CHAPTER 3

Emerging Technologies in the 21st Century for Teaching and Learning in Science Education

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Preamble

This article discusses the emerging technologies for teaching and learning in education, particularly science education. Teaching and learning have metamorphosed from the traditional method of imparting knowledge through the apprenticeship/storytelling methods of the old, through the chalk/talk and lecture methods to the current 21st-century era of digitally mediated learning environments. The 21st century is witnessing astronomic growth in the field of Information and Communication Technology (ICT) coupled with the digitisation and virtualisation of the learning environment. This has led to innovative methods of delivery of instruction and imparting knowledge to learners through the usage of technologically mediated learning environments. Several emergent technologies are identified and discussed in this article, they include; Augmented Reality, Virtual Reality, Adaptive Learning Algorithms, Artificial Intelligence, and 5G Technology. Also identified are Competency-based Education, Learning Analytics, 3D Printing Technology and Robotics. Some benefits and challenges associated with the technologies are highlighted. It is deduced that with the deployment of emerging technologies for education, the methodology would be made easier so also will be the comprehension and internalisation of knowledge by students. In conclusion, education is set to experience a huge level of reshaping from many emerging technologies and it is recognised that this paradigm shift will have attendant implications for educational policy formulators and curriculum developers.

Keywords: Emerging technologies, digitisation, virtualisation, information, and communication technology.

Introduction

Nigeria like most nations globally places the education of its citizens on the front burner as it is perceived as the agent in chief for national development and social growth, this assertion is clearly stated in the policy of the nation on education section 1 (3a), (FGN, 2013). The 21st century is an era that has ushered in innovations in the field of education globally and observably the art of teaching and learning has indeed gone through some form of metamorphosis over time. Indeed, there have been paradigm shifts from the traditional method of imparting knowledge by the

apprenticeship/storytelling methods of the old through the chalk/talk and lecture methods to the current digitally mediated modes of the 21st-century era. According to Ikpe (2014), the 21st century is an era that is characterised by outstanding growth and development in the field of Information and Communication Technology (ICT), this along with the digitisation and virtualisation of the learning environment has thrown up new vistas for the teaching and learning process in education generally. Begum (2018) similarly opined that the educational system of any country is the backbone of the progress of its institutes and that it was necessary to change our traditional ways of teaching and adopt new educational strategies to keep up with these contemporary times.

For Rotolo, Hicks, and Martins (2015) emerging technology is a radically novel and relatively fast-growing technology that includes a variety of technologies such as educational technology, information technology, nanotechnology, biotechnology, robotics, and artificial intelligence. When discussing emerging technologies, the number is almost endless and they are revolutionising the learning and teaching process in the various fields of education as they are enhancing the manner teachers and students work in institutions of learning (TeachThought Staff, 2023). The emergence of these cutting-edge technologies is innovatively and unimaginably reshaping education, providing unique experiences and opportunities for students as they avail themselves of amazing new resources. At the onset, the focus was largely on digitally mediated learning environments such as provided by e-learning platforms and methods such as The Cloud, Mobile Learning, Tablet Computing, Massive Open Online Contents (MOOCs), and Open Educational Resources (OERs), so also, Virtual and Remote Laboratories to Wearable Technology. These are considered as previous emerging education technologies since currently; the followings are identified as some of the emergent technologies for teaching and learning in sciences and other fields of education. They are; Augmented Reality, Virtual Reality, 3D-Printing, Robotics, Adaptive Learning Algorithms, Synchronous Learning and Microlearning, Live Streaming, Artificial Intelligence, Learning Analytics, Social Learning, and Learning Games and Simulations, etc. as enumerated by TeachThought Staff (2023). This article informs about some of these 21st-century emerging technologies for teaching and learning in education. In-depth deliberation of the technicalities of these emerging technologies is however beyond the scope of this article.

Emerging technologies in the 21st century for teaching and learning

The following is a brief discussion of some of the emerging technologies in the 21st century deployable for teaching and learning in the various fields of education and as earlier stated, the discussions will be limited to the salient features of these emerging technologies and not an in-depth deliberation of the technicalities involved in their operation.

Augmented Reality (AR) and Virtual Reality

Augmented Reality (AR) according to Young and Sauter (2023) is a form of emerging technology where graphics are loaded onto live footage and has found usage in education and apps such as Pokémon Go, Snapchat, and Instagram filters. Augmented Reality has been very impactful

when talking about visuals and this is manifested in the manner it exerts control on the way students learn as well as the way they collaborate with their teachers. Since AR has debuted for a while now, its dynamic nature, as it is continuously evolving has earned it a reputation as one of the world's best emerging technologies.

Figures of AR and VR. Source: www.google.com

According to TeachThought Staff (2023), research on Augmented Reality (AR) as it relates to education has revealed that it will make a greater impact by the year 2023. Serosoft (2023) further buttressed the assertion that AR is to be considered one of the best-emerging technologies in the world and could be deployed by educators innovatively to develop interesting and interactive lessons. The authors further informed that AR is useful in overlaying interactive digital elements to give real-time experience and for promoting skills like creativity, critical thinking analysis and problem-solving.

Virtual Reality (VR) is a product of a combination of many technologies which are used to visualise and facilitate interaction in a virtual environment. Often, the environments depict three-dimensional space which could be realistic or imaginary, macroscopic or microscopic based on physical laws of dynamics or imaginary dynamics Christou (2010). Virtual Reality as informed by Christou (2010) enables a user to interact with a 3-dimensional model or virtual environment which may be realistic, in other words, it is capable of depicting the physical world as known to science but unobservable or could be used to visualise an entirely imaginary world. Given this VR enjoys wide applicability in numerous fields such as; education, sciences, archaeology, architecture, and history.

Furthermore, with VR a student is opportune to experience subject matters that are difficult or nearly impossible to describe or illustrate via the conventional methods of delivering instructions. Christou (2010) further asserted that the experimental nature of VR coupled with some of its salient features and interactivity makes it a valuable aid to conventional learning paradigms. In this era, students are required to comprehend abstract concepts or scenarios that are no longer in existence, and given that, instructors usually resort to the usage of analogies and metaphors to drive home such concepts, especially in the field of science education. this is done by vividly describing events and abstract concepts in the form of commonly observable realities.

Serosoft (2023) informed that Virtual Reality (VR) is another very important phenomenon in education that enhances students learning and engagement as it aids them to internalise information better by immersing students in what they are learning thus helping them to process information better.

Adaptive Learning

Figure of Adaptive Learning. Source: www.google.com

Another emerging technology to be considered is adaptive learning. It is noted to be primarily applicable in education and it is also regarded as one of the many that will reshape education in the year 2023. Adaptive learning as the name implies is one technology that makes learning experiences available to students promptly, taking into cognisance their specific needs, behaviour, and learning styles. Thus, adaptive learning is viewed as a piece of technology which has the capability of adapting to every students need enabling them to adapt to unique learning paths based on individual's interest and learning ability (TeachThought Staff, 2023). Its worthy to note that this position is similar to that assumed by Serosoft (2023) who also informed that studies on the technology revealed that it will play a significant role in the educational system of the world in the year 2023. The system uses computer algorithms to facilitate interaction among learners and it is noted that adaptive learning has its root in artificial intelligence, it provides customised resources alongside top learning activities which can address the special needs of learners.

Artificial Intelligence (AI)

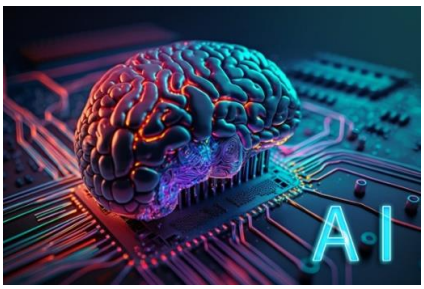


Figure on Artificial Learning (A.I.). Source: www.google.com

An emerging technology making waves globally currently is Artificial Intelligence (AI) which is seen as a subfield of computer science focusing on how machines can replicate human intelligence. It is defined by the English Oxford Living Dictionary as the "theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages." Similarly, the Merriam-Webster dictionary puts it as a branch of computer science dealing with the simulation of intelligent behaviour in computers and their capability to imitate intelligent human behaviour. Copeland (2023) in Encyclopedia Britannica, defined artificial intelligence (AI), as "the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings." Wikipedia informs that AI is the sub-intelligence exhibited by machines or software and that it is the study and design of intelligent agents which are a system that can perceive their environment and undertake actions that can maximise their chances of success.

Serosoft (2023) averred that Artificial Intelligence (AI) in education is already impacting on the implementation of the curriculum in schools through the use of innovations that were not feasible in the recent past. Through AI it was enthused, the world of academics has become more convenient and personalised. An obvious impact of artificial intelligence as reported by Serosoft (2023) is that from the kindergarten level of schooling, through to the graduate school level, different levels of individualized learning and adaptive learning programs, games and software are available for students and they can resultantly work at their own pace.

One notable way in which AI aims to reshape education is by supporting the sharing of first-person perspectives which will be quite useful for students doing research works (Serosoft, 2023). Instructively, from artificially generated content to image recognition and smart tagging systems, among other salient features of AI is the automation of basic activities such as grading of takeaway assignments and tests which are usually time-consuming for teachers. AI helps provide a detailed breakdown of students' performance in examinations though it cannot replace human input entirely, it has however led to the automation of administrative work and as a result, saved time for the educator.

Though it has been predominantly used in education, AI has found applicability in other fields of endeavour thus helping the world to evolve and more of this will be witnessed in the field of education. The author further asserted that one way AI is most likely going to reshape the world is via supporting the distribution of first-person perspectives. This is useful for the students as it can be deployed when working on essays, term papers, or research papers about an identified culture or tradition.

5G Technology

Figure on 5G technology. Source: www.google.com

Next to be discussed is the fifth generation of wireless technology which is referred to as 5G technology. A salient feature of this technology is that it is a high-speed and low-latency wireless technology as such, the interaction between institutions will experience some change, and activities such as download of materials will be much quicker. Also, the efficiency and scope of connected devices and technology within the classroom will be expanded, some universities have started integrating and conducting lectures and discussions on specialized topics through virtual reality experiences in higher education Serosoft (2023), a view similarly expressed by TeachThought Staff (2023).

Competency-Based Education (CBE)

Competency-Based Education (CBE) as explained by Erstad (2021) is a method of instructing and evaluating students based on the level of mastery of a subject demonstrated by them. The method it was further reiterated, focuses on having the learners show what they know and applying the concepts learned to evaluations that will attest to the fact that indeed they have internalised the subject. So also, Borkar (2021) opined that Competency-Based Education (CBE) is an approach to teaching-learning that enables students to develop and grow based on their ability to learn or master skills at their own pace and space. The method was further emphasised to assist students in improving their learning outcomes and attaining different learning abilities. According to Borkar (2021), "Competency-based Education (CBE) is an educational method that has an outcome-based approach for better proficiency of students in learning using a demonstration of the skills, knowledge, values, and attitudes that help in real-life situations at the age and grade-appropriate levels". The researcher further described the approach as unique, as it is outcome-based and enables educators to assist students in developing knowledge and values that will make them lifelong learners' post-graduation. In a nutshell, therefore, CBE could be aptly described as an educational model that attaches premium priority to the overall development of students.

Figure on Competency Education. Source: www.google.com

Competency-Based education is expected to play a very vital role in education from 2023 as students can be matched with learning activities that are designed in congruence with their level of learning ability. Imperatively, competency-based education provides a means for students to advance their learning experience based on their ability to master a skill thus allowing students to learn at their own pace and space. One advantage of this emerging technology is that students are capable of providing better outcomes based on objective demonstration of competency in a specific area.

Learning Analytics

Yet another of the emerging technology for teaching and learning in the 21st century to be visited in this article is learning analytics. This technology as informed by Nunn, Avella, Kanai, and Kebritchi (2016) can be rationalised as the "measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs".

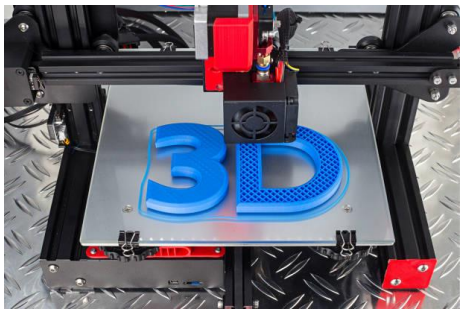
Figures on Learning Analytics. Source: www.google.com

Instructors in educational institutions use this technology to record the learning patterns, rates and behavioural outcomes of students in a better manner. This technology essentially brings

about improvement in the learning experience of students and also helps teachers record learning rate and behaviour of students, teachers in the final analysis, will be able to provide targeted improvements to courses on offer. (TeachThought Staff, 2023; Serosoft, 2023).

3D Printing technology

Three-dimensional printing technology (3D printing) has turned out to be a laudable development which is making great strides in the education firmament currently (Arvanitidi, Drosos, Theocharis and Papoutsidakis, 2019). If armed with the right tools, learning is a lot easier, and 3D technology does arm teachers, educators as well as students with the capability to marry theory and reality in the face of prevailing situations. It is observed that with the advent of 3D printing technology in education, students have found a study of certain concepts in various subjects such as chemistry, agriculture, and architecture easier to comprehend. Nazha (2021) pointed out that with 3D printing technology in schools and universities, most things are within the reach of students; geography students for instance will be able to print three-dimensional models of terrains, mountains, etc. while those studying some science courses will be able to see and feel organs more accurately.



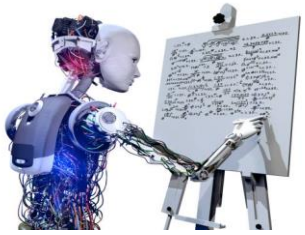
Source: www.google.com

Engineering students on the other hand can make more realistic designs of perceived models. This in the final analysis will encourage innovative and creative thinking amongst the students.

Robotics

The last of the emerging technologies to be discussed is robotics. It is a branch of technology that has to do with the design, construction, operation, and application of robots along with the computer system that controls them and their sensory feedback and information processing mechanism, (Scaradozzi et al. 2015). Furthermore, Scaraduzzi et.al (2015) asserted that robotics deals with automated machines which are capable of assuming the roles of humans in diverse fields of endeavour and look like replicas of humans in appearance cum behaviour, and cognition.

Robots can be classified as educational, industrial, or service robots, and educational robots are further classified into two; educational robotics and robotics for education. Educational robotics as implied can be incorporated into the teaching and learning process focusing principally on competencies to be developed and pedagogical principles to adhere to. As reported in the document e-Media (2018) the usage of robotics in teaching has several advantages, some of these are that; from observation, young people learn more quickly and easily if they are dealing with objects that are physical as well as concrete. So also, from handling sophisticated apparatus, the learners are not only motivated, they are also able to explore novel learning fields elaborately. Other benefits mentioned are that the learners develop technical skills that are relevant for computational activities as well as some basic skills like logic and communication.



A Robot teacher. Source: www.google.com

Miller, Nourbakhsh, and Siegwart (2008) stated that in recent years robots have penetrated the education sector serving as motivational tools for research programmes for scholars. Robots in education are unique as they interact with individuals and groups with the sole aim of inspiring learning, providing engaging recreation, and even providing therapeutic value.

Implication of emerging technologies to education

The 21st century has indeed witnessed an avalanche of emerging technologies which has indeed impacted on the teaching and learning of science in schools in various ways. As aptly put by Adeoye and Ikpe (2005) "a new tune demands a new dance"**,** so it is with the emergence of new technologies for teaching and learning in the 21st century, it is expected that there will be several changes, especially in pedagogy and other aspects of curriculum development in line with the paradigm shift. This is in line with the assertion by Mormah and Bassey (2019) who stated that "the emergence of various technologies for teaching and learning has brought a new face to the classroom. The 21st-century classroom requires a new face of teachers with an ICT-compliant status and mindset to support the teaching processes".

In recognition of the need for currency amongst 21st-century learners who are the major users of emerging technologies, the federal government of Nigeria harped on the importance of keying into global best practices in education in its policy on education by stating that "teaching and learning should be activity-based, learner-centered and experimental as well as Information and Communication" (FRN, 2013). Furthermore, the government did emphasise that "Teacher Education programmes shall be structured to equip teachers for the effective performance of their

duties. Information Communication Technology (ICT) training shall be incorporated into all teacher-training programmes" (FRN, 2013). The 21st century teacher in the face of these emerging technologies is thus faced with the challenge of deploying these technologies to innovate teaching and learning, while not losing sight of the relevant pedagogy. To be able to surmount this albatross, the Organisation for Economic Cooperation and Development (OECD, 2016) suggested that teachers need to be provided with appropriate software and training that provides technological knowledge and also teaches them how to incorporate this into their lessons.

Challenges associated with the usage of emerging technologies

Laudable as the emergence, deployment, and usage of emerging technologies may be to the teaching and learning of science courses, there are however many challenges mitigating their usage. Some of the challenges as identified by scholars such as Mormah and Bassey (2019) are highlighted following. They include but are not limited to issues of budget, skills as well as attitudinal issues, and experience. Some other challenges identified are; lack of computers, poor funding, lack of time, technical issues, resistance to changes and innovations, poor level of support administratively, low levels of computer literacy, absence of incentives, and incompatibility of the curriculum with the technologies. So also issues like poor training opportunities and the inability to integrate technology into the learning processes and some teacher-related difficulties such as negative attitudes, beliefs, and unwillingness towards technology. were also identified.

It was also revealed by Mormah and Bassey (2019) that factors militating against the usage of emerging technologies in schools include certain factors bothering social and moral ethics such as inequitable access to technology for all students, given some teachers avoid tasks such as assignments that require the usage of technologies by the students. Some schools reportedly restrict the use of various technologies due to potential negative consequences and ethical considerations.

Conclusion

The emerging technologies for teaching and learning in this 21st century is almost limitless. Several such emergent technologies were identified and briefly discussed and conclusively, it is pertinent to state that education is set to experience a huge level of reshaping from these emerging technologies and it is anticipated that this paradigm shift will have attendant implications for stakeholders in education such as the policy formulators and curriculum developers. Since the world is fluid and dynamic and witnessing changes constantly so are new and novel technologies emerging with associated upgrades daily. So, the classroom of the 21st century must always be on the lookout for these changes and ultimately key in as they emerge.

There is no gain in emphasising that the 21st-century science educator must be prepared to be developed and be relevant in these novel classrooms. The teachers of this era must as such endeavour to improve their knowledge, skills, and competency in the use of emerging technologies for the dissemination of knowledge to the learners. Education is set to witness some monumental

transformation from emerging technologies with attendant implications for educational policy formulators and curriculum developers as a result of the paradigm shift.

Recommendations

From the discussion, the following recommendations are advanced; government and other stakeholders in education should assist in ameliorating the paucity of funds and provision of adequate computers in institutions. Teachers and learners should be offered opportunities for training to improve on computer literacy level via workshops, induction courses, seminars, conferences, and in-service training.

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