Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Revolutionizing Education: Exploring Technological Innovations, Opportunities and Challenges Across IoT, AR, VR, AI, LMS, ML, Gamification and Emerging Technologies

Asep Bayu Dani Nandiyanto[1,*], Nor Azwadi Che Sidik[1,2]

[1] Universitas Pendidikan Indonesia, Bandung, Indonesia
[2] Semarak Ilmu Publishing, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 31 January 2025
Received in revised form 24 February 2025
Accepted 30 June 2025
Available online 10 July 2025

Keywords:
Bibliometric; educational technology; engineering education; immersive learning; science education

ABSTRACT

Technological advancements are reshaping science and engineering education by fostering interactive, hands-on, and personalized learning experiences. This review examines the role of key technologies, including the Internet of Things (IoT), Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI), Learning Management Systems (LMS), Gamification, 3D Printing, Blockchain, Cloud Computing, Robotics, Big Data, and machine learning (ML), in making a modern education. Bibliometric analysis was employed to identify patterns in publication growth, disciplinary focus, and geographical distribution, providing quantitative insights into the evolution of research on educational technologies. Each technology offers unique contributions, such as IoT-enabled smart classrooms, AR and VR for immersive visualizations, AI-driven analytics for personalized learning, and 3D printing for prototyping. The findings highlight the benefits of these innovations, including enhanced engagement, deeper understanding, and global access to resources. Challenges such as high costs, digital divides, inadequate infrastructure, and the need for educator training persist. Using a qualitative review approach, the study synthesizes recent research to provide insights for educators, policymakers, and researchers. It underscores the need for collaborative efforts to overcome barriers and maximize the potential of these technologies in science and engineering education. The results point to future directions, emphasizing the importance of equitable access, teacher training, and scalable solutions to ensure that technology continues to enhance educational outcomes.

1. Introduction

In the era of digital transformation, the use of technology in education is a key factor in improving the quality of learning and supporting the achievement of the Sustainable Development Goals (SDGs). Traditional teaching methodologies, while foundational, often fall short in addressing the diverse needs of learners in today’s fast-paced, digitally connected environment. With the increasing demand for more engaging and accessible education, technologies such as the Internet of Things (IoT), Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI), Learning Management

[*] *Corresponding author*
E-mail address: nandiyanto@upi.edu

https://doi.org/10.37934/ard.136.1.108137

Systems (LMS), Gamification, 3D Printing, Blockchain, Cloud Computing, Robotics, Big Data, and machine learning (ML) have emerged as pivotal tools. These innovations enable dynamic teaching strategies, offering real-time data analysis, personalized learning pathways, and immersive simulations that make abstract scientific principles more tangible. The potential impact of these technologies is particularly profound in science and engineering education, where practical skills, problem-solving, and innovation are paramount. IoT-enabled smart classrooms provide opportunities for remote experimentation and data collection. AR and VR transform learning by immersing students in virtual environments where they can interact with scientific phenomena or engineering processes. AI systems adapt to individual learners' needs, optimizing their educational experiences through tailored feedback and predictive analytics. Gamification strategies motivate students by integrating game elements into learning activities, fostering engagement and collaboration. However, the integration of these technologies is not without challenges. Issues such as cost, infrastructure gaps, digital divides, and the need for extensive educator training present significant barriers. In developing regions, the lack of internet connectivity and limited access to devices exacerbate these challenges, creating disparities in educational quality and opportunities [1,2].

This paper aims to comprehensively review technological innovations in science and engineering education, focusing on their contributions, challenges, and prospects. By synthesizing recent research, it seeks to guide educators, policymakers, and researchers in optimizing the use of these tools for enhanced learning outcomes (see Figure 1). The discussion explores the diverse applications of technologies in classrooms worldwide, addressing both the benefits they bring and the hurdles that must be overcome for their effective implementation. The findings of this study emphasize the importance of continued innovation and investment in educational technologies. Collaborative efforts among governments, educational institutions, and private sectors are crucial to bridging gaps and ensuring equitable access to these advancements. As the educational landscape evolves, these technologies hold the potential to redefine teaching and learning, preparing students for the challenges of a rapidly changing technological era.

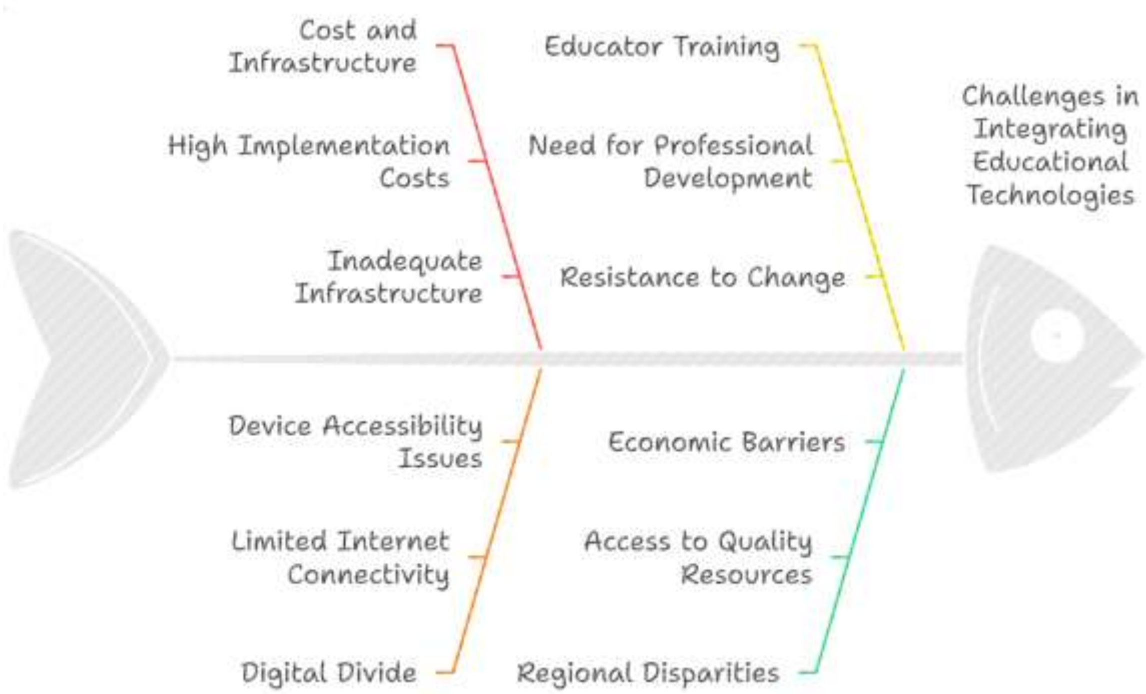

Fig. 1. Overcoming barrier to technology-enhanced education

2. Methodology

This study employed a qualitative review approach to explore the integration of advanced technologies in science and engineering education. The methodology focused on synthesizing recent research to identify trends, opportunities, and challenges associated with these innovations. Data were collected from scholarly articles published in reputable international journals. The primary database used for this review was Scopus, which provided access to a broad spectrum of peer-reviewed literature. But, for some cases, articles from Google Scholar were also analyzed in the discussion section. Articles were selected based on their relevance to the keywords "Technology" and "Education," with the search conducted on January 6, 2025, to ensure the inclusion of the most recent developments. Detailed information on how to use bibliometrics is explained elsewhere [3,4].

Inclusion criteria required articles to focus on the application of technologies such as IoT, AR, VR, AI, LMS, Gamification, 3D Printing, Blockchain, Cloud Computing, Robotics, Big Data and ML in educational contexts. Studies addressing both the benefits and challenges of these technologies in science and engineering education were prioritized. Articles lacking empirical data or focusing solely on theoretical models without practical applications were excluded. The review followed a thematic analysis framework, organizing findings into key categories such as trends, technological contributions and barriers to implementation. Bibliometric analysis was employed to identify patterns in publication growth, disciplinary focus, and geographical distribution, providing quantitative insights into the evolution of research on educational technologies.

To ensure the reliability of findings, cross-referencing with other databases and citation analyses was conducted. Relevant studies from interdisciplinary fields, including social sciences, computer science, and engineering, were incorporated to enrich the analysis. As the study relied exclusively on secondary data, ethical approval was not required. However, all sources were appropriately cited to maintain academic integrity and acknowledge original contributions. The study's scope was limited to articles available in the Scopus database, which may exclude valuable research from other platforms or regions. Additionally, the reliance on English-language articles may have introduced a linguistic bias. This methodology provided a structured and comprehensive approach, enabling the synthesis of diverse perspectives on the integration of technology in education while highlighting key challenges and opportunities.

3. Results and Discussion

3.1. Bibliometric Analysis

Figures 2, 3 and 4 collectively highlight significant trends, disciplinary focus, and geographical distribution in research related to "technology" and "education" using bibliometric analysis. These insights provide a comprehensive understanding of the growing academic interest and global engagement in this field. Bibliometric analysis is one of the effective methods for understanding research trends. Several examples from bibliometric analysis are shown in Table 1.

Figure 2 shows the growth in the number of published documents related to the keywords "technology" and "education" from 1914 to 2024, totaling 292,684 publications. The data reveals a significant upward trend in academic interest, particularly from the late 20th century onward. Initially, there were very few publications each year, reflecting the limited focus on the intersection of these fields during the early and mid-20th century. However, the growth becomes more prominent after 2000, aligning with the rapid adoption of digital technologies, widespread internet access and increasing efforts to integrate technological innovations into educational practices. This period marks a shift in the global academic landscape, as researchers and educators began exploring the transformative potential of technology in teaching and learning. The trend has become particularly steep in recent years, with the highest number of publications recorded in 2024, at 27,700 documents. This surge reflects the growing importance of digital tools in education, especially after the COVID-19 pandemic accelerated the shift toward online learning and digital pedagogy [35,36]. The chart accompanying the data visually underscores this growth, with a near-exponential increase in publications from around 2000 to the present. This dramatic rise in academic output indicates a sustained and intensifying focus on topics such as e-learning, virtual classrooms, artificial intelligence in education, and the integration of emerging technologies like virtual reality and augmented reality. Overall, the data highlights a robust and ongoing interest in how technology can enhance educational practices, making it a critical area for research and innovation in the modern era.

Figure 2 demonstrates a dramatic increase in research publications over time, particularly from the early 2000s onward. This exponential growth corresponds to the widespread adoption of digital technologies and their integration into educational systems worldwide. The surge in publications between 2020 and 2024 reflects the accelerated emphasis on technology in education due to the COVID-19 pandemic, which necessitated a global shift toward remote and hybrid learning. This rapid increase in research output underscores the growing recognition of technology as a vital tool for advancing educational practices and addressing emerging challenges.

Table 1
Previous studies on bibliometric analysis

No.	Title	Ref.
1	Sustainable Production-inventory model with multi-material, quality degradation, and probabilistic demand: From bibliometric analysis to a robust model	[5]
2	Phytochemical profile and biological activities of ethylacetate extract of peanut (Arachis hypogaea L.) stems: In-vitro and in-silico studies with bibliometric analysis. *Indonesian Journal of Science and Technology*, *8*(2), 217-242.	[6]
3	Biomass-based supercapacitors electrodes for electrical energy storage systems activated using chemical activation method: A literature review and bibliometric analysis	[7]
4	Antiangiogenesis activity of Indonesian local black garlic (Allium Sativum 'Solo): Experiments and bibliometric analysis	[8]
5	Characteristics of tamarind seed biochar at different pyrolysis temperatures as waste management strategy: Experiments and bibliometric analysis	[9]
6	The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach	[10]
7	How eyes and brain see color: Definition of color, literature review with bibliometric analysis, and inquiry learning strategy for teaching color changes to student with mild intelligence barriers	[11]
8	Corncob-derived sulfonated magnetic solid catalyst synthesis as heterogeneous catalyst in the esterification of waste cooking oil and bibliometric analysis	[12]
9	Prototype of greenhouse effect for improving problem-solving skills in science, technology, engineering, and mathematics (STEM)-education for sustainable development (ESD): Literature review, bibliometric, and experiment	[13]
10	Spatial visualization ability assessment for analyzing differences and exploring influencing factors: Literature review with bibliometrics and experiment	[14]
11	Augmented reality for cultivating computational thinking skills in mathematics completed with literature review, bibliometrics, and experiments for students	[15]
12	Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs)	[16]
13	Neuroscience intervention for implementing digital transformation and organizational health completed with literature review, bibliometrics, and experiments	[17]
14	Phylogenetic analysis of Bengkulu citrus based on DNA sequencing enhanced chemistry students' system thinking skills: Literature review with bibliometrics and experiments	[18]

15	The ship's propeller rotation threshold for coral reef ecosystems based on sediment rate indicators: Literature review with bibliometric analysis and experiments	[19]
16	Empowering engineering female students to improve retention and progression: A program evaluation study completed with bibliometric analysis	[20]
17	Dental suction aerosol: Bibliometric analysis	[21]
18	Bibliometric analysis of nano metal-organic frameworks synthesis research in medical science using VOSviewer	[22]
19	Research trends from the Scopus database using keyword water hyacinth and ecosystem: A bibliometric literature review	[23]
20	Bibliometric analysis using VOSviewer with Publish or Perish of role-play in the teaching and learning	[24]
21	Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages	[25]
22	Chatbots as Digital Language Tutors: Revolutionizing Education Through AI	[26]
23	Effects of sustained deficit irrigation on vegetative growth and yield of plum trees under the semi-arid conditions: Experiments and review with bibliometric analysis	[27]
24	Hydroxyapatite as Delivery and Carrier Material: Systematic Literature Review with Bibliometric Analysis	[28]
25	Development of intelligent tutoring system model in the learning system of the Indonesian national armed forces completed with bibliometric analysis	[29]
26	Artificial intelligence (AI)-based learning media: Definition, bibliometric, classification, and issues for enhancing creative thinking in education	[30]
27	The role of information and communication technology in increasing work creativity through transformational leadership between Generation X and Y Employees: A bibliometric analysis using Publish or Perish	[31]
28	Analysis of Computational Bibliometric Mapping in Multimedia for Art Learning Media Publications using VOSviewer	[32]
29	A Bibliometric Analysis of the Global Trend of Residual Stress Induced by WAAM Process and Stress Relief Heat Treatment	[33]
30	Global Research on Emerging Digital Technology: A Bibliometric Analysis	[34]

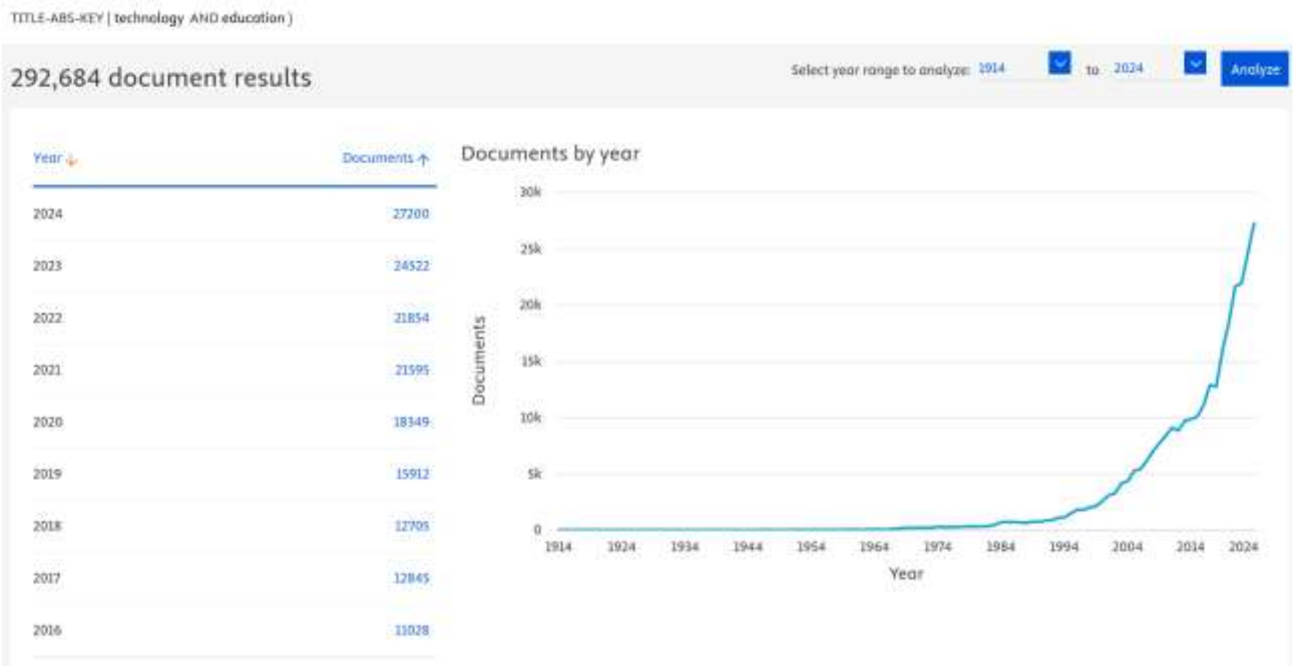

Fig. 2. Publication as a function of time

Figure 3 provides a breakdown of the 292,684 documents related to "technology" and "education" based on their subject areas in the Scopus database. It highlights how different disciplines have contributed to the body of research in this field:

i. Social Sciences emerge as the largest contributor, accounting for 22.9% of the total publications. This reflects the focus on the societal and educational implications of technology integration, including its impact on teaching practices, learning outcomes and policy development.
ii. Computer Science ranks as the second most prominent area, comprising 19.4% of the publications. This underscores the significant role of technological innovation and computational tools in shaping modern education, including e-learning platforms, artificial intelligence and other digital advancements.
iii. Engineering contributes 15.1% of the documents, indicating a strong interest in the technical and infrastructural aspects of integrating technology into educational systems.
iv. Medicine follows with an 8.4% share, which likely relates to research on technology-based medical education, such as simulations, telemedicine training and other advancements in healthcare education.
v. Mathematics, with a 7.8% contribution, reflects research on the use of technology for enhancing mathematical learning and problem-solving tools.
vi. Other fields, including Business, Management, Arts and Humanities, Decision Sciences and Physics and Astronomy, show smaller contributions, ranging between 2 and 6%. These areas highlight diverse applications of technology in specific contexts, such as business education, creative disciplines and STEM learning.
vii. The pie chart also allocates 16.6% of the publications to "Other" categories, representing multidisciplinary studies or areas not explicitly classified. This distribution showcases the interdisciplinary nature of research on technology and education, with diverse academic fields exploring its integration and impact. It reflects the growing recognition of technology as a critical component in improving education across various domains.

Figure 3 reveals the multidisciplinary nature of research in this field. Social sciences dominate, reflecting a strong focus on the societal, pedagogical and policy implications of educational technology. Substantial contributions from computer science and engineering highlight the technical foundations and innovations driving advancements in digital education. Disciplines such as medicine, mathematics and business indicate the application of technology in domain-specific educational contexts. A significant proportion of research falls under "Other" categories, emphasizing the broad and varied impact of technology across diverse fields.

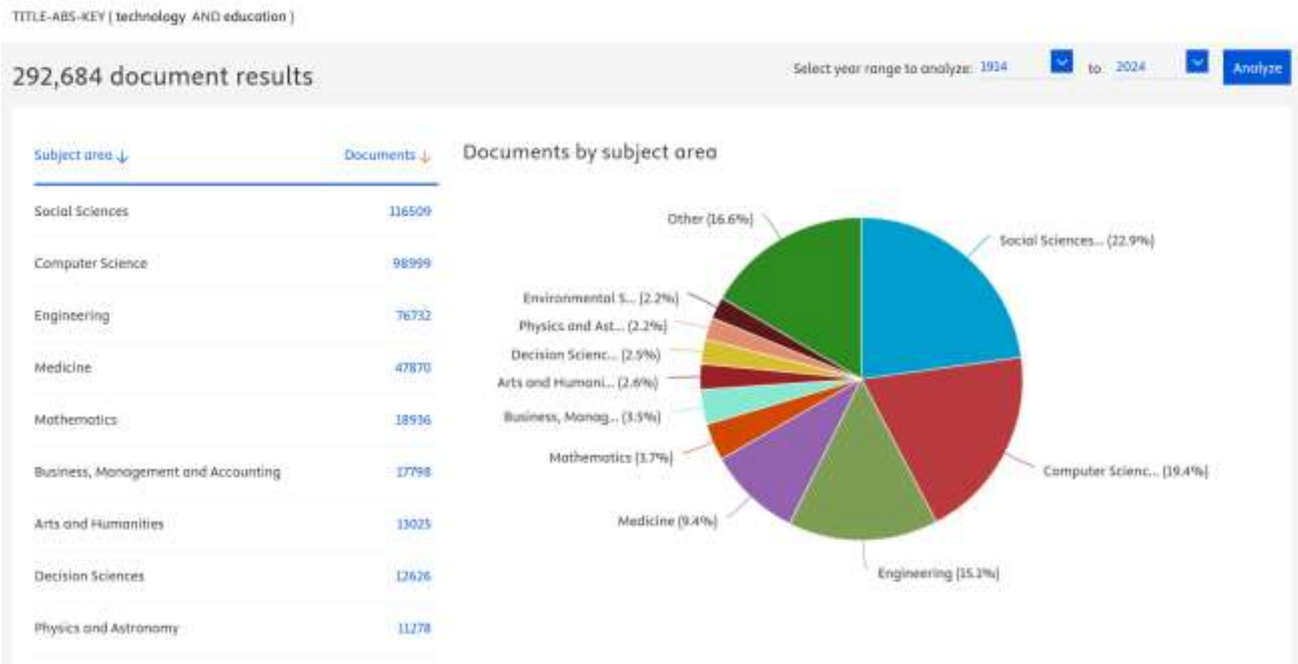

Fig. 3. Publication as a function of subject area

Figure 4 shows the distribution of publications related to "technology" and "education" across various countries or territories, based on 292,684 documents. The United States is the leading contributor, with 78,900 documents, which reflects its strong emphasis on research, technological advancements, and educational innovation. This high output aligns with the country's significant investments in technology-driven education systems and its position as a global leader in academic research. China is the second-largest contributor, with 30,194 publications. This demonstrates China's growing focus on integrating technology into education to support its rapid development in the science, technology and education sectors. The United Kingdom ranks third, with 19,346 documents, showcasing its robust academic output in addressing technology and education, likely driven by its well-established educational institutions and technology adoption in learning. Australia and India follow, with 12,839 and 11,112 documents, respectively. Australia's focus may stem from its emphasis on online learning and educational technology in remote areas. At the same time, India's growing output reflects its efforts to enhance educational access and quality through technology in its large and diverse population.

Countries such as Spain, Canada, the Russian Federation, Germany and Indonesia have lower, yet notable, contributions, ranging between 8,000 and 10,000 publications each. These figures highlight varying degrees of focus on technology and education research, shaped by regional priorities, investments and academic infrastructure.

Figure 4 visually emphasizes the disparity in contributions among nations. This distribution reflects the global nature of research in technology and education, influenced by economic, technological, and institutional factors across regions. Indonesia is listed among the countries contributing to research on "technology" and "education," with approximately 8,000 publications. While this number is lower compared to leading contributors like the United States and China, it signifies Indonesia's growing interest and investment in integrating technology into its education system. Indonesia's research efforts likely focus on addressing challenges unique to its context, such as improving access to education across its vast archipelago. Technology has been pivotal in bridging gaps for students in remote or underserved areas through online learning platforms, digital literacy programs, and mobile-based education solutions. Government initiatives, such as "Merdeka Belajar"

(Freedom to Learn), emphasize the role of technology in enhancing educational equity and quality. Collaboration with international organizations and local universities has further boosted research output, targeting topics like e-learning, educational technology and digital transformation in schools and higher education. Despite these advances, Indonesia faces challenges such as uneven internet infrastructure, digital divides and limited resources in some regions. However, the ongoing research indicates a strong commitment to leveraging technology as a tool for transforming education and addressing these barriers. Indonesia's contribution to this field, while smaller in scale, reflects a significant effort to align its education system with the global shift toward technology-enhanced learning, highlighting its potential for future growth and innovation in this area.

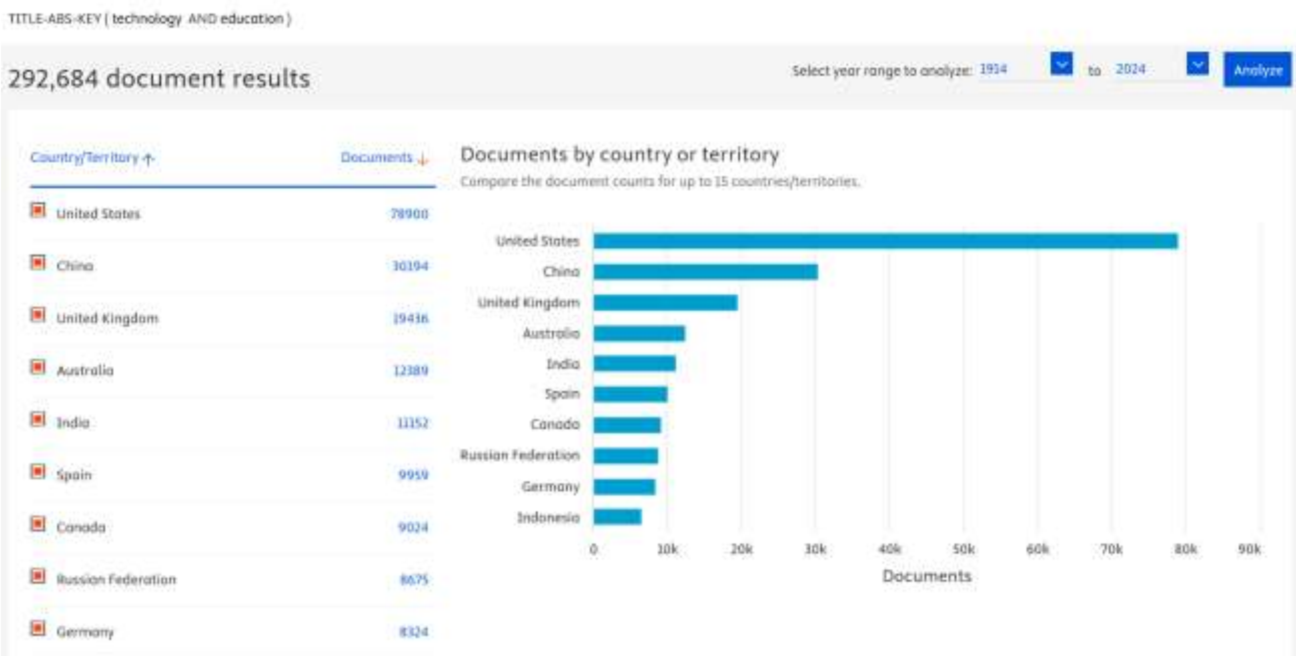

Fig. 4. Publication as a function of countries

These findings collectively suggest that technology and education are increasingly intertwined in academic research and practical applications. The global and multidisciplinary nature of this field emphasizes the need for continued collaboration, innovation and investment to harness technology's transformative potential in addressing educational challenges and advancing learning outcomes. The results reinforce the importance of ongoing research in bridging digital divides, developing effective strategies for implementation and ensuring inclusive access to technology-enhanced education worldwide.

3.2. Current Technology in Education

The review of articles revealed key insights into the application of advanced technologies in science and engineering education.

3.2.1. Internet of things (IoT)

Current research on IoT is presented in Table 2. IoT technologies are widely used to create smart classrooms and facilitate real-time data collection in experiments. IoT-enabled devices, such as sensors and RFID systems, enhance hands-on learning and automate administrative tasks like attendance tracking. IoT facilitates smart classrooms and enhances experimental learning. Devices like sensors and RFID systems are used for real-time data collection, automating tasks such as attendance tracking and environmental monitoring during experiments. This technology has an impact in providing hands-on learning opportunities and streamlines administrative tasks.

Table 2
Research on IOT

No.	Title	Ref
1	A systematic review of the IoT in smart university: Model and contribution	[37]
2	Mesh network based on MQTT broker for smart home and IIoT factory	[38]
3	Easy-mushroom mobile application using the Internet of Things (IoT)	[39]
4	Greening the internet of things: A comprehensive review of sustainable IOT solutions from an educational perspective	[40]
5	Water quality monitoring in citarum river (Indonesia) using IoT (internet of thing).	[41]
6	A systematic literature review of internet of things for higher education: Architecture and implementation	[42]
7	Greening the Internet of things: A comprehensive review of sustainable IOT solutions from an educational perspective.	[43]

IoT in education is revolutionizing how schools, teachers, and students interact with technology, fostering a more connected and efficient learning environment. IoT refers to the network of interconnected devices that collect, share and analyze data to automate tasks and improve decision-making. In the educational context, IoT enhances learning experiences, streamlines administration and improves campus management. IoT-enabled devices like smartboards, interactive displays and wearable technology make classrooms more engaging and interactive. Smartboards, for instance, allow teachers to integrate multimedia content, conduct polls and share notes in real-time, creating dynamic lessons. Wearable devices can track students' health metrics or physical activity, promoting wellness programs and enabling personalized interventions.

For students, IoT facilitates personalized learning through smart devices that adapt to individual needs. IoT tools, like connected tablets or educational apps, can analyze a student's performance and provide tailored recommendations for improvement. These devices enable self-paced learning, giving students control over how and when they learn. Additionally, IoT-powered tools help teachers monitor student progress and engagement, identifying areas where support is needed.

IoT also plays a critical role in campus management and safety. Smart security systems with connected cameras, sensors and alarms enhance the physical security of educational institutions. IoT-based attendance systems automate roll calls and track student attendance accurately. In energy management, smart lighting and HVAC systems reduce operational costs by optimizing resource use, contributing to eco-friendly campuses.

Despite its promise, IoT in education faces challenges such as data privacy, cybersecurity risks and high implementation costs. Schools must ensure that sensitive data, including student information, is protected from breaches. Additionally, educators need training to effectively use IoT technologies.

As IoT continues to evolve, its potential in education will expand, creating smarter classrooms, personalized learning experiences and more efficient institutions that cater to the diverse needs of modern learners.

3.2.2. Augmented Reality (AR)

Current research on AR is presented in Table 3. AR integrates virtual elements with real-world settings, enabling students to visualize abstract scientific concepts. For instance, AR applications can display 3D models of molecules or anatomy directly over textbooks or physical objects. This technology has an impact on enhancing the understanding of complex concepts through interactive and immersive experiences.

Table 3
Research on AR

No.	Title	Ref.
1	How to create augmented reality (AR) applications using unity and vuforia engine to teach basic algorithm concepts: Step-by-step procedure and bibliometric analysis.	[44]
2	Augmented reality for cultivating computational thinking skills in mathematics completed with literature review, bibliometrics, and experiments for students.	[45]
3	Development of augmented reality application for exercise to promote health among elderly.	[46]
4	Application of augmented reality technology with the fuzzy logic method as an online physical education lecture method in the new normal era	[47]

AR in education enhances traditional learning by overlaying digital information in the real world, creating an interactive and engaging learning experience. Unlike VR, which immerses users in a completely virtual environment, AR integrates virtual elements, such as images, text, or animations, with the physical surroundings, accessible through devices like smartphones, tablets, or AR glasses.

AR transforms how students interact with educational content by making learning more visual and hands-on. For instance, in a biology class, students can use AR apps to visualize the anatomy of a human body in 3D, allowing them to explore and understand complex systems interactively. Similarly, in geography, AR can bring maps to life by displaying dynamic data, such as population density or climate patterns, directly on a physical globe.

One of AR's most significant advantages is its ability to make abstract or complex concepts more accessible. By providing contextualized, interactive experiences, AR fosters a deeper understanding of subjects that may be challenging to grasp through traditional methods. It also promotes active learning, keeping students engaged and encouraging exploration.

AR is particularly effective in promoting inclusivity and accessibility. It can support diverse learning styles by offering multimodal content, catering to visual, auditory and kinesthetic learners. For example, AR can include real-time language translation or interactive sign language tools to aid students with different needs.

Despite its benefits, AR in education faces challenges such as high development costs, limited access to compatible devices, and the need for teacher training. Additionally, ensuring the content aligns with curricula and enhances learning outcomes is critical.

As AR technology advances and becomes more affordable, its integration into education is expected to grow, providing dynamic, immersive learning experiences that bridge the gap between theory and real-world application.

3.2.3. Virtual Reality (VR)

Current research on VR is presented in Table 4. VR creates fully immersive virtual environments where students can perform engineering experiments, explore historical sites, or simulate hazardous conditions safely. This technology gives impact in Offers risk-free practical learning and engagement with inaccessible environments.

Table 4
Research on VR

No.	Title	Ref.
1	Immersive intelligent tutoring system for remedial learning using virtual learning environment	[48]
2	The use of virtual reality as a substitute for the pre-school students' field trip activity during the learning from home period	[49]
3	Colleges of education lecturers' attitude towards the use of virtual classrooms for instruction	[50]
4	Students' learning experiences and preference in performing science experiments using hands-on and virtual laboratory	[51]
5	The effectiveness of using a virtual laboratory in distance learning on the measurement materials of the natural sciences of physics for junior high school students	[52]
6	Perception of early childhood education lecturers on the use of virtual learning	[53]
7	Lecturers perceived proficiency in the use of virtual classrooms for instruction in colleges of education	[54]
8	Development and acceptability of virtual laboratory in learning systematics	[55]
9	Utilization of virtual reality chat as a means of learning communication in the field of education	[56]

VR in education is transforming traditional learning by creating immersive, interactive environments that enhance engagement and understanding. VR technology uses 3D simulations and virtual spaces to allow learners to experience lessons as if they were physically present in the scenario, making abstract concepts more tangible and memorable.

In VR-based education, students can explore historical sites, conduct virtual science experiments, or interact with simulations of real-world situations. For example, a history student can "walk" through ancient Rome, while a medical student can practice surgical procedures in a risk-free, virtual environment. This hands-on approach promotes active learning, deepens comprehension and boosts retention compared to passive methods like reading or watching videos.

One of the key advantages of VR is its ability to provide experiential learning. It bridges the gap between theoretical knowledge and practical application, especially in subjects requiring high levels of visualization or practice. Fields like engineering, medicine, architecture and even soft skills training, such as public speaking, benefit from VR's immersive capabilities.

Additionally, VR enhances accessibility by bringing unique experiences to students regardless of their geographic or economic limitations. Schools can offer simulations that might otherwise be impossible due to cost, location or safety concerns, such as space exploration or dangerous lab experiments.

Despite its potential, VR in education has challenges. High initial costs for equipment, technical training for educators and the need for high-quality, curriculum-aligned content are barriers to widespread adoption. Prolonged use can also raise health concerns like motion sickness or eye strain.

As VR technology advances and becomes more affordable, its role in education is expected to grow, creating more personalized, engaging and effective learning experiences. By making learning immersive and interactive, VR helps bridge the gap between knowledge and real-world application, preparing students for future challenges.

3.2.4. Artificial Intelligence (AI)

Current research on AI is presented in Table 5. AI tools are increasingly being used for personalized learning and predictive analytics. AI-powered tutors and chatbots help students learn at their own pace, while AI analytics identify strengths and weaknesses to guide interventions. AI-powered tools personalize learning experiences, identify individual student needs and automate grading. AI-based chatbots provide round-the-clock assistance, while predictive analytics guide interventions for struggling students. This technology has an impact on increasing learning efficiency and supports educators with data-driven insights.

Table 5
Research on AI

No.	Title	Ref.
1	A review of artificial intelligence in security and privacy: Research advances, applications, opportunities, and challenges	[57]
2	Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages	[58]
3	Artificial intelligence (AI)-based learning media: Definition, bibliometric, classification, and issues for enhancing creative thinking in education	[59]
4	Trends in the use of artificial intelligence (AI) technology in increasing physical activity	[60]
5	Bibliometric analysis of research trends in conceptual understanding and sustainability awareness through artificial intelligence (AI) and digital learning media	[61]
6	The future of learning: ethical and philosophical implications of artificial intelligence (AI) integration in education	[62]
7	University students' awareness of, access to, and use of artificial intelligence for learning in Kwara State	[63]
8	Bibliometric analysis on artificial intelligence research in Indonesia vocational education	[64]
9	Primary education undergraduates' competency in the use of artificial intelligence for learning in Kwara State	[65]

AI is a branch of computer science focused on creating systems that can perform tasks typically requiring human intelligence. These tasks include learning, reasoning, problem-solving, understanding natural language and perception. AI aims to develop machines capable of mimicking cognitive functions, enabling them to make decisions, adapt to new information and interact intelligently with their environment.

AI can be categorized into two main types: narrow AI and general AI. Narrow AI is specialized in performing specific tasks, such as virtual assistants like Siri, recommendation algorithms, or facial recognition software. General AI, which remains a theoretical concept, would possess human-like intelligence and the ability to solve a wide range of problems across different domains.

AI relies on techniques such as machine learning, where algorithms learn from data and improve their performance over time without explicit programming. Deep learning, a subset of machine learning, uses artificial neural networks to process large amounts of data and recognize patterns. These technologies power applications like image recognition, natural language processing, and autonomous vehicles.

In various fields, AI has brought transformative changes. In healthcare, it aids in diagnosing diseases and analyzing medical data. In education, AI personalizes learning experiences and automates administrative tasks. In business, it enhances customer service, optimizes operations, and drives innovation. However, AI raises ethical concerns, including data privacy, bias, and the potential displacement of jobs. Ensuring responsible AI development requires addressing these issues and maintaining transparency and accountability.

AI continues to evolve, offering immense potential to solve complex problems and improve human life. As it integrates further into society, the challenge lies in balancing innovation with ethical and equitable use.

3.2.5. Learning Management Systems (LMS)

Current research on LMS is presented in Table 6. LMS is a software platform designed to facilitate the delivery, management, and tracking of educational content. In education, LMS platforms have become essential tools for managing online learning, blending traditional teaching methods with digital technology and enhancing the overall learning experience. LMS platforms like Moodle and Google Classroom manage educational content, track student progress and support blended learning approaches. This technology has an impact on centralizing educational resources and facilitates collaboration and feedback.

Table 6
Research on LMS

No.	Title	Ref.
1	Determinants of learning management system (LMS) adoption by university students for distance learning	[66]
2	The influence of spada learning management system (LMS) on algorithm learning and programming of first grade students at Universitas Pendidikan Indonesia	[67]
3	Diving deeper on their realms: The prominence of education on street children	[68]
4	The effectiveness of distance learning using learning management system media and whatsapp groups at senior high school	[69]
5	The attitude of distance learners towards the utilization of learning management system (A case study of National Open University of Nigeria)	[70]

At its core, an LMS serves as a centralized hub where educators can create, deliver and manage course materials, while students can access lessons, assignments and assessments. It supports both synchronous and asynchronous learning, allowing students to engage with content at their own pace or participate in real-time virtual classrooms. These systems are widely used in K-12 education, higher education, corporate training and professional development programs, providing flexibility and scalability to accommodate diverse learning needs.

One of the primary functions of an LMS is content delivery. Educators can upload various resources, such as lecture notes, videos, quizzes and interactive activities, and organize them into structured courses. Many LMS platforms also include tools for creating multimedia-rich content, which can improve student engagement. Students can easily access these materials through a user-friendly interface, often accessible on multiple devices, including computers, tablets and smartphones.

Another significant feature of an LMS is its ability to track and analyze student performance. Educators can monitor metrics such as course completion rates, grades, attendance and participation. This data-driven approach allows for personalized interventions, enabling teachers to identify struggling students and provide targeted support. Similarly, students can track their progress, view grades, and receive feedback, fostering a sense of accountability and self-direction in their learning journey.

Collaboration and communication are also integral to an LMS. Many platforms include features like discussion forums, group workspaces and messaging systems to facilitate interaction among students and between students and instructors. These tools help create a virtual learning community, even in fully online or hybrid environments. Real-time features like video conferencing and live chat further enhance communication, making remote learning more interactive and engaging.

Accessibility and inclusivity are additional advantages of LMS platforms. Features such as text-to-speech, subtitles for video content and adjustable text sizes ensure that learning materials are accessible to students with diverse needs. Additionally, LMS platforms can support multiple languages, enabling global accessibility and inclusivity.

Despite its many benefits, the implementation of an LMS comes with challenges. Setting up and maintaining the system can require significant technical expertise and resources. Teachers and students may also face a learning curve in adapting to the platform. Furthermore, ensuring data security and privacy is critical, as LMS platforms often store sensitive information about students and educators.

The role of LMS in education continues to evolve, driven by advancements in technology and the increasing demand for flexible learning solutions. By integrating features like artificial intelligence, gamification and adaptive learning, modern LMS platforms are becoming more effective at meeting the diverse needs of learners and educators. As a cornerstone of digital education, an LMS empowers institutions to provide accessible, personalized and scalable learning experiences for students worldwide.

3.2.6. Gamification

Current research on games in education is presented in Table 7. Gamification uses game elements in education, such as badges, leaderboards and challenges, through platforms like Kahoot and Quizizz. Minecraft Education also engages students in engineering and design tasks. This technology has an impact on boosting motivation and engagement, especially in younger learners.

Table 7
Research on gamification

No.	Title	Ref.
1	The use of the Natuna game about the natural wealth of the natuna marine on national awareness of the post-millennial generation	[71]
2	Examining the effects of online games on the academic performance of BPEd students of Sultan Kudarat State University, Philippines	[72]
3	Basic arithmetic learning through math online games for elementary school students during the pandemic	[73]
4	Ways to develop education for obtaining general physical qualities of young wrestlers through action games	[74]
5	Post-traumatic counselling through group games	[75]
6	Designing a notation card game media to improve the ability to read rhythmic music of 7th grade junior high school	[76]
7	Game-based activity method: A case of grade 5 students	[77]
8	Influence of gamification elements on students’ academic performance	[78]
9	Students’ attitude towards gamification-based teaching in mathematics in basic schools	[79]
10	Designing English education game application for early childhood	[80]
11	Application of scrabble game in improving learning of simple sentence structure on the student with hearing impairment	[81]
12	Undergraduate students’ awareness to adopt gamification for learning in University of Ilorin, Nigeria	[82]
13	Effect small side games (SSG) on playing skills in handball sports	[83]
14	Rehabilitation program for surgical shoulder joint protrusion among team games players injured	[84]

Gamification in education refers to incorporating game-like elements into learning environments to enhance engagement, motivation, and participation. By leveraging features such as points, badges, leaderboards, challenges, and rewards, gamification transforms traditional educational activities into interactive and enjoyable experiences, making learning more appealing and effective.

The primary goal of gamification is to tap into students’ natural curiosity and competitive instincts. It creates a sense of achievement and progression, which motivates learners to stay engaged with the material. For instance, a language-learning app like Duolingo uses gamified elements such as streaks, levels and rewards to encourage consistent practice and skill mastery.

Gamification can be applied across various educational contexts. In classrooms, teachers might use systems where students earn points for completing assignments, answering questions or participating in discussions. These points could be exchanged for rewards or used to achieve higher ranks on a leaderboard, fostering friendly competition. In online learning platforms, gamification enhances user engagement by breaking content into levels or modules that students must "unlock" as they progress.

One of the significant advantages of gamification is its ability to make learning more immersive. Complex subjects become easier to grasp through game-like scenarios or simulations. For example, a history lesson might involve role-playing games where students take on characters from a specific era, deepening their understanding of historical events.

Gamification also promotes active learning by encouraging problem-solving, critical thinking and collaboration. Team-based challenges and multiplayer games foster communication and teamwork, helping students develop social and interpersonal skills alongside academic knowledge.

Despite its benefits, effective gamification requires thoughtful implementation. Overemphasis on rewards can shift focus away from intrinsic learning goals, and poorly designed systems may lead to disengagement or frustration. When balanced correctly, gamification creates an engaging, motivating and impactful learning experience, making education enjoyable and relevant in today’s digital age.

3.2.7. 3D Printing

Current research on 3D printing for education is presented in Table 8. 3D printing enables students to prototype designs, create physical models and test engineering concepts. It supports hands-on learning and creativity. This technology has an impact on bridging the gap between theoretical and practical applications in engineering.

Table 8
Research on 3D printing

No.	Title	Ref.
1	Application of alum fixator for eco print batik making using a pounding technique in fine arts learning in junior high school	[85]
2	Potholes in the implementation of printed module in mathematics and feedbacks of learners in Lambayong national high school during covid-19 pandemic	[86]
3	Mechanical design and analysis of eco-print textile pounding machine	[87]
4	Analysis of student’s awareness of sustainable diet in reducing carbon footprint to support sustainable development goals (SDGs) 2030	[88]

3D printing in education is transforming how students learn by enabling hands-on, experiential learning through the creation of physical objects from digital designs. This technology allows students to turn abstract concepts into tangible items, fostering creativity, problem-solving and a deeper understanding of complex subjects.

In education, 3D printing plays a vital role. Students can design and print prototypes of engineering projects, visualize mathematical models or create biological structures, such as molecules or organs. This tactile approach enhances comprehension by bridging the gap between theoretical concepts and real-world applications. For example, in physics, students can print models of mechanical systems to study forces and motion, while in chemistry, they can build 3D representations of atomic structures.

3D printing also supports subjects like art, history and geography. In art, students can experiment with digital sculpting and create custom designs. In history, educators can use 3D printing to recreate artifacts, allowing students to study historical objects up close. Geography lessons can include printed topographical maps, giving students a physical sense of landscapes and terrains.

3D printing promotes problem-solving and critical thinking by encouraging students to engage in the design process. From conceptualizing and designing a model to iterating on prototypes, students learn to think creatively and iteratively. This hands-on experience prepares them for future careers in industries like engineering, healthcare, architecture and manufacturing.

While the benefits of 3D printing in education are substantial, challenges remain. These include high costs for equipment and materials, the need for technical expertise and integrating 3D printing into existing curricula. Educators must also address the environmental impact of plastic waste generated during printing. As 3D printing technology becomes more accessible and affordable, its role in education is expected to grow, offering innovative ways to enhance learning and inspire future innovators.

3.2.8. Robotics

Current research on robotics in education is presented in Table 9. Robotics education fosters programming, mechanics and automation skills. Tools like LEGO Mindstorms and Arduino introduce students to building and coding robotic systems. This technology has an impact on developing problem-solving abilities and encourages innovation.

Table 9
Research on robotics in education

No.	Title	Ref.
1	Smart materials and their application in robotic hand systems: A state of the art	[89]
2	Measurement enhancement of ultrasonic sensor using pelican optimization algorithm for robotic application	[90]
3	Detail experimental procedure for the construction process of robotic devices to teach aspect of auto mechanic	[91]
4	Evaluation of robotics class in a private school in the Philippines	[92]

Robotics in education is transforming traditional learning methods by integrating hands-on, interactive experiences that teach students about programming, engineering and problem-solving. By incorporating robots and robotics kits into classrooms, educators can engage students in STEM (science, technology, engineering and mathematics) fields while fostering critical thinking, creativity and teamwork.

One of the key benefits of robotics in education is its ability to make abstract concepts tangible. Through designing, building and programming robots, students gain practical experience with concepts such as coding, mechanics and electronics. For example, programming a robot to navigate a maze helps students understand algorithms and logic in a real-world context, making coding skills more accessible and relatable.

Robotics also supports collaborative and project-based learning. In many cases, students work in teams to design and program robots, which enhances communication, teamwork and leadership skills. These experiences mimic real-world engineering projects and prepare students for future careers in technology-driven industries.

For younger students, robotics kits like LEGO Mindstorms or VEX Robotics provide an introduction to problem-solving and engineering basics in a fun and engaging way. As students’ progress, more advanced robotics platforms introduce them to artificial intelligence, machine learning and IoT integration, broadening their understanding of cutting-edge technologies.

Robotics education is not limited to science and technology subjects. It can also be integrated into interdisciplinary lessons. For instance, students can use robots in art projects to create dynamic, interactive installations or in social studies to simulate historical events.

Despite its benefits, implementing robotics in education presents challenges, including high costs for equipment, the need for teacher training and ensuring equitable access. Schools must address these barriers to maximize the potential of robotics in education. As technology advances, robotics will play an increasingly vital role in education, inspiring innovation and equipping students with skills for the jobs of the future.

3.2.9. Cloud computing

Current research on cloud computing is presented in Table 10. Cloud platforms like Google Drive and Office 365 facilitate resource sharing, collaboration and remote learning. Students and teachers can work on projects in real-time from different locations. This technology has an impact on enhancing accessibility and fostering teamwork.

Table 10
Research on cloud computing

No.	Title	Ref.
1	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis	[93]
2	Cloud computing and education: A state-of-the-art survey	[94]
3	Teachcloud: a cloud computing educational toolkit	[95]

Cloud computing in education refers to the use of online services and resources, hosted on the internet, to support teaching, learning and administrative activities. It allows institutions, teachers and students to access, store and share data and applications remotely, facilitating greater flexibility, collaboration and scalability in the educational process.

One of the primary benefits of cloud computing in education is its ability to enable access to resources anytime and anywhere. This is particularly valuable in remote learning environments, where students can access course materials, assignments and lectures from any device with an internet connection. Teachers can upload lesson plans, multimedia content and assessments to the cloud, ensuring that students can easily access up-to-date resources.

Collaboration is another key advantage of cloud computing. Tools like Google Drive, Microsoft OneDrive, and Dropbox allow students and educators to share documents, work on group projects and provide real-time feedback. These platforms enable synchronous and asynchronous communication, fostering collaborative learning and reducing barriers related to location or time zones. Students can work together on presentations, research and assignments without needing to be physically present in the same location. Cloud-based LMS, such as Moodle, Canvas or Google Classroom, streamline administrative tasks, helping educators manage grades, assignments, attendance and student progress in a centralized platform. These systems also provide valuable data analytics, enabling teachers to track student performance and make data-driven decisions to improve instruction.

Cloud computing also supports personalized learning by offering scalable resources that can be tailored to meet individual students' needs. For example, cloud platforms can host adaptive learning tools and educational apps that adjust content and difficulty levels based on students' progress.

Moreover, cloud computing reduces the need for costly on-premise hardware and software, as resources are hosted remotely and can be accessed through any device. This makes it a cost-effective solution, especially for schools with limited budgets. Additionally, cloud platforms typically offer high levels of security and data protection, ensuring that student information is kept safe.

Despite its advantages, the widespread adoption of cloud computing in education requires overcoming challenges such as reliable internet access, data privacy concerns and the need for adequate training for educators. However, as cloud infrastructure continues to improve and become more affordable, its role in education is expected to grow, providing more efficient, flexible and collaborative learning environments.

3.2.10. Blockchain

Current research on blockchain in education is presented in Table 11. Blockchain technology ensures secure digital credentialing and transparent tracking of student achievements. It also addresses issues of data integrity in certifications and records. This technology has an impact on building trust and security in educational credentials.

Table 11
Research on Blockchain

No.	Title	Ref.
1	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis.	[96]
2	Blockchain in education management: present and future applications	[97]

Blockchain in education is an emerging technology that has the potential to transform how educational records, credentials, and learning experiences are managed and verified. Blockchain is a decentralized, distributed ledger system that ensures data is securely stored, transparent, and tamper-proof. In education, this technology can streamline processes, improve security, and empower learners by offering more control over their academic achievements.

One of the most promising applications of blockchain in education is the verification and management of academic credentials. Traditionally, verifying educational qualifications involves contacting institutions, which can be time-consuming and prone to errors or fraud. With blockchain, academic records such as diplomas, transcripts and certificates are securely stored in a digital ledger. This ledger is immutable, meaning that once a record is created, it cannot be altered or falsified. As a result, employers, universities or other institutions can verify credentials quickly and with confidence, reducing the risk of fraud.

Blockchain can also empower learners by giving them ownership of their educational data. Students can have access to a lifelong, portable academic record that they control and share with others as needed. This allows for more personalized learning experiences, as students can track their progress, achievements, and skills over time. Additionally, blockchain can facilitate the recognition of micro-credentials and digital badges, which are increasingly used to highlight specific skills and competencies gained outside traditional degree programs, such as through online courses or internships.

Another application of blockchain in education is the development of smart contracts. These self-executing contracts are programmed to automatically fulfill certain conditions once specific criteria are met. In education, smart contracts could automate administrative tasks such as payments for tuition fees, releasing certificates upon course completion, or ensuring that specific teaching materials are provided to students when certain conditions are met.

Blockchain also has the potential to enhance transparency in educational processes. By recording interactions, transactions, and academic performance on an immutable ledger, stakeholders can gain insights into decision-making and institutional operations. This transparency can build trust in educational institutions and ensure accountability. However, the adoption of blockchain in education faces challenges, including technological infrastructure, regulatory concerns, and widespread acceptance by institutions and employers. Additionally, integrating blockchain into existing educational systems requires significant investment in research, development and training for both educators and administrators.

Despite these challenges, blockchain holds great promise in reshaping the educational landscape. By improving security, streamlining administrative tasks and empowering students, blockchain has the potential to create a more efficient, transparent and student-centric educational ecosystem.

3.2.11. Machine learning (ML)

Current research on ML in education is presented in Table 12. ML in education is revolutionizing how students learn and how teachers teach by leveraging algorithms to analyze data, make predictions and deliver personalized experiences.

Table 12
Research on ML

No.	Title	Ref.
1	Prediction and classification of low birth weight data using machine learning techniques	[98]
2	Handwritten digit recognition using machine learning algorithms	[99]
3	Quality sorting of green coffee beans from wet processing by using the principle of machine learning	[100]
4	Evaluating the performance of supervised machine learning algorithms in breast cancer datasets	[101]
5	Online assessment of electric circuit based on machine learning during covid-19 pandemic situation	[102]
6	Machine learning-based CO2 hydrogenation to high-value green fuels: A comprehensive review for computational assessment	[103]

At its core, ML is a branch of artificial intelligence that enables systems to learn from patterns in data and improve their performance without explicit programming. In the educational context, this translates to more adaptive, efficient and inclusive solutions for students and educators alike. One of the most significant applications of machine learning in education is personalized learning. ML-powered systems can tailor educational content to meet individual students' needs, preferences and learning styles. For instance, adaptive learning platforms dynamically adjust the pace and complexity of lessons based on a learner's performance, helping them progress at their speed. This customization enhances engagement and ensures that students grasp foundational concepts before moving on to more advanced material. Another area where ML excels is predictive analytics. By analyzing data such as attendance, grades, and engagement levels, ML models can identify students at risk of falling behind or dropping out. These insights enable educators to intervene early, offering targeted support and resources to help struggling learners.

Similarly, ML can assist in career guidance by analyzing a student's skills, interests and academic achievements to recommend suitable career paths or higher education opportunities. Machine learning also plays a crucial role in automating assessments. Automated grading systems, powered by natural language processing, can evaluate both objective and subjective responses, saving educators significant time. Additionally, these systems can provide detailed feedback to students, helping them understand their mistakes and improve their performance. This not only streamlines the grading process but also enhances the quality of feedback, which is vital for effective learning. In the classroom, ML can optimize teaching strategies by analyzing data on student engagement and participation. It can suggest ways to make lessons more effective, improving outcomes for diverse groups of learners.

Furthermore, ML-driven tools enhance accessibility by supporting students with disabilities. Speech-to-text and text-to-speech technologies and real-time language translation services make education more inclusive and equitable. Despite its potential, the integration of machine learning in education comes with challenges. Data privacy is a major concern, as the use of student data must adhere to strict ethical guidelines. Bias in ML models, stemming from imbalanced or flawed training data, is another issue that can affect fairness. Moreover, implementing ML solutions often requires significant resources, including infrastructure and teacher training, to ensure these tools are used effectively. Looking ahead, machine learning promises even greater transformations in education. From immersive virtual classrooms to deeper insights into learning behaviors, the future holds immense possibilities. When implemented thoughtfully, ML can make education more personalized, efficient, and inclusive, empowering students and educators to achieve their full potential.

3.3. Discussion

The integration of these technologies has significantly enhanced the quality of science and engineering education by promoting engagement, accessibility and practical skills development (Figure 5). IoT and Big Data have enabled real-time analysis and personalized feedback, making experiments more interactive and data-driven. AR and VR address the challenge of visualizing abstract concepts, making subjects like physics and engineering more comprehensible.

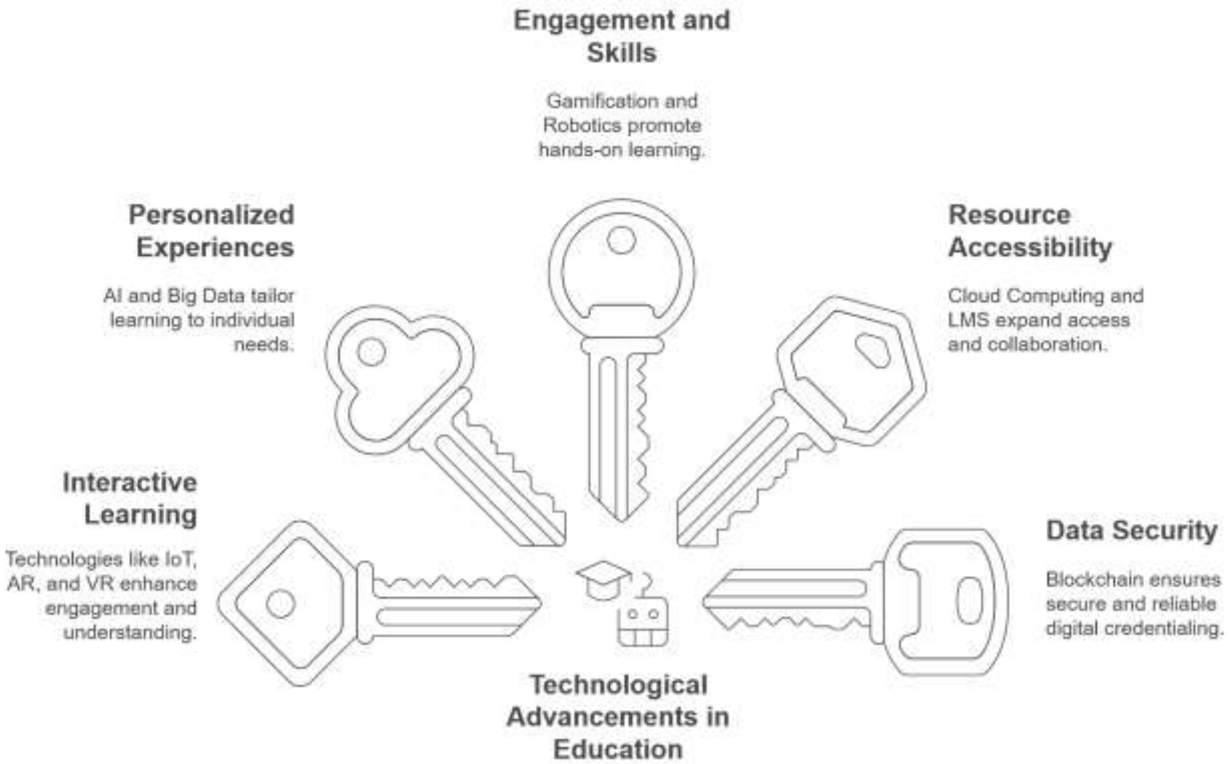

Fig. 5. Transformative technologies shaping future education landscapes

Each technology uniquely contributes to the advancement of education in science and engineering:

i. IoT, AR, and VR make learning more interactive and immersive, breaking down barriers to understanding complex topics.
ii. AI and Big Data provide personalized learning experiences and actionable insights for educators, optimizing teaching strategies.
iii. Gamification and Robotics increase engagement and foster practical skills development through hands-on projects and interactive learning.
iv. Cloud Computing and LMS democratize access to resources, promoting collaboration and flexibility in education.
v. Blockchain ensures data security and integrity, addressing concerns around digital credentialing.

The integration of advanced technologies such as VR devices, 3D printers and robotics kits into educational settings continues to face numerous challenges, with the high costs associated with implementing these tools significantly limiting their accessibility, particularly in underfunded institutions and schools in economically disadvantaged areas. These financial barriers are compounded by the lack of comprehensive teacher training programs and insufficient technological proficiency among educators, which together hinder the effective adoption and use of these innovations in classrooms. Furthermore, infrastructure issues, such as unreliable internet connectivity and inadequate power supply, particularly prevalent in developing regions, further widen the digital divide, making it even more difficult for students and teachers in these areas to benefit from the transformative potential of such technologies.

Despite the undeniable promise these tools hold for reshaping STEM education and equipping students with essential skills for a rapidly evolving technological landscape, their widespread adoption remains constrained by the aforementioned barriers. The persistence of these issues, especially in developing regions, underscores the urgent need to bridge the digital divide and create opportunities for equitable access to modern educational resources.

To overcome these challenges and fully harness the potential of these advanced technologies, it is essential to prioritize the development of affordable and scalable solutions that can be implemented even in resource-constrained environments. This effort should be complemented by significant investments in expanding teacher training programs, which would empower educators with the knowledge and skills necessary to effectively integrate these tools into their teaching practices. Additionally, policymakers must design and enforce strategies that promote equitable access to these technologies, ensuring that all students, regardless of their socioeconomic background or geographic location, can benefit from the advancements in educational innovation.

By addressing these interconnected challenges with a multifaceted approach, we can unlock the full potential of VR, 3D printing, robotics and other emerging tools to transform the way science and engineering are taught and learned. Such efforts will not only prepare students for a future defined by technological advancements but also create a more inclusive and equitable education system that leaves no one behind.

3.4. Challenges in Applying Technological Innovations

A challenge is a difficulty or obstacle that must be overcome to achieve a desired goal or outcome (Figure 6). In the context of integrating technology into science and engineering education, challenges are the barriers that hinder the effective adoption and implementation of technological tools and methods.

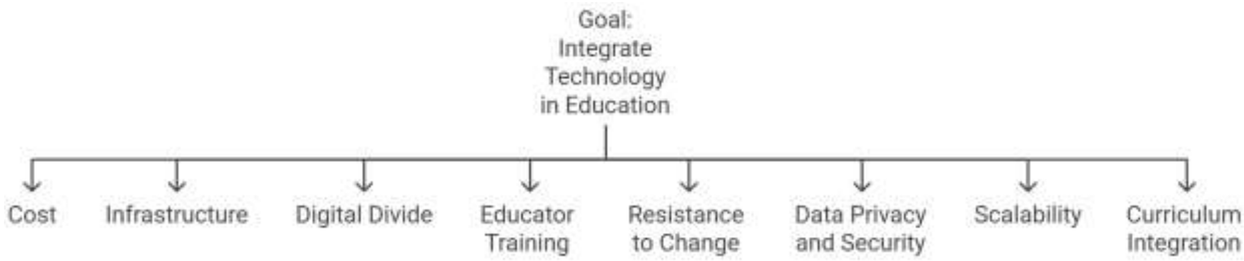

Fig. 6. Challenges in integrating technology in education

Some common challenges include:

i. Cost: High expenses associated with acquiring, maintaining, and upgrading advanced technologies such as IoT devices, AR/VR systems, and robotics can limit access, especially in underfunded institutions.
ii. Infrastructure: Inadequate internet connectivity, power supply issues, and lack of technological resources are significant barriers, particularly in rural or developing regions.
iii. Digital Divide: Unequal access to technology creates disparities in educational opportunities between different socioeconomic groups, regions, or countries.
iv. Educator Training: Teachers and instructors often lack the skills or training necessary to effectively integrate and use advanced technologies in their teaching practices.
v. Resistance to Change: Some educators or institutions may resist adopting new technologies due to comfort with traditional methods, fear of complexity, or skepticism about their effectiveness.
vi. Data Privacy and Security: The use of connected technologies, such as IoT and AI, raises concerns about protecting students' personal information and ensuring cybersecurity.
vii. Scalability: Implementing these technologies on a large scale while maintaining quality and effectiveness can be difficult, especially in regions with limited resources.
viii. Curriculum Integration: Aligning technological tools with existing educational curricula and ensuring that they contribute meaningfully to learning objectives can be a challenge.

By addressing these challenges through collaborative efforts, targeted investments, and innovative solutions, it is possible to maximize the benefits of technology in education and create more equitable and effective learning environments.

3.5. Future Prospects in Technological Innovations for Science and Engineering Education

The future of integrating technological innovations into science and engineering education is promising, as advancements continue to reshape teaching and learning environments (Figure 7).

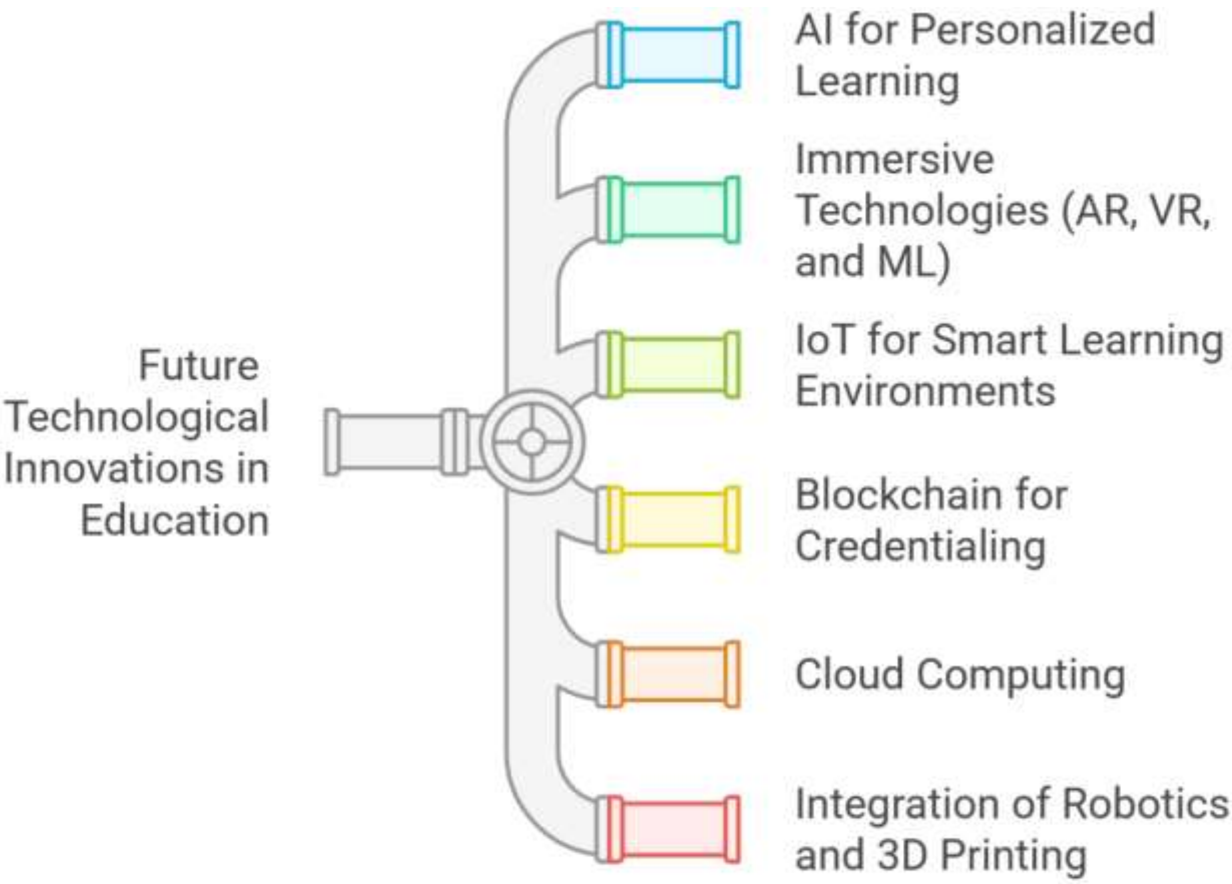

Fig. 7. Unveiling the future of EdTech

Several emerging trends and developments point to significant growth and potential impact in this domain.

i. AI for Personalized Learning. AI is expected to play a more significant role in tailoring educational experiences to individual learners. Adaptive learning systems, powered by AI, can analyze students' performance in real-time, identify their strengths and weaknesses, and adjust the difficulty level of tasks to optimize their learning outcomes. Additionally, AI-driven virtual tutors and chatbots will offer round-the-clock assistance to students, bridging gaps in traditional instruction.
ii. Immersive Technologies (AR, VR, and MR). Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) will revolutionize science and engineering education by providing immersive experiences. These technologies will enable students to engage with complex concepts, such as molecular structures or engineering systems, through simulations that mimic real-world scenarios. As the hardware for these technologies becomes more affordable, their adoption in classrooms is likely to expand.
iii. Internet of Things (IoT) for Smart Learning Environments. The IoT will continue to enhance learning environments by enabling interconnected smart classrooms. These settings can integrate sensors, wearables, and data-driven tools to monitor and improve student engagement, provide real-time feedback, and facilitate hands-on learning through remote experimentation.
iv. Blockchain for Credentialing and Transparency. Blockchain technology will revolutionize credentialing by ensuring secure, transparent, and tamper-proof records of academic

achievements. This will simplify verification processes for employers and institutions while empowering students with lifelong ownership of their educational records.

i. Increased Accessibility through Cloud Computing. Cloud computing will further democratize education by enabling seamless access to resources, collaboration tools, and learning management systems. This accessibility will bridge geographical and economic divides, making quality education available to underserved communities.
ii. Integration of Robotics and 3D Printing. Robotics and 3D printing will become more prevalent in science and engineering curricula, allowing students to engage in hands-on design and prototyping activities. These tools will not only enhance creativity but also prepare learners for careers in technology-driven industries.
iii. Big Data and Learning Analytics. Big data will be used to gain insights into student behaviors, preferences, and performance. This data will help educators refine their teaching strategies, predict learning outcomes, and implement targeted interventions for struggling students.
iv. Addressing Global Challenges. Technological innovations will increasingly focus on addressing global educational challenges, such as bridging the digital divide, promoting equity, and providing training for educators in resource-constrained regions. Collaborative international efforts will be crucial to ensure the benefits of these technologies are distributed equitably.
v. Sustainability and Eco-Friendly Practices. The future will see a stronger emphasis on sustainable practices in education technology, with efforts to minimize environmental impact. For example, eco-friendly materials in 3D printing and energy-efficient IoT devices will be prioritized.

The future of technological innovations in science and engineering education lies in creating more inclusive, engaging, and effective learning experiences. With continued advancements, these tools will empower educators to overcome traditional limitations and prepare students for the demands of a rapidly evolving technological landscape.

4. Conclusion

Technological innovations are profoundly transforming science and engineering education, offering interactive, immersive and hands-on learning opportunities that address traditional educational limitations. Technologies such as IoT, AR, VR, AI, Gamification and Blockchain have introduced new possibilities for engagement, accessibility and personalized learning. However, challenges such as high costs, digital divides, inadequate infrastructure and the need for educator training persist, particularly in resource-constrained regions. This study has emphasized the potential of these technologies to enhance educational outcomes by bridging gaps in understanding complex concepts, fostering critical thinking and preparing students for a technology-driven future. Addressing the barriers to integration requires collaborative efforts from educators, policymakers and technologists, as well as targeted investments to ensure equitable access. Future research should focus on scalable solutions, strategies to mitigate the digital divide and innovative ways to enhance teacher training programs. By addressing these challenges, the transformative potential of technology in science and engineering education can be fully realized, fostering an inclusive and dynamic learning environment.

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