Digital Literacy as a Catalyst for Promoting Secondary School Students' STEM Learning Outcomes in the 21st Century Classrooms

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Abstract

The 21st century is a technological driven era and requires citizens with both Science Technology Engineering and Mathematics (STEM) skills and digital literacy to adapt and navigate in the technological world. Digital literacy is the ability to use information and communication technology to find, evaluate, create and communicate information. Digital literacy an essential component of STEM education and empowers students with robust digital literacy skills that prepare them for careers in STEM fields. This paper therefore posits digital literacy as a gateway to promoting students' learning outcomes in STEM subjects based on the existing interrelationship between digital literacy and STEM education. The 21st century is a technological era and focuses on citizens possession of knowledge, skills and competencies to navigate in the technological era, Thus, lack of digital literacy among citizen and particularly teachers and students may limit the ability to access. communicate, explore, evaluate and create knowledge in the digital and technological world. It may also limit the chances of citizens global employability in the labour force. Integrating digital tools into STEM education in the 21st century classroom can enhance students' engagement, critical reasoning, creativity and ultimately learning outcomes in STEM subjects. Nevertheless, many challenges have been identified with achieving digital literacy in the Nigerian classroom environments. These challenges range from lack of fund, lack of internet services, digital divide and lack of regular teachers' regular training and knowledge upgrading among others. Suggestions such as integration of emerging technology into STEM pedagogies and classroom environment, upgrading teacher ICT knowledge through workshops regular training, provision of digital instructional facilities, redesigning of school curriculum to reshape both teaching and learning environment to align with the pace of the intensified technological changes in the 21st century.

Keywords: Digital Literacy, STEM Education, 21st Century Classroom, Learning Outcomes

Introduction

The increasingly technological advancement and transformations in all sectors of life including education in the 21st century is gradually positioning digital literacy as a core prerequisite for effective teaching and learning of STEM subjects. Technology offers a range of tools for teaching and learning and digital literacy dictates how these emerging technologies can be integrated into instructions to create smart learning environment. Digital literacy is the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital technologies (UNESCO, 2026). It encompasses digital competency which is the ability to effectively evaluate, create and communicate information using digital technologies. According to Junus et al, (2026) to become digitally literate one must possess digital skills which is the ability to use digital tools to: access and evaluate, utilize and manage, analyze, create and interact. These are basically the skills that are needed in using digital tools. To become successful in the digital world these digital skills are very crucial as citizens with such skills operate effectively in the technological world. Digital literacy and skills coexist with STEM literacy and skills. While STEM literacy is all about the ability to understand and communicate about topics related to the subject of science, technology, engineering and mathematics effectively, digital literacy is centered on the use of technology to access, create and communicate information which include but not limited to teaching of STEM subjects. Digital literacy therefore is perceived by this article as a catalyst that will help to promote students' learning outcomes in STEM subjects. The use of basic digital literacy skills such as information processing and retrieval, social networking, creation and sharing of knowledge serve as transformative skills in the 21st century classroom for effective search for reliable information in STEM subjects (Taylor, 2024). Digital literacy skills and proficiency are essential for students' engagement and acquisition of knowledge in STEM fields. Digital proficiency is the effective use of digital devices to complete tasks, solve problems and achieve a specific goal. It goes beyond basic digital device operation to include the mastery of digital devices and operation as well as a confident digital mindset (Slagle, 2025) identified digital literacy as an investment in the future of STEM education as it does not only empower students to be consumers of digital contents but also make students to be active and informed participants in the digital landscape that underpin modern STEM education instructional processes.

Digital literacy enable students to acquire robust skills that prepare them for future careers in STEM fields. Nwafor (2023) stated that digital literacy equips students in STEM fields with essential tools to navigate and contribute to an increasingly digital world. The EU Science Hub as cited by Taylor, (2024) identified five areas of digital competency that can give individuals the ability to interact successfully and responsibly with the ever -evolving digital landscape. The five identified areas of digital competencies include: Information and digital literacy -aimed at finding and accessing appropriate content, communication and

collaboration – which is the ability to navigate and utilize digital technologies and collaborate with other individuals or organization, digital content – the ability to create and share digital content with due respect to appropriate copyright and licensing regulations, safety – understanding the risk involved in digital interaction and how to protect personal privacy and other peoples' information and finally problem solving -which encompasses using digital tools to solve real-world problems. Taylor (2024) noted that these digital literacy skills coexist with STEM education skills which aim at promoting critical thinking, creativity and innovation skills. Hence digital literacy is a crucial aspect of STEM education and needs to be integrated in the school curriculum to promote students learning outcomes STEM subjects.

The technological transformation experienced in the 21st century has helped to reshape both teaching and learning environment towards digitalization. Digitalization is the adoption of digital technology to transform traditional educational processes and content delivery (Govender,2025) The 21st century classroom requires both teachers and students in STEM fields to adopt digital tools to enable them navigate in the ever-changing digital world (Slagle, 2025). Digital literacy therefore is a necessity and perceived as a catalyst for promoting students' learning outcomes in the 21st century classroom. Nwafor (2023) opined that digital literacy should not be seen as an educational agenda but as the key to unlocking a realm of impossibilities for students to engage with, comprehend and contribute to the globalized technology-driven society.

Digital Literacy and STEM education in the 21st Century Classroom

The technological advancement and transformation in the 21st century necessitate a paradigm shift from traditional teacher-centered lecture -oriented classroom to a more nuanced modern learning environment with varying characteristics in the teaching and learning of STEM subjects. The 21st education emphasis on sustainability of life-long learning through skill acquisition, critical thinking, creativity and development of competencies for adaptability and employability in the technological world (Govender,2025). The development of these skills and competencies are promoted by varying range of technological tools. The use of these differentiates the 21st century classroom from the traditional classroom. Hughes (2015) defined the 21st century classroom as a student-centered learning environment where teachers act as facilitators rather than lecturers, integrating digital technology and collaborative, project-based task to build critical thinking and real-world problem -solving skills in students

Digital tools have been identified to significantly promote the development 21st century skills and learning outcomes in STEM subjects. STEM is an interdisciplinary approach that connects ideas and practices across multiple disciplines to develop problem-solving, creativity, and critical thinking skills in learners. Reyannte et al., (2020) defined STEM as a teaching method that integrates practices, concepts and processes from

different domains with the aim of promoting critical reasoning and creativity for solving life related problems. The integration of emerging technological tools and pedagogies in teaching STEM subjects require basic skills and knowledge in digital technologies. Taylor (2024) noted that STEM literacy which is the ability to effectively understand and communicate about topics related to science, technology, engineering and mathematics subjects is interlinked with digital literacy and that both coexist to produce learners with 21st century adaptational skills. The author stated that while digital tools help in accessing, creating and communicating information about STEM subjects that the effective use of these tools in communicating information about STEM rely on digital literacy. The knowledge and skills from both STEM and digital literacy are vital for the Fourth Industrial Revolution (4.0) era. An era described by Govender (2025) as the integration of emerging and new technologies such as the Internet of Things (IoT) robotics, virtual reality (VR), and artificial Intelligence (AI) into manufacturing practices, and our works and lives. Ramaila and Molwele (2022) noted that the advent of the Fourth Industrial Revolution (4.0) presented enormous opportunities for the technological integration in science teaching and learning with a view to foster the development of 21st century skills and competences in students. The author maintained that while digital literacy and skills emerge as avenue that enables individual to navigate, evaluate and create information in a technological – driven society, STEM education provides the knowledge and skills such as critical thinking and problem-solving skills that help to address global challenges and sustainability.

Thus, effective and successful technological transformation in the education processes in the 21st century STEM classroom can be effectively achieved through the adoption of digital technologies (digitalization) and digital literacy. Digitalization according to Govender (2025) is the adoption of digital technologies to transform traditional educational processes and content delivery. Honey et al, (2014) noted that in STEM programmes that digitalization encompasses tools such as online simulations, virtual labs, coding platforms, and AI-based learning systems. Digital tools enable interactive and flexible learning environment, which are particularly beneficial for the learning and understanding STEM complex topics that often require visualization and experimentation. Digital literacy is therefore important in STEM education as it helps both teachers and students to access, create and evaluate information, utilize STEM tools and technologies to solve problems and improve educational processes. According to Nugent, et al, (2023) incorporating digital literacy into the school curriculum, enhances students; ability to engage with complex STEM concepts and encourages critical thinking in learners. Integrating digital literacy into STEM curriculum is therefore considered very crucial to preparing students for lifelong learning in a digitally mediated world.

Digital literacy and competence complements STEM education. Hence, digital literacy is perceived by this study as a gateway to promoting students' learning outcome in STEM education in the 21st century classrooms

Digital Literacy and Students' Learning Outcome in STEM Subjects in the 21st Century

Technological advancement of the 21st century in education provides students with array of learning opportunities and tools in analysing, exploring and discovering new concepts and ideas that promote knowledge. Digital literacy requires the ability to produce and analyze knowledge that incorporates electronic literacy skills (Junus et al., 2026). Digital literacy promotes students' competitiveness and better opportunities in the digital world. Digital literacy skills on the other hand skills help students to access, evaluate, create, and communicate information in STEM education (Slagle, 2025). Students' possession of adequate digital literacy and skills help them to effectively use digital tools to access learning materials, complete academic tasks faster, and demonstrate a significant improvement in learning outcomes in STEM subjects. Hence, in the educational sector digital literacy is increasingly becoming important such that many learning activities involve digital tools such as virtual simulations, interactive whiteboards and smartboards, virtual laboratories, Augmented Reality (AR and Virtual Reality (VR), Educational Apps and Games in science, 3D printing, Robotics and Artificial Intelligence (AI) among others (Yilmaz, 2023).

Several studies indicated the importance of digital literacy in the teaching and learning environment. A study by Lorenzo et al., (2026) indicated that use of digital tools in STEM education promote the development of problem-solving skills and also promote overall academic achievement. Subsequently, Yilmaz (2023) indicated that the use of digital tools such as virtual laboratories have been found to be highly effective in STEM education in promoting both students' engagement and learning outcomes. In the same vein, the study by Ramaila and Molwele (2022) also reported that digital technology promoted the acquisition of STEM skills. Francis et al, (2021) noted that the use of digital literacy such as 3D printing technology significantly enhanced students understanding and retention in complex scientific concepts. Fung, (2020) noted that the use of digital- based innovative pedagogies such as flipped classroom, videoconferences and interactive readings among others promoted students' learning outcomes in STEM subjects. Similarly, Hanif et. al (2019) reported that project-based learning instructional strategy where students use digital tools to solve real world problems help students to develop teamwork and critical thinking skills that are core competencies for the STEM workforce. From the fore going, it could be deduced that effective use of digital tools could serve as a gateway for promoting students' learning outcomes in STEM education.

Challenges to Digital Literacy in the 21st Century Classrooms

Regardless, the transformative potentials of digital technologies in the 21st century classroom environment in promoting personalized learning, collaboration, real-world connections, preparation for the future, assessment and feedback, flexibility and accessible among other benefits digital literacy is not without some

setbacks. These challenges may directly or indirectly affect students' learning outcomes in the STEM subjects. Some of the potential challenges include:

- **High cost of digital tools:** Educational digital tools such as computers, smartphones and software appliances are major concern in the digital world. Nevertheless, the educational institutions may encounter difficulties in procuring these digital tools thereby hindering students' accessibility and utilization of such tools to promote learning and learning outcome (Afolabi & Loto,2021).
- **Lack of adequate training and support:** most teachers lack digital literacy and skills whereas the successful integration and use of technology depends on teachers' level of digital literacy and competence. Hence, without adequate training teachers may struggle to effectively utilize and integrate digital technologies effectively into classroom instruction. (Ogegbo,2023).
- **Irregular/ lack of power supply:** lack of adequate powers supply or power interruption can disrupt and affect the use of computers, projectors, internet routers and other electronic learning devices, particularly in rural or remote areas with unreliable or no power supply
- **Technical Issues:** Technical problems such as glitches, connectivity issues or equipment malfunctions can disrupt the learning process and create frustration for both students and teachers . These challenges not only hinder seamless communication but also impede the smooth flow of educational content delivery and students' learning outcomes ((Yilmaz, 2023))
- **Inequality and Access disparities**: The digital divide, which refers to unequal access to technology among students, poses a significant challenge in education. This disparity can potentially exacerbate existing education inequalities and limit learning opportunities for certain students (Yilmaz, 2023)

To address these challenges, combined efforts from teachers, schools, government, and other relevant educational stakeholders are required.

Strategies for Promoting Digital Literacy in the 21st Century Classrooms

Digital literacy is a crucial factor to technological transformation and adaptation in the 21st century classroom. Digital literacy and skills facilitate access. evaluation and communication of information that promote learning outcome in STEM subjects and skills. Increased knowledge and skills in STEM education promote workforce and competencies in the 21st century skills. This is because effective use of digital tools in the teaching and learning process depends on the literacy level and competence of the teacher. Hence, promoting digital literacy in the 21st century classroom is a necessity and not an option and should be of a

major concern to attaining the SDG4 goal, which aims at equitable quality education and lifelong learning opportunities for all by 2030 (Obe & Oladepo, 2023). Promoting digital literacy in the 21st century classroom, requires a multi-faceted strategies that should integrate technology, pedagogy and teachers' competences in navigating the technological world. Mor, (2025) outlined arrays of strategies that can be adopted by the educational stakeholders to promote digital literacy in STEM subjects in the 21st century classroom as follows:

- **Access to Digital Devices:** Schools should try to provide students with good access to digital devices by provide adequate computers, tablets, smartphones and other digital learning tools to promote digital literacy
- **Encouraging Collaborative Online learning**
  Schools should encourage digital learning platforms such as learning management systems, shared documents, discussion forums and educational communication platforms to encourage students to work together and digitally building a learning community with good digital literacy skills that will promote STEM skills and learning outcomes.
- **Using Interactive Digital Learning Resources:**
  Teachers to use digital tools such as educational videos, virtual simulations, virtual laboratories, animations, quizzes, and interactive presentations that make learning more engaging to develop students' interest to promote digital literacy and students' learning outcomes in STEM education.
- **Incorporating Digital Assessment and Evaluation:** Teachers should adopt the use of online quizzes, electronic assignments, computer-based tests, and digital portfolios to help students develop digital literacy and confidence in using technology for academic purposes and self-assessment to promote learning outcomes in STEM education.
- **Provision of Functional Internet Services**
  The government should provide reliable and affordable internet connectivity that should enable students to access online educational materials, virtual libraries, videos, and learning platforms to promote their digital literacy, competence and learning outcomes in STEM education.
- **Encouraging Teachers professional training in digital skills**
  The government should encourage serving teachers to continuously to undergo professional development to equip themselves with digital knowledge and skills in the emerging technologies and integration of digital tools in pedagogy and assessment methods to promote students' digital literacy and learning out comes in STEM education.
- **Bridging digital gaps /opportunity gap**
  Government and educational stakeholders should strive towards bridging digital gap between

communities by providing equal access to technological tools and facilities to students and all individuals regardless of location to promote digital literacy and students' learning outcomes in STEM education.

- **Promoting Online Safety and Responsible Technology Usage**
  The educational stakeholders should ensure and enforce policies on digital privacy and security with regards to passwords security, cyberbullying, digital footprints, plagiarism, and responsible online communication, these could facilitate students' confidence in adopting digital technology and usage to promote learning outcomes.
- **Creating a supportive digital learning environment**
  School administrators should develop policies, provide facilities and technical supports to schools and encourage teaching and learning of STEM subjects with appropriate digital tools and technologies to promote digital literacy and learning outcomes particularly in STEM education.

Conclusion

Digital and STEM literacy skills are essential components to effective adaptation and employability in the 21st century technologically-driven world. Digital technologies provide an engaging environment for the STEM subjects which subsequently foster critical thinking and problem- solving skills in students for lifelong learning and sustainable development. However, effective utilization of digital technology to access, create, evaluate and communicate information depends on digital literacy. Digital literacy is a vital force in transforming the 21st century education in as it influences the use of digital tools in teaching and learning processes in STEM education to promote students' interest, engagement, motivation, collaboration and overall learning outcomes. Nevertheless, some challenges ranging from lack of resources to inequality and access disparities limit the harnessing of the potential benefits of digital literacy in STEM education. Effective teachers, schools Government and stakeholder intervention in encouraging digital literacy and providing digital tools, facilities and policies could promote students' learning outcomes in STEM education.

Recommendation

Digital literacy is an important driving force in the technological era and as such should be given an important priority in the contemporary educational environment particularly in STEM education. Promoting digital literacy among teachers and students therefore, will facilitate the adoption and use of digital tools in STEM education to promote students' learning outcomes.

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