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INTERNET OF THINGS (IOT) APPLICATIONS IN EDUCATION: BENEFITS AND IMPLEMENTATION CHALLENGES IN GHANAIAN TERTIARY INSTITUTIONS

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ABSTRACT

Aim/Purpose	The Internet of Things (IoT) application modules have covered diverse sectors, and the educational domain is no exception. In this survey, we discuss the specific application benefits of IoT in education and further examine implementation challenges in Ghanaian tertiary institutions.
Background	This survey examines pertinent applications for IoT benefits in education and offers present and future opportunities to enhance educational outcomes. The survey includes anticipated IoT technologies that will have a significant impact on education. Each module contains concise definitions accompanied by analysis and application-specific relevance.
Methodology	In order to accomplish the objectives of the survey, a search review was conducted across relevant databases, including Scopus, Hindawi, IEEE, MPDI, ScienceDirect, Informing Science Institute, Springer, and Wiley. In addition, a thorough search was carried out using Google Scholar to cover all relevant repositories. The phrases and keywords for the search were made up of five cate-

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	gories. The literature search resulted in 300 articles, of which 200 were considered relevant for the survey. Of the 200 articles, 95 of them shared common themes and discussed the same application integration and challenges.
Contribution	This paper discusses the revolution involving IoT deployments in education and covers many aspects of the educational domain.
Findings	IoT integration in education will transform Education 4.0 and improve learning outcomes significantly.
Recommendations for Practitioners	Educational institutions are to embrace IoT integrations even with the emerging Education 4.0 and Industry 4.0 use cases.
Recommendations for Researchers	Educational IoT is the next big thing and research directions on unique use cases for educational institutions are eminent with 5G and other disruptive technologies.
Impact on Society	Effective IoT implementation in education will positively affect all stakeholders in the educational ecosystem and create a society with much access to information, connectivity, and convenience.
Future Research	To survey the integration of blockchain-based IoT applications in education.

Keywords	Internet of Things, smart campus, intelligent objects, smart school, tertiary institutions

INTRODUCTION

The Internet of Things (IoT) revolution continues to be a buzzword in the twenty-first century, spanning numerous application sectors. Unlike decades ago, the connectivity of objects has proliferated rapidly and attracted various infrastructure supports from many nations. IoT has been defined as the network of physical objects fitted with sensors, software, and other technologies (Kumar et al., 2019). The numerous innovative and intelligent solutions IoT provides have rejuvenated the idea of total convenience of life to its primary beneficiary, the human being. IoT has evolved into a vast network of smart systems that have opened up new technological possibilities in every industry (Nord et al., 2019). Interoperability is one of the fundamental elements of the IoT that contributes to its growing popularity. Connected objects can gather and share data from their monitored environments with other devices and networks. Devices can now fulfil their duties with little or no need for human intervention as a result of the analysis and processing of data (Ali et al., 2019). It is not surprising that IoT continues to evolve as more and more devices are connected, resulting in more complex algorithms and higher levels of automation (Elijah et al., 2018). Since it can link to so many different "things", IoT has opened up many possibilities for individual users and large industries. According to the Ericsson Mobility Report (Ericsson, 2018), the number of connected devices will reach 22.3 billion by 2024, including 4.1 billion cellular IoT connections, 17.8 billion short-range IoT connections, and 4.5 billion wide-area IoT connections. The subsequent Ericsson Mobility Report (Ericsson, 2020), as indicated in Figure 1, anticipates an increase to 20.6 billion short-range IoT connections, 5.9 billion cellular IoT connections, and 6.3 billion wide-area IoT connections. This brings the total linked devices to 26.9 billion by 2026, up from 22.3 billion in 2024 and 12.6 billion in 2020. IoT's compound annual growth rate (CAGR) is 13% based on the growth forecasts.

The rise and application deployment of IoT devices has been thoroughly explored in several sectors. The IoT smart monitoring domains cover health, homes, transportation, grids, cities, agriculture, industries, and education (Jabbar et al., 2018). Home automation using IoT devices provides comfort, improves security, and makes home appliances more energy-efficient (Mocrii et al., 2018). Smart home deployments, safety, benefits, and challenges have been studied in depth (Cyril Jose & Malekian, 2015; Paul et al., 2018).

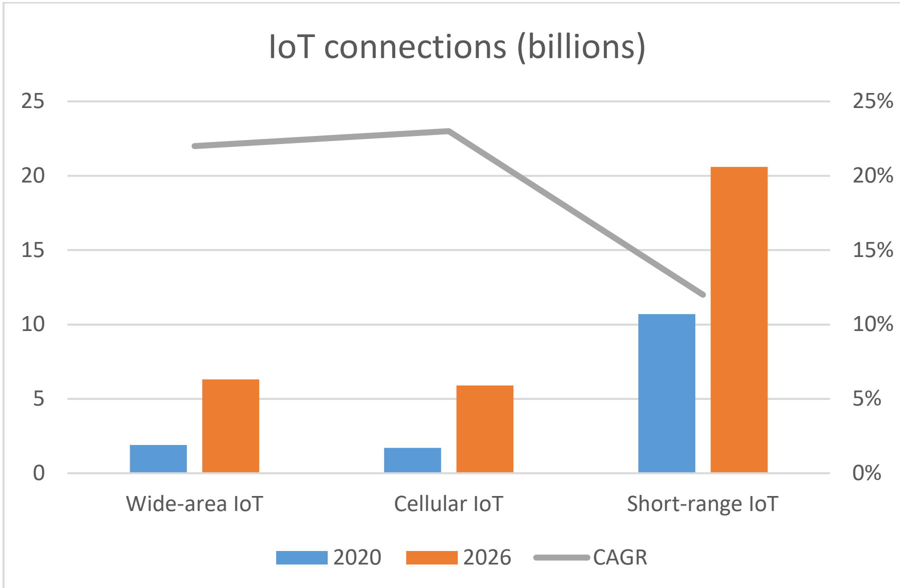

Figure 1. Ericsson Mobility Report (Ericsson, 2020)

Smart healthcare helps deliver quality healthcare and monitors patients' health information via wearable devices (M. Gupta et al., 2021). A considerable amount of research has provided solutions to the security lapses of IoT healthcare and advanced the healthcare sector with different architectures (Baker et al., 2017). Other specific benefits of IoT in agriculture, industry, transportation, and grids have been comprehensively studied with improvements in sector automation (Dambal et al., 2016; Ghasempour, 2019; Zantalis et al., 2019).

Recently, there has been a growing interest in IoT deployments in education. Such interests go beyond theoretical research to architecture developments and physical implementations. The fundamental objective of this survey is to discuss the applications of IoT in education, its benefits, and foreseeable challenges.

IoT has the potential to transform education with technological integrations that will increase the interconnectivity of divisions within academic institutions. Over the years, academics have undertaken substantial research on the desire for student performance improvement. Initially, teacher-centred pedagogy was the norm, with the instructor as the master of knowledge and the learner as the receiver (Serin, 2018). The behaviourist theory laid the foundation of teacher-centred pedagogy, which later received criticism in educational domains. Constructivism, a learner-centred theory, was then introduced. Constructivism is a pedagogy that enables learners to build representation and develop new knowledge rather than passively receiving information from their teachers (Feyzi Behnagh & Yasrebi, 2020). The constructivism model's pedagogical goals include student-centred learning, learner reflection, and diverse perspectives (Ekpenyong & Edokpolor, 2016). Collaborative pedagogy became widespread, based on interdependence or a joint intellectual focus where learners form groups and build learning strategies to complete tasks (Scager et al., 2016). Another popular learning philosophy is inquiry-based pedagogy, which encompasses constructivism and collaborative pedagogy, enabling learners to follow scientific methods and practices in constructing knowledge (Nunaki et al., 2019). The emergence of IoT in education will improve the various pedagogical philosophies. The IoT paradigm will redefine the teacher and learner, creating an intelligent campus hub that will improve educational outcomes significantly. The question, however, is whether countries and educational institutions are positioned economically and with policies to integrate IoT and take advantage of its numerous benefits.

Over the years, the Ghanaian government has strived to implement innovative policies to improve the quality of education at the pre-tertiary and tertiary levels. One major intervention was the Free Compulsory Universal Basic Education (FCUBE) Act of 1996, which increased enrolment rates average to 90% in 2017 at both the primary and junior high school levels (JHS) (Ministry of Education, 2017). At the senior high school (SHS) level, the government in 2017 replaced the progressively free SHS education policy with the free SHS policy, rendering SHS education completely free (Chanimbe & Dankwah, 2021; Ministry of Education, 2017). The tertiary level has its fair share of policies, including, converting polytechnics into technical universities, aggressively promoting science, technology, engineering, and mathematics (STEM) education, expanding access to technical, vocational, and agricultural education and training (TVAET), and a presidential assent Act in 2020 for the inauguration of the Ghana Tertiary Education Commission (GTEC) (Ministry of Education, 2017). GTEC exists primarily as an oversight agency in providing guiding policies for world-class tertiary education (Ghana Tertiary Education Commission, 2020).

Even though the Government has made progressive gains in education, educational institutions continue to suffer from severe infrastructure and technological deficiencies due to crippling economic downturns that have ripple effects on other important sectors of the economy (Arthur & Arthur, 2016). The damaging economic challenges, including debt overhang, high budget deficit, high inflation, cedi depreciation, low productivity, unstable power, and high unemployment, have been exacerbated further by the ravaging COVID-19 pandemic (Aduhene & Osei-Assibey, 2021; Ministry of Finance, 2022; Owusu-Manu et al., 2019). The drawn conclusion is that the implementation of immersive and interactive technologies in Ghanaian tertiary institutions has low priority since there are other sensitive sectors of the economy the Government is trying to salvage.

The rest of this survey is organised as follows. First, the methodological procedure is described, then the benefits of IoT in education are discussed, followed by the challenges of implementing IoT in Ghanaian tertiary institutions. Finally, we conclude by summarising the significance of the survey.

METHODOLOGY

The survey focuses on the benefits of IoT in education and the implementation challenges in Ghanaian tertiary institutions. As depicted in Figure 2, the first phase of the survey discusses the relevance of IoT in education. Significant application integrations of IoT in smart classroom, smart library, smart data, smart learner, smart administration, smart teacher, smart hostel, and smart healthcare are covered in the study.

The second aspect of the survey discusses the implementation difficulties in Ghanaian tertiary institutions. As depicted in Figure 3, the following challenges of IoT integration were examined: trust, security, and privacy; internet connectivity; network bandwidth; cost of IoT devices; device incompatibility; wireless coverage and battery life; institutional policies and priorities; scalability and reliability; ethical concerns; and dehumanization.

In order to accomplish the objectives of the survey, a search review was conducted across relevant databases, including Scopus, Hindawi, IEEE, MPDI, ScienceDirect, Informing Science Institute, Springer, and Wiley. In addition, a thorough search was carried out using Google Scholar to cover all relevant repositories. The phrases and keywords for the search were made up of five categories. The first category contains keywords associated with IoT and its impacts on diverse sectors. The second category zoomed in on IoT in education. The third search criterion was restricted to the application benefits of IoT in education (smart classrooms, smart libraries, smart data, smart learners, smart administration, smart teachers, smart hostels, and smart healthcare). The fourth aspect of the search includes the difficulties faced with IoT implementation in general and in education. The final category involves integration challenges in Ghanaian tertiary institutions.

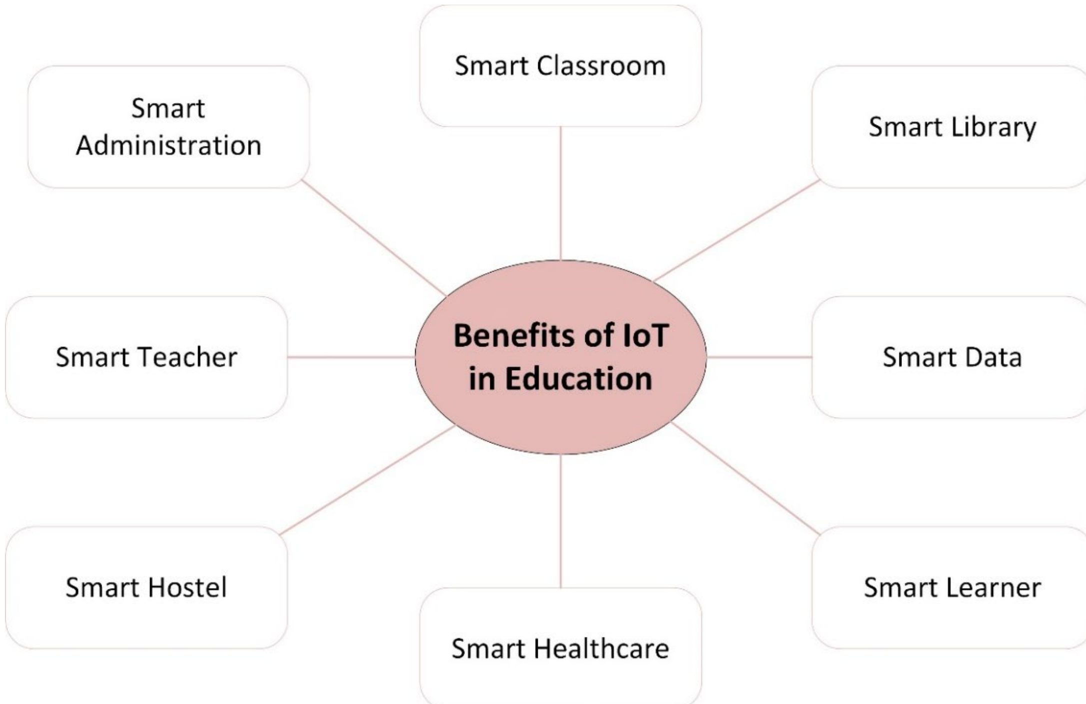

Figure 2. Benefits of IoT in education

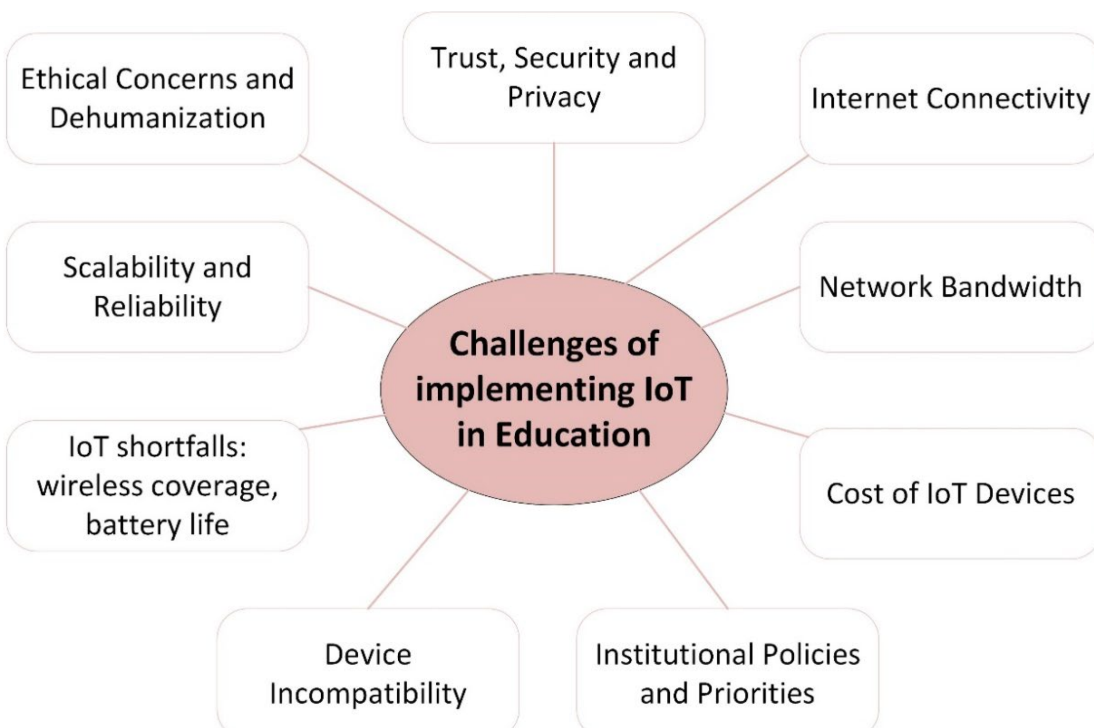

Figure 3. Challenges of IoT in education

An advanced search was performed further using several free-text keywords of Internet of Things and education: "Internet of Things" OR "Smart Campus" OR "Artificial Intelligence" OR "Machine Learning" OR "Smart Teacher" OR "IoT and Big Data" OR "Smart Student" OR "Smart Learner" OR "Smart Classroom" OR "Smart Hostel" OR "Smart Administration" OR "Smart Library" OR "Smart Data" OR "Smart School" OR "Ghana Economy" OR "Ghana and IMF" OR "Ghana and Ghanaian Cedi" OR "IoT in Ghana" OR "IoT in Ghanaian Institution" OR "Challenges of IoT in Ghanaian Institution" OR "Network issues in Ghana" OR "Bandwidth issues in Ghana" OR "IoT and Device Incompatibility" OR "IoT and Scalability" OR "IoT and Reliability" OR "IoT and Ethical Concerns in Ghana" OR "IoT and Cost in Ghana" OR "IoT and Security Challenges" OR "IoT and Battery Life" etc.

The literature search resulted in 300 articles with 200 considered relevant for the survey. Of the 200 articles, 95 shared common themes and discussed the same application integration and challenges. The article selection was based mainly on the application integration of IoT in education and the publication year of the article which generally should not be more than ten years. Other relevant selection criteria include detailed challenges in the implementation of IoT, especially for developing countries, and the articles indexing databases.

BENEFITS OF IOT IN EDUCATION

This survey section discusses relevant applications regarding IoT benefits in education and provides present and futuristic possibilities to improve educational outcomes. The survey includes foreseeable IoT technologies relevant to education. Each module consists of brief definitions with analysis and relevance to diverse applications.

SMART CLASSROOM

As depicted in Figure 4, smart classroom IoT-enabled education encompasses classroom technologies and equipment capable of automating and enhancing engagement with pattern insight during teaching and learning. Saini and Goel (2019) defined a smart classroom as a technology-assisted closed environment that fosters classroom interaction with an intelligent physical engagement between the learner and the teacher. Aguilar et al. (2019) redefine a smart classroom as a confined space that integrates sensor technology, communication technology, and artificial intelligence for a better classroom experience. Any smart classroom must have IoT connectivity capable of developing the next generation of learners (El Mrabet & Ait Moussa, 2017).

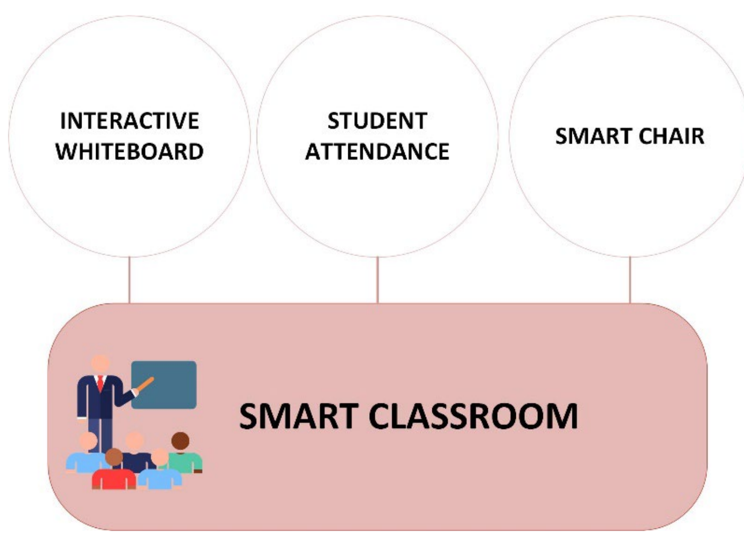

Figure 4. Smart classroom

The IoT-enabled interactive whiteboards project visual elements to enrich the learner's experience. The interactive whiteboards provide various functions through a single device, including tactile effects (Promwongsa et al., 2021), since it is connected to the internet. While students interact with graphics, applications, and videos on the interactive whiteboard using a tool or a finger, teachers gain real-time access to multitudes of educational content with save mode functionalities via fast internet connections. This phenomenon increases learner engagement, curiosity, and active participation while promoting diverse pedagogical philosophies in the learning process (Ormanci et al., 2015). Intel, Amazon, Microsoft, and Google are leading companies that have provided multi-layer IoT-based interactive whiteboards.

Students' attendance and absenteeism have long been a contention for educational institutions (Ezeofor & Georgewill, 2020; Kovelan et al., 2019). In several studies, class attendance has been linked with students' academic performance and has affected learner graduation (Chenneville & Jordan, 2008; Karnik et al., 2020; Nordmann et al., 2019).

An IoT-enabled attendance tracker automates and tracks learners using radio frequency identification (RFID) or fingerprint sensor technology at the perception layer of the IoT-based framework (Al Tarshia et al., 2020; Sittampalam & Ratnarajah, 2019). As an extra perfect attendance measure, modern IoT-based attendance trackers use a camera installed in the classroom to detect images of learners and simultaneously match their faces against a class database (El Mrabet & Ait Moussa, 2020; Turkane et al., 2019). The students' attendance reports are subsequently saved in connected folders with notifications to parents and school administration.

The IoT-enabled smart chair fitted with sensors has tremendous application dynamics in a smart classroom. From reporting learner information to duration in class, the smart chair provides comprehensive data to the instructor about the learners in the classroom (Sodhi et al., 2017). Smart chairs are fitted with RFID readers, pressure sensors, reflection sensors, and indoor localization technologies in the interconnected classroom (Kunhoth et al., 2020; Turgut et al., 2016). The smart chairs have wireless communication capabilities (Enugala & Vuppala, 2018) that connect to camera-based facial recognition detectors to determine learner mood and attentiveness in the smart classroom (Singh & Kaur, 2019). The smart chair collects real-time data, which can be used to make learning more engaging, manage classroom resources, group students, and tailor instruction.

Smart Library

Libraries play a critical role in the growth of academic institutions and serve as the focal point for the scholarly works of learners (Deo et al., 2020). As depicted in Figure 5, the central functional units of a conventional library span keeping records, book classification, provision of online resources, and tracking book defaulters. The modern-day IoT-enabled library comprises sensing technologies for object connectivity. The data collected from the objects reveals previously undetectable patterns in a conventional library system.

An IoT-enabled physical book recommender system increases the depth of preference of a library user and exposes the student to similar materials (Makwana, 2021). In the connected library, a learner interested in a book is connected to a central database with similar books based on titles and content. Since the bookshelves are linked to the main database, there is a trigger for the learner to find related books with shelf numbers. Soft copy versions of similar books are sent concurrently to the email and phone number of the learner to facilitate downloads and purchases.

The smart library allows user authentication and creates individual profiles for easy borrowing and return. The connected library linked to a central database triggers a notification to users of due dates to return library materials. The issue, renewal, and return of library materials are digitalised, and all these actions are automatically updated in a database. The incorporation of quick response (QR) technology provides a robust authentication system to prevent book theft (Abuarqoub et al., 2017).

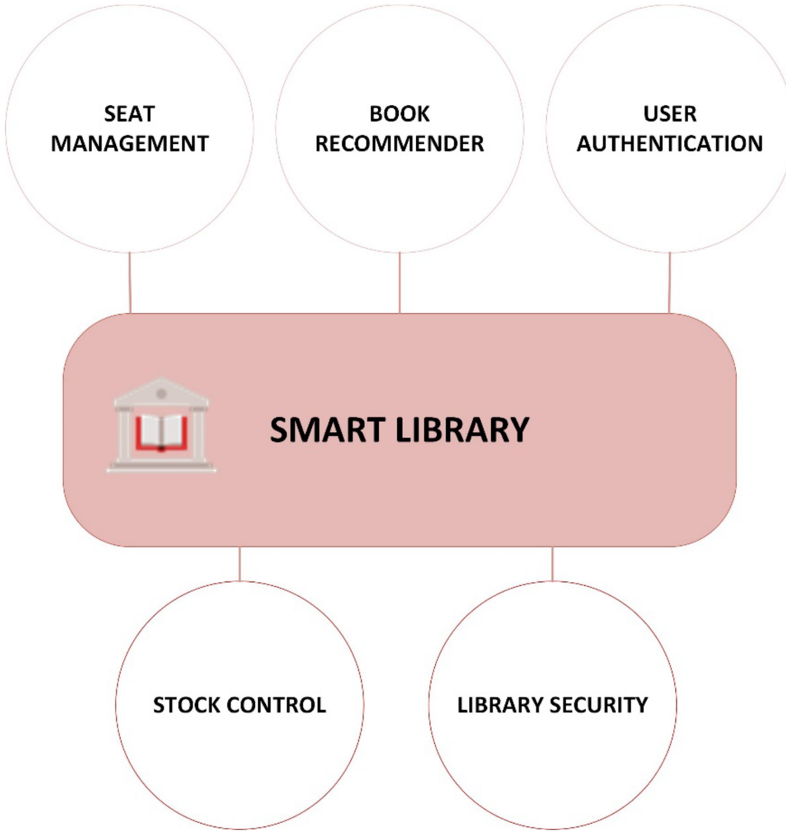

Figure 5. Smart library

Seat management and availability occur in an IoT-based library. Microcontrollers and infrared (IR) sensors are primarily used in a smart library for seat management (Bansal et al., 2018). The work of the IR sensor is to check for seat availability and send information to the microcontroller. The microcontroller processes the information received from the IR sensor and forwards it to the server. The Librarian is mandated to add seats, view student details, and again view seat availability. Users can check seat availability in the library on their smartphones and proceed to book seats.

Stock control possibilities of library contents. Sensors are connected to other library sources, including microfiche, sound, and video. The connectivity enables the monitoring of numerous daily developments in other library materials. The library manager is notified in real-time of the inventory of such materials, resulting in less work for library faculty in stock verification (Bansal et al., 2018).

Security of library premises. Dangerous flames could be managed securely from outside the library by introducing web-associated fire sensors. Sensor-integrated fire detection and prevention gadgets in an IoT-based connected library sound an alert and trigger a message to the fire officers. This automated fire detection secures the library and prevents damage via early detection (Abdel-Basset et al., 2019; Bansal et al., 2018).

Smart Learner

The implementation of IoT in education primarily focuses on developing smart learners, as shown in Figure 6. A student in an IoT-based educational environment has the potential to identify new skills and personalised learning patterns through technology and integrated analytics (Aini, 2020). Digitisation in Education 4.0 completely changes the reactive to proactive learning narrative with informed decisions by the learner. In a connected environment driven by IoT, limitless opportunities exist for the student, from intelligent content downloads to course selection modules (Abdel-Basset et al., 2019).

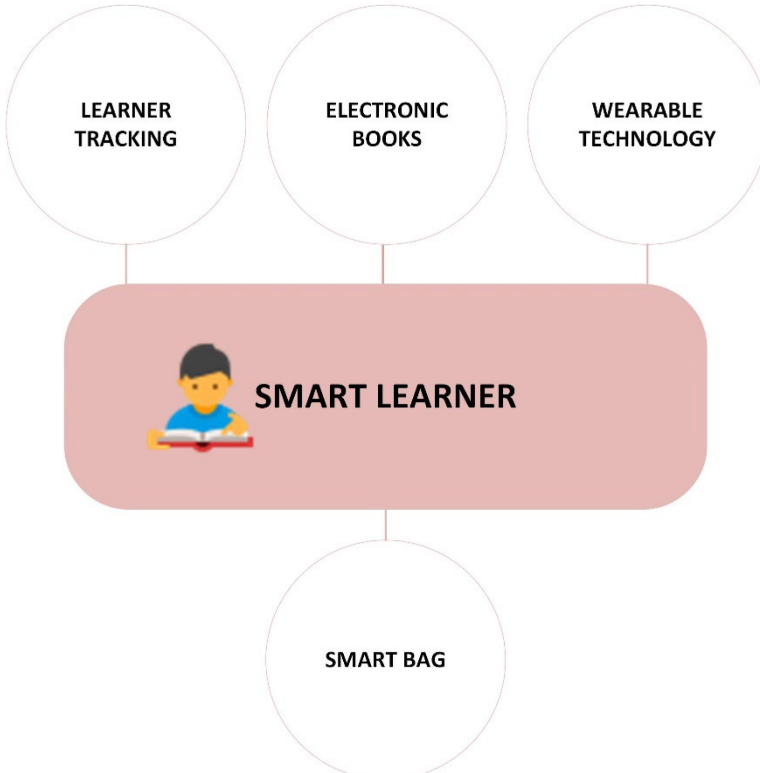

Figure 6. Smart learner

IoT implementation in the learning environment has helped improve students' learning and supported the tracking of students' activities. According to Yakoubovsky and Sarian (2021), integrating IoT tools in online education helps raise learners' performance and efficiency by up to 20 percent. Learners can now individually monitor their progress since IoT sensors can measure one's fatigue level and keep the brain active via continuous engagement.

Learners follow lessons and get interactive with the assistance of smartphone-based online classes, or e-classes. E-books with barcodes arouse learners' interest in reading in an interactive environment. An IoT device, a scanmaker, is used to scan editable text from documents, including books, magazines, and articles, directly into a computing device (Zeeshan & Neittaanmaki, 2021). The scanmaker translates text into 40 languages. Learners, therefore, engage in studying from these interactive-based learning media, which keeps their attention span with diverse educational feedback (Zeeshan et al., 2022).

IoT wearable technology provides seamless learner development. IoT wearable technology integrates students' location information, exercise logs, and social media activities to generate big data for personalised learning (Ciolacu, Binder, & Popp, 2019). A good example is an IoT-ready platform from the MaTHiSiS H2020 EU project (Spyrou et al., 2019). These wearable devices collect data from learners in the form of games by capturing their interaction with learning material using IoT sensing devices. The data collected is then processed, which helps customise the learning environment according to the learner's needs (Spyrou et al., 2019).

The smart bag is an intelligent bag that carries learning materials (Shweta et al., 2016). This responsive bag helps students and parents with innovative services. The smart bag provides the learner with quick timetable management and notifications about missed books and other vital school items (Ajayakumar et al., 2019). The parent of the smart learner simultaneously receives notifications about misplaced school items, which automatically triggers a restock.

Smart Data

In a connected educational environment, the volume, variety, and velocity of data, termed Big Data, has increased tremendously (Daniel, 2019; Reidenberg & Schaub, 2018). This structured and unstructured data is generated from diverse aspects of the educational ecosystem, with complexity usually analysed with machine learning algorithms (Athmaja et al., 2018). The objective of smart data, as shown in Figure 7, varies with monitored pedagogy and analytics, which are crucial to educational growth and reform.

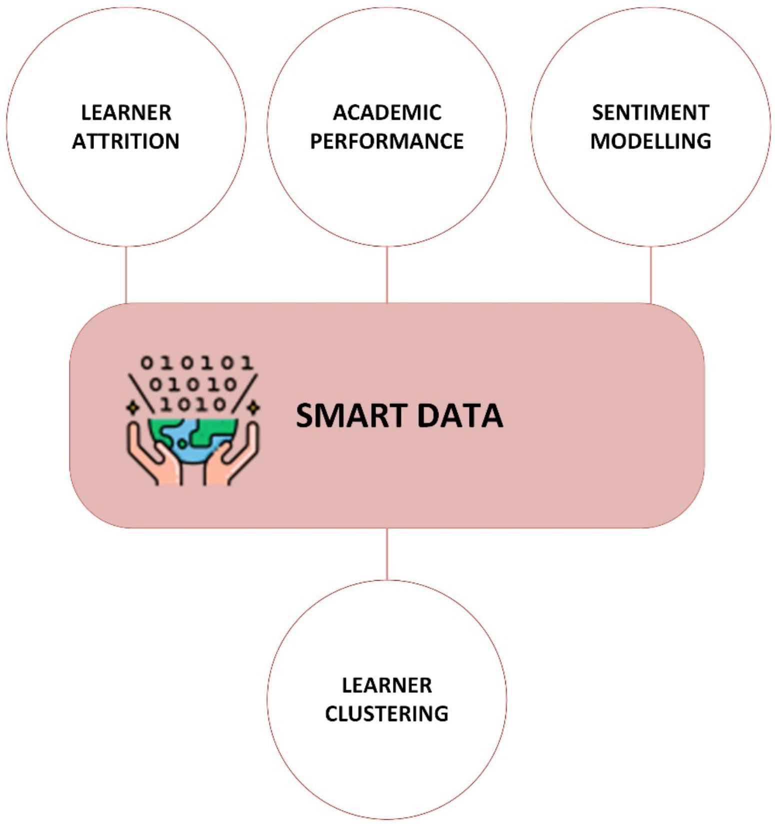

Figure 7. Smart data

The smart data enables academic authorities to identify at-risk students capable of dropping out. Learner drop-out has been problematic for educational institutions even with robust counselling units (Segura et al., 2022). In reducing attrition rates, data analytics with pattern detection trends is a necessity in the prediction and modelling of student behaviours. These proactive, intelligent patterns will inform authorities of dominant factors causing high attrition among learners for personalised counselling (Kemper et al., 2020; Romero & Ventura, 2020).

Students' academic performance prediction is possible because of smart data. Multiple reviews and surveys have discussed the relevance of learner academic performance prediction for early counselling (Alyahyan & Düştegör, 2020; Namoun & Alshanqiti, 2021). Students' academic success, aside from counselling, plays a role in institutions ranking globally. Students' academic performance has other far-reaching consequences, including career success, skills acquisition, academic achievement, learning outcomes attainment, and learner retention (Alyahyan & Düştegör, 2020; Dake et al., 2021).

Sentiment modelling is possible with unstructured data where the tonation behind a text is determined using natural language processing (NLP) (Dake & Gyimah, 2023). Machine learning sentiment detection in an IoT-based environment that generates smart data has become more relevant during the COVID-19 pandemic (Mujahid et al., 2021). The opinion mining of learners has diverse applications, including analysing learner experiences, instructor reflective practices, and institutional recommender systems.

Intelligent learner groupings have a focal point in collaborative learning (Kaendler et al., 2015). In unsupervised learning, smart data generated is essential for learner clustering in educational projects and collaborations (Scheuer & Mclaren, 2012). The clusters generated provide differential guidelines for group projects and skills enhancement (Maina et al., 2017). Even with the increased usage of e-learning systems, learner clustering transcends the traditional classroom into online groupings and monitoring (Peach et al., 2019).

Smart Administration

Smart administration, as depicted in Figure 8, is the application of modern educational technologies that increases the efficiency and effectiveness of day-to-day administrative activities (Zeeshan et al., 2022). In an IoT-based educational environment, connected features allow school administrators to effect changes in a centralised location with Big Data. Smart administration covers all aspects of institutional management, from classroom management, staff management, financial unit procurement, academic calendar, maintenance, recruitment, and security.

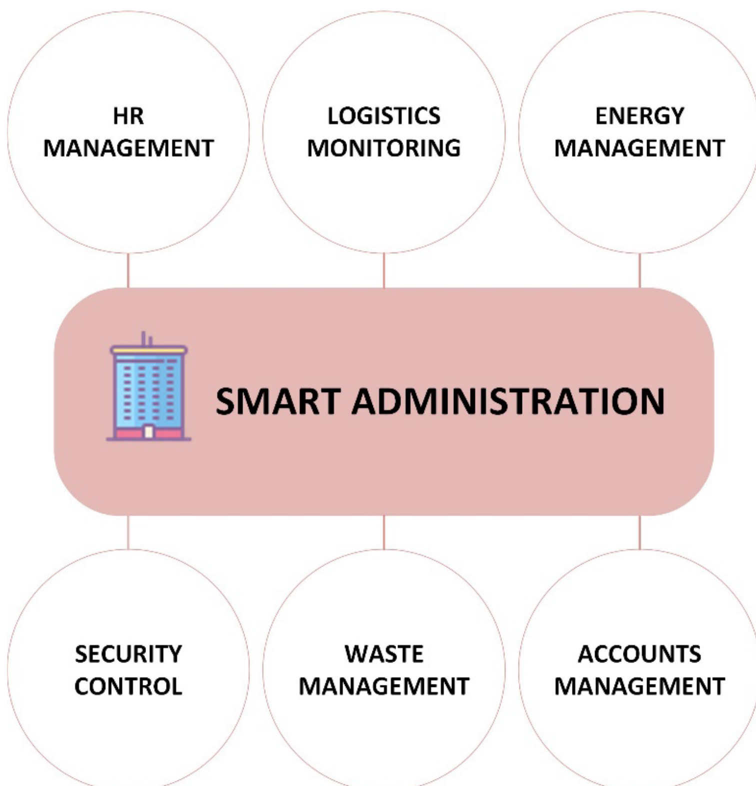

Figure 8. Smart administration

Smart human resource management assigns roles to employees through their smartphones and smartwatches with sensors linked to the human resources division of the school. Teachers are monitored regarding classroom duties and the school environment without managers of such institutions being physically present (Mogas et al., 2022).

Smart logistics dispatch monitoring uses RFID innovation to monitor assets, including laboratory equipment, projectors, vehicles, and other valuables. This intelligent monitoring prevents theft. The module uses RFID tags and hand-held scanners to confirm the stock items in a warehouse, which facilitates automatic stock checking. The global positioning system (GPS) coordinates broadcasts for geographically dispersed assets and monitors asset location to deal with theft issues (Song et al., 2021).

Smart energy management integrates school buildings with IoT for intelligent energy management. This module has a base station with the IoT gateway to provide a communication network, a user interface that interacts and communicates with the system, and appliance controllers that can be controlled remotely (Kim & Lim, 2018). It gathers and analyses the energy data in residential and classroom areas within the school and displays the data in real-time. The system then sends notifications and recommendations to the occupants to help them properly manage their energy consumption and save costs. Smart energy modules in buildings use semantic web technologies (Patel & Jain, 2021) to combine building data with occupants' behaviour, energy prices, and weather information to monitor and learn the energy behaviour of the building. The analytics generated recommend energy-saving solutions to occupants. For occupant demand modification and the building's characteristics, flexibility and scalability are considered.

Smart security uses intelligent devices and sensor nodes for continuous monitoring of the school environment, such as intelligent tagging systems, RFI, GPS-based smart bags, smart watches, and other sensor-based devices (Gul et al., 2017). An authentication mechanism is in place to make these components more secure, and only the owner of the devices can access them and deliver messages from them. Since most tertiary institutions have vehicles, the security extends to smart devices for learners' safety through automatic vehicle entrance records, existing records, and total travelling time in the vehicles. This data is updated and stored in the cloud using high-speed networks (Qiu et al., 2021). Security in the school starts with using RFID cards with auto-tagging and photo authentication, integrated with a tag to ensure more safety, especially when the tag is stolen or misused. In the school environment, sensor nodes are installed at diverse locations to monitor learner activities, location, and presence. Security cameras also help with monitoring. A learner in school wears a smart tag, a band, and a smart bag. These components are connected to parents and school databases using high-speed cellular network capabilities. In case of theft, an immediate surrounding picture is triggered, and an automatic alert message is sent to the school, parents, or nearby security point.

The smart waste management module for the school has garbage bins classified as master and slave dustbins. Master dustbins are equipped with a Raspberry Pi and slaves with an IoT module (Yamanoor & Yamanoor, 2017). Each dustbin with a unique ID has a database of dustbin positions. The dustbin is equipped with ultraviolet (UV) and load sensors for level detection and a humidity sensor for wet and dry garbage detection. Both dustbins communicate with the Raspberry Pi 3 (Pagnutti et al., 2017). The Raspberry Pi 3 gathers the data from sensors attached to master and slave dustbins and sends the data to a server using wi-fi. The message from the Raspberry Pi 3 to the server includes the levels of garbage in a bin, wet and dry waste segregation levels, and dustbin ID. The server matches IDs with the database of dustbins and finds levels of dustbins located in different areas of the school environment. The data gathered from the cloud is analysed using Storm as an analytic tool (Shadroo & Rahmani, 2018). After data collection and analysis, users and garbage vehicles are alerted about real-time garbage levels. The data regarding wet and dry segregation levels will aid in evaluating the current garbage management plans and fine-tuning the strategies for more efficiency.

Smart accounting involves data collection and analysis from the account section linked to management devices via sensors to help management determine the institution's financial status. Fee collection will be done electronically, with no physical cash. Unnecessary employee check-in visits are avoided, reducing costs using remote monitoring and sensors. Accountants are often involved with school risk management (Budding & Wassenaar, 2021). The IoT provides real-time data for accountants to identify, understand, and manage risks. If accountants combine IoT data with financial information, the root cause of financial irregularities is promptly addressed. Priorities are set for improvements by analysing data on asset utilisation, cost, quality, and risk. It is easy to visualise processes within and between other institutions using IoT, CCTV, and augmented reality (López-Belmonte et al., 2023). This improves efficiency and expedites overcoming challenges.

Smart Teacher

As depicted in Figure 9, the smart teacher uses immersive technologies to improve teaching and learning in an IoT-based environment. A shift from standard learning processes to a technologically enhanced environment positively affects the teacher, especially in reflective guides and practices (Karnieli-Miller, 2020). As an expert in the subject area, a teacher facilitates learning and impacts knowledge in learners (Ozen & Yildirim, 2020). A teacher plays a central role in a smart campus architecture, and lapses in teaching philosophies ultimately affect the learner (Xu et al., 2018).

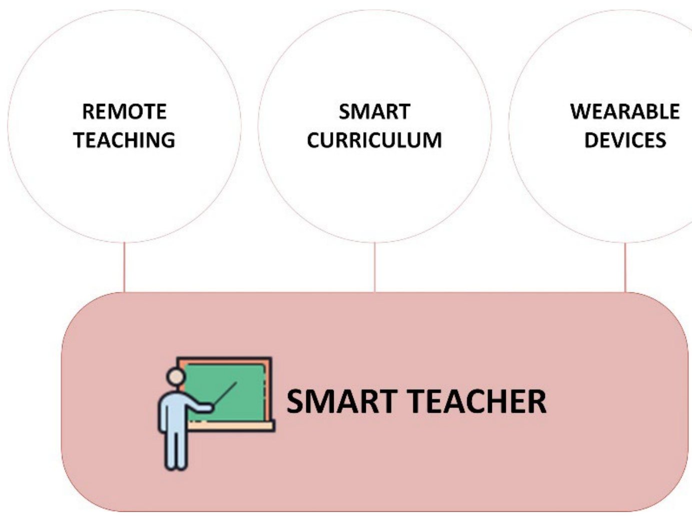

Figure 9. Smart teacher

Remote teaching and assessment administration in an IoT-enabled environment extends learning beyond the classrooms with convenience (Bucea-Manea-Ţoniş et al., 2022). Distance and online learning are more efficient with IoT devices that remove time and location constraints and make education accessible for everyone (Moore et al., 2011). IoT-fitted sensors capture data from webcams, microphones, and other distance-learning embedded devices to track learner activities and inform the instructor of learner sentiment, location, attendance, and visuals (Dake et al., 2022). The data collected guides the instructor in content modification, teaching philosophies, class policies, and personalised learning.

The smart curriculum includes course manuals, electronic books, and other resources available across learning platforms that learners can access, devoid of distance and time (Al-Emran et al., 2020). Curriculum primarily refers to lesson content with instructional and assessment policies (Campbell-Phillips, 2020). Automatic suggestions and modifications to the curriculum from learner evaluation feedback inform the smart teacher of best reflective practices and curriculum redesign policies for educational growth. Curriculum assessment and evaluation in an IoT-based environment enables remote tracking of failed instructor policies, with recommendations automatically channelled to appropriate authorities.

In the classroom, IoT-enabled technologies facilitate the teaching and learning process. Interactive smart boards are handy in classrooms to aid the teacher's work instead of the traditional ones (Promwongsa et al., 2021). Wearable devices such as wristbands assist teachers in monitoring the location of learners to track learner patterns and behaviour (Bagheri & Movahed, 2017). Instructors easily check attendance automatically with cameras mounted at vantage points in the classroom and analytic reports sent to parents and management (Alassery, 2019).

SMART HOSTELS

Students' accommodation, as depicted in Figure 10, at tertiary institutions is vital for effective learning (Spio-kwofie et al., 2016; Swanson et al., 2022). Student accommodation challenges negatively impact teaching and learning (Ahmed, 2021; Zakaria et al., 2021). Smart hostels are fitted with sensors and provide diverse application modules to students. The IoT-enabled modern-day hostels are connected to other smart campus architectures to aid the learner (Singhal et al., 2017).

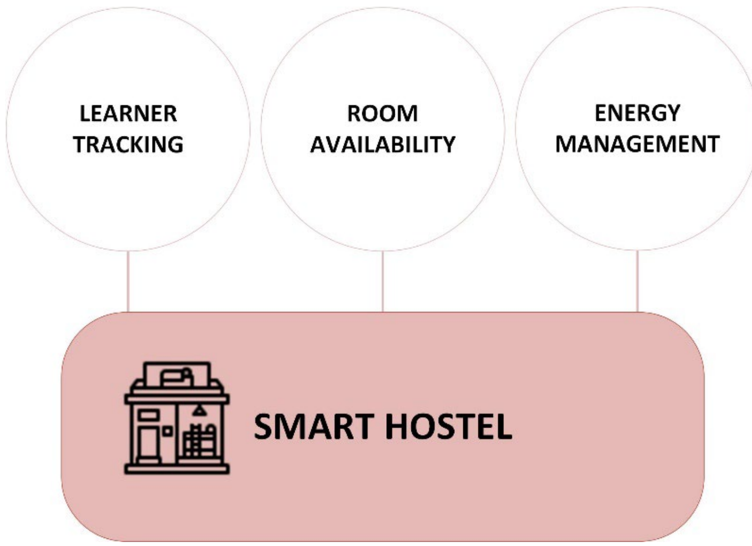

Figure 10. Smart hostel

Students' safety remains a priority to academic authorities and parents. In an IoT-enabled hostel, authorities and parents are notified when respective learners leave and return to the hostel. In an intelligent campus architecture, a time tracker based on the hostel location and means of transportation estimates the students' arrival time on campus (Shouran et al., 2019; Singhal et al., 2017). Automated messages are sent to appropriate authorities and parents when learners don't check in at the IoT-enabled gated entrance within the estimated time.

The availability of rooms, types, and prices connected to students' wearable and mobile devices is one key application area of a smart hostel (Ciolacu, Binder, Svasta, et al., 2019). At the beginning of every academic year, especially in developing countries, room location and pricing remain stressful for students (Shinohara et al., 2020; Simpeh, 2018). In a connected campus, notifications of rooms available across hostels are sent to students with directional maps.

Energy efficiency and management functionality in an IoT-enabled hostel reduce the cost of operation. IoT sensors detect empty rooms and automatically switch unused devices off, which triggers a message to the learner and hostel administrators (Lytvyn et al., 2019). In a smart hostel, greater control of energy utilisation and monitoring saves costs in running the hostel facility.

SMART HEALTHCARE

Students' health is fundamental to learning and key to campus medical facilities and hospitals. According to Tian et al. (2019), innovative healthcare comprises several stakeholders, including doctors, parents, students, authorities, hospitals, and research institutes. It encompasses numerous facets, including disease prevention and monitoring, diagnosis and treatment, hospital administration, health decisions, and medical research (Ahad et al., 2020; Tian et al., 2019).

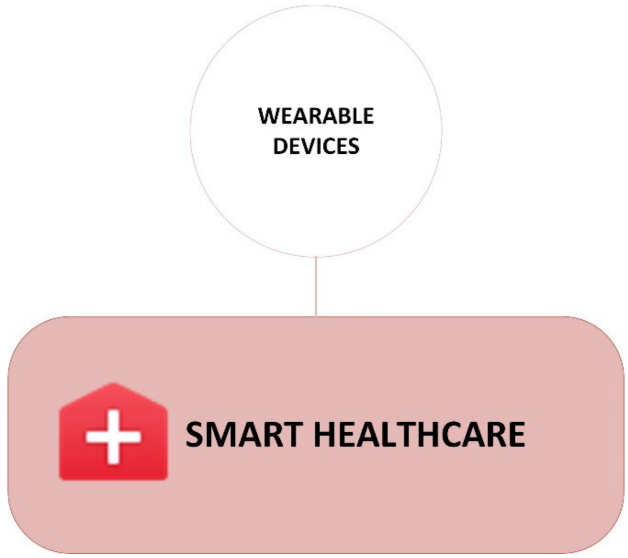

Figure 11. Smart healthcare

Wearable medical devices, as shown in Figure 11, track learners' health and trigger notifications to students, parents, authorities, and medical facilities in an emergency (Hemapriya et al., 2017; Y. Khan et al., 2016). In such emergencies, signals are sent with location trackers of the patients' current location, level of emergency, and type of condition. Automated bed availability or referrals are triggered to ensure speedy healthcare delivery without delays or casualties.

Challenges of IOT Implementation in Ghanaian Tertiary Institutions

The second aspect of the survey considers the challenges of implementing IoT in Education, but some negatives are largely limited to Ghanaian tertiary institutions. As depicted in Figure 3, the challenges to be discussed include trust, security, and privacy; internet connectivity; network bandwidth; cost of IoT devices; device incompatibility; institutional policies and priorities; wireless coverage and battery life; scalability and reliability; ethical concerns and dehumanisation.

Cost of IOT Devices

An IoT-based setup can generally be expensive (Evdokimov et al., 2019; L. Li et al., 2012; Villamil et al., 2020). One cost aspect is the number of IoT devices necessary to cover the implementation modules of an intelligent campus architecture (Barry, 2017). Aside from the cost of purchasing IoT devices, import prices in a developing nation like Ghana are constantly rising due to significant economic constraints (Aduhene & Osei-Assibey, 2021; Yennu, 2018). In addition, Dzawu (2022) recently ranked the Ghana cedis as the worst-performing currency in the world. Ghanaian tertiary institutions are already facing enormous challenges, from infrastructure shortfalls to the devastating COVID-19 outbreak, which has erased the progress made over the years (Arthur & Arthur, 2016; Upoalkpajor & Upoalkpajor, 2020). Even though there are futuristic possibilities to implement an IoT-based connected campus architecture, the current economic outlook makes it infeasible.

DEVICE INCOMPATIBILITY

According to the Ericsson Mobility Report (Ericsson, 2020), 26.9 billion connected devices will be available by 2026. Additionally, countless IoT-based applications are implemented daily with varying technological support (Pradhan et al., 2021; Siddiqui et al., 2021; Zikria et al., 2021). The lack of consensus over which languages, protocols, and standards are acceptable for various IoT layers leads to device incompatibility. Due to the variability of connected objects, it lacks a single standardisation platform and is constantly changing. Even though these numerous devices from diverse manufacturers operate on the same platforms and perform the same functions, their data formats can vary greatly. Too many firms adopt individual standards, resulting in the development of devices that cannot communicate with each other (Al-Qaseemi et al., 2016). Standardisation makes interoperability possible, improving successful integration and information sharing between remote systems. This indicates a requirement for standard protocols and platforms that can connect numerous devices from various vendors to communicate with one another. IoT standards that are uniform across the board will enhance overall security by making it simpler to secure connected devices for all models (Saimounika & Kishore, 2017).

SCALABILITY AND RELIABILITY

Scalability is the capacity of a device to adapt to environmental changes and meet future demands (A. Gupta et al., 2017). Any system that can manage the increasing volume of work must have this crucial component. The elements for scalability are essential and include aspects of commerce, advertising, hardware, software, and networks (A. Gupta et al., 2017; Luntovskyy & Globa, 2019). There is a continuous need for new technologies in education, like high-speed wireless networks, which provide the bandwidth for audio and video streaming of lessons. The devices in IoT are usually deployed in a highly dynamic environment with unreliable connectivity and the extreme possibility of failure in service delivery. Atomic services may exhibit higher dynamicity and lower reliability (L. Li et al., 2012). Even as the 5G network is being trumpeted in other parts of the world, the case of Ghana is different since the 3G and 4G networks are yet to be fully operational (Egho-Promise & Ola, 2020; Gohar & Nencioni, 2021). Since the connected devices need a high-speed network to work efficiently, unstable internet connectivity will affect the reliability of data transfer among devices.

TRUST, SECURITY, AND PRIVACY

Typically, devices and systems are designed to be reliable, robust, and secured by cryptographic algorithms and security protocols (El-Haii et al., 2019; Mousavi et al., 2021). Even though IoT provides great opportunities in the educational sector, adding new devices to the network increases the risk of cyberattacks (Stellios et al., 2018). According to Sicari et al. (2015), 57% of IoT devices are vulnerable to cyberattacks. One of the security challenges concerning the implementation of IoT is encryption (Kharroub et al., 2020; Yousefi & Jameii, 2017). Encryption is a common way to keep attackers from accessing data, but attacks have been on the rise with IoT because hackers can easily change the algorithms meant to protect data (Samuel & Sipes, 2019). IoT device manufacturers are more concerned about producing IoT devices without emphasising security. Most of these IoT products are prone to attacks and other security issues since they do not get enough testing and updates (Bures et al., 2019). Emerging IoT devices are vulnerable to brute-force attacks due to weak credentials and default login details (Stiawan et al., 2019; Wang et al., 2017). Educational institutions that rely entirely on the factory default credentials on the IoT devices they acquire put the institution, its assets, and students' and employees' sensitive data at risk of a brute-force attack. IoT usage raises privacy concerns to the point where companies have adopted IoT legal frameworks as policies (Chakray, 2020). The information from users of IoT devices needs protection in an IoT environment, but the autonomous nature of IoT coupled with endpoint communication with other devices primarily exposes user data (Chanal & Kakkasageri, 2020; Gope & Sikdar, 2019; Wigmore, 2014).

Internet Connectivity

The full functionality of IoT devices comes with good internet connectivity (Abdul-Qawy et al., 2015). Internet connectivity is a significant challenge in Ghana, with unreliable service providers and unstable connectivity challenges (Aheto-Domi et al., 2021; Kwapong, 2022). Connecting devices to provide useful fronts and information is enormously valuable, but poor internet connectivity becomes a considerable challenge because IoT sensors are required to monitor process data, and supply information (Mois et al., 2017). According to Samuel and Sipes (2019), 24% of users find connectivity issues the utmost challenge in global IoT deployment. With IoT implementation in education, it is a requirement for various institutions to have a robust communication network to gather data in harsh conditions and transfer it back for analysis at the data centre. However, the signal quality collected by sensors to transmit over to the networks greatly depends on the routers (Samuel & Sipes, 2019). In this regard, a well-connected network via various technologies is needed to facilitate quality and quick communication. These conditions now hinder connectivity since the number of connecting devices is increasing faster than the network coverage (Ericsson, 2020).

Network Bandwidth

Network bandwidth is the maximum amount of data transmitted over a network path in a fixed amount of time (Albishi et al., 2017; Froehlich & Ferguson, 2021; Rikic et al., 2021). While IoT devices are often connected using wired media, most of them operate wirelessly. Though some IoT devices use very little bandwidth, the sheer volume of devices going online asserts that more bandwidth is required. With the rise of IoT implementation, it is prudent to ensure the network can accommodate these changes (I. H. Khan et al., 2020). Even though the network bandwidth of Ghana keeps increasing yearly (Statista, 2022), it is still ranked 135th among countries globally (Speedtest, 2022). The amount of data IoT devices gather and transmit rises as the technology develops, which contributes to the need for increased bandwidth. With IoT demand increasing daily, network capacity is required to be available at the fastest speed possible. With the rise of IoT services and connectivity options, institutions must decide which techniques or methods to employ to ensure they have the required data throughput and range.

Ethical Concerns

Ethics in IoT primarily occurs when vendors are not transparent about client data and usage (Groth, 2022). Information consent is relevant in IoT to alleviate consumer information gathering without permission (Allhoff & Henschke, 2018). Full disclosure and legal documentation between vendors and clients are just as crucial as the devices acquired. IoT devices continue to face information security lapses that unintentionally invalidate consent agreements, leading to mistrust and privacy bridges (Allhoff & Henschke, 2018; Righetti et al., 2018). Ethical concerns also arise when IoT devices meant for a specific function capture other peripheral information without client knowledge and agreement (Allhoff & Henschke, 2018). Vendor negligence coupled with updated functionality without consent agreements raises enormous ethical concerns and privacy concerns in IoT deployments (Atlam & Wills, 2020; Chang et al., 2021).

Internet of Things Shortfalls: Wireless Coverage and Battery Life

IoT devices exist to cover wide ranges based on applications and deployments (S. Li et al., 2018; Whitmore et al., 2015). Linking dispersed devices to process big data adequately requires wireless sensor networks with maximum signal strength (Whitmore et al., 2015). In Ghana, internet connectivity and network bandwidth, as alluded to earlier, remain an issue in successfully deploying IoT in an educational environment. In IoT deployment, battery life is crucial in keeping connected devices online. The low battery life of IoT devices has been studied significantly by Samuelsson (2019) and Chen (2012). In an educational environment where real-time analytics is vital for successful learning outcomes and learner security, IoT sensors going off due to low battery and power fluctuations is a major challenge.

Institutional Policies and Priorities

A shift in institution policies and priorities is vital to the implementation of IoT in Ghanaian tertiary institutions. The Act that establishes tertiary institutions in Ghana defines the mandate, which is integrated into their vision and mission statements (Edu-Buandoh, 2011). Most tertiary institutions in Ghana rely heavily on the limited internally generated fund (IGF) to carry out their primary mandate since government subventions are mostly in arrears (Apaak, 2022; Awotwe et al., 2020). As alluded to earlier, since the Ghanaian economy is already facing enormous challenges, tertiary institutions, instead of investing in long-term innovations and gains, are rather focusing on utilising the IGF for short-term survival and keeping the institutions operational (Awotwe et al., 2020). IoT integration in education will transform teaching and learning positively across all educational levels, but institutional policies and financing must appropriately capture its relevance (Al-Taai et al., 2023).

Conclusion

IoT deployment in educational institutions has significant applications and will speed up the realisation of Education 4.0. With sensors, IoT can collect and transmit big data from varying modules of the educational sector for real-time analytics. With the appropriate machine learning algorithm, hidden patterns can be exposed to guide the learner, instructor, and management. Even as the benefits of IoT deployments are overwhelming in education, the challenges, especially in Ghanaian educational institutions, require urgent attention.

This survey analysed and discussed diverse application deployments of IoT in education. Significantly, we discussed major aspects of educational modules and peculiar application deployments of IoT. The Ghanaian economy currently faces extreme challenges, with IoT deployment non-existent in educational institutions. Even though the benefits of smart campus architecture deployments are apparent, the implementation challenges in Ghana require aggressive policies.

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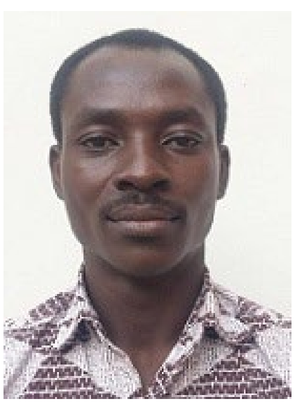

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