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ARTIFICIAL INTELLIGENCE, EDUCATION AND NATIONAL DEVELOPMENT

AGANA, MOSES ADAH
DEPARTMENT OF CYBERSECURITY
FACULTY OF COMPUTING, UNIVERSITY OF CALABAR

Abstract

Evolving from the ideas of Alan M. Turing and his colleagues in computer design who worked on the analogy between the human brain and the computer in the 1940s and early 1950s, Artificial intelligence (AI) has permeated many disciplines. This paper x-rays the concept of AI and its branches, dwelling on the role of AI in education and national development (AIEDND). In this review paper, insights have been sought into three critical questions: (1) How does artificial intelligence contribute to teaching, learning and research? (2) How does artificial intelligence contribute to national development? (3) What are the challenges of the use of AI in education and national development? The extensive literature review followed by the content analytical review of some research articles reveals a plethora of AI applications in education and national development, encompassing those for adaptive learning and personalized tutoring, intelligent assessment and management, profiling and prediction, and emerging products. Research topics reviewed and analyzed delve into both the technical design of education systems, agricultural systems, health sector applications of AI, security systems, etc. that contribute to strengthening education and national development. The paper also examines the adoption, impacts, and challenges associated with AIEDND. Furthermore, this review highlights the diverse range of theories applied in the AIED literature, the multidisciplinary nature of publication venues, and underexplored research areas. In summary, this research offers valuable insights for interested scholars to comprehend the current state of AI applications in education and national development (AIEDND) and to identify future research opportunities in this dynamic field.

1. Introduction

This paper aims to provide an in-depth understanding of the conceptual structure of how artificial intelligence contributes to education and national development. Specifically, it addresses the following research questions:

- How does artificial intelligence contribute to teaching, learning and research?
- How does artificial intelligence contribute to national development?
- What are the challenges of the use of AI in education and national development?

To address these questions, this study employs a mixed research methodology, combining analytical review, aligning with Shan et al. (2024) and Donthu et al. (2021) with a systematic literature review (Snyder, 2019). The analytical review involves the quantitative summarization of some research articles, including publication year, title, abstract, citations, authors, and institutions. It serves as an efficient method for grasping the state of a research field, particularly when the review scope is broad and the dataset is too extensive for manual examination (Donthu et al., 2021). The systematic literature review on the other hand, through content analysis of research articles, can delve into research nuances that are of interest to researchers (Snyder, 2019). Together, these two complementary approaches provide a comprehensive view of the conceptual structure and emerging trends in the research field of AI applications in education and national development (Donthu et al., 2021).

2. Literature Review

2.1 The concept and origin of Artificial Intelligence (AI)

The odyssey of Artificial Intelligence (AI) mirrors the relentless human endeavor to transcend the customary bounds of capability and knowledge.

Artificial Intelligence (AI) is a branch of computer science that is concerned with the creation of computers that ***think*** and react to information, ultimately being able to wholly reach accurate and unique conclusions for any given situation (Robert, Edward & Louanna, 2025).

AI is a paradigm of computing that aims to mimic human intelligence, enabling machines to learn from experience, adapt to new inputs, and perform tasks that traditionally require human intervention. At the core of AI is the ambition to create systems that can understand, learn, and apply knowledge, thereby extending human capabilities and automating routine tasks (Rainer et al., 2016).

The puzzling question then is: ***can computers think?*** The response is: ***somehow, YES.*** Artificial intelligence is a bold enterprise. As a discipline, it is taking on the centuries-long religious, philosophical and technological debates over whether ***machines are equal to man***. Researchers in the discipline are optimistic that they are about to put this argument to rest. Their conclusion is that, indeed, the machine will measure up to man (Rothfeder, 1985).

The journey of Artificial Intelligence is a rich tapestry that is woven through centuries of human civilization. The allure of crafting beings with a semblance of human intellect dates back to ancient civilizations and mythologies, where stories of artificial beings endowed with intelligence intrigued the imagination of societies.

The ancient Greeks, for instance, dreamed of automatons capable of mimicking human actions. In their mythology, the skilled craftsman Hephaestus was said to have created mechanical servants. Similarly, in ancient China and Egypt, there were legends of mechanical entities and automatons. These early human narratives reflect a deep-rooted fascination with the idea of artificial intelligence, although in a rudimentary form (Robert, et al., 2025).

The concept of AI has since evolved, with the philosophical and scientific foundations laid down by some of the most brilliant minds across centuries, paving the way for the modern-day AI that we are familiar with. For instance:

- **René Descartes (1596-1650)**, who was a French philosopher and mathematician, conceptualized the idea of machines imitating or mimicking human behavior. Although his machines, as conceived were mere mechanical entities devoid of soul, his thoughts ignited the idea of creating machines capable of complex actions akin to human beings.
- **Alan Turing (1912-1954)** laid much of the groundwork for AI through his Turing Test, proposed in 1950 to determine whether a machine exhibits human-like intelligence. Turing's ideas about machine intelligence were revolutionary and paved the way for the development of AI as a distinct field.

Despite being conceived about a decade earlier by various researchers such as Boger Schank, Ernest Kent, Edward Feigenbaum, a professor at Stanford University, Alan Turing, the 'grandfather of computing', and Jaime Carbonell of Carnegie-Melon University amongst others, artificial intelligence was finally born in 1956 and given a modicum of public prominence at a summer-long conference held at Dartmouth University, New Hampshire, dubbed the Dartmouth Sumer Research Project on Artficial Intelligence (Rothfeder, 1985).

Though creating artificial intelligence may seem at first blush to be the outlandish fantasy of god playing researchers, teaching cognitive skills to computers in the laboratory has turned out to be a practical practice of machine education. In fact, the achievements of AI research to date are even more significant than any ballyhoo ever imagined (Rothfeder, 1985). AI systems now exist in computers that possess medical diagnostic skills, understand and process natural language and learn from human conversations, or by reading texts, as well as robots with sights that can distinguish objects, and arms that can perform tasks even too difficult for humans to perform.

Despite the many philosophical disagreements over whether "true" intelligent machines actually exist, when most people who use the term AI today are referring to a suite of machine learning enabled technologies, such as Chat GPT or computer vision, that enable machines to perform tasks such as generating written content, steering a car, or analyzing data that previously only humans could perform.

2.2 Branches of AI

Rainer et al. (2016) and Robert, et al. (2025) identified six major branches of artificial intelligence.
The six branches are illustrated in Figure 1.

Figure 1: Branches of Artificial Intelligence (Robert, et al., 2025)

Expert Systems: An expert system is an intelligent computer program that uses knowledge and inference procedure to solve problems that are difficult enough to require significant human expertise for their solution. An expert system refers to a computer system that mimics the decision making intelligence of a human expert. It conducts this by deriving knowledge from its knowledge base by implementing reasoning and insights rules in terms with the user queries (Belpaeme & Tanaka, 2022).

The term expert system is thus reserved for programs whose knowledge base contains the knowledge used by human experts, in contrast to knowledge gathered from textbooks or nonexperts.

The ***Mycin*** is by all accounts is the quintessential expert system. According to Jeffrey (1985), the Mycin was a program developed at Stanford in the late 1970s by Edward Shortliffe, then an assistant professor of medicine and computer science at Stanford University. He achieved this under the tutelage of his mentor Dr. Robert Greenaes of Massachusetts General Hospital who was at the time completing a Ph.D. in computer science after having received an MD from Harvard. It was designed to diagnose and recommend drug treatments for blood and meningitis infections (Perrotta & Selwyn, 2020).
The Mycin was one of the earliest backward chaining expert systems that was designed to find the bacteria causing infections like bacteraemia and meningitis. It was also used for the recommendation of antibiotics and the diagnosis of blood clotting diseases.
Apart from the Mycin, some of the other earlier commercially available expert systems include the *Dendral* developed in 1964 by Edward Feigenbaum at Stanford University in USA to determine the molecular structure of

chemical compounds. **The Dendral** was an artificial intelligence project that was made as a chemical analysis expert system. It was used in organic chemistry to detect unknown organic molecules with the help of their mass spectra and knowledge base of chemistry.

The *prospector* was another expert system created in 1978 by Richard Duda, Peter Hard and Rene Reboh and used for mineral exploration. The *R1* or *XCON* was also an expert system which was developed by John Mcdermott and his colleagues at the Carnegie-Melon University, USA which was a knowledge-based VAX configuration system used to help sales force and the customer to select coherent configurations that best match requirements as well as to help with site preparation, to schedule the production and delivery of the configuration in order to help factory scheduling, material and stores control, etc. (GrandViewResearch, 2021). Other ES examples are:

- **PXDES:** It is an expert system that is used to determine the type and level of lung cancer. To determine the disease, it takes a picture from the upper body, which looks like the shadow. This shadow identifies the type and degree of harm.
- **CaDeT:** The CaDet expert system is a diagnostic support system that can detect cancer at early stages.

Today, there are varieties of expert systems in use covering a broad spectrum of difficult tasks like diesel engine repair, computer design, telephone line troubleshooting, educational instruction delivery, medical diagnosis, chemical molecular analysis, etc. These are predominantly developed within the academia and are yielding essential clues to the efficacy of a huge number of heuristic thought strategies.

The effectiveness of the expert system completely relies on the expert's knowledge accumulated in a knowledge base. The more the information collected in it, the more the system enhances its efficiency. For example, the expert system provides suggestions for spelling and errors in Google Search Engine.

Expert systems are built to deal with complex problems via reasoning through the bodies of proficiency, expressed especially in particular of "if-then" rules instead of traditional agenda to code. The key features of expert systems include ***extremely responsive, reliable. Figure 2 illustrates the components of an expert system.***

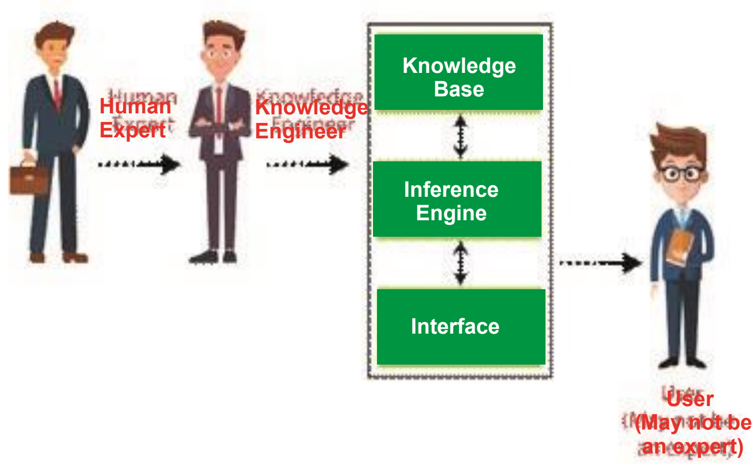

Figure 2: The components of an expert system (Belpaeme & Tanaka, 2022).

A typical expert system consists of the knowledge base, the inference engine and the user interface as illustrated in Figure 2. The human actors that contribute to building the expert system are the domain expert (e.g. a medical doctor, a subject teacher, or a lawyer) and the knowledge engineer (a computer scientist and programmer who collects and organizes the knowledge from the human expert and programs it into the computer). The user (end user) is anyone who uses the services of an expert system.

1. ***User Interface:*** With the help of a user interface, the expert system interacts with the user, takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user. In other words, **it is an interface that helps a non-expert user to communicate with the expert system to find a solution**.
2. ***Inference Engine:*** The inference engine is known as the **brain** of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution, responds to queries asked by the user and acts on the knowledge from the knowledge base.
3. ***Knowledge Base:*** The knowledge base is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as the big storage of knowledge. The more the knowledge base, the more precise the expert system will be. It is similar to a database that contains information and rules of a particular domain or subject. One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are: it is a mammal, it is not a domestic animal, etc.

Robotics: This branch of AI has emerged as a very sizzling field, an interesting field of research and development that mainly focuses on designing and constructing robots (Perrotta & Selwyn, 2020). Robotics is an interdisciplinary field of science and engineering incorporated with mechanical engineering, electrical engineering, computer science, and many others. Robotics determines the designing, producing, operating, and usage of robots. It deals with computer systems for their control, intelligent outcomes, and information transformation.

Robots are deployed often for conducting tasks such as drilling, irrigation, car assembly and mining, that might be laborious for humans to perform steadily. AI researchers are also developing robots using machine learning to set interaction at social levels.

Machine Learning (ML): In terms of advanced technology, one of the most demanding fields of AI is Machine Learning. ***Machine Learning is the technique that gives computers the potential to learn without being programmed.*** Fundamentally, it is the science that enables machines to translate, execute and investigate data for solving real-world problems. With the deployment of complex mathematical expertise, programmers design machine learning algorithms that are coded in a machine language in order to make a complete ML system. By this way, ML enables us to perform tasks to categorize, decipher and estimate data from a given dataset (Perrotta & Selwyn, 2020). The derivatives of machine learning in our contemporary times include unmanned drones, self-driving cars, image and speech recognition, demand forecasting models, useful web search and various extensive applications. It basically converges on the applications that adapt from experience and advance their decision-making potential or predictive accuracy over a period of time.

Neural Network: Neural network is a branch of artificial intelligence that makes use of neurology (a part of biology that concerns the nerve and nervous system of the human brain) and incorporates cognitive science and machines to perform tasks. Neural network replicates the human brain where the human brain comprises an infinite number of neurons and to code brain-neurons into a system or a machine is what the neural network functions.

In simple terms, a neural network is a set of algorithms that are used to find the elemental relationships across the bunches of data via the process that imitates the human brain operating process (Belpaeme & Tanaka, 2022). So, a neural network refers to a system of neurons that are original or artificial in nature, where artificial neurons are known as perceptrons. From forecasting to market research, they are extensively used for fraud detection, risk analysis, stock-exchange prediction, sales prediction and many more.

Fuzzy Logic: Fuzzy logic is the branch of AI that represents and modifies uncertain information by measuring the degree to which the hypothesis is correct. In the real world, sometimes we face a condition where it is difficult to recognize whether the condition is true or not, this is where fuzzy logic gives relevant flexibility for reasoning that leads to inaccuracies and uncertainties of any condition. Fuzzy logic is also used for reasoning about naturally uncertain concepts. Fuzzy logic is convenient and flexible to implement machine learning techniques and assist in imitating human thought logically. It is simply the generalization of the standard logic where a concept exhibits a degree of truth between 0.0 to 1.0. If the concept is completely true, standard logic is 1.0 and 0.0 for the completely false concept. But in fuzzy logic, there is also an intermediate value too which is partially true and partially false (Belpaeme & Tanaka, 2022).

Natural Language Processing (NLP): In layman words, NLP is the part of computer science and AI that can help in communicating between computer and human by natural language. It is a technique of computational processing of human languages. It enables a computer to read and understand data by mimicking human natural language. NLP is a method that deals in searching, analyzing, understanding and deriving information from the text form of data. In order to teach computers how to extract meaningful information from the text data, NLP libraries are used by programmers. A common example of NLP is spam detection, computer algorithms can check whether an email is a junk or not by looking at the subject of a line, or text of an email (Bicknell et al., 2023).

2.3 AI Applications in Education

The field of education especially lends itself to AI technologies since educational activities, including learning and teaching, are knowledge-intensive cognitive activities, and AI applications, which are created for cognition and problem-solving based on algorithms and knowledge base, can effectively support and augment educators' and learners' abilities in teaching and learning. Since the advent of AI in the mid-1950 s, AI technologies have been increasingly applied to facilitate education and training in various subjects, including language, STEM, and medicine (Perrotta & Selwyn, 2020).

Artificial intelligence in educational research facilitates data-driven insights through learning analytics, automates literature reviews, and provides predictive modeling for student outcomes. Key applications include intelligent tutoring systems (ITS), personalized learning platforms, automated grading, and Generative AI for content creation, significantly accelerating research workflows.

The applications of artificial intelligence in education (AIED) are rapidly evolving, reshaping the overall teaching and learning landscape (Popenici & Kerr, 2017). The advent of generative AI technologies has introduced further opportunities, attracting investment into and development of the AIED industry. The global AIED market, valued at USD 1.82 billion in 2021, is projected to grow at a compound annual rate of 36 % from 2022 to 2030 (GrandViewResearch, 2021). Learners, teachers, and educational institutions are quickly embracing AIED. Recent statistics indicate that 43 % of college students in the US and between 35% to 40% in Sub-Saharan Africa use AI tools like ChatGPT and half of instructors employ AI to develop their lessons.

Information technologies, particularly artificial intelligence (AI), are revolutionizing modern education. AI algorithms and educational robots are now integral to learning management and training systems, providing support for a wide array of teaching and learning activities (Costa et al., 2017; García et al., 2007). Numerous applications of AI in education (AIED) have emerged. For example, Khan Academy offers Khanmigo, an AI tutor harnessing GPT-4 capabilities, delivering personalized learning support and intelligent feedback across various subjects, including mathematics, programming, and language learning. Similarly, Duolingo, a language learning platform, uses sophisticated AI systems to improve learner experiences (Bicknell et al., 2023). iFlyTek offers intelligent assessment systems tailored for various grading scenarios, including the national college entrance examination in China (iFlyTek, 2024). AI-powered learning management systems (LMS), such as Absorb LMS and Docebo, deliver multiple AI capabilities to support teaching and learning activities, such as intelligent content creation, administrative task automation, and personalized learning (Leh, 2022). In the realm of educational robots, SoftBank Robotics Nao and Pepper robots are developed to serve as language-teaching social robots (Belpaeme & Tanaka, 2022).

In a related development, Agana (2010) developed and instruction delivery expert system to teach mathematics, especially algebra. Similarly, Agana & Wario (2018) developed a Fuzzy logic based skill predictor for early childhood educators. The study presented a model of a two-input single output (TISO) Fuzzy Skill Predictor based on Howard Gardner's theory of multiple intelligences to assist early childhood educators in discovering latent skills in children of early school age as to tailor them towards professional skill development in their future lives.

Moreover, AIED demonstrates its efficacy and effectiveness. Adaptive learning enabled by AIED has been shown to improve student test results by 62 %, while AI usage, in general, enhances student performance by 30 % and reduces anxiety by 20. Concurrently, research on AIED has surged in recent years, yielding a substantial body of work exploring various aspects of these applications, including design, effectiveness, and outcomes (Chiu et al., 2023).

Artificial Intelligence (AI) also has great potentials for inclusive education. AI has the potential to transform the learning experiences of all students, particularly those with diverse learning needs or disabilities. By leveraging AI technologies, educators can design more personalized, engaging, and equitable learning environments that address individual learners' strengths and challenges (Luckin et al., 2016).

Hussaini & Firdausi (2025) posited that AI enables the customization of curricula to meet the unique needs of learners with disabilities. Intelligent tutoring systems and adaptive learning platforms can adjust content difficulty, pace, and presentation style based on real-time learner performance. For example, AI-driven platforms can provide visual, auditory, or kinesthetic learning materials tailored to each student's preferred learning mode, ensuring that learners with physical, cognitive, or sensory impairments are actively engaged in the learning process (Holmes et al., 2019). Tools such as speech-to-text and text-to-speech applications help students with visual impairments or dyslexia access learning materials effectively. Predictive tools, including AI-based word completion and grammar checkers, assist students with writing difficulties in expressing their ideas clearly (Almalki et al., 2021).

Similarly, AI-powered hearing aids and captioning systems enable learners with hearing impairments to follow classroom instructions and participate in discussions. Such technologies reduce barriers to learning and empower students to achieve academic success in mainstream classrooms. By offering individualized learning pathways, AI can help to reduce educational disparities and promotes equal access to quality education.
Key areas of AI application in educational research (iFlyTek, 2024; Leh, 2022; Bicknell et al., 2023) include:
Predictive Analytics and Data Mining: AI analyzes educational data to detect patterns, such as identifying at-risk students, predicting dropout rates, and improving student retention.
Intelligent Tutoring Systems (ITS) and Adaptive Learning: Systems like Khanmigo and adaptive platforms tailor content to individual learning speeds, providing 24/7 personalized tutoring.
Research Workflow Automation: AI tools assist researchers with literature reviews, text mining, summarizing papers, and generating research ideas.
Educational Chatbots and Robots: AI-powered agents are used for instant feedback, language learning, and providing supportive educational interactions.

Assessment and Feedback: Automated grading systems, such as Gradescope, increase efficiency in evaluating student assignments.
Generative AI (GAI) in Research: Large Language Models (LLMs) help with drafting, paraphrasing, and structuring academic papers, enhancing productivity and research writing.

These technologies are aimed at enhancing personalization, reducing administrative workloads, and providing deeper insights into the learning process. Table 1 highlights some major researches and reviews of the application of AI in education in recent years.

Table 1: Major Review of Studies on AI application in Education in Recent Years

Authors	**Article Types**	**Review Content**	**Time Articles were Reviewed**	**Research Domains**
Kulik & Fletcher, 2016	Systematic review of 50 papers	Synthesized and analyzed the effect sizes of the effectiveness of intelligent tutoring systems	Not specified	Intelligent tutoring systems
Chassignol et al., 2018	Narrative review	Developed a framework that classifies AIED applications by different components of education process: content, teaching methods, assessment and communication	Not specified	General
Zhang et al., 2018	Bibliometric study of 1,579 papers	Conducted descriptive analyses of bibliometric data, including top authors and journals; Summarized four methods in learning analytics and their evolution patterns	1995–2008	Learning analytics
Agana, M.A., 2010	M.Sc. Thesis	Developed an instruction delivery system for the teaching of mathematics	2009-2010	Higher education
Agana, M.A. & Wario, R.D. (2018)	Fuzzy Logic Design	Developed a Fuzzy skill predictor for early childhood educators	2018	Higher education
Hinojo-Lucena et al., 2019	Bibliometric study of 132 papers	Conducted a descriptive study of bibliometric data, including publication trend, sources, authors, organizations, and countries	2007–2017	Higher education
Zawacki-Richter et al., 2019	Systematic review of 146 papers	Conducted descriptive analyses of bibliometric data, including publication trends, journals, countries, author affiliation and methods; Summarized AIED applications.	2007–2018	Higher education

Charitopoulos et al., 2020	Systematic review of 316 papers	Coded education problems addressed, learning contexts, soft computing methods employed and major journal outlets for each area of educational data mining and learning analytics; Coded education problems addressed, learning contexts, soft computing methods employed and major journal outlets for each area of educational data mining and learning analytics	2010–2018	Educational data mining and learning analytics research
Chen, Xie, & Hwang, 2020	Bibliometrics of 9,560 papers	Conducted a descriptive study of bibliometric data, including grants, conferences, journals, software tools, institutions, and researchers	1999–2019	General
Celik et al., 2022	Systematic review of 44 papers	Reviewed the role of teachers in AIED, the advantages that AI offers teachers, the challenges teachers face when using AI, and AI methods in AI-based research with teachers	2004–2020	Teachers' perspective
Xu & Ouyang, 2022	Systematic review of 63 empirical AI-STEM studies	Summarized AI applications in STEM education and their associated elements such as educational information (content), subjects (leaners and instructors), medium, and environment	2011–2021	AI in STEM education
Chiu et al., 2023	Systematic review of 92 papers	Summarized AIED applications and outcomes, including applications in the domains of learning, teaching, assessment and	2012–2021	General

2.4 AI Applications in National Development in National Development (AIND)
National development is measured based on various parameters ranging from education of the citizens, manufacturing, agriculture, security, the health sector, and so on.

2.4.1 AI in Manufacturing
AI in manufacturing uses machine learning, computer vision, and data analytics to optimize production, enhance quality control, and predict equipment failures. By integrating with IoT sensors, AI reduces downtime through predictive maintenance, optimizes supply chains, and automates routine tasks, leading to higher efficiency and cost savings. It is crucial for Industry, transforming data into actionable insights. Most developed countries such as China, Japan, USA and Russia rely greatly on the utilization of AI in automation processes, which is why they are

always ahead of most other nations of the world that are still developing. Key applications of AI in the manufacturing sector as identified by Balasubramanian (2023) include:

Predictive Maintenance: AI analyzes sensor data to detect anomalies (like vibrations or temperature changes) and predict equipment failure, preventing costly shutdowns.

Quality Control and Inspection: Computer vision systems examine products in real time, identifying defects faster and more accurately than humans.

Supply Chain Optimization: AI improves demand forecasting and manages inventory by analyzing market trends, reducing waste, and optimizing logistics.

Generative Design: AI creates, tests, and optimizes product designs based on specific parameters (e.g., material weight, cost), fostering innovation.

Factory Automation and Robotics: AI-powered robots and autonomous agents handle dangerous or repetitive tasks, enhancing workplace safety.

These applications promote national development by enhancing:

Increased Productivity: Automation speeds up production cycles and reduces human error. **Cost Reduction:** Improved efficiency and predictive maintenance significantly lower operational expenses.

Reduced Waste: AI optimizes raw material usage and reduces defective products.

Enhanced Safety: AI monitors hazards and allows robots to perform dangerous jobs, protecting human worker.

2.4.2 AI applications in National Security

Artificial intelligence (AI) in security enables real-time threat detection, automated incident response, and proactive vulnerability management, significantly reducing risks for both cybersecurity and physical surveillance. Key applications include AI-powered phishing detection, user behavior analytics to prevent insider threats, network traffic analysis, and video analytics for automated perimeter security.

Aswah (2025) reported that the US, Israel, and Russia are actively integrating AI into national security for faster battlefield decision-making, automated targeting, and intelligence analysis, intensifying a global technological arms race. The U.S. and Israel often collaborate on AI research, focusing on surveillance and autonomous systems, while Russia prioritizes AI-driven drones, cyber-sabotage, and EW capabilities. Aswah chronicled some of the security advancements as a result of the utilization of AI in these three countries as follows:

Targeting & Intelligence: The U.S. military utilizes AI, including commercial AI chatbots like Claude, for targeting and analyzing vast intelligence datasets.

Autonomous Drones: Developing massive fleets of inexpensive, autonomous, AI-driven drones for battlefield operations. Russia deploys AI-driven kamikaze drones and autonomous devices on the battlefield.

Logistics & Maintenance: AI is deployed to enhance logistical efficiency, ensuring operational readiness.

Security & Policy: The National Security Agency (NSA) has created a dedicated center to manage AI integration and protect against foreign AI threats.

Targeting Systems: Israel, in partnership with U.S. tech giants, heavily uses AI models for intelligence, surveillance, and target identification, especially in high-conflict areas.

Automated Intelligence: AI platforms, such as those using Microsoft Azure and OpenAI models, analyze large volumes of data for surveillance.

Startup Integration: Israel's national security strategy leverages its robust startup ecosystem to embed AI in defense solutions.

Cyber Warfare & EW: AI is used for enhanced electronic warfare (EW), cyber-sabotage, and information operations.

Strategic Focus: Russian strategy focuses on using AI to disrupt command-and-control systems and gain information superiority.

Some key applications of AI in national security are:
Cybersecurity Threat Detection: AI analyzes vast amounts of data to detect anomalies and identify potential cyber threats faster than traditional methods.
Automated Response & Mitigation: AI-driven security tools, such as SOAR (Security Orchestration, Automation, and Response) platforms, can isolate compromised devices and block malicious traffic instantly.
Predictive Analytics & Vulnerability Management: AI analyzes network data to predict highrisk areas and identify vulnerabilities before they are exploited.
User Behavior Analytics (UBA): AI monitors for unusual behavior (e.g., atypical login times or data access) to identify compromised accounts or insider threats.
Phishing and Spam Prevention: Machine learning algorithms analyze email content and links in real-time to block phishing attempts.
Physical Security & Surveillance: AI powers smart video surveillance systems can detect unauthorized access, analyze behaviors, or flag suspicious objects.
Biometric Authentication: AI enhances identification through facial recognition, voice analysis, and typing patterns.

The ultimate gains of AI applications in security are faster response time, reduced human error and proactive security posture.

2.4.3 **Artificial Intelligence in Health Service Delivery**

AI in health service delivery improves patient outcomes and operational efficiency through AIpowered diagnostics, precision medicine, and predictive analytics. Key applications include analyzing medical imaging to detect diseases like cancer, automating administrative tasks, virtual nursing assistants, and optimizing resource allocation. As noted by Omar et al. (2023), administrative and medical processes of the healthcare organizations are rapidly changing due to the use of artificial intelligence (AI) systems. This change demonstrates the critical impact of AI at multiple activities, particularly in medical processes related to early detection and diagnosis. While promising, challenges such as algorithmic bias, data privacy, and the need for regulatory frameworks must be addressed to ensure safe implementation.

Sasa et al. (2025) examined the current regulatory landscapes governing AI in healthcare, particularly in the European Union (EU) and the United States (USA), and proposed practical tools to support the responsible development and implementation of AI systems. **In a related development, Agana, Ofem & Ele (2019) in their study developed** a framework for a fuzzy smart home IoT e-health support system. The study provided a conceptual framework for a smart home with

an embedded electronic health (e-Health) support, utilizing the Internet of Things (IoT) technology and driven by fuzzy logic (a branch of AI). Figure 3 illustrates the conceptual framework of the Fuzzy smart home IoT e-health support system.

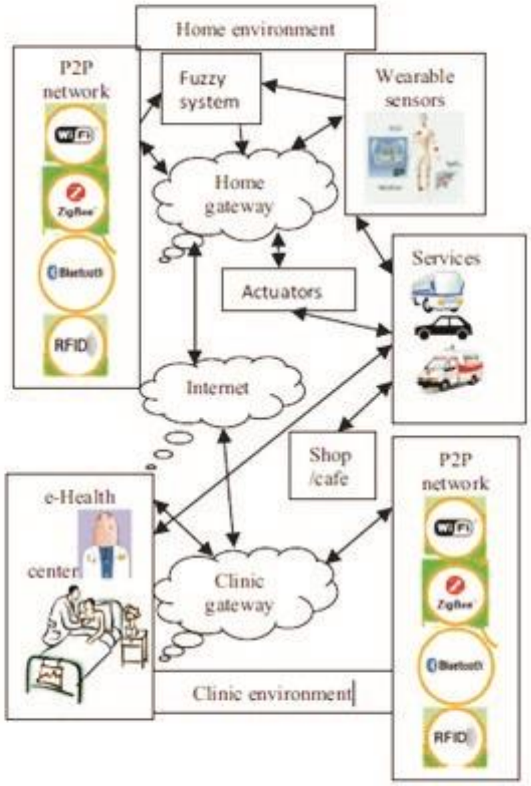

Figure 3: Conceptual Framework of the Fuzzy Smart Home IoT E-health Support System

Notable applications of AI in health service delivery according to Omar et al. (2023) include: **Diagnostics and Imaging:** AI algorithms, particularly in deep learning, demonstrate high accuracy in interpreting medical images for early disease detection, including pathology and radiology cases. **Virtual Assistants & Telemedicine:** AI-powered, 24/7 virtual assistants assist with patient triage, appointment management, and routine health recommendations.

Robotics in Care: AI-driven robotic surgical assistants increase precision and enhance recovery speed.

Predictive Analytics: AI identifies high-risk patients for proactive intervention and optimizes hospital workflows, reducing waiting times and resource management.

Drug Discovery: Machine learning is used to accelerate pharmaceutical research, bringing new medicines to market faster.

Drug Delivery: AI-powered drones these days seamlessly deliver drugs to health centers anhwhere, even in rural communities in Nigeria.

Personalized Treatment: AI analyzes massive amounts of patient data to create tailored treatment plans.

Closing Workforce Gaps: AI tools assist in managing shortages by automating routine tasks, allowing professionals to focus on direct patient care.

Long-term Potential: Future developments point to AI-driven virtual assistants, autonomous surgeries, and "digital twins" of patients to simulate and test treatments.

2.4.4 AI Applications in Agriculture

AI in agricultural service delivery transforms farming by leveraging precision agriculture, drones, and machine learning to optimize crop management and increase productivity. It facilitates realtime crop monitoring, pest/disease detection, and tailored irrigation to save resources. AI improves rural access to specialized knowledge while automating tasks to bridge labor gaps. Food production and sufficiency is an index of national development. Abiodun et al. (2025) identified notable AI application services in agriculture to include:

Smart Farming & Monitoring: Drone imagery and IoT sensors monitor crop health, soil moisture, and nutrient levels in real-time, allowing for targeted nutrient management.

Pest and Disease Management: AI-driven computer vision detects crop diseases and pest infestations early, enabling precise herbicide or pesticide applications and reducing chemical usage.

Agricultural Extension & Advisory: AI algorithms provide customized insights to farmers, such as tailored fertilizer recommendations or crop variety suggestions based on local conditions. **Predictive Analytics:** AI forecasts weather-related risks and optimal planting/harvesting times to help farmers adapt to changing climates.

Robotics and Automation: Automated tractors and drones handle labor-intensive tasks like harvesting, weeding, and spraying, which is crucial for managing labor shortages.

Supply Chain & Logistics: AI assists in improving agricultural logistics, reducing waste of perishable products through better supply chain management.

Agana & Akima (2024) developed an Internet of Things (IoT)-based **food crop security model for grazing monitoring and reporting using convolutional neural network(CNN), which is an aspect of AI** using a network of interconnected computing devices, mechanical and virtual machines, objects, animals, and living beings that can be remotely controlled via the Internet, utilizing the Internet-enabled mobile phone as a user interface and reporting system for detection of grazing on food crops to farmers and security agencies for appropriate response and mitigation. Figure 4 shows the use case model of the (IoT)-based **food crop security model for grazing monitoring and reporting using convolutional neural network(CNN)**

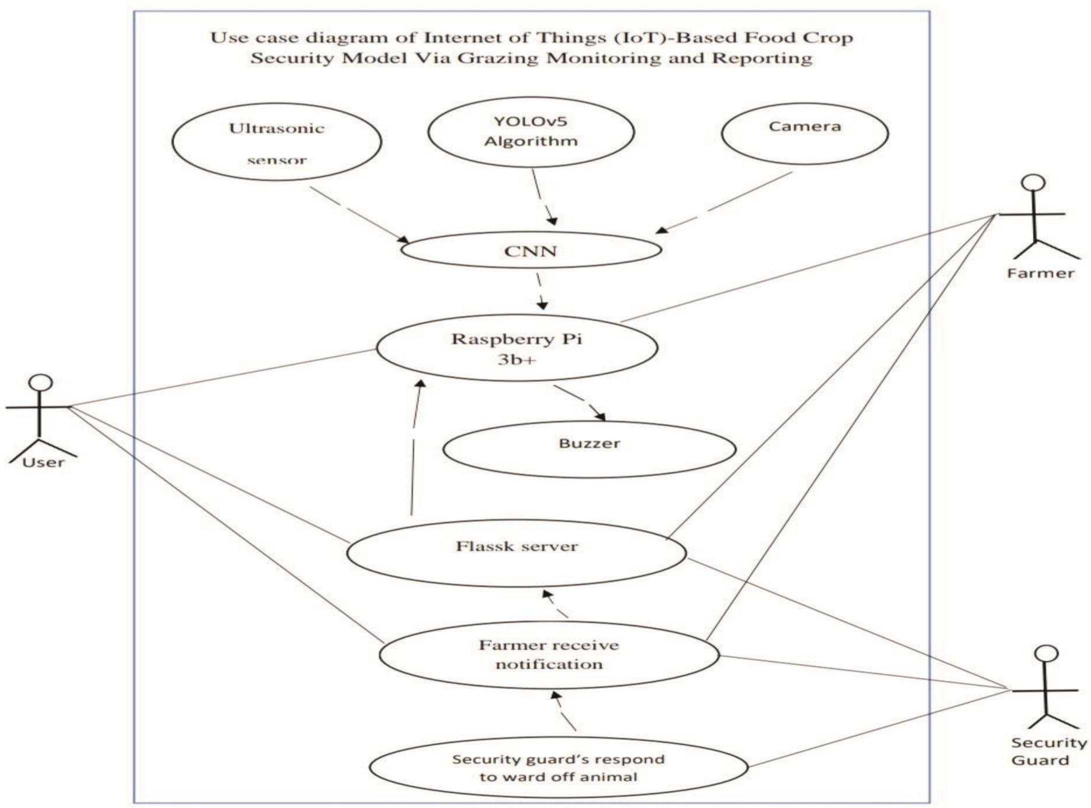

Figure 4: Use case model of the** (IoT)-based **food crop security model for grazing monitoring and reporting using convolutional neural network(CNN) (Agana & Akima, 2024).

3. Accountability, Legal and Ethical Considerations and Frameworks for AI Deployment The advancement of artificial intelligence (AI) prompts a plethora of ethical considerations and challenges, alongside exciting future possibilities. The ethical milieu of AI is as complex as the technology itself, intertwining with societal, economic, and individual aspects of life. Traditional privacy frameworks were largely developed in response to earlier forms of data processing and may not fully account for the complexity, opacity, and speed of AI-driven decision-making. In practice, AI systems can process personal data in ways that challenge established legal principles, including meaningful consent, transparency, and accountability. Organizations deploying AI in Nigeria must navigate these complexities within the Nigeria Data Protection Act (NDPA) framework. The use of automated decision-making and profiling further heightens the risk of privacy intrusion, unfair outcomes, and discriminatory effects if not properly regulated.

Regulatory regimes across jurisdictions have begun to address these challenges by reinforcing foundational data protection principles such as data minimization, purpose limitation, and individual rights in relation to automated processing. In Nigeria, ethical and legal considerations are embedded in the Nigeria Data Protection Act (NDPA, 2023).

Accountability in applying any AI tool ultimately rests on the user of the tool. Furthermore, this accountability is nested in an ecosystem of regulatory agencies, professional organizations, software developers, and third-party implementers that can support and encourage innovation. This delicate balance between individual and organizational accountability that leverages industry innovation requires cooperation among all stakeholders within this ecosystem. As the former head of the U.S. Food and Drug Administration (FDA), Robert Califf acknowledged that the agency cannot and does not have the resources to monitor every possible problem that could arise within the FDA's domain (Warraich, Tazbaz & Califf, 2025). As such, they rely on clear channels of communication and governance within this ecosystem to ensure the safety of any product. Without this fine-tuned balance, unintended harm can occur, such as when an algorithm cannot be generalized to an entire population or when the model that is the basis of a prediction tool has drifted in ways that had not been accounted for.

The primary ethical concerns of the deployment of AI in security as observed by Warraich, Tazbaz & Califf (2025) **include.**

Reduced Human Oversight: The shift toward AI-automated targeting raises critical ethical and safety concerns regarding human control over life-and-death decisions.

Arms Race & Security Dilemma: The rapid development of autonomous weapons is causing a global "arms race" in AI capabilities.

Vulnerabilities: AI systems can suffer from faulty data or flawed algorithms, leading to targeting errors.

Bias and Fairness: AI systems can perpetuate or even exacerbate existing societal biases if the data they are trained on is biased. Ensuring fairness and mitigating bias in AI applications is a pressing ethical concern.

Privacy and Data Security: The massive data requirements for training and operating AI systems pose significant privacy risks. Ensuring data security and privacy in an AI-driven world is paramount.

Transparency and Accountability: Understanding how AI systems make decisions and holding them accountable for those decisions is crucial for building trust and ensuring ethical operation. **Autonomy and Decision-Making:** As AI systems take over more decision-making roles, the question of autonomy and the potential loss of human oversight in critical areas arises.

Job Displacement: Automation through AI could lead to job displacement in various sectors, posing economic and social challenges.

Long-term Existential Risks: The potential future development of super-intelligent AI poses long-term existential risks that are crucial to consider and mitigate.

Challenges to AI Adoption

Notable challenges to the adoption of AI, especially in developing nations like Nigeria include:

Infrastructure Gaps: Limited access to high-speed internet and necessary technology in rural areas hampers implementation.
High Costs: The high expense of AI technology, drones, and sensors creates barriers to entry for many smallholder farmers.
Technical Knowledge: A lack of trained personnel to manage these systems in many agricultural regions.
Trust and Training: Experienced farmers may be hesitant to adopt new technologies, preferring traditional methods

Aniella & Gabriel (2025) identified challenges such as over-reliance on AI, diminished critical thinking skills, data privacy risks, and academic dishonesty as the negative impacts of AI on students' academic performance.

The ethical considerations and future developments in AI carry profound implications for society. They challenge existing frameworks of ethics, governance, and public policy, necessitating a robust societal discourse to navigate the AI landscape responsibly. The potential benefits of AI, from improved healthcare to enhanced productivity, are enormous. However, they come with equally significant challenges that require foresight, multidisciplinary engagement, and proactive governance.

As we stand at the cusp of an era where AI could redefine the boundaries of what is possible, engaging with the ethical dimensions and preparing for future developments is imperative. It is a collective endeavor that involves policymakers, technologists, the public, and other stakeholders coming together to shape a future where AI serves humanity positively and ethically. Through thoughtful consideration and responsible action, the journey into the next frontier of AI can be directed toward creating a future that reflects our shared values and aspirations.

Conclusion

The odyssey of Artificial Intelligence (AI) mirrors the ceaseless human endeavor to transcend the customary bounds of capability and knowledge. From ancient civilizations' musings on artificial beings to the modern-day prowess of machine learning and deep learning, AI has traversed a remarkable journey. The narrative wove through the philosophical and scientific contemplations of luminaries like Alan Turing, transitioning into a formal discipline in the mid-20th century, maturing through various stages, and blossoming into the present-day behemoth poised to revolutionize myriad facets of human existence.

Through the lens of AI, we see not only the reflection of human intelligence but the silhouette of a future where the confluence of man and machine opens doors to uncharted territories of innovation and exploration. The integration of AI, if properly managed, can bridge educational gaps, promote equity, and significantly improve the quality of inclusive education in Nigeria.

Recommendations

To maximize AI's potential, this study recommends deliberate strategies including investment in infrastructure, teacher professional development, establishment of a national AI-in-education policy, culturally relevant AI applications, and strong data protection frameworks. By adopting these measures, Nigeria can effectively harness AI to create equitable, engaging, and inclusive learning environments.

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