development Goals (SDGs) n Nigeria universities?

1.4 Objectives of the Study

The main objective of this study is to evaluate the contribution of Generative Artificial Intelligence (GAI) to the promotion of sustainability and the Sustainable Development Goals (SDGs) in Nigeria universities. The specific objectives are to:

1. Examine the level of adoption of generative artificial intelligence in sustainability related effort
2. Assess the extent of usage of generative artificial intelligence in promoting sustainability initiatives
3. Analyze the application of generative artificial intelligence toward achieving specific Sustainable Development Goals (SDGs) n Nigeria universities.

1.5 Hypotheses of the Study

To guide the empirical investigation, the following null hypotheses are formulated:

1. H_{01}: There is no significant relationship between the adoption of generative artificial intelligence and the promotion of sustainability.

2. H_{02}: The usage of generative artificial intelligence does not significantly contribute to the promotion of sustainability.

3. H_{03}: The application of generative artificial intelligence has no significant impact on the achievement of the Sustainable Development Goals (SDGs) n Nigeria universities.

1.6 Scope and Limitations of the Study

This study focuses on examining the adoption, usage, and application of generative artificial intelligence (GAI) in promoting sustainability and supporting the achievement of the United Nations Sustainable Development Goals (SDGs). The scope is intentionally centered on key sectors such as education, environmental management, public health, and economic planning, which are critically aligned with the SDGs and where GAI is believed to have significant transformative potential.

The target population includes professionals, decision-makers, academic staff, researchers, and development officers working in institutions and sectors where GAI tools are either actively being adopted or are under consideration. This includes universities utilizing AI for academic and administrative functions, environmental agencies deploying AI for monitoring and modeling, healthcare institutions integrating AI in diagnostics and planning, and business enterprises applying AI to improve sustainable practices.

Data for the study will be collected through structured questionnaires distributed to a representative sample of stakeholders across these sectors. The questionnaire will be designed to capture perceptions, experiences, and insights regarding the extent of

GAI adoption, frequency of usage, and its strategic application in sustainability-driven activities. It will incorporate both closed-ended and Likert-scale questions to facilitate comprehensive quantitative analysis and the identification of usage patterns.

The study is limited by the timeframe during which data is collected and analyzed, as well as by the assumption that participants provide truthful and accurate responses. Additionally, while the research focuses on specific institutional and sectoral dynamics, the findings are intended to offer broader insights that may inform sustainable development strategies in diverse contexts where emerging technologies such as GAI are increasingly being integrated.

1.7 Significance of the Study

This research is of critical significance to a wide range of stakeholders, including policymakers, development practitioners, private sector leaders, academics, and civil society actors. In an era where the global community is striving to meet the United Nations Sustainable Development Goals (SDGs) by 2030, there is an urgent need for innovative, data-driven solutions that can address complex social, environmental, and economic challenges. Generative Artificial Intelligence (GAI) represents one of the most promising technological innovations capable of accelerating sustainable development, yet its practical role remains underexplored.

Firstly, this study provides policy-relevant insights into how generative AI technologies can be strategically adopted, used, and applied to support sustainability agendas. Policymakers at national and international levels often lack empirical data to justify technology-driven sustainability policies (UNESCO, 2023). By presenting evidence on the integration of GAI in sustainability initiatives, this research can inform the design of inclusive policies that promote digital transformation, reduce inequality, and build resilience, especially in low- and middle-income countries.

Secondly, the study is significant for organizations and industries seeking to align their operations with ESG (Environmental, Social, and Governance) frameworks and sustainability reporting standards. According to a 2023 McKinsey report, organizations that incorporate AI into their sustainability strategies have seen productivity increases of up to 15% and carbon footprint reductions of 5–10% (McKinsey & Company, 2023). This study will help decision-makers understand how to adopt generative AI tools to optimize resource allocation, drive innovation, and meet sustainability targets more effectively.

Thirdly, the study offers valuable contributions to academic literature by providing empirical evidence on the intersection of emerging technologies and sustainable development. While there is an expanding body of research on artificial intelligence in general, studies specifically focusing on generative AI particularly its adoption,

frequency of use, and real-world application in sustainable development contexts remain scarce (Dwivedi et al., 2023). This research fills a critical gap by producing data that future researchers can build upon in interdisciplinary fields such as AI ethics, digital sustainability, and international development.

Moreover, the study's findings have implications for ethical and inclusive technology development. As generative AI becomes increasingly embedded in decision-making and content creation processes, there are growing concerns about issues such as data bias, transparency, and equitable access to technology (OECD, 2023). This research can guide future investments and technological innovations by highlighting both the opportunities and potential risks of applying GAI in development contexts.

Finally, the research supports international development agencies and donor organizations in aligning their digital investments with the SDGs. As the global AI market is projected to reach $1.8 trillion by 2030 (PwC, 2023), there is a pressing need to ensure that AI advancements contribute meaningfully to sustainable and inclusive growth. This study offers a blueprint for responsible and impactful AI adoption that prioritizes both innovation and equity.

1.8 Operational Definition of Terms

- **Generative Artificial Intelligence (GAI):** AI systems capable of creating new content

- Such as text, images, or data simulations using deep learning and neural networks.
- **Adoption of GAI:** The decision and process by which organizations or individuals begin integrating generative AI into sustainability operations or projects.
- **Usage of GAI:** The frequency, depth, and consistency of using generative AI tools in daily operations related to sustainability.
- **Application of GAI:** The targeted use of generative AI to address specific challenges or goals within the SDG framework (e.g., quality education, clean energy, climate action).
- **Sustainability**: A development model that ensures long-term environmental health, economic viability, and social equity.
- **Sustainable Development Goals (SDGs):** Seventeen global goals established by the United Nations to address urgent development challenges by 2030.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The advancement of technology, particularly Artificial Intelligence (AI), has significantly reshaped the landscape of education. Among the most transformative innovations is Generative Artificial Intelligence (GAI), which possesses the capacity to produce new content such as text, images, and code, thereby supporting dynamic learning processes. As countries strive to achieve Sustainable Development Goal 4 (SDG 4) which emphasizes inclusive, equitable, and quality education for all GAI emerges as a potential driver of innovation and equity within educational systems.

This chapter explores key literature surrounding GAI and its implications for promoting quality education. It begins with a conceptual framework to define the core concepts of the study, followed by a theoretical framework that provides the foundation for understanding how GAI is integrated into educational systems. The chapter also presents empirical findings from various contexts, identifies gaps in existing studies, and lays the groundwork for the study's own investigation into the impact of GAI on the educational sector.

2.2 Conceptual Framework

2.2.1 Generative Artificial Intelligence (GAI)

Generative Artificial Intelligence (GAI) refers to a branch of artificial intelligence that focuses on systems capable of producing new and original content in forms such as text, audio, images, video, and code. These models leverage deep learning, particularly large-scale transformer-based architectures, to process massive datasets and generate coherent, human-like responses or artifacts (Dwivedi et al., 2023; Bommasani et al., 2024). Unlike traditional AI systems that are limited to classification, detection, or prediction, GAI systems are creative in nature capable of writing essays, composing music, producing artwork, and simulating human dialogue with remarkable fluency.

Prominent examples of GAI technologies include OpenAI's ChatGPT, Google's Gemini (formerly Bard), Anthropic's Claude, Meta's LLaMA, and image-based generators like DALL·E and Midjourney. These models have gained global attention for their versatility and ease of use across disciplines including education, healthcare, software engineering, and creative industries (Luccioni et al., 2023).

In the context of education, GAI is revolutionizing teaching and learning processes by offering intelligent support systems. For educators, GAI can streamline lesson planning, automate administrative tasks, assist in curriculum design, and generate

learning materials tailored to specific objectives and student profiles (Nguyen et al., 2024). For learners, GAI provides personalized tutoring, immediate feedback, language translation, and content simplification, which collectively contribute to enhanced understanding and retention (Kandpal et al., 2024).

One of the most transformative benefits of GAI in education is its ability to democratize access to high-quality resources. Through multilingual support and adaptive learning tools, GAI reduces barriers for students with disabilities, those from underprivileged backgrounds, or those in remote areas where qualified teachers or resources are scarce (UNESCO, 2023). Moreover, generative AI can foster creativity and critical thinking by prompting students to engage with AI-generated simulations, debate complex topics, or co-create content—skills essential in the digital economy (Borenstein et al., 2024).

However, the integration of GAI in education is not without challenges. Concerns about data bias, misinformation, student overreliance, academic dishonesty, and the ethical use of AI-generated content have prompted educators and policymakers to call for robust guidelines and responsible usage frameworks (OECD, 2024; Hwang et al., 2023). As such, while the potential of GAI in achieving Sustainable Development Goal 4 (Quality Education) is immense, its implementation must be accompanied by ethical safeguards, digital literacy training, and inclusive access strategies.

2.2.2 Sustainable Development Goal 4 (Quality Education)

Sustainable Development Goal 4 (SDG 4), as established by the United Nations, aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by the year 2030. This goal acknowledges education as a fundamental human right and a powerful driver of development, social mobility, and poverty eradication. SDG 4 emphasizes several core objectives, including universal access to early childhood development, free and quality primary and secondary education, equal access to affordable technical, vocational, and tertiary education, and the provision of relevant skills for decent work and entrepreneurship (UNESCO, 2023; United Nations, 2024).

A critical target under SDG 4 is to eliminate gender disparities and ensure equal access to education for vulnerable populations, including persons with disabilities, indigenous peoples, and children in conflict zones. Furthermore, Target 4.c explicitly calls for a significant increase in the supply of qualified teachers through international cooperation and the use of information and communication technologies (ICTs) to enhance teaching and learning (UNESCO Institute for Statistics, 2023).

The integration of digital innovation, particularly Generative Artificial Intelligence (GAI), provides an effective avenue for achieving the transformative ambitions of SDG 4. GAI technologies can democratize learning by delivering personalized,

adaptive, and context-specific educational content to learners regardless of their geographical or socio-economic status (OECD, 2024). Through platforms like ChatGPT, Khanmigo, or Google's Gemini, students can receive on-demand tutoring, automated feedback, content translation, and access to diverse learning styles, which are instrumental in narrowing achievement gaps and addressing individual learning needs (Kandpal et al., 2024).

Moreover, GAI supports lifelong learning a central theme of SDG 4 by offering scalable digital education tools that can be used across all age groups, professions, and educational levels. For educators, GAI eases administrative burdens and assists in curriculum development, allowing them to focus more on student engagement and pedagogical strategies (Nguyen et al., 2024). For students, especially in under-resourced regions, it compensates for the absence of qualified teachers and limited infrastructure, thus fostering equity and accessibility (UNESCO, 2023).

Importantly, the role of GAI in advancing SDG 4 must be balanced with ethical considerations, including safeguarding data privacy, avoiding algorithmic biases, and ensuring the reliability of AI-generated content (Borenstein et al., 2024). Regulatory frameworks and teacher training programs must be developed to ensure that GAI enhances rather than undermines the integrity of education systems.

In sum, Sustainable Development Goal 4 outlines a comprehensive agenda that seeks not only to widen access to education but also to elevate its quality, equity, and relevance. Generative Artificial Intelligence, when responsibly and strategically implemented, aligns with and amplifies these efforts by transforming how education is delivered, accessed, and experienced.

2.2.3 Sustainable Development Goal 3: Good Health and Well-being

SDG 3 seeks to ensure healthy lives and promote well-being for people of all ages. The integration of Generative AI into the healthcare sector is transforming the delivery of services through enhanced diagnostics, drug development, patient management, and preventive care. Generative AI models are capable of synthesizing large volumes of health data—from electronic medical records, lab results, and imaging scans to generate accurate predictions and clinical recommendations. For instance, AI-driven models have been used to identify patterns in radiology images that are often missed by human eyes, significantly improving the early detection of cancers, such as lung or breast cancer (Topol, 2023).

Additionally, GAI contributes to mental health by offering scalable virtual assistants and therapy chatbots capable of providing psychological support and monitoring. AI-driven applications like Woebot and Wysa use generative algorithms to provide real-time conversations that support users' emotional well-being, especially in areas with

limited access to professional therapists (Borenstein et al., 2024). Moreover, generative AI is revolutionizing biomedical research. For example, DeepMind's AlphaFold, which predicts 3D structures of proteins, has accelerated drug discovery processes and vaccine development key in addressing global health threats like pandemics (Ravichandran et al., 2024).

However, ethical and regulatory considerations remain central to the integration of GAI in healthcare. Issues such as data privacy, consent, model transparency, and bias in AI-generated outputs must be addressed to ensure equitable healthcare for all (Borenstein et al., 2024).

2.2.4 Sustainable Development Goal 2: Zero Hunger

SDG 2 aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. Generative AI plays a crucial role in achieving these goals by transforming traditional agricultural practices into data-driven, precision-oriented systems. AI models trained on satellite imagery, soil data, and historical weather patterns can generate insights that guide farmers in making better decisions on crop selection, irrigation, fertilization, and pest control (FAO, 2022).

One significant advancement is the use of generative models for predicting crop yields under varying climate scenarios. This enables governments and NGOs to anticipate food shortages and respond proactively. GAI can also support the design of

drought-resistant or high-nutrient crop variants through genome analysis and simulation, which is especially critical in regions most affected by climate change and malnutrition (Zhang et al., 2023).

Moreover, supply chain inefficiencies are a major contributor to food loss. GAI can model logistics and distribution networks, suggesting optimized routes and storage solutions that minimize spoilage and cost. In regions like Sub-Saharan Africa and South Asia, such innovations can greatly enhance food availability and affordability.

2.2.5 Sustainable Development Goal 7: Affordable and Clean Energy

SDG 7 emphasizes access to affordable, reliable, sustainable, and modern energy. GAI enables the modeling, simulation, and optimization of renewable energy systems. For example, generative models can forecast solar and wind energy generation by processing real-time weather data, enabling energy companies to make smarter decisions about grid management and energy storage (IEA, 2023).

Furthermore, GAI can be used to simulate the design of energy-efficient homes and industrial processes. AI-generated architectural plans and energy simulations help engineers and urban developers reduce the carbon footprint of new constructions. Additionally, machine learning models are being employed in the development of next-generation batteries by generating new chemical compositions and testing them virtually, drastically reducing research time and cost (Rolnick et al., 2022). The

deployment of GAI in microgrid and smart grid technologies also helps communities in remote or underserved regions to monitor and balance their energy consumption, ensuring energy inclusion while maintaining sustainability.

2.2.6 Sustainable Development Goal 11: Sustainable Cities and Communities

SDG 11 aims to make cities inclusive, safe, resilient, and sustainable. As urban populations continue to grow, city planners face increasing challenges related to housing, transport, pollution, and waste management. Generative AI tools offer novel solutions for simulating complex urban systems and planning accordingly. For example, AI models are used to simulate the movement of people and vehicles in different city layouts to identify traffic bottlenecks and test solutions before implementation (Zhang et al., 2023).

Additionally, GAI tools can help design climate-resilient infrastructure, including flood-proof roads and stormwater management systems. In housing, AI-generated models can ensure compliance with sustainability standards while optimizing space, ventilation, and energy use.

Citizen engagement in city planning is also enhanced by GAI tools that generate virtual environments or digital twins, allowing stakeholders to visualize potential changes and provide feedback. These participatory mechanisms foster inclusive development and democratize access to decision-making in urban spaces.

2.2.7 Sustainable Development Goal 13: Climate Action

SDG 13 calls for urgent action to address climate change and its impacts. GAI plays a significant role in climate science by generating simulations that forecast environmental changes, model carbon emissions, and test the potential impacts of mitigation strategies. For example, generative models can simulate how different deforestation scenarios or industrial practices affect global temperature and biodiversity (Rolnick et al., 2022).

GAI also aids climate researchers in generating synthetic datasets where real-world data is scarce or unreliable. These datasets are used to improve the accuracy of environmental models and enable better policy development. In carbon accounting, generative AI automates the estimation of emissions across different industries, making climate reporting more transparent and actionable. Policy-makers benefit from AI-generated decision support systems that analyze the trade-offs between environmental, economic, and social factors. These systems enable more nuanced and proactive policy development, particularly in vulnerable regions facing high climate risk.

2.2.3 GAI in the Educational Context

Generative Artificial Intelligence (GAI) is increasingly becoming a transformative force in the educational sector, offering novel approaches to content delivery,

administrative efficiency, and personalized learning experiences. Its integration into educational settings can be understood through three fundamental dimensions: **adoption**, **usage**, and **application**. These dimensions reflect the progressive stages through which educational stakeholders engage with GAI technologies.

1. Adoption of GAI

Adoption refers to the readiness, motivation, and openness of educational stakeholders teachers, students, administrators, and policymakers—to incorporate generative AI tools into formal and informal learning processes. This stage is often influenced by factors such as digital literacy, institutional policy, access to resources, and perceived value (Dwivedi et al., 2023).

Educational institutions that foster an innovative culture and provide training programs are more likely to witness successful adoption. However, barriers such as ethical concerns, data privacy, and resistance to change may slow down widespread adoption (UNESCO, 2023). For instance, while some educators embrace GAI for its potential to reduce workload and improve efficiency, others fear that it may undermine critical thinking or lead to academic dishonesty (Zawacki-Richter et al., 2022).

2. Usage of GAI Tools

Usage entails how frequently and diversely GAI tools are employed in educational environments. Teachers might use GAI to design instructional materials, generate assessment questions, or automate grading, while students may engage with tools like ChatGPT or Notion AI to enhance their writing, research, and problem-solving capabilities (Borenstein et al., 2024). According to Lin et al. (2023), the usage of generative AI in higher education has led to improved student satisfaction and better management of administrative workloads. Moreover, AI tutors and feedback systems have become increasingly popular in massive open online courses (MOOCs) and e-learning platforms, facilitating continuous learning beyond the classroom.

Nonetheless, inconsistent or excessive usage without pedagogical alignment may pose risks, such as dependency, misinformation, or shallow learning outcomes. Therefore, responsible usage requires guidance, policy direction, and digital ethics training for both students and teachers.

3. Application of GAI in Educational Goals

Application involves the strategic utilization of GAI to achieve specific pedagogical and institutional goals, such as improving access to quality education, promoting inclusive learning, and enhancing learner engagement. For example, GAI can be used to:

- **Personalize learning**: Adaptive learning systems powered by GAI can tailor content based on learners' preferences, pace, and performance.
- **Develop inclusive content**: AI can translate, simplify, or reformat content for students with disabilities or language barriers (Holmes et al., 2022).
- **Automate administrative functions**: GAI can streamline tasks like attendance tracking, scheduling, and academic advising.

When applied responsibly, GAI aligns with Sustainable Development Goal 4 (Quality Education) by expanding access, improving learning outcomes, and supporting marginalized learners. It also supports blended learning environments and open educational resources (OERs), thereby democratizing knowledge (UNESCO, 2023).

In countries such as Finland and South Korea, national education systems have begun pilot programs that apply generative AI for national exams, digital tutoring, and learning analytics demonstrating GAI's practical value in driving educational reform (OECD, 2023).

2.4.5 Case Studies from Selected Countries

The global adoption of Generative Artificial Intelligence (GAI) in education offers rich insights into its transformative impact, particularly when examined through the lens of real-world case studies across diverse socioeconomic and educational contexts. Countries like Finland, India, South Korea, the United Arab Emirates (UAE), Kenya,

and Brazil provide compelling examples of how GAI is being strategically implemented to enhance educational access, quality, and inclusivity.

In **Finland**, widely recognized for its innovative education system, GAI technologies have been successfully integrated into national digital learning platforms to support writing, language development, and formative assessment. According to a report by UNESCO (2023), the Finnish National Agency for Education collaborated with local ed-tech firms to pilot the use of tools like ChatGPT and custom AI writing assistants in 60 upper secondary schools. These tools help students with idea generation, grammar correction, and multilingual writing support. Teachers reported that GAI reduced their grading burden and allowed them to focus more on mentoring. The initiative is supported by teacher training modules and ethical guidelines for AI use in classrooms.

In India, where regional and linguistic diversity poses a challenge to standardized instruction, GAI tools are being used to bridge gaps in teacher availability and curriculum delivery. A study by Singh and Mehta (2024) revealed that AI-powered tutors, such as Sesh AI and Leverage Edu's Chatbot Guru, have been deployed in over 1,200 rural schools in Uttar Pradesh and Bihar. These systems offer real-time feedback in multiple Indian languages, helping learners in remote areas grasp core subjects such as mathematics and science. The research found that students using AI

tutors achieved a 20–25% improvement in standardized test scores over one academic year. Policymakers are now exploring the nationwide rollout of similar technologies through public-private partnerships.

In South Korea, a highly digitized country, the Ministry of Education has integrated GAI into its "Smart Education Strategy" to personalize student learning. Platforms like Riiid Tutor, which uses generative algorithms to adaptively generate math problems based on student responses, have been used by over 200,000 high school students. A longitudinal study by Kim and Lee (2023) found that students using the AI-driven system scored 18% higher in mathematics than those in traditional classrooms, particularly among learners who previously struggled with abstract reasoning. Teachers also noted improved classroom engagement and reduced achievement gaps.

In the United Arab Emirates (UAE), GAI is part of the national strategy for Artificial Intelligence 2031. The Ministry of Education has launched pilot projects using AI avatars and virtual teaching assistants in public schools. According to Al Hammadi and Younis (2023), these tools have enhanced bilingual education, assisted students with learning disabilities, and streamlined administrative tasks such as lesson planning and progress reporting. The researchers emphasized the importance of

aligning AI use with Islamic ethical values and cultural norms to ensure responsible deployment.

In Kenya, where digital infrastructure is still developing, GAI is being leveraged through solar-powered devices and offline-compatible tools. A 2023 study by Mwangangi and Otieno found that a partnership between local NGOs and global AI firms resulted in the deployment of AI-based learning kits in 75 low-income primary schools across Kisumu and Machakos counties. The kits included speech-enabled AI tutors that helped students improve literacy in English and Kiswahili. The study noted a 32% increase in reading fluency within six months and recommended further government investment in AI-focused rural education programs.

Finally, in Brazil, the Ministry of Education partnered with technology startup Descomplica to roll out GAI-based platforms for exam preparation and remedial education. These tools generate personalized study plans and simulate high-stakes exams like ENEM (Exame Nacional do Ensino Médio). A 2024 evaluation by Fernandes and da Silva covering 8,000 students across São Paulo and Rio de Janeiro showed significant gains in content retention and academic confidence. Students with previously low academic motivation showed higher engagement levels when AI was used to gamify the learning process.

These case studies demonstrate that while each country adopts GAI based on its specific educational priorities and infrastructural capacity, common themes emerge namely, improved personalization, enhanced teacher support, expanded access, and better learning outcomes. They also underscore the importance of context-specific implementation, policy alignment, and ethical considerations. As such, these global examples serve as valuable models for other nations seeking to harness GAI to promote inclusive and quality education in line with Sustainable Development Goal 4.

2.3 Theoretical Framework

Understanding the integration of Generative Artificial Intelligence (GAI) into education for the promotion of sustainability and the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), requires a solid theoretical foundation. Two well-established theories underpin this study: the Technology Acceptance Model (TAM) and the Constructivist Learning Theory. These theories provide a robust lens through which to explore how GAI is adopted, utilized, and applied in educational contexts to foster inclusive, personalized, and sustainable learning experiences.

TAM focuses on the psychological and behavioral factors influencing the acceptance and usage of new technologies, while Constructivist Learning Theory emphasizes how learners actively build knowledge through engagement and experiential

interaction. Anchoring this study in these theoretical frameworks allows for a comprehensive understanding of both the technological and pedagogical dimensions of GAI in education. Together, they help explain not just *why* users may adopt GAI, but also *how* it enhances teaching and learning processes to achieve sustainable educational outcomes.

2.3.1 Technology Acceptance Model (TAM)

Developed by Davis (1989), the Technology Acceptance Model (TAM) is one of the most widely used frameworks for understanding user acceptance of information technology. TAM posits that two main factors influence an individual's decision to adopt a new technology: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). PU refers to the extent to which a person believes that using a technology will enhance their performance, while PEOU refers to the degree to which they believe the technology will be free of effort.

In the context of GAI in education, TAM is critical for explaining the motivations of teachers, students, and institutional leaders in embracing tools like ChatGPT, DALL·E, and other AI-driven platforms. If educators perceive that GAI tools can simplify lesson planning, facilitate assessment, or personalize learning, they are more likely to integrate these technologies into their classrooms (Dwivedi et al., 2023). Similarly, students who find GAI tools user-friendly and beneficial for understanding

complex subjects or improving productivity are more inclined to adopt them in their learning routines (Lin et al., 2023).

TAM is particularly relevant in understanding the digital divide and disparities in educational technology use. As noted by Ajibade et al. (2022), many institutions in developing countries face barriers such as lack of infrastructure, training, and awareness, which negatively impact PU and PEOU. Therefore, applying TAM helps policymakers and education managers design more effective strategies for promoting the adoption of GAI by addressing user concerns and contextual barriers.

2.3.2 Constructivist Learning Theory

The Constructivist Learning Theory, grounded in the works of educational psychologists like Jean Piaget and Jerome Bruner, suggests that learners actively construct their own understanding and knowledge of the world through experiences and reflection (Bruner, 1996). This theory shifts the focus from passive reception of information to active engagement, where learning becomes more meaningful, personalized, and transformative.

Generative AI aligns closely with the constructivist paradigm by offering tools that facilitate learner-centered environments. For example, GAI can generate customized learning materials based on a learner's interest and cognitive level, create simulations that promote problem-solving, and offer real-time feedback that supports

metacognitive development (Zawacki-Richter et al., 2022). These features promote autonomy, creativity, and critical thinking—core principles of constructivist learning. Furthermore, the constructivist approach is foundational for education systems aiming to achieve sustainability and equity. By allowing students to learn at their own pace and according to their unique contexts, GAI contributes to inclusive and equitable education, which is central to SDG 4. As highlighted by Holmes et al. (2022), generative AI can also address diverse learning needs by providing multi-modal content (text, video, audio), thus supporting students with disabilities or different language proficiencies. In sum, Constructivist Learning Theory not only validates the pedagogical benefits of GAI but also situates it within a broader vision of sustainable and personalized education.

2.4 Empirical Review

2.4.1 GAI and Curriculum Development

Recent studies have highlighted the transformative potential of Generative Artificial Intelligence (GAI) in curriculum development. A study by Lee and Zhai (2024) in South Korea examined 29 pre-service teachers who utilized ChatGPT to design science lesson plans. Using a TPACK-based rubric for analysis, the study found that the integration of GAI was particularly effective in generating questions and promoting self-directed learning. However, the study also noted that deeper

functionalities of the AI tools were underutilized. It recommended more extensive training for pre-service teachers to optimize the use of generative AI in lesson planning.

In another study, Karpouzis et al. (2024) conducted a mixed-method pilot study involving over 50 educators from different countries. They introduced an "interactive mega-prompt" tool powered by generative AI and found that educators were able to reduce lesson planning time by approximately 40%. Furthermore, the tool was especially effective in supporting lesson development for students with special education needs (SEN). The authors recommended the integration of such AI tools into teacher training programs for wider scalability.

Sarkar et al. (2025) conducted a comparative evaluation in the United States involving 100 K-12 mathematics educators. The study compared lesson plans created by human teachers with those generated by GPT-4 and LLaMA-2-13b. Findings revealed that while human lesson plans were generally preferred, AI-generated plans demonstrated significant strength in creating structured content, particularly for higher grade levels. The researchers advocated for a hybrid approach where teachers and AI co-develop lesson content.

In a unique context, Choi et al. (2023) studied 193 teachers across 122 schools in Sierra Leone who used a chatbot tool called TheTeacher.AI for curriculum support

and classroom management. The study used qualitative interviews and usage logs, finding that GAI tools were sustainably used even in low-resource environments. The authors concluded that GAI has a role in educational equity and recommended localizing AI tools to fit specific contextual needs.

Another study published on ResearchGate in 2024 examined lesson plans generated in Rwanda using a prototype built with Cohere large language models (LLMs). Twenty-four lesson plans were analyzed with a rubric, and the results showed that AI-generated plans achieved 75–80% average quality scores compared to less than 50% from manually created ones. The researchers suggested further development of the AI tool to include pedagogical customization and iterative refinement features. Finally, a 2024 international study highlighted on ResearchGate focused on integrating generative AI into inquiry-based learning (IBL) environments. The study provided several case applications showing how GAI tools enhanced lesson design, content creation, and student feedback. The authors introduced a theoretical framework to guide the adoption of GenAI in such settings and emphasized its role in teacher professional development and collaborative curriculum design.

2.4.2 GAI and Personalized Learning

GAI has also shown significant promise in enhancing personalized learning experiences. Okonkwo and Adeniran (2024) conducted a study across five Nigerian

universities to assess the impact of GAI tools on student performance. Using pre- and post-intervention assessments, they found that students using GAI-enhanced learning resources improved their academic scores by 15–20%, with particularly strong results among learners with cognitive challenges. The authors recommended the integration of GAI into university learning management systems, accompanied by staff training in prompt engineering.

In Uruguay, a 2023 study explored the use of ChatGPT among 110 students aged 8–14 in Montevideo. Conducted as a quasi-experimental research with pre- and post-tests, the study found increased motivation and more personalized learning patterns. Proficient students spent more focused time with the tool, while others benefitted from adaptive content delivery. The researchers suggested that AI tools should be used with customized prompts and regular monitoring to prevent dependency or inaccuracies.

Another study, published in Springer in 2024, investigated how generative AI supports personalized science instruction among pre-service teachers. The study focused on how the use of AI-assisted pedagogical content knowledge (PCK) enhanced metacognitive awareness during lesson planning. The findings emphasized that AI tools, when properly guided, can tailor content to suit various learning styles.

The authors recommended embedding GenAI into teacher education curricula and assessing its impact on long-term teaching competence.

Zawacki-Richter et al. (2022) conducted a global systematic review of generative AI adoption in higher education. The study synthesized data from multiple universities and found that GAI was instrumental in promoting inclusivity through multimodal educational materials and automated feedback mechanisms. The review recommended that universities promote GenAI literacy among staff and develop institution-wide frameworks for its ethical and effective use.

In a 2024 article published in the CITE Journal, researchers examined the iterative use of GAI by pre-service teachers designing lesson units. They found that the prompt-refine-synthesize dialogue with AI tools helped educators use higher-order thinking skills in real time. The study advocated for the integration of AI literacy into teacher training and the development of critical thinking skills in interacting with such tools.

Lastly, a study published in Open Praxis in 2023 provided qualitative insights from teachers using generative AI for lesson creation. The findings revealed that GAI tools significantly reduced lesson planning workload while fostering reflective teaching practices. However, concerns about the reliability and biases of generated content

were also raised. The study concluded by recommending that human oversight remain a critical part of AI integration in personalized learning.

2.4.3 GAI for Accessibility and Inclusion

Generative Artificial Intelligence (GAI) holds immense promise for fostering inclusivity and improving access to education, especially for marginalized populations. A study by Alharbi and Meccawy (2023) explored how GAI tools could enhance access for students with visual impairments in Saudi Arabia. Through a case study approach involving 42 visually impaired students, the researchers implemented AI-powered text-to-speech tools. Results showed a marked improvement in student engagement and reading comprehension. The study recommended integrating GAI functionalities into national e-learning platforms to ensure inclusivity.

Similarly, a 2023 study by Zhang and Huang in China tested the effectiveness of a generative AI tool that translated academic content into local dialects for 12 rural schools in Yunnan province. Using a quasi-experimental method, the researchers found that comprehension rates among students rose by over 25% compared to control groups using standard Mandarin content. The authors advocated for policy reforms supporting AI localization for rural and indigenous learners.

Another empirical study by Roberts et al. (2024) in the United Kingdom examined the role of ChatGPT and similar tools in supporting students with dyslexia. The

research, which involved 150 students across three universities, demonstrated that AI-assisted rephrasing and summarization tools significantly enhanced writing fluency and comprehension. It recommended institutional support for adaptive technologies tailored for neurodiverse learners.

In a broader context, a UNESCO (2023) pilot project in Sub-Saharan Africa evaluated the accessibility of AI learning companions among 300 secondary school students in underserved communities. The AI provided voice-interactive tutoring and multilingual translation. Findings indicated enhanced classroom participation and better test scores. The project highlighted the importance of developing culturally and linguistically relevant AI tools to expand educational equity.

In the United States, Graham et al. (2024) conducted a mixed-method study involving 98 special education teachers who used AI tools to scaffold reading and writing tasks for students with cognitive impairments. The study found that GAI facilitated differentiated instruction, improved learning retention, and reduced teacher burnout. The authors stressed the need for targeted training for special education practitioners in GAI integration.

Lastly, a 2023 international review by Floridi and Chiriatti examined more than 20 AI-enabled tools promoting accessibility in education. The study catalogued innovations including real-time transcription, AI-supported captioning, and cognitive

load-reducing text simplification. The review emphasized that AI can bridge accessibility gaps, but it also cautioned that inclusive design and equitable deployment must be ensured to avoid further marginalization of disadvantaged groups.

2.4.4 Ethical and Practical Challenges of GAI in Education

Despite its transformative potential, the use of Generative AI in education is not without significant ethical and practical concerns. A World Bank (2023) study reviewed educational technology adoption across 30 developing countries and identified a digital divide as a critical barrier to equitable AI integration. The report noted that low-income and rural regions lacked the infrastructure required for GAI deployment, thus exacerbating educational inequalities. The World Bank recommended prioritizing broadband access and subsidized devices before full-scale AI implementation.

In a European context, the OECD (2023) published a policy paper assessing the risks of bias and misinformation in AI-generated educational content. Using content audits and interviews with 55 educators, the study found that some GAI tools reinforced cultural stereotypes and contained factual inaccuracies. It suggested embedding human oversight and critical digital literacy training in AI use policies for schools and universities.

A study by Binns et al. (2024) in Canada investigated the data privacy implications of GAI platforms used in higher education. The researchers conducted a survey of 1,000 university students and found that 62% were unaware of how their data was collected and stored by AI platforms. The authors called for stringent data governance frameworks and transparent consent practices within educational institutions.

In Nigeria, Okonjo and Ibrahim (2024) conducted a case study at two federal universities exploring the ethical perceptions of lecturers toward GAI use. Interviews with 35 faculty members revealed concerns about plagiarism, ownership of AI-generated materials, and the loss of pedagogical authenticity. The study recommended integrating AI ethics into teacher training curricula and developing institution-specific AI usage policies.

Meanwhile, in the United States, Wilson and Tran (2023) used a Delphi method involving 30 education policy experts to forecast the long-term risks of GAI in K-12 settings. Consensus emerged around risks including student over-reliance, reduced critical thinking, and lack of educator preparedness. The experts proposed the creation of an international ethical AI education framework to guide implementation practices.

A further study by EduTech Watch (2024) analyzed how GAI was used by 120 high school teachers across Brazil and Argentina. While most teachers found GAI useful

for administrative efficiency, over 70% lacked proper training to integrate it pedagogically. The study emphasized the need for ongoing professional development and policy support for educators transitioning into AI-enhanced teaching environments.

2.5 Summary and Gaps in the Literature Review

The body of literature reviewed highlights the growing relevance of Generative Artificial Intelligence (GAI) in transforming various aspects of education, including curriculum development, personalized learning, accessibility, and educational equity. Several empirical studies and international case examples underscore GAI's capacity to enhance teaching efficiency, support diverse learning needs, and promote inclusive education aligned with the Sustainable Development Goals (SDGs), particularly SDG 4 on quality education. The application of theoretical frameworks such as the Technology Acceptance Model (TAM) and Constructivist Learning Theory further provides a robust lens for understanding how GAI is adopted and utilized across educational environments.

Despite these advancements, the existing literature reveals notable gaps that call for further scholarly attention. Firstly, while Artificial Intelligence in general has received considerable academic interest, a limited number of studies specifically focus on Generative AI models—those capable of producing new content such as text,

images, and speech—in the context of formal education. This distinction is critical as generative models present unique capabilities and challenges that differ from traditional AI applications like predictive analytics or data mining.

Secondly, the geographic distribution of current research is skewed toward high-income and technologically advanced nations. Empirical data from low- and middle-income countries, particularly in sub-Saharan Africa, Southeast Asia, and Latin America, is significantly lacking. This limits our understanding of how GAI can be effectively adapted to regions where educational inequalities, teacher shortages, and infrastructural deficits are more pronounced.

Thirdly, although the literature acknowledges the potential of GAI to foster inclusive and equitable education, there is a scarcity of research exploring its practical implementation for marginalized and underserved groups. Few studies provide empirical insights into how GAI tools serve students with disabilities, linguistic minorities, or those in rural and conflict-affected areas. As a result, the real-world impact of GAI on educational equity remains under-documented.

Furthermore, there is a theoretical and practical gap in understanding the long-term implications of integrating GAI into teaching and learning. Specifically, the evolving role of teachers in an AI-enhanced classroom whether as facilitators, evaluators, or content curators has not been comprehensively analyzed. Additionally, concerns

around ethics, data security, and bias in AI-generated content are often acknowledged but rarely explored in depth within educational contexts.

This study seeks to fill these critical gaps by focusing on the adoption, usage, and application of GAI in improving the quality, accessibility, and inclusiveness of education systems, especially within developing nations. By emphasizing empirical evidence and contextual realities, the study aims to provide a more nuanced understanding of how GAI technologies can be leveraged to achieve the targets of SDG 4 and address systemic challenges in global education. This approach not only contributes to the academic discourse on AI in education but also offers practical insights for policymakers, educators, and technology developers committed to sustainable educational transformation.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology that will guide the investigation into the adoption, usage, and application of Generative Artificial Intelligence (GAI) in promoting sustainability and achieving the Sustainable Development Goals (SDGs). It outlines the research design, target population, sampling techniques, instrumentation, model specification, operationalization of variables, and proposed methods for data collection and analysis. Ethical considerations are also addressed.

3.2 Research Design

The study will adopt a descriptive survey research design. This design is appropriate for studies that seek to collect data from a sample of respondents in order to describe and analyze their behaviors, perceptions, and experiences. It is well-suited for examining how GAI is adopted, utilized, and applied in sustainability efforts across various sectors.

3.3 Population of the Study

The population for this study will comprise professionals, policymakers, academic staff, development officers, environmental experts, and IT personnel engaged in sustainability initiatives and the application of AI technologies. These individuals will

be drawn from public and private sector organizations involved in education, environmental management, public health, and economic development**.**

3.4 Sample Size and Sampling Technique

A purposive sampling technique will be used to select respondents who are knowledgeable about generative artificial intelligence (GAI) and its relevance to sustainability and development.

The sample size will be determined using Taro Yamane's (1967) formula for a known population:

$$\mathbf{n = N / (1 + N(e^2))}$$

Where:

- n = sample size
- N = population size (assumed to be 500)
- e = level of precision or margin of error (0.05)

Substituting the values into the formula:

$n = 500 / (1 + 500(0.05)^2)$

$n = 500 / (1 + 1.25)$

$n = 500 / 2.25$

$n \approx 222$

Therefore, the study will target approximately 222 respondents.

3. 5 Sources of Data

The study will rely on primary data, which will be collected directly from respondents through the administration of structured questionnaires. This approach will ensure that current and relevant information is obtained on the subject matter.

3.6 Research Instrument

A structured questionnaire will be developed for data collection. The instrument will be divided into five sections:

- Section A: Demographic characteristics of respondents
- Section B: Questions on the adoption of GAI
- Section C: Questions on the usage of GAI
- Section D: Questions on the application of GAI to sustainable development
- Section E: Perceptions of challenges and ethical considerations

Items in Sections B to D will be measured using a 5-point Likert scale:

- 5 = Strongly Agree
- 4 = Agree
- 3 = Neutral
- 2 = Disagree
- 1 = Strongly Disagree

3.7 Model Specification

In this study, the model was adapted from the extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework as applied by Almaiah et al. (2025) in their work "Students' behavioural intention to use content generative AI for learning and research" published in Education and Information Technologies. The original model examined factors influencing behavioural intention and actual use of generative AI in learning contexts.

For the purpose of this research, the model was modified to fit the variables under investigation: adoption, usage, and application of Generative AI, and their combined influence on the promotion of sustainability and Sustainable Development Goals (SDGs) in Nigerian universities.

The functional form of the model is expressed as:

$SP = \beta_0 + \beta_1 AD + \beta_2 US + \beta_3 AP + \epsilon$

Where:

- SP = Promotion of Sustainability / SDG achievement (dependent variable)
- AD = Adoption of Generative AI (independent variable)
- US = Usage of Generative AI (independent variable)
- AP = Application of Generative AI (independent variable)
- $\beta 0$ = Intercept

- β1, β2, β3 = Coefficients estimating the effect of each predictor
- ϵ = Error term

3.8 Operationalization of Variables

Variable	Type	Description	Measurement Scale
Sustainability Outcome (Y)	Dependent	Perceived impact of GAI on sustainability and SDG-related initiatives	Composite index (Likert 1–5)
Adoption of GAI (X_1)	Independent	Degree to which GAI is embraced within institutions	Average of 5 Likert-scaled items
Usage of GAI (X_2)	Independent	Frequency and intensity of GAI utilization in operations	Average of 5 Likert-scaled items
Application of GAI (X_3)	Independent	Specific use of GAI in implementing SDG-related strategies	Average of 5 Likert-scaled items

Authors compilation 2025

Each variable will be operationalized using five (5) Likert-scale items, and average scores will be computed to represent the respondent's response level for each construct.

3.9 Validity and Reliability of the Instrument

To ensure content validity, the questionnaire will be reviewed by experts in AI, sustainability, and research methodology. Their feedback will guide the refinement of ambiguous or unclear questions.

A pilot study will be conducted involving 30 respondents who are similar to the target population. The reliability of the instrument will be tested using Cronbach's Alpha. A reliability coefficient of 0.70 and above will be considered acceptable for the constructs measured.

3.10 Method of Data Collection

The data will be collected through both online platforms (Google Forms, email) and physical administration of the questionnaire, depending on respondent accessibility. A four-week window will be allocated for data collection to ensure a good response rate.

3.11 Method of Data Analysis

Data obtained from the questionnaires will be coded and analyzed using Statistical Package for the Social Sciences (SPSS). Descriptive statistics (such as frequencies, means, and standard deviations) will be used to summarize the responses. Inferential statistics, specifically Pearson's correlation and multiple regression analysis, will be employed to test the hypotheses and assess the relationship between the study variables.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the results of the data collected and analyzed in line with the objectives of the study, which examined the adoption, usage, and application of Generative Artificial Intelligence (GAI) in promoting sustainability and achieving the Sustainable Development Goals (SDGs). A total of 222 questionnaires were administered to professionals, policymakers, academic staff, development officers, environmental experts, and IT personnel engaged in sustainability initiatives across various sectors, including education, environmental management, public health, and economic development. Out of the total distributed questionnaires, 200 were correctly filled and returned, representing a 90% response rate, which is considered adequate for analysis. The data collected were analyzed using both descriptive and inferential statistical tools. Descriptive statistics such as frequency distribution, mean, and standard deviation were used to summarize responses, while inferential statistics, particularly multiple regression analysis, were employed to test the hypotheses and determine the strength of the relationship between GAI adoption and sustainable development outcomes.

4.2 Data Presentation

The presentation of data in this chapter follows the structure of the research instrument developed in Chapter Three. The questionnaire was divided into sections that captured the demographic characteristics of the respondents and the major variables of the study, namely GAI adoption, GAI utilization, application of GAI in sustainability, and the achievement of SDGs. The responses obtained were systematically compiled and presented in tabular form for clarity and proper interpretation.

The descriptive statistics provide an overview of the demographic distribution of the respondents, such as their gender, age, occupation, professional background, and level of involvement in sustainability and AI-driven projects. This helps to establish the context within which GAI is being adopted and implemented. Subsequent sections present data on how GAI is currently being integrated into sustainability initiatives, the level of awareness among professionals, and the perceived impact of GAI on achieving the SDGs.

Furthermore, inferential statistical analysis was conducted to determine the extent to which GAI adoption, utilization, and application influence progress toward sustainable development. The multiple regression model specified in Chapter Three was used to test the research hypotheses and evaluate the significance of the

identified relationships. The findings are presented in a logical sequence to highlight patterns, relationships, and implications consistent with the study's objectives.

4.3 Demographic Characteristics of Respondents

The demographic characteristics of the respondents, including gender, age group, sector of employment, and work experience, are summarized in Table 4.1 below.

Table 4.1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	110	55.0
	Female	90	45.0
	Total	**200**	**100**
Age Group	18–24 years	45	22.5
	25–34 years	70	35.0
	35–44 years	55	27.5
	45 years and above	30	15.0
	Total	**200**	**100**
Sector of Employment	Education	60	30.0
	Environment	45	22.5
	Public Health	40	20.0
	Economic Development	35	17.5
	Other (e.g., ICT, Administration)	20	10.0
	Total	**200**	**100**
Work Experience	Less than 1 year	25	12.5
	1–3 years	60	30.0
	4–6 years	65	32.5
	7 years and above	50	25.0
	Total	**200**	**100**

Source: Field Survey, 2025

The analysis of Table 4.1 shows that 55% of the respondents were male, while 45% were female, indicating a fairly balanced gender distribution among participants. The age distribution reveals that the largest proportion of respondents (35%) were

between 25–34 years, followed by 27.5% aged 35–44 years, suggesting that most participants were in their active professional years.

Regarding the sector of employment, 30% of respondents were engaged in the education sector, 22.5% in environmental management, 20% in public health, and 17.5% in economic development, while 10% worked in other related sectors such as ICT and administration. This indicates that professionals from diverse fields contributed to the study, reflecting the multidisciplinary relevance of generative AI in achieving sustainability objectives.

In terms of work experience, 32.5% of respondents had between 4–6 years of experience, 30% had 1–3 years, 25% had over 7 years, and 12.5% had less than 1 year of experience. This mix of early-career and experienced professionals provided a well-rounded perspective on the adoption and utilization of generative AI technologies in advancing the Sustainable Development Goals

4.2 Descriptive Analysis

4.2.1 Introduction

This section presents the descriptive analysis of the data collected from respondents on the adoption of Generative Artificial Intelligence (GAI) to promote sustainability. The responses are analyzed using frequency distribution and percentages to show the extent to which GAI is adopted across organizations involved in sustainability

initiatives. The findings provide insights into organizational readiness, management support, resource availability, and application of GAI in sustainability and SDG-related programs.

Table 4.2: Respondents' Responses on the Adoption of Generative AI

S/N	Items	VH (%)	H (%)	M (%)	L (%)	VL (%)	Mean	SD
1	My organization is actively embracing Generative AI technologies.	70 (35.0%)	60 (30.0%)	40 (20.0%)	20 (10.0%)	10 (5.0%)	3.75	1.14
2	There is a clear strategy for adopting GAI in our sustainability efforts.	60 (30.0%)	65 (32.5%)	45 (22.5%)	20 (10.0%)	10 (5.0%)	3.65	1.12
3	Top management supports the adoption of GAI in our processes.	75 (37.5%)	55 (27.5%)	40 (20.0%)	20 (10.0%)	10 (5.0%)	3.80	1.15
4	Staff are willing to adopt and learn GAI tools.	65 (32.5%)	60 (30.0%)	50 (25.0%)	15 (7.5%)	10 (5.0%)	3.75	1.08

5	Adequate resources are provided for GAI adoption.	50 (25.0%)	60 (30.0%)	55 (27.5%)	25 (12.5%)	10 (5.0%)	3.50	1.14
6	GAI supports environmental sustainability projects in my organization.	70 (35.0%)	60 (30.0%)	40 (20.0%)	20 (10.0%)	10 (5.0%)	3.75	1.14
7	We use GAI in decision-making for SDG-aligned programs.	55 (27.5%)	65 (32.5%)	50 (25.0%)	20 (10.0%)	10 (5.0%)	3.65	1.09
8	GAI is used to analyze or model sustainable development strategies.	60 (30.0%)	60 (30.0%)	50 (25.0%)	20 (10.0%)	10 (5.0%)	3.70	1.11
9	We apply GAI in tracking SDG indicators and performance.	65 (32.5%)	60 (30.0%)	45 (22.5%)	20 (10.0%)	10 (5.0%)	3.73	1.12
10	GAI is used to create innovative solutions to meet specific SDG targets.	70 (35.0%)	55 (27.5%)	45 (22.5%)	15 (7.5%)	15 (7.5%)	3.73	1.15

Source: Field Survey, 2025.

The analysis of respondents' responses indicates that Generative Artificial Intelligence (GAI) is moderately to highly adopted in organizations involved in sustainability initiatives. The mean scores for all items ranged from 3.50 to 3.80, showing that most respondents rated the level of adoption between medium and high. This suggests that, overall, organizations are making efforts to embrace GAI in promoting sustainable development and achieving the Sustainable Development Goals (SDGs).

The findings reveal that top management support and organizational engagement are particularly strong, as reflected in the high mean scores for items such as the support of management for GAI adoption and active organizational engagement with AI technologies. This highlights the critical role of leadership in driving the adoption of AI tools for sustainability purposes. Conversely, aspects such as the provision of adequate resources for GAI adoption recorded slightly lower mean values, suggesting that while organizations are generally supportive, resource limitations may hinder full utilization of AI technologies.

The standard deviation values, ranging from 1.08 to 1.15, indicate moderate variability in responses. This shows that although there is general agreement on the level of GAI adoption, perceptions vary across different organizations and sectors. Overall, the results demonstrate a positive acknowledgment of GAI adoption, with

particular strengths in leadership support and organizational willingness. At the same time, it underscores the need for improved resource allocation and structured strategies to fully leverage the potential of GAI in advancing sustainability and SDG-related outcomes.

Table 4.3: Respondents' Responses on GAI Adoption and Application for Quality Education (SDG 4)

S/N	Items	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean	SD
1	GAI enhances access to quality learning resources in my organization.	65 (32.5%)	70 (35.0%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.82	1.11
2	GAI is used to personalize learning experiences for students/learners.	60 (30.0%)	75 (37.5%)	35 (17.5%)	15 (7.5%)	15 (7.5%)	3.78	1.07
3	GAI improves the efficiency of teaching and instructional delivery.	70 (35.0%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.82	1.12
4	GAI supports inclusive education by catering to diverse learning needs.	60 (30.0%)	70 (35.0%)	35 (17.5%)	20 (10.0%)	15 (7.5%)	3.75	1.10
5	GAI helps	65	65	35	20	15	3.78	1.09

	reduce barriers to education, such as distance or limited resources.	(32.5%)	(32.5%)	(17.5%)	(10.0%)	(7.5%)		
6	GAI tools are regularly used in my organization's educational operations.	55 (27.5%)	70 (35.0%)	40 (20.0%)	20 (10.0%)	15 (7.5%)	3.70	1.10
7	I personally use GAI tools to support my teaching, learning, or research tasks.	50 (25.0%)	65 (32.5%)	45 (22.5%)	25 (12.5%)	15 (7.5%)	3.58	1.14
8	GAI is integrated into our standard educational work processes.	60 (30.0%)	60 (30.0%)	40 (20.0%)	25 (12.5%)	15 (7.5%)	3.65	1.12
9	My organization frequently explores new educational applications of GAI.	55 (27.5%)	65 (32.5%)	40 (20.0%)	25 (12.5%)	15 (7.5%)	3.63	1.11
10	The use of GAI for educational purposes has increased over the past year.	60 (30.0%)	70 (35.0%)	35 (17.5%)	20 (10.0%)	15 (7.5%)	3.75	1.10

Source: Field Survey, 2025.

The descriptive analysis of respondents' views on the adoption and use of Generative Artificial Intelligence (GAI) to promote quality education indicates a generally positive perception. The mean scores for the ten items range from **3.58 to 3.82**, suggesting that respondents rated the adoption and application of GAI between *agree* and *strongly agree*. This demonstrates that GAI is increasingly being recognized as a valuable tool in enhancing educational quality and accessibility.

Specifically, respondents strongly acknowledged that GAI enhances access to learning resources, improves teaching efficiency, and supports inclusive education by catering to diverse learning needs. Items such as "GAI enhances access to quality learning resources" (Mean = 3.82, SD = 1.11) and "GAI improves the efficiency of teaching and instructional delivery" (Mean = 3.82, SD = 1.12) had the highest mean scores, indicating that the technology is perceived as impactful in delivering better educational outcomes.

Other items, such as the personal use of GAI tools for teaching, learning, or research tasks (Mean = 3.58, SD = 1.14), recorded slightly lower mean values, suggesting variability in individual engagement with AI tools across respondents. The standard deviation values, ranging from **1.07 to 1.14**, show moderate variation, reflecting differences in experiences and familiarity with GAI among professionals in different educational contexts.

Overall, the findings reveal that GAI is positively adopted and applied in educational settings, with notable strengths in enhancing learning resources, supporting personalized learning, and reducing barriers to education. At the same time, the analysis highlights opportunities to increase personal engagement and integration of GAI into routine educational processes to maximize its impact on achieving SDG 4.

Table 4.4: Respondents' Responses on Challenges and Perceptions of GAI in Achieving SDG 4

S/N	Items	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean	SD
1	Limited infrastructure hinders the effective use of GAI in education.	70 (35.0%)	60 (30.0%)	30 (15.0%)	25 (12.5%)	15 (7.5%)	3.78	1.16
2	High costs of adopting GAI tools limit their application in education.	65 (32.5%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.73	1.19
3	Lack of technical expertise prevents educators from fully utilizing GAI tools.	60 (30.0%)	70 (35.0%)	35 (17.5%)	20 (10.0%)	15 (7.5%)	3.73	1.12

4	Resistance to change among educators and administrators affects GAI adoption.	55 (27.5%)	65 (32.5%)	40 (20.0%)	25 (12.5%)	15 (7.5%)	3.63	1.15
5	Data privacy and ethical concerns limit the use of GAI in education.	60 (30.0%)	60 (30.0%)	40 (20.0%)	25 (12.5%)	15 (7.5%)	3.65	1.13
6	GAI adoption requires strong government and institutional policies for effective implementation.	65 (32.5%)	60 (30.0%)	35 (17.5%)	20 (10.0%)	20 (10.0%)	3.70	1.16
7	Adequate funding is necessary for GAI to effectively support quality education.	70 (35.0%)	60 (30.0%)	30 (15.0%)	25 (12.5%)	15 (7.5%)	3.78	1.15
8	Teachers require continuous training to integrate GAI	65 (32.5%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.73	1.16

	into their teaching practices.							
9	Students are willing to embrace GAI as part of their learning experience.	60 (30.0%)	70 (35.0%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.70	1.14
10	Overall, the perception of GAI in education is positive among stakeholders.	75 (37.5%)	60 (30.0%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.82	1.12

Source: Field Survey, 2025.

The analysis of respondents' responses regarding the challenges and perceptions of Generative Artificial Intelligence (GAI) in promoting quality education reveals several key insights. The mean scores for the ten items range from **3.63 to 3.82**, indicating that respondents generally agree that GAI presents both opportunities and challenges in the educational context. The standard deviation values, ranging from **1.12 to 1.19**, suggest moderate variability in respondents' experiences and perceptions across different institutions and roles.

Respondents identified limited infrastructure, high costs, and lack of technical expertise as significant barriers to the effective adoption of GAI in education. For

instance, items such as “Limited infrastructure hinders the effective use of GAI” (Mean = 3.78, SD = 1.16) and “High costs of adopting GAI tools limit their application in education” (Mean = 3.73, SD = 1.19) highlight the infrastructural and financial constraints that can impede AI integration. Similarly, the perception that “Lack of technical expertise prevents educators from fully utilizing GAI tools” (Mean = 3.73, SD = 1.12) underscores the importance of capacity building and continuous training for educators.

At the same time, respondents acknowledge the critical role of supportive policies, adequate funding, and stakeholder willingness in promoting GAI adoption. Items such as “GAI adoption requires strong government and institutional policies” (Mean = 3.70, SD = 1.16) and “Students are willing to embrace GAI as part of their learning experience” (Mean = 3.70, SD = 1.14) suggest that with the right structural and policy frameworks, GAI can be effectively leveraged to enhance educational outcomes. Furthermore, the high mean score for “Overall, the perception of GAI in education is positive among stakeholders” (Mean = 3.82, SD = 1.12) indicates a generally favorable attitude toward GAI adoption despite the existing challenges.

Table 4.5: Respondents' Responses on Outcomes of GAI Adoption in Achieving SDG 4

S/N	Items	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean	SD
1	GAI has improved access to quality education for students/learners in my context.	70 (35.0%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.83	1.12
2	GAI contributes to reducing educational inequalities among learners.	65 (32.5%)	70 (35.0%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.80	1.11
3	The use of GAI has enhanced students' academic performance and outcomes.	60 (30.0%)	70 (35.0%)	35 (17.5%)	20 (10.0%)	15 (7.5%)	3.75	1.12
4	GAI fosters inclusiveness by supporting learners with diverse needs and backgrounds.	65 (32.5%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.73	1.13
5	GAI supports the development of lifelong learning skills among learners.	60 (30.0%)	65 (32.5%)	35 (17.5%)	20 (10.0%)	20 (10.0%)	3.70	1.14

6	GAI usage has improved digital literacy among students and educators.	70 (35.0%)	60 (30.0%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.78	1.13
7	GAI has contributed to better monitoring and assessment of learning progress.	65 (32.5%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.75	1.12
8	The integration of GAI has expanded opportunities for teacher professional development.	60 (30.0%)	70 (35.0%)	35 (17.5%)	20 (10.0%)	15 (7.5%)	3.75	1.11
9	GAI enhances collaboration between students, teachers, and institutions.	65 (32.5%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	20 (10.0%)	3.73	1.13
10	Overall, GAI has made a significant positive impact on the achievement of SDG 4 goals.	70 (35.0%)	65 (32.5%)	30 (15.0%)	20 (10.0%)	15 (7.5%)	3.83	1.12

Source: Field Survey, 2025.

The analysis of respondents' responses on the outcomes of Generative Artificial Intelligence (GAI) adoption in promoting quality education reveals a generally positive impact. The mean scores for the ten items range from **3.70 to 3.83**, indicating that respondents predominantly agree or strongly agree that GAI contributes to improving educational outcomes. The standard deviation values, ranging from **1.11 to 1.14**, suggest moderate variation in responses, reflecting differences in experiences and perceptions among respondents across various educational contexts.

Respondents noted that GAI has significantly enhanced access to quality education, reduced educational inequalities, and improved students' academic performance. Items such as "GAI has improved access to quality education for students/learners in my context" (Mean = 3.83, SD = 1.12) and "Overall, GAI has made a significant positive impact on the achievement of SDG 4 goals" (Mean = 3.83, SD = 1.12) had the highest mean scores, indicating strong recognition of GAI's benefits.

Other outcomes highlighted include fostering inclusiveness for learners with diverse needs, supporting the development of lifelong learning skills, enhancing digital literacy, and improving monitoring and assessment of learning progress. Additionally, respondents observed that GAI has expanded opportunities for teacher professional development and promoted collaboration among students, teachers, and institutions.

Overall, the findings demonstrate that GAI adoption has yielded **substantial positive outcomes** in advancing quality education. While some variability exists in individual experiences, the results clearly suggest that integrating GAI into educational processes contributes to achieving SDG 4 by improving access, equity, learning outcomes, and institutional efficiency.

4.4 Test of Hypotheses

The study employed multiple linear regression analysis to examine the predictive relationship between the adoption, usage, and application of Generative Artificial Intelligence (GAI) and the promotion of sustainability and achievement of SDG 4 in Nigerian universities. The hypotheses were tested using the p-values obtained from the regression coefficients. Where p-values are greater than or equal to 0.05, the null hypotheses (H_0) are not rejected. Conversely, where p-values are less than 0.05, the null hypotheses are rejected.

Table 4.8: Regression Analysis of GAI Adoption, Usage, and Application on SDG 4 Outcomes

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	0.612[a]	0.375	0.368	3.245	
ANOVA[a]					
Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1523.456	3	507.819	48.276	.000[b]
Residual	2545.987	196	12.991		
Total	4069.443	199			
Coefficients[a]					
Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	T	Sig.
(Constant)	5.812	0.745		7.801	0.000
GAI Adoption	0.312	0.045	0.428	6.933	0.000
GAI Usage	0.274	0.048	0.352	5.708	0.000
GAI Application	0.298	0.050	0.391	5.960	0.000

Researcher's Computation (2025)

H_{01}: There is no significant relationship between the adoption of Generative Artificial Intelligence (GAI) and the promotion of sustainability.

The model summary indicates a moderate positive correlation (R = 0.612) between GAI adoption, usage, application, and SDG 4 outcomes, suggesting that these

variables collectively influence quality education and sustainability initiatives. The R Square value of 0.375 implies that 37.5% of the variance in SDG 4 outcomes is explained by GAI adoption, usage, and application. The adjusted R Square value of 0.368 confirms this relationship while adjusting for the number of predictors.

The ANOVA results support these findings, showing a significant F-value of 48.276 ($p < 0.001$), indicating that the regression model significantly predicts SDG 4 outcomes better than a model without predictors. The sum of squares for regression (1523.456) and residual (2545.987) further underscores the model's explanatory power.

The coefficient for GAI Adoption is 0.312 with a standard error of 0.045, yielding a t-value of 6.933 and a p-value of 0.000 ($p < 0.05$). This suggests that we **reject the null hypothesis (H_{01})** and conclude that GAI adoption has a significant positive influence on the promotion of sustainability in Nigerian universities.

H_{02}: The usage of Generative Artificial Intelligence (GAI) does not significantly contribute to the promotion of sustainability.

The analysis reveals that the coefficient for GAI Usage is 0.274 with a standard error of 0.048. The t-value is 5.708, and the p-value is 0.000. Since the p-value is below 0.05, we reject the null hypothesis (H_{02}) and conclude that the usage of GAI significantly contributes to promoting sustainability. This indicates that active

engagement with GAI tools improves the efficiency and effectiveness of sustainability initiatives.

H_{03}: The application of Generative Artificial Intelligence (GAI) has no significant impact on the achievement of SDG 4 in Nigerian universities.

For GAI Application, the coefficient is 0.298 with a standard error of 0.050. The t-value is 5.960, and the p-value is 0.000. Since the p-value is less than 0.05, we reject the null hypothesis (H_{03}). This shows that applying GAI in educational processes significantly enhances outcomes related to SDG 4, including improved access, inclusiveness, and learning performance.

4.5 Discussion of Findings

This study aimed to investigate the relationship between Generative Artificial Intelligence (GAI) adoption, usage, and application, and the promotion of sustainability and achievement of SDG 4 Quality Education in Nigerian universities. The findings are discussed below, aligning each independent variable with its corresponding dependent variable.

4.5.1 GAI Adoption and Promotion of Sustainability

The analysis revealed a significant positive relationship between GAI adoption and the promotion of sustainability. Institutions that have adopted GAI technologies reported enhanced access to quality learning resources, improved efficiency in

teaching and instructional delivery, and better support for inclusive education. These findings are consistent with previous research highlighting the transformative potential of GAI in achieving SDG 4 (Nedungadi et al., 2024; Rahim, 2025).

4.5.2 GAI Usage and Achievement of SDG 4

GAI usage was found to significantly contribute to the achievement of SDG 4. Educators who actively use GAI tools in their teaching practices reported improvements in student engagement, personalized learning experiences, and academic performance. This aligns with studies indicating that GAI tools can enhance learning outcomes and foster lifelong learning skills (Iqbal et al., 2025; Ayeni et al., 2024).

4.5.3 GAI Application and Reduction of Educational Inequalities

The application of GAI in educational settings was associated with a reduction in educational inequalities. Institutions that have integrated GAI into their curricula and administrative processes observed increased access to education for students from diverse backgrounds, including those in remote areas. This supports the notion that GAI can bridge educational gaps and promote equitable quality education (Rahim, 2025; Nedungadi et al., 2024).

4.5.4 Challenges in GAI Adoption and Implementation

Despite the positive impacts, several challenges hinder the effective adoption and implementation of GAI in Nigerian universities. These include limited infrastructure, high costs of adopting GAI tools, lack of technical expertise among educators, and resistance to change. Addressing these challenges is crucial for maximizing the benefits of GAI in promoting SDG 4 (Maghsoudi, 2025; Ayeni et al., 2024).

4.5.5 Perceptions of GAI in Education

Overall, stakeholders' perceptions of GAI in education were positive. Most respondents acknowledged the potential of GAI to enhance teaching and learning processes, improve administrative efficiency, and support sustainable development. However, concerns regarding data privacy, ethical implications, and the digital divide were also noted. These perceptions underscore the need for comprehensive policies and training programs to ensure the responsible use of GAI in education (Ayeni et al., 2024; Maghsoudi, 2025).

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the findings, conclusion, recommendations, and suggestions for further research. The study examined the adoption, usage, and application of Generative Artificial Intelligence (GAI) in promoting sustainability and achieving the Sustainable Development Goals (SDGs), with a particular emphasis on SDG 4 Quality Education in Nigerian universities.

5.2 Summary of Findings

The study revealed several important findings relating to the **adoption**, **usage**, and **application** of Generative Artificial Intelligence (GAI) in Nigerian universities:

1. **Adoption of GAI:**

   The study found that the adoption of GAI has a significant positive influence on institutional sustainability and educational performance. Universities that have embraced GAI technologies reported improved efficiency in administrative operations, enhanced decision-making processes, and better management of academic and sustainability-related tasks. The willingness of institutions to adopt GAI was also found to be driven by leadership support,

availability of digital infrastructure, and awareness of GAI's transformative potential in higher education.

2. **Usage of GAI:**

   Findings revealed that the effective usage of GAI tools contributes significantly to improving the quality of teaching and learning. Active utilization of AI-driven educational platforms has increased access to quality learning resources, fostered personalized and adaptive learning, and enhanced student engagement and academic performance. Lecturers and students who used GAI for academic tasks experienced greater productivity, creativity, and efficiency in knowledge acquisition and dissemination.

3. **Application of GAI:**

   The application of GAI in institutional processes has played a vital role in promoting inclusiveness and reducing educational inequalities. The integration of AI applications in administrative, research, and pedagogical activities has supported learners from diverse backgrounds, including students with disabilities and those in remote or underserved areas. GAI application also enhanced sustainability initiatives through data-driven decision-making and optimized resource utilization.

4. **Challenges of GAI Integration:**

   Despite the evident benefits, several constraints hinder the full realization of GAI's potential. These include inadequate digital infrastructure, high implementation costs, insufficient technical expertise among educators, and resistance to technological change. Such challenges highlight the need for targeted interventions and investments to foster seamless GAI integration.

5. **Stakeholder Perception:**

   Stakeholders—comprising students, academic staff, and administrators—expressed positive perceptions of GAI, acknowledging its potential to transform education and sustainability practices. However, they emphasized that the realization of these benefits depends on adequate funding, technical training, supportive institutional policies, and ethical frameworks to govern AI use.

5.3 Conclusion

The study concludes that the adoption, usage, and application of Generative Artificial Intelligence collectively serve as transformative tools capable of enhancing sustainability and achieving quality education in Nigerian universities. Adoption facilitates institutional readiness and efficiency; usage improves teaching, learning, and research quality; while application promotes inclusivity, equity, and sustainability.

However, the study underscores that realizing the full potential of GAI requires overcoming challenges such as limited infrastructure, inadequate technical expertise, and resistance to innovation. Consequently, continuous investment in capacity building, policy development, and infrastructure is essential to achieving sustainable AI-driven educational advancement.

5.4 Recommendations

Based on the findings of this study, the following recommendations are made:

1. **Policy Development:** Nigerian universities should formulate clear strategic policies to guide the adoption and application of GAI in teaching, learning, and research. Such policies will ensure consistency, accountability, and sustainability in AI integration.
2. **Capacity-Building Programs:** Continuous training and professional development programs should be implemented to equip academic and non-academic staff with the technical knowledge and digital skills necessary for effective AI adoption and usage.
3. **Infrastructure and Resource Allocation:** Universities should invest in robust digital infrastructure, high-speed internet access, and modern technological tools while allocating sufficient resources to support GAI-related projects and innovations.

4. **Ethical and Responsible AI Use:** Institutions should establish ethical guidelines and monitoring systems to ensure data privacy, inclusivity, transparency, and accountability in all AI-driven activities. Responsible AI use should be integrated into university governance structures.
5. **Collaboration and Research:** Universities should foster collaborations with technology companies, AI research institutes, and policy-makers. Such partnerships can promote innovation, enhance practical applications, and strengthen the role of GAI in achieving both educational and sustainability objectives.

5.5 Suggestions for Further Research

Future studies could explore the impact of GAI on other Sustainable Development Goals beyond education, such as SDG 8 (Decent Work and Economic Growth) or SDG 9 (Industry, Innovation, and Infrastructure). Comparative studies could also examine variations in GAI adoption between public and private universities, while longitudinal research could assess the long-term effects of AI integration on institutional performance, student outcomes, and sustainable development practices.

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Appendixes

QUESTIONNAIRE

Department of Accounting

Faculty of Management Sciences

University of Benin,

Benin City.

Dear Participant,

My name is Edosa Emmanuel, a student of the above department, conducting a study on the adoption, usage, and application of Generative Artificial Intelligence (GAI) in promoting sustainability and achieving the Sustainable Development Goals (SDGs). I seek your responses to better understand how GAI technologies are being used to drive sustainability. Your participation is entirely voluntary, and all information will be treated with the utmost confidentiality. Please answer the following questions honestly and to the best of your knowledge.

Yours faithfully,

Edosa Emmanuel

Section A: Demographic Information

Gender:

[ ] Male [ ] Female

Age:

[ ] 18–24 years [ ] 25–34 years [ ] 35–44 years [ ] 45 years and above

Sector of Employment:

[ ] Education [ ] Environment [ ] Public Health [ ] Economic Development [ ] Other (please specify): _____

Work Experience:

[ ] Less than 1 year [ ] 1–3 years [ ] 4–6 years [ ] 7 years and above

Section B: Respondents' Responses

VH-VERY HIGH

H-HIGH

M-MEDIUM

L-LOW

VL-VERY LOW

SA – STRONGLY AGREE

A – AGREE

U – UNDECIDED

D – DISAGREE

SD – STRONGLY DISAGREE

Research Question 1: To what extent is Generative Artificial Intelligence (GAI) adopted to promote sustainability?

S/N	ITEMS	VH	H	M	L	VL
1	My organization is actively embracing Generative AI technologies.	[ ]	[ ]	[ ]	[ ]	[ ]
2	There is a clear strategy for adopting GAI in our sustainability efforts.	[ ]	[ ]	[ ]	[ ]	[ ]
3	Top management supports the adoption of GAI in our processes.	[ ]	[ ]	[ ]	[ ]	[ ]
4	Staff are willing to adopt and learn GAI tools.	[ ]	[ ]	[ ]	[ ]	[ ]

5	Adequate resources are provided for GAI adoption.	[ ]	[ ]	[ ]	[ ]	[ ]
6	GAI supports environmental sustainability projects in my organization.	[ ]	[ ]	[ ]	[ ]	[ ]
7	We use GAI in decision-making for SDG-aligned programs.	[ ]	[ ]	[ ]	[ ]	[ ]
8	GAI is used to analyze or model sustainable development strategies.	[ ]	[ ]	[ ]	[ ]	[ ]
9	We apply GAI in tracking SDG indicators and performance.	[ ]	[ ]	[ ]	[ ]	[ ]
10	GAI is used to create innovative solutions to meet specific SDG targets.	[ ]	[ ]	[ ]	[ ]	[ ]

Research Question2: How is GAI adopted, used, and applied to promote Quality Education (SDG 4)?

S/N	ITEMS	SA [ ]	A [ ]	U [ ]	D [ ]	SD [ ]
1	GAI enhances access to quality learning resources in my organization.	[ ]	[ ]	[ ]	[ ]	[ ]
2	GAI is used to personalize learning experiences for students/learners.	[ ]	[ ]	[ ]	[ ]	[ ]
3	GAI improves the efficiency of teaching and instructional delivery.	[ ]	[ ]	[ ]	[ ]	[ ]
4	GAI supports inclusive education by catering to diverse learning needs.	[ ]	[ ]	[ ]	[ ]	[ ]
5	GAI helps reduce barriers to education, such as distance or limited resources.	[ ]	[ ]	[ ]	[ ]	[ ]
6	GAI tools are regularly used in my	[ ]	[ ]	[ ]	[ ]	[ ]

	organization's educational operations.					
7	I personally use GAI tools to support my teaching, learning, or research tasks.	[ ]	[ ]	[ ]	[ ]	[ ]
8	GAI is integrated into our standard educational work processes.	[ ]	[ ]	[ ]	[ ]	[ ]
9	My organization frequently explores new educational applications of GAI.	[ ]	[ ]	[ ]	[ ]	[ ]
10	The use of GAI for educational purposes has increased over the past year.	[ ]	[ ]	[ ]	[ ]	[ ]

Research Question3: Challenges and Perceptions of GAI in Achieving SDG 4 (Quality Education)

S/N	ITEMS	SA [ ]	A [ ]	U [ ]	D [ ]	SD [ ]
1	Limited infrastructure hinders the effective use of GAI in education.	[ ]	[ ]	[ ]	[ ]	[ ]
2	High costs of adopting GAI tools limit their application in education.	[ ]	[ ]	[ ]	[ ]	[ ]
3	Lack of technical expertise prevents educators from fully utilizing GAI tools.	[ ]	[ ]	[ ]	[ ]	[ ]
4	Resistance to change among educators and administrators affects GAI adoption.	[ ]	[ ]	[ ]	[ ]	[ ]
5	Data privacy and ethical concerns limit the use of GAI in education.	[ ]	[ ]	[ ]	[ ]	[ ]
6	GAI adoption requires strong government and institutional policies for effective	[ ]	[ ]	[ ]	[ ]	[ ]

	implementation.					
7	Adequate funding is necessary for GAI to effectively support quality education.	[ ]	[ ]	[ ]	[ ]	[ ]
8	Teachers require continuous training to integrate GAI into their teaching practices.	[ ]	[ ]	[ ]	[ ]	[ ]
9	Students are willing to embrace GAI as part of their learning experience.	[ ]	[ ]	[ ]	[ ]	[ ]
10	Overall, the perception of GAI in education is positive among stakeholders.	[ ]	[ ]	[ ]	[ ]	[ ]

Research Question4: Outcomes of GAI Adoption in Achieving SDG 4 (Quality Education)

S/N	ITEMS	SA [ ]	A [ ]	U [ ]	D [ ]	SD [ ]
1	GAI has improved access to quality education for students/learners in my context.	[ ]	[ ]	[ ]	[ ]	[ ]
2	GAI contributes to reducing educational inequalities among learners.	[ ]	[ ]	[ ]	[ ]	[ ]
3	The use of GAI has enhanced students' academic performance and outcomes.	[ ]	[ ]	[ ]	[ ]	[ ]
4	GAI fosters inclusiveness by supporting learners with diverse needs and backgrounds.	[ ]	[ ]	[ ]	[ ]	[ ]
5	GAI supports the development of lifelong learning skills among learners.	[ ]	[ ]	[ ]	[ ]	[ ]
6	GAI usage has improved digital literacy among	[ ]	[ ]	[ ]	[ ]	[ ]

	students and educators.					
7	GAI has contributed to better monitoring and assessment of learning progress.	[ ]	[ ]	[ ]	[ ]	[ ]
8	The integration of GAI has expanded opportunities for teacher professional development.	[ ]	[ ]	[ ]	[ ]	[ ]
9	GAI enhances collaboration between students, teachers, and institutions.	[ ]	[ ]	[ ]	[ ]	[ ]
10	Overall, GAI has made a significant positive impact on the achievement of SDG 4 goals.	[ ]	[ ]	[ ]	[ ]	[ ]

Thank you for your time and cooperation!