Humanities and Social Sciences Communications

Article in Press

https://doi.org/10.1057/s41599-026-06565-w

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Received: 30 April 2024

Accepted: 20 January 2026

Cite this article as: Nedungadi, P., Thushara, M.G., Veena, G. *et al.* Emerging technologies for STEM education: global evidence on learning, equity, and SDG4. *Humanit Soc Sci Commun* (2026). https://doi.org/10.1057/s41599-026-06565-w

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Emerging technologies for STEM education: Global evidence on learning, equity, and SDG4

This study synthesizes research on emerging technologies in STEM education, investigating their potential to transform learning environments, enhance gender equity, use learning theories and impact SDG4 targets. In accordance with the PRISMA guidelines, the present study included 1,990 publications pertaining to STEM education from the Scopus database during the last decade. BERTopic modeling was used for the analysis, and the results identified four pivotal technologies: robotics, artificial intelligence (AI), extended reality (ER), and interconnected smart systems. The findings suggest that these technologies enhance technical and cognitive skills. The study identifies strategies used for gender equity and inclusion through these technologies. Although cognitive and psychological theories, social and behavioral theories, and experiential and action-based learning have been used in learning systems, the lower numbers of such studies indicate that gaps remain in the adaptation, integration, and evaluation of educational theories with these technologies. The study identified SDG4.4 as the most researched target for equipping students with essential skills for the modern workforce through immersive, practical experience. Key implications for practice and policy include integrating learning theories with emerging technologies, advancing SDG4 outcomes, and enhancing professional development and educational equity. This highlights the incorporation of generative AI to further personalize learning experiences and the metaverse to facilitate collaborative environments.

Keywords:

Introduction

Emerging technologies such as robotics, artificial intelligence (AI), and metaverse have transformed science, technology, engineering, and mathematics (STEM) education, redefining learning paradigms with personalized learning, programming education, adaptive assessment and learning, entrepreneurship, and immersive technologies (Achuthan et al., 2025; Bybee, 2010; Dwivedi et al., 2022; Guo et al., 2019; Nedungadi et al., 2025; Parvathy et al., 2025). A report on U.S. graduate STEM education emphasized enhancing student core competencies, technical literacy, inclusive environments, and mentorship to meet evolving career demands (Ananthram et al., 2024; Cheryan et al., 2025; Leshner, 2018). The importance of skill acquisition in undergraduate STEM programs, which is crucial for economic growth, highlights the positive relationship between a nation's human capital and its economic development (Loyalka et al., 2021; Parada-Contzen & Jara, 2025).

Despite significant progress in recent decades, gender disparities in STEM participation and retention remain a global concern, with women and girls from historically marginalized communities facing compounded barriers to accessing and succeeding in these critical fields. However, innovative technological approaches are reshaping how we approach gender equity in STEM education, offering new paths to create more inclusive learning environments. Effective strategies for gender equity, such as strong faculty mentorship, hands-on learning, and culturally responsive teaching methods, increase female participation and retention in STEM fields (Delgado et al., 2019; Keller & John, 2020; Raman et al., 2025; Yu et al., 2023). Inclusive programs connect students from historically marginalized communities to real-world STEM opportunities and professionals (Leal Filho et al., 2023; Ludwig et al., 2024; Parada-Contzen & Jara, 2025). Furthermore, online and blended STEM instruction can match traditional class outcomes at lower costs, increasing access and affordability (Chirikov et al., 2020; Li et al., 2025; Peng et al., 2025), whereas AI-driven predictive analytics help address high dropout rates in STEM MOOC courses to increase learning effectiveness (Xia & Qi, 2024).

This study is important because emerging technologies for learning systems can support student engagement and learning outcomes by addressing global educational disparities (Nedungadi et al., 2024). It further looks at learning theories that are integrated into educational systems. With respect to emerging technologies in STEM education, we first focus on AI, as it can be used with other emerging technologies. AI-based learning systems offer insights into complex subjects through customized learning experiences and enhanced support systems (Wu et al., 2024), the use of natural language processing for intelligent tutoring system feedback mechanisms (Fong et al., 2022), eye tracking in programming education (Chandrika & Amudha, 2025) and predictive analytics to support students who require additional aid (Chiang et al., 2021), and generative neural networks (GNNs) to study student susceptibility to misinformation from AI-generated learning content (Yu & Wu, 2021).

Transitioning from AI, the Internet of Things (IoT) offers hands-on learning experiences. IoT-based learning offers practical and hands-on learning experiences (He et al., 2016; He et al., 2018) and promotes inquiry-based and project-oriented learning (Kusmin, 2019). Extended reality (XR) technologies, including augmented reality (AR) and virtual reality (VR), enhance STEM education through immersive and interactive learning to understand and retain complex concepts (Holly et al., 2021; Kaviyaraj R. et al., 2022; Nagpal N. et al., 2023). These technologies foster active participation and collaboration, impacting problem-solving and critical-thinking skills (Raman et al., 2024). The transition toward digital twins, digital humans, and 3D internet represents a significant advancement toward connected, interactive, and comprehensive digital learning environments (Acker et al., 2023; Gómez-Carrasco et al., 2019; Li & Zaki, 2024; Pellas et al., 2017; Rahman et al., 2024).

Educational robots and chatbots enhance learning modes (Chen et al., 2023), influence early education by developing critical cognitive skills and environmental awareness (Alam, 2022; Andruseac et al., 2016; Ioannou & Makridou, 2018), and advance computational thinking. Educational outcomes align with labor market demands through collaboration between academia and industry (Abidin et al., 2021; Çetin & Demircan, 2020; Sergeyev et al., 2019). Robotics have enhanced education with practical applications across disciplines (Dolgopolovas and Dagienė, 2021; Hsu & Tsai, 2022; Lehmann & Rossi, 2019), such as a robotic testbed for real-time control to conduct efficiency experiments in transportation (Chalaki et al., 2022). Updates to engineering education platforms highlight evolving design considerations and evaluation practices (Cecil et al., 2021). In South Africa, a dialog-based early-grade STEM reading programme proposes a conceptual framework to seed STEM foundations within primary curricula (Bezuidenhout, 2021).

Integrating cybersecurity principles into STEM education increases students' awareness of digital threats and helps them responsibly navigate and secure digital environments (Boltsi et al., 2024; Botha-Badenhorst & Veerasamy, 2023; Wusylko et al., 2022). Emerging fields such as blockchain (Dziatkovskii et al., 2022) and quantum computing (Holincheck et al., 2024) are being gradually integrated into STEM curricula, with implications for data security, computational capabilities, and the development of new computational algorithms. Quantum dicturalism, a visual approach to quantum education, has made quantum theories accessible (Dundar-Coecke et al., 2023).

Learning cybersecurity through gender-inclusive digital forensics programs has been shown to increase girls' interest in related careers while maintaining boys' engagement (Casey et al., 2023). Curricular modernization is also driven by the application of computational and mathematical methods that connect coursework to domains such as cybersecurity, data analytics, and robotics (Ortiz-Rojas et al., 2025; Riabov, 2020; Zárate-Navarro et al., 2024). Undergraduate biology curricula are shifting from merely using computational tools to actively developing them, positioning programming and data skills as core competencies for 21st-century STEM graduates (Archila et al., 2024; McDonald et al., 2022).

Considerable research has enriched our understanding of effective teaching methodologies, student assessments, and the roles of teachers and parents in nurturing children's education. Spatial thinking and cognitive processes in visualization comprehension play a key role in interpreting visualizations across STEM fields (Taylor et al., 2023), whereas a multiaspect visualization framework supports pedagogy for computer science virtual labs (Swaminathan et al., 2024). Psychomotor performance in task-based STEM learning in Arduino-based educational robotics utilized a convergent parallel mixed method (Chang & Chen, 2022). An assessment scale for student collaboration abilities in STEM classes uses item response theory (Arlinwibowo et al., 2021). A maker literacy assessment model was developed for Chinese primary school students (Min et al., 2024). The effectiveness of dropout prediction and intervention in MOOCs involves the use of behavioral data to enhance STEM learning (Xia and Qi, 2024), whereas another study investigated the prediction of the risk of failure from student data from an intelligent tutoring system (Haridas et al., 2020). The influence of parental beliefs and behaviors on students' motivation in science shows the positive impact of parental education and involvement (Pinneo & Nolen, 2024; Zhan & Niu, 2023). The challenges and opportunities of online learning were illustrated in the Ed+gineering project (Gutierrez et al., 2023) and for online proctored exams (Raman et al., 2021a; Zhang et al., 2023).

The incorporation of learning theories such as constructivism, social cognitive theory, and universal design for learning (UDL) into learning systems can improve engagement and understanding (Al-Azawi et al., 2019; Alsoliman, 2022; Cecil et al., 2013; Johnson-Glenberg et al., 2018; Ntemngwa & Oliver, 2018). One study used the theory of change to broaden participation in education with communications technologies (Moon et al., 2015). Another group offers teachers various pedagogical approaches that are suitable for computing education for autistic children and identifies teachers' knowledge of concept maps as a gap (Shah et al., 2024).

Having outlined the significant enhancements that emerging technologies bring to STEM education, we now turn to specific research questions. We begin with emerging technologies owing to their potential to transform educational environments and methodologies. The next step is to focus on gender, address equity challenges, and understand how technological interventions can foster inclusive practices. Learning theories are analyzed to ensure that technological advances are pedagogically effective. Finally, we ground our analysis in SDG4 to assess how these technologies contribute to broader educational goals. The study answers the following research questions (RQs):

- RQ1: How do emerging technologies influence learning outcomes and engagement in STEM education?
- RQ2: What are the effective strategies and interventions for promoting gender equity in STEM education through emerging technologies?
- RQ3: How do various learning theories enhance the implementation and effectiveness of emerging technologies in STEM education?
- RQ4: How can STEM education through emerging technologies be aligned with and contribute to achieving the SDGs?
- RQ5: What are the necessary policy measures and practical strategies to support the integration of emerging technologies in STEM education?

Theoretical background

Integrating learning theories into the design and implementation of emerging technologies such as AI and metaverse STEM can enhance engagement and deepen the understanding of STEM concepts (Johnson-Glenberg et al., 2018). Technologies such as AI and adaptive systems are pivotal because they customize content to meet diverse learners' needs by providing multiple ways to engage, represent, and express educational content (Nedungadi & Raman, 2012; Yoel & Dori, 2022).

Constructivism argues that learners build knowledge through hands-on experiences. VR aligns with this theory by allowing students to manipulate virtual environments, enhancing learning and comprehension (AlGerafi et al., 2023; Johnson-Glenberg et al., 2018). Cognitive load theory considers the brain's processing capacity, and AI can be used to adjust content difficulty on the basis of the learner's current understanding, optimizing educational efficacy (Xu & Ouyang, 2022). Furthermore, social cognitive theory emphasizes learning through observation and social interaction, which is particularly effective when integrated with robotics. These technologies facilitate collaborative, hands-on projects that enrich learning through active and social engagement, offering real-time interaction and feedback that underpins this theory (Ntemngwa & Oliver, 2018). Transitioning from social interaction to broader accessibility, universal design for learning (UDL) advocates for educational access for all students.

Behaviorism views learning as a response to external stimuli and is supported by immediate feedback, adaptive quizzes and interactive simulations that respond to students' actions (Kewalramani et al., 2020). Learners can achieve more with targeted guidance within the Zone of Proximal Development (Vygotsky, 1978), facilitated by AI tutors or peer collaboration in digital settings (Thompson et al., 2018). Virtual labs support experiential learning by allowing students to interactively engage and reflect on these experiences to gain deeper insights (Achuthan et al., 2020; Raman et al., 2021b; Raman et al., 2022). Integrating game-based learning elements in context-dependent educational settings enhances motivation (Petrović et al., 2022) and aligns with situational learning theory. Thus, emerging technologies informed by learning theories have the potential to transform STEM education.

Methods

PRISMA protocol. The present study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, as detailed by Page et al. (2021). This protocol has been found to be effective for bibliometric studies across various fields of research (Raman et al., 2023; Raman et al., 2024). On the basis of the literature, the search incorporated STEM-related keywords (e.g., STEM, STEM education; Huang et al., 2022) and keywords related to emerging educational technologies (e.g., Dwivedi et al., 2023; Xu & Ouyang, 2022; MD & Krishnamoorthy, 2025; MD & Krishnamoorthy, 2022). The search was conducted in the Scopus database. The search period was set from 2013--2024 to capture the latest trends in STEM education research. The search yielded 2,120 publications.

The selection criteria for eligible papers are outlined below. First, to include as many research publications as possible, this study included the full range of educational levels within STEM education (e.g., primary, secondary, and higher education). However, erratum, retracted documents, and documents written in a language other than English were excluded from the analysis. Consequently, 130 out of 2,120 publications were excluded, resulting in the retention of 1,990 publications for subsequent BERTopic modeling analysis. The analysis focused on the primary content of these documents, such as titles, abstracts, and indexed keywords (Fig. 1).

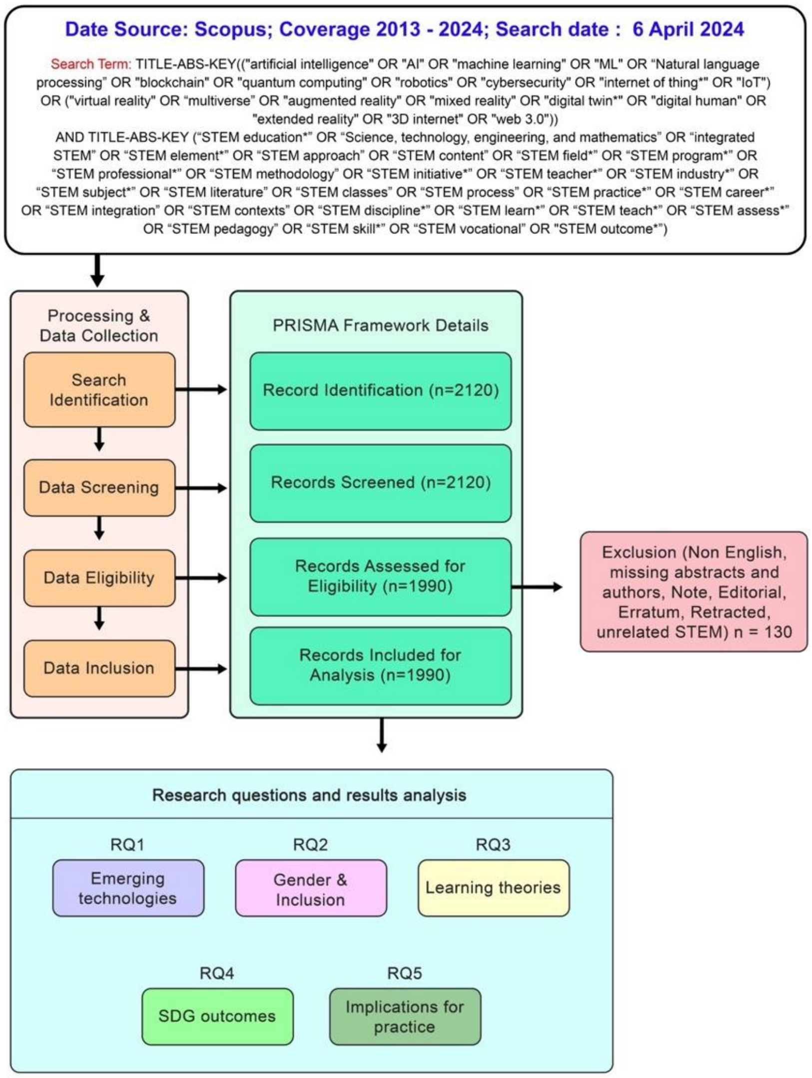

Fig. 1 Process of data inclusion via the PRISMA protocol

Topic modeling. BERTopic modeling was used to identify the main themes (Grootendorst et al., 2022). Compared with traditional methods such as latent Dirichlet allocation, it uses pretrained BERT embeddings to improve accuracy in detecting topics (Egger & Yu, 2022). BERTopic was implemented in a Python framework with transformers and a Class-Tf-idf-Transformer to cluster topics effectively. The methodology includes data preprocessing, such as text cleaning, NLP technique application, and tokenization. The BERTopic algorithm then analyzes the texts to extract and align topics, using probability analysis to improve interpretability. Coherence analysis and publication distribution review provide insights into thematic alignment.

SDG mapping. The "Knowledge Base for the Sustainable Development Goals" features the SDG Mapper tool, a central resource for analyzing EU policy, indicators, and data related to the SDGs (European Commission, 2021). Using bubble charts, the tool shows SDG interconnections and relevance across records. It employs NLP techniques to detect SDG mentions in bibliometric records, with machine learning algorithms analyzing the data to link publications to the corresponding SDGs. This process uses a rule-based approach to identify keywords or phrases related to each SDG, facilitating efficient mapping.

Results

BERTopic modeling identified five distinct themes, as shown in Fig. 2, including robotics in STEM, AI in STEM education, extended realities for STEM learning, and smart connected systems that inform RQ1. It also identifies a topic for gender equity in STEM that informs RQ2. Additional analyses show the integration of learning theories in STEM technologies (RQ3) and their alignment with SDG4 (RQ4). Evidence from embodied VR activities shows learning and agency gains relative to 2D conditions (Johnson-Glenberg et al., 2020).

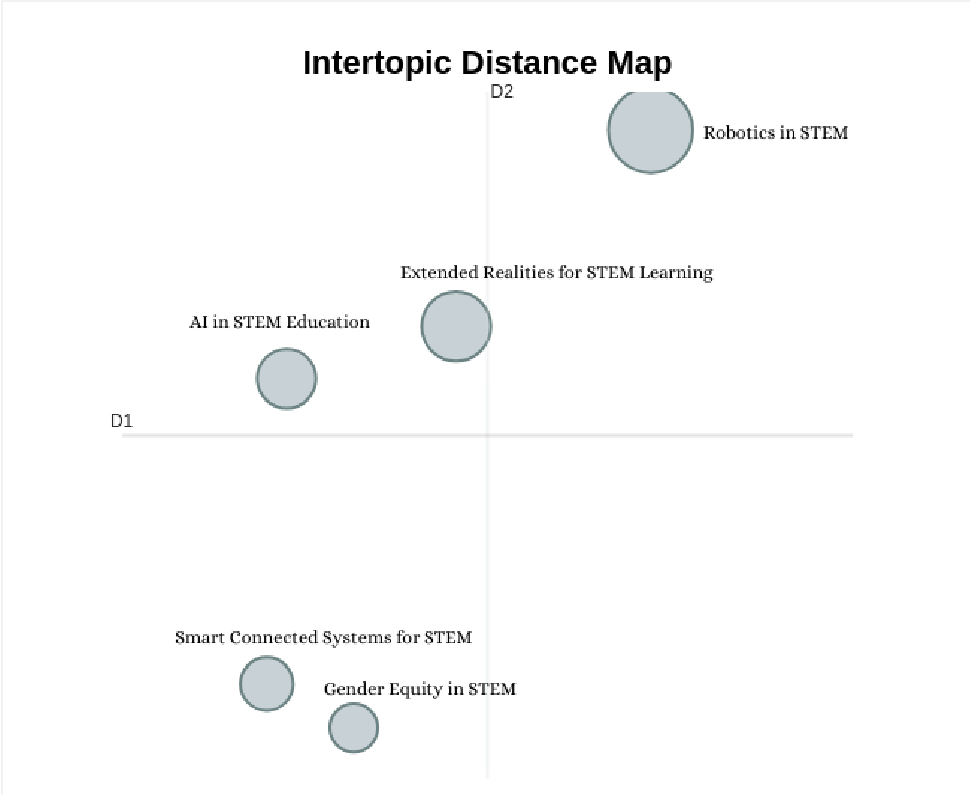

Fig. 2. An intertopic distance map of AI and emerging technologies in STEM education research

RQ1: Emerging topics

Table 1 (Annexure) shows a representative list of articles mapped to emerging topics.

Robotics in STEM. By exploring the dynamic integration of robotics in STEM education, a systematic review and various studies revealed its significant impact on the development of critical competencies among students.

Darmawansah et al. (2023) highlighted the prevalent use of LEGO tools and project-based learning in robotics-based STEM education, emphasizing technology and programming. It reveals a focus on enhancing student competencies in problem-solving and interdisciplinary applications. Recommendations include expanding research methodologies, diversifying educational tools, broadening the geographic scope of studies to enhance robotics integration in STEM curricula, and fostering critical thinking, problem solving, and collaboration skills among students. A study by Zhong et al. (2020) revealed that integrating virtual and physical robots (VRRs) in robotics education not only enhanced engineering design skills, indicating improved higher-order thinking and complex problem-solving abilities but also reduced the cognitive load, making the learning process less mentally taxing and more efficient. These findings demonstrate the benefits of incorporating virtual technologies into robotics education to develop complex skills and ease cognitive demands. Educational robotics interventions report gains in student motivation within Latin American classrooms (Lancheros-Cuesta & Fabregat, 2022). Preschool robotics interventions increase task engagement while fostering early computational thinking (Gerosa, Koleszar, Tejera, Gómez-Sena, & Carboni, 2022).

In a STEM project in which elementary students were programmed to assess primate intelligence, notable improvements in computational thinking were observed, along with sustained or increased interest in STEM fields such as animal science, computers, and robotics (Cantlon et al., 2024). Teacher feedback highlighted enhancements in students' critical thinking and leadership skills, supporting the efficacy of experiential and authentic learning environments in elementary education. This approach effectively engages students and enriches their educational experience, offering a viable model for similar STEM educational settings.

Overall, the integration of robotics, both virtual and physical, as well as programming in elementary education settings, not only enhances specific technical skills but also fosters essential soft skills such as critical thinking and collaboration, aligning with the broader goals of SDG4 to ensure inclusive and equitable quality education. European collaborations report structured robotics pedagogy for primary settings with documented learning gains (Mangina et al., 2024).

AI in STEM education. AI is transforming STEM education, with various applications ranging from predictive analytics to intelligent tutoring systems that personalize learning experiences. In Latin America, classroom studies have used conversational AIs such as ChatGPT and Bing Chat as 'objects to think with' to support reflection and concept understanding in STEM activities (Vasconcelos & Dos Santos, 2023).

A systematic review of AI applications in STEM education identified key areas of focus that can transform and enhance STEM education (Xu & Ouyang, 2022). These include learning prediction, identifying at-risk students, and intelligent tutoring systems (ITS). AI can provide personalized learning and feedback to enhance adaptive learning (Samala et al., 2024).

The study also highlights student behavior detection, highlighting AI's ability to monitor and analyze learning behaviors. Additionally, the role of automation in assessment and question generation is discussed as a supportive tool for instructors and students. Finally, educational robots are noted for their ability to improve interactive learning experiences and teach operational skills. A professional development program designed to integrate AI methods into STEM classrooms features interactive tools and exercises within Google Colab notebooks and aims to enhance teachers' practical understanding of AI technologies (Lee & Perret, 2022). The findings indicate that teachers improved their AI knowledge through the program and suggest the need for further curriculum refinement to address challenges in AI coding and integration into existing educational frameworks. This study highlights the importance of teacher professional development in advancing AI literacy to prepare students for a future where AI is integral to education. Such integration aligns well with the SDG4 goal of ensuring inclusive and equitable quality education for all (Zawacki-Richter et al., 2019). Context-bound cognitive scores enable early-risk prediction and feedback, whereas knowledge graphs track cross-platform progression for targeted support in STEM courses (Md & Krishnamoorthy, 2022; MD & Krishnamoorthy, 2025). By enhancing AI literacy among educators and students alike, these AI implementations in STEM education not only improve immediate educational outcomes but also prepare students for future challenges and opportunities in a rapidly evolving technological landscape.

Extended realities for STEM learning. Extended reality systems are emerging as powerful educational tools that provide immersive experiences to improve both retention and comprehension of scientific concepts. A study on vector instruction reports improved understanding through VR-based manipulation of abstract representations (Campos, Hidrogo, & Zavala, 2022).

The metaverse promises opportunities for gamified learning and role-playing, which can make complex STEM concepts accessible and engaging. These technologies provide learners with firsthand experiences that traditional educational settings cannot offer, presenting new opportunities for engagement and instructional delivery (El Said, 2023).

A study on the use of augmented reality (AR) in museums and science centers revealed that AR not only increases visitor engagement but also significantly enhances the understanding and retention of scientific concepts (Goff et al., 2018). The study highlights that AR applications allow visitors to interact with exhibits in ways that are otherwise impossible, providing immersive experiences that make complex scientific data more comprehensible and engaging. A review of the use of immersive virtual reality (VR) across various educational settings revealed that VR significantly boosts learning outcomes, student engagement, and motivation (Pellas et al., 2020). The findings suggest that VR facilitates an immersive learning environment that enhances students' spatial reasoning and problem-solving abilities, allowing for a deeper understanding of STEM concepts. Furthermore, VR has been shown to increase student presence and empathy within learning scenarios, which can lead to more profound educational experiences. Another systematic review documented the impactful role of AR in STEM education, with improvements in conceptual understanding and student engagement (Sırakaya & Alsancak Sırakaya, 2022). This review details how AR aids in visualizing abstract concepts and provides hands-on experiences that are crucial for effective learning. Additionally, the review noted that AR can significantly enhance collaborative learning opportunities and tailor educational experiences to individual learning styles. AR smartglasses have supported the visualization of circuit principles and streamlined measurement workflows in undergraduate laboratories (Kapp et al., 2019). Studies from Bulgaria report that AR interventions improve motivation and learning outcomes in informatics coursework (Petrov & Atanasova, 2020).

Haptic-glove virtual laboratories further broaden access by enabling visually impaired and sighted students to perform multisensory STEM lab work in VR, improving participation and learning outcomes (Kaufhold & Steinert, 2024).

These extended reality technologies, through hands-on, engaging learning experiences, are reshaping traditional educational environments and are pivotal in fostering a deeper understanding of STEM disciplines among students.

Smart Connected Systems for STEM. Smart connected systems, which utilize the Internet of Things (IoT) and cloud computing, provide more interactive, connected, and responsive learning environments. African higher-education pilots also report digital game-based tools that improve engagement in electronics instruction (Ajayi, Adetiba, Ifijeh, Abayomi, Wejin, Thakur, & Moyo, 2024).

A systematic review of publications on the IoT curriculum, pedagogy, and assessment for STEM education focused on the implementation of the IoT curriculum and instructional approaches across educational levels (Abichandani et al., 2022). Their analysis revealed that IoT-based educational initiatives in K-12 and university settings enhance STEM education by integrating low-cost IoT hardware and open-source software. The study highlights the effective use of active learning approaches and various assessment methods to equip students with essential IoT skills. Fabrication-as-a-service (FaaS) is a novel, cost-effective approach for overcoming the financial and logistical barriers associated with the establishment of fabrication laboratories (Fab Labs) in educational settings (Cornetta et al., 2020). Their study, which was part of the European Union Horizon 2020 NEWTON project, demonstrated how FaaS utilizes a cloud-based hub and network of distributed Fab Labs to ensure scalability, high availability, and security. The deployment uses a master–slave architecture with inexpensive external hardware to monitor and control high-cost fabrication equipment, presenting a sustainable model for educational institutions. This approach facilitates hands-on learning experiences but also prepares students for future careers in manufacturing and engineering by providing practical, real-world applications of IoT technologies.

The incorporation of the IoT and other smart technologies in educational settings enhances the learning experience through greater interactivity, training learners for future careers in a connected world and supporting sustainable development goals by promoting inclusive and lifelong learning opportunities.

RQ2: Gender equity in STEM.

Gender equity in STEM fields remains a critical issue, as highlighted by studies focusing on disparities in the participation rates and experiences of female participants in competitive STEM environments.

A study on gender disparities in STEM education focusing on female participants in the World Robot Olympiad from 2015--2019 revealed that girls accounted for only 17.3% of the participants in the finals, with a notable decrease in participation as age increased (Chiang et al., 2024). The findings underscore the necessity for coaches, mentors, and parents to provide more support and encouragement to nurture girls' interest in STEM, particularly through increased exposure in competitive settings such as robotics competitions. This support is crucial in junior high school for maintaining and enhancing girls' engagement in STEM fields. Environmental influences on female students' perceptions of STEM studies emphasize the need for supportive educational environments to encourage greater female participation in engineering and other STEM fields (Tsakalerou et al., 2024). The findings show a lack of gender parity in STEM disciplines, which impacts innovation and development. Kazakhstan's efforts to promote gender equality in education are crucial for achieving diversity and inclusion in the workforce. Generative AI (GAI) in educational curricula in STEM fields broadens student engagement, but there is a need for research on how early GAI exposure can influence students' interest in STEM careers, with a focus on gender disparities (Nedungadi et al., 2025). GAI has the potential to update content on the basis of culture and context, increase inclusivity and support remote education

(Shankar et al., 2025). While the GAI offers supportive features, challenges include security and privacy (Samala et al., 2025). Latin American initiatives document gender-equity programming and curricular innovations in engineering education (Lara-Prieto et al., 2024).

RQ3: Learning theories.

When integrated with specific learning theories, emerging technologies can enhance understanding, accessibility, and engagement in STEM education. Table 2 (Annexure) shows a representative list or articles that used learning theories with STEM and emerging technologies.

AI-based technologies, for example, optimize educational systems within the frameworks of general systems theory, addressing diverse learning needs and contexts (Xu & Ouyang, 2022). VR technologies enhance spatial awareness and problem-solving skills through immersive experiences (Johnson-Glenberg et al., 2018) and potentially improve cognitive processes and biology education outcomes by engaging multiple sensory modalities (Klingenberg et al., 2023; Christopoulos et al., 2023). Robotics support hands-on and inquiry-based learning, which is essential for developing critical thinking and scientific inquiry skills. It facilitates integrated STEM learning through practical, technology-based teaching (Ntemngwa & Oliver, 2018), enhances student engagement and interest in STEM fields (Zainal et al., 2018), and examines the influence of robotics on career choices (Yoel & Dori, 2022). Furthermore, robotics helps develop instruments to measure science identity, linking participation to STEM persistence (Lockhart et al., 2022). Augmented reality (AR) and smart sensors have been used in interactive electrical experiments that incorporate visual and tactile feedback, enhancing learning through multimedia learning theories (Kapp et al., 2022). For the IoT and practical applications, a STEM teaching model that combines theory, practice, and innovation and focuses on cohesive learning experiences is grounded in design-based learning (Chen et al., 2020). Situated learning has also been utilized to enhance engineering education by applying theory in real-world settings, making education more practical and contextually relevant (Marouani, 2022). Overall, these educational integrations highlight how various theories effectively support the adoption of emerging technologies to revolutionize STEM education, ensuring more engaging and inclusive learning experiences for students.

RQ4: SDG4 outcomes.

Fig. 3 presents the integral role of emerging technologies in STEM not only for SDG 4 but also for other SDGs, including (listed here from highest to lowest number of mapped responses

The most frequently cited target was SDG4.4, which appeared in 175 papers (Table 3 of Annexure). The most frequently cited target in this study was SDG4.4—the importance of the skills dimension. This suggests that a key focus of STEM education research is the use of emerging technologies to provide students with practical, hands-on learning experiences that prepare them for the demands of the modern workforce. For example, the integration of robotics in STEM education has been shown to enhance students' problem-solving, collaboration, and critical thinking skills (Tan et al., 2023; Xu et al., 2023). Researchers have also indicated that the use of virtual and augmented reality technologies in STEM classrooms can create immersive learning environments that simulate real-life scenarios, enabling students to apply their knowledge and skills in a realistic setting (Ibáñez & Delgado-Kloos, 2018; Sırakaya & Sırakaya, 2022). The second most frequently cited goal was SDG4.c (n = 108 papers). Researchers have highlighted the critical role of teacher professional development in achieving the SDG4.c goal in STEM education (Huang et al., 2022). Other frequently cited targets, such as SDG4.b (n = 27 papers), SDG4.5 (n = 26 papers), and SDG4.1 (n = 24 papers), emphasize the potential of STEM education to promote educational equity and inclusion.

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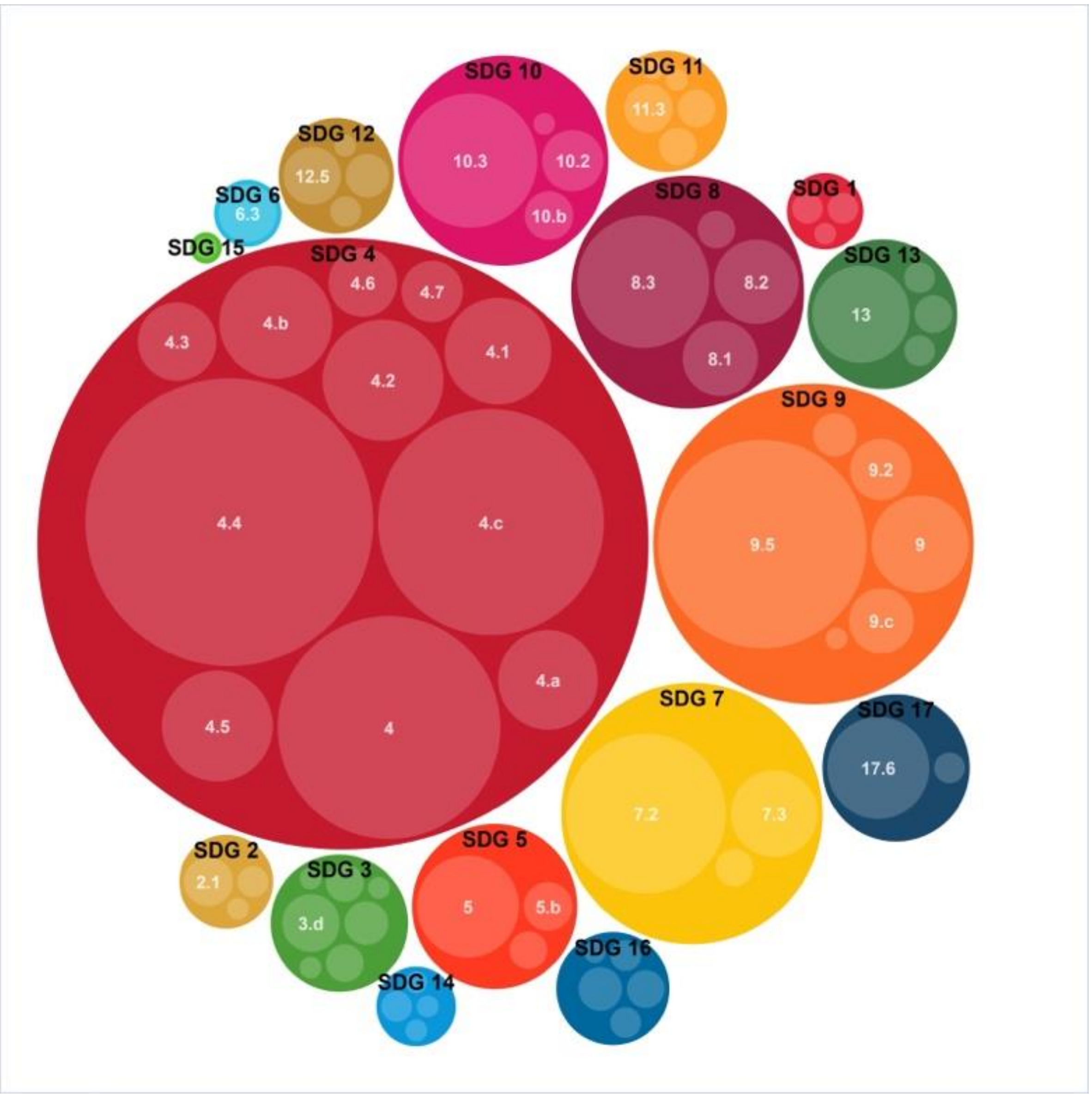

Fig. 3. Mapping SDGs and targets to research articles (SDGs are ordered from the highest to lowest number of mapped responses).

Discussion

This research explores the integration of emerging technologies in STEM education, mapping it to SDG4 targets. It further looks at the learning theories and pedagogical approaches that are used in research and practice with emerging technologies for STEM and suggests implications for practice and policy.

RQ1: Emerging topics

This study identified research on the emerging technologies used for STEM. Robotic integration in STEM education enhances technical and cognitive skills, fosters engineering and programming skills, and promotes higher-order thinking and problem-solving abilities through interdisciplinary and project-based learning, which prepares students for future workforce demands (Chiazzese et al., 2019; Darmawansah et al., 2023; Zhong et al., 2020). Extended reality (ER) can transform informal and formal education settings by making learning more engaging and immersive but with high costs and the need for specialized educator training (Goff et al., 2018; Pellas et al., 2020; Sırakaya & Sırakaya, 2022). The metaverse promises opportunities for gamified learning and role-playing, along with making complex scientific concepts more accessible and engaging students (Solanes et al., 2023). Artificial intelligence (AI) personalizes learning in STEM through tools such as predictive analytics and intelligent tutoring systems. Continuous professional development is essential for effective AI integration, addressing AI's potential ethical concerns and long-term impact on learning outcomes (Lee and Perret, 2022; Lin et al., 2021). Expanding IoT education is crucial for preparing students for a technology-driven world, whereas the Fabrication-as-a-Service model offers a scalable and secure way to integrate advanced fabrication technologies into educational curricula (Abichandani et al. 2022; Cornetta et al., 2020; He et al., 2016. Primary-school–ready "digital twin" classroom infrastructures now allow learners to design robots and connect cyber and physical elements in near real time, making systems and control concepts tangible from the earliest grades (Screpanti et al., 2022).

Ethical Implications of Emerging Technologies in STEM Education

The integration of emerging technologies in STEM education, while offering significant pedagogical benefits, raises important ethical considerations that must be addressed to ensure responsible implementation. For example, AI-driven systems present concerns about algorithmic bias, data privacy, and the potential reinforcement of educational inequalities through biased training data. Extended reality technologies require careful consideration of digital equity, prolonged virtual exposure effects, and the collection of biometric data through eye tracking and behavioral monitoring. Robotic integration must balance technological assistance with essential human interactions while ensuring transparent data handling practices. Educational institutions must develop comprehensive ethical frameworks that address these concerns in STEM education.

RQ2: Gender equity in STEM

Analyses of automation risk indicate disproportionate impacts on women, underscoring equity considerations alongside STEM technology adoption (Egana-delSol, Bustelo, Ripani, Soler, & Viollaz, 2022). A perspective in systems science emphasizes democratizing the technology–innovation–society nexus to advance gender parity and inclusion in STEM (Hamdi, Mulder, & Abdelhak, 2022).

Challenges in gender equity are illustrated by differences in participation rates that impact innovation and educational goals. Specifically, designed STEM camps and programs can increase girls' self-efficacy and attitudes toward STEM fields (Yabas et al., 2022). Mentorship programs and peer support can enhance girls' confidence and engagement (Sullivan & Bers, 2019; Üçgül & Altıok, 2022; Yang et al., 2022). Culturally responsive teaching strategies that respect and incorporate students' diverse backgrounds help create inclusive learning environments (Bailey et al., 2023). Exposure to GAI in educational curricula influences female students' interest in STEM careers (Nedungadi et al., 2024). Parental role models in affluent countries influence girls' interest in STEM, whereas in less wealthy countries, girls entering STEM may be driven by economic incentives despite fewer mothers in professional STEM careers (Guo et al., 2019). Supportive educational practices and mentorship can enhance the participation of all genders and inclusion success. Current research spans early education, policy shifts, and institutional efforts, all of which are essential to achieving lasting change.

Early Education

Children develop the thought process of what they can do or cannot do from an early age. Research shows that gender stereotypes start shaping these perceptions in early childhood. To counter this, educators are increasingly focusing on inclusive teaching practices that introduce STEM concepts in everyday contexts, making them relatable and accessible to all students (Xu et al., 2025). By weaving in real-life examples and career role models, especially women in science and technology (Elliniadou et al., 2025), young girls are more likely to see themselves as capable and interested in these fields. Programs introduced at the primary school level have also proven effective in building confidence and challenging outdated notions about gender and ability in science and math classrooms.

Higher Education and Teaching Practice

Creating inclusive spaces at universities is not just about the mention of policies in paper; it depends on the culture of institutions on a daily basis. A real difference in how women see their future (Ro et al., 2021) in STEM will occur when universities actively come forward to promote gender equity and foster supportive environments. National reforms also play a major role unless the campus culture welcomes the change. At the same time, many teacher training programs still fall short (Battey et al., 2007) in regard to preparing educators to recognize and address gender bias in their classrooms, leaving a critical gap in efforts to make STEM education more equitable. For example, regions such as MENA (the Middle East and North Africa) face additional challenges due to cultural norms and limited resources. Improving outcomes in these regions requires localized strategies (Alhashem et al., 2023; Islam & Jirattikorn, 2024). Mentoring plays a critical role in supporting the progression of women in STEM. Professional networks and role models help retain talent and foster leadership (García-Silva et al., 2025).

Policy Shifts and Institutional Efforts

In countries such as Australia, national STEM policies have gradually shifted focus from promoting gender equity as a social justice issue to emphasizing economic growth and innovation (Cuthbert & Sidelil, 2019). Although this approach focuses on the importance of STEM for national development, it may sideline equity goals. However, initiatives such as Girls4STEM in Spain take a more community-centered approach. By engaging directly with students, families, and teachers, these programs help breakdown barriers and encourage more girls to explore and stay in STEM fields (López-Iñesta et al., 2020). Closing the gender gap in STEM demands early, sustained engagement, supportive institutional practices, inclusive teaching, and targeted mentoring. Recognizing structural and intersectional barriers is key to designing effective and equitable solutions.

RQ3: Learning theories.

Our findings show that only a small percentage of studies in our data incorporate learning theories, which widens the gap between research findings and practical application in classrooms. This gap in the relatively less robust theoretical foundation can limit the potential and effectiveness of these technologies. Teacher training is critical for adoption; for example, faculty who participate in a relevant professional development program are more likely to adopt active learning strategies in undergraduate geoscience education (Manduca et al., 2017). In teacher preparation, edTPA-aligned assessments are related to preservice STEM performance and program design decisions (Moon et al., 2021).

Cognitive and psychological theories include embodied learning, which involves learning through physical interaction and embodiment in VR environments; embodied cognition, which focuses on enhancing children's design thinking and engineering skills through play-based learning; cognitive theory, which assesses the effectiveness of learning strategies within immersive VR environments; social cognitive theory, which examines the influence of robotics on career choices and evaluates interpersonal skills and career choices in STEM; and multiple intelligences, which enhances learning through active strategies that leverage diverse cognitive skills. Mayer's cognitive theory of multimedia learning and cognitive-affective theory suggest that effective learning leverages multiple information channels and addresses both the cognitive and emotional responses of learners, enhancing the educational impact of immersive technologies (Klingenberg et al., 2023; Strzys et al., 2019).

Contextualizing robotics projects in local heritage and blending multiple active-learning strategies with the theory of multiple intelligences increased university students' motivation, performance, and commitment (Quesada-Real et al., 2023). Disciplinary identity research shows how a field's theoretical core evolves over time, underscoring the need to align technology-enhanced STEM pedagogy with disciplinary ways of knowing, not just tools (LiCausi & McFarland, 2022). Sociopolitical analyses of high-school robotics teams reveal how racialized and gendered positioning can both enable and constrain participation, indicating that representation alone is insufficient for justice-oriented STEM learning (Hennessy Elliott, 2020).

Instructional design and learning models encompass constructionism and constructivist theories, which advocate for an active learning process in which learners construct knowledge through hands-on creation. Learning systems that align with constructivist principles foster knowledge construction through direct interaction and personalized feedback, effectively managing cognitive load. Gamification and social media can increase motivation and facilitate collaborative learning (Klingenberg et al., 2023). It also includes a universal design for learning, which supports the creation of inclusive educational environments, and game-based learning, which uses gamification to enhance engagement and understanding.

Social and cultural contexts include positioning theory, which highlights the social dynamics and power structures within educational settings, and social constructivism, which improves students' resilience and engagement through socially constructed learning activities. Activity theory and cultural-historical activity theory provide frameworks for designing learning environments that emphasize sociocultural contexts in learning (Li & Zaki, 2024).

Applied learning environments include grounded theory, which facilitates integrated STEM learning through practical, technology-based teaching, and situated learning, which enhances education through practical, context-based activities. Research on postpandemic distance learning using transactional distance theory (TDT) suggests that engaging in OOC design and increased social presence may improve online engagement and retention (Achuthan et al., 2024).

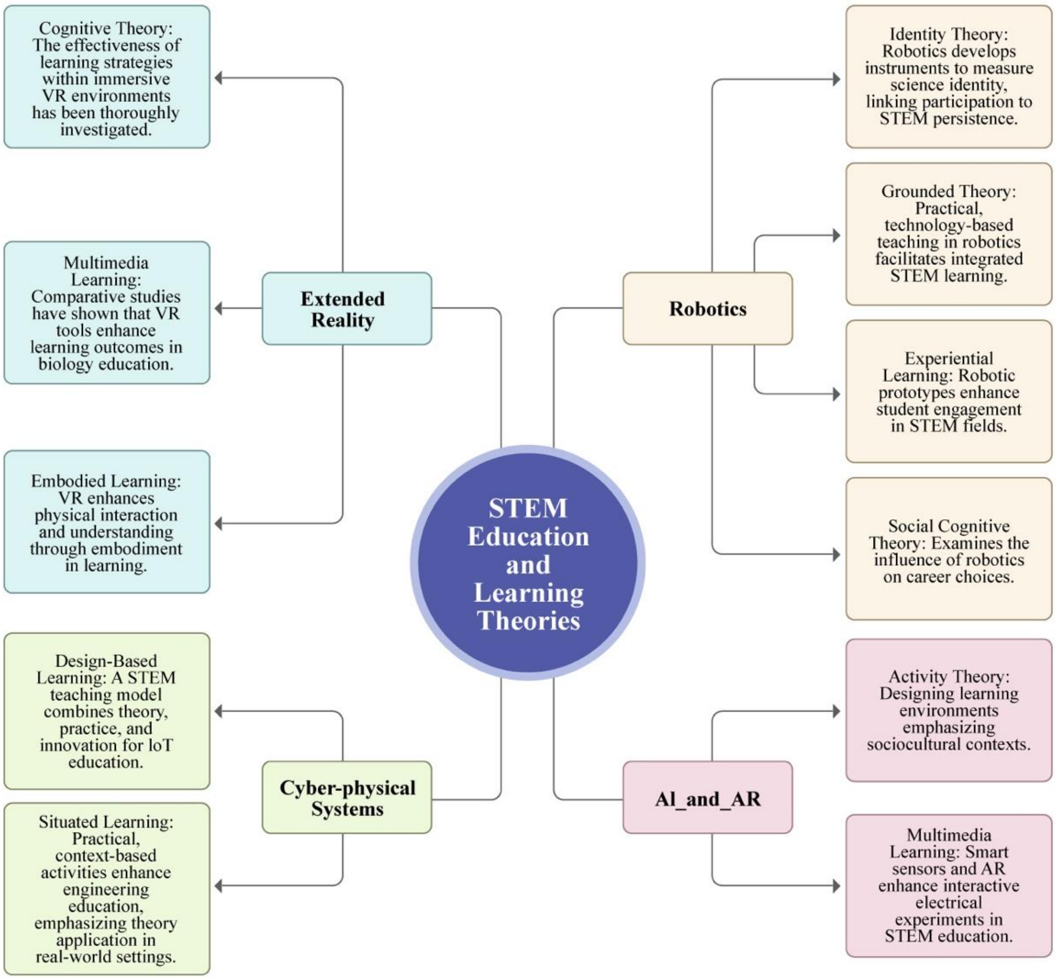

Fig 4. Learning theories used in emerging technologies for STEM research

RQ4: SDG outcomes

Figure 5 provides an overview of how STEM education technologies intersect with various SDG4 targets. Predictive analytics that combine expectancy–value theory with machine-learning models can forecast engineering persistence with competitive performance, enabling earlier, targeted retention interventions that strengthen SDG4 outcomes (Wang et al., 2022). By leveraging technologies, STEM education can expand access to quality learning opportunities, reduce barriers to education, and provide personalized support for disadvantaged groups. For example, emerging mobile technologies and online learning platforms can provide STEM education resources, such as mobile game-based learning, to students in remote or underserved areas (Miles et al., 2021). In addition, assistive technology and adaptive learning systems can support the learning needs of students with physical and mental disabilities to ensure that they have equal opportunities to participate in STEM education (Chun et al., 2024; Prema & Dhand, 2019). Gender equity in STEM education is another key area where emerging technologies can have a significant impact (Yu et al., 2023). Research suggests that the use of inclusive teaching methods, such as project-based learning and collaborative problem solving (Naik & Jayaraman, 2024), can help create a more welcoming and supportive environment for female students in STEM (Klimaitis & Mullen, 2021; Yabas et al., 2022). As emerging technologies continue to shape the educational landscape, there is a growing need for teachers to acquire the skills and knowledge to effectively use these technologies in their teaching. Research in this area has also explored innovative ways to leverage emerging technologies to improve the quality and efficiency of teacher development. For example, artificial intelligence and machine learning technologies can be used to create personalized learning paths for teachers and adapt to their needs and preferences (Xu & Ouyang, 2022). In addition, online platforms and virtual learning environments facilitate collaboration and knowledge sharing of best practices and experiences among teachers (Felder & Brent, 2024; Margot & Kettler, 2019).

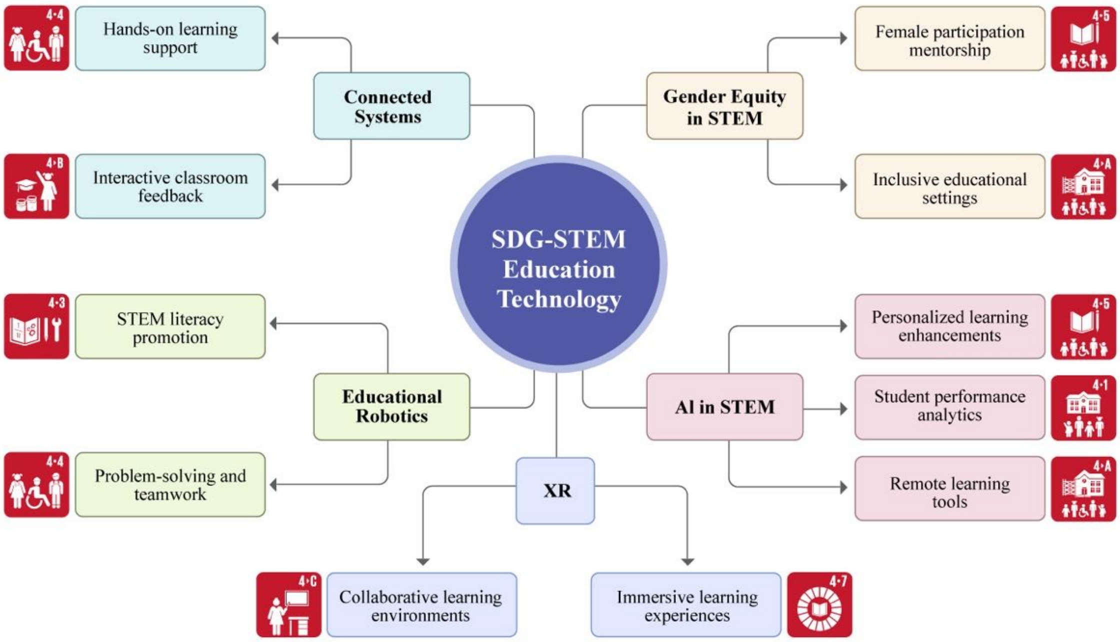

Fig 5. SDG4 outcomes of emerging technologies for STEM research

RQ5 Implications for practice and policy

With respect to RQ5, the findings have the following implications for practice and policy:

1. **Bridging the research-practice gap in the theoretical foundation**: The lack of sufficient research on learning theories in educational technologies can diminish their impact. Learning theories provide critical insights into student learning processes; hence, incorporating these theories in the design and evaluation of technologies to support diverse learning styles and outcomes is essential. Learning theories and frameworks may need to be adapted on the basis of the specific affordances provided by an emerging technology. Furthermore, the adapted frameworks need to be rigorously tested to assess their effectiveness and usability in real-world educational settings. Educators need to be trained to incorporate these theoretical frameworks and emerging technologies into their teaching practices.
2. **Emerging technologies and STEM**: To maximize the potential of emerging technologies in STEM education, platforms should integrate AI and emerging technologies with adaptive and immersive systems. Such approaches enhance the accessibility, inclusivity, and quality of STEM education, catering to diverse student needs. To prepare students for the ethical issues associated with AI, educators are encouraged to integrate AI ethics into the STEM curriculum. It is also important to implement pilot programs that systematically evaluate learning outcomes and ethical impacts before adopting technology on a larger scale.
3. **Advancing SDG4 outcomes with STEM technologies**: Emerging educational technologies create realistic, immersive experiences that prepare students for the modern workforce. Professional development for teachers on the effective use of these technologies emphasizes the importance of customized training programs that use AI and online platforms to promote continuous learning and collaboration among peers. Using technology to promote educational equity and inclusion ensures that all students have access to quality learning opportunities and supports broader educational goals and lifelong learning. As such, we suggest integrating technologies such as robotics and virtual/augmented reality into STEM education to achieve SDG4.
4. **Professional development and evaluation**: Professional development programs should be enhanced to equip educators with the necessary skills and knowledge for implementing these technologies effectively. Continuous monitoring and evaluation of the impacts of technology-enhanced learning on student outcomes are essential to ensure that these tools meet educational goals. We suggest that institutional administrators and policymakers prioritize investments in technology that supports innovative teaching methods.
5. **Persistent, intersecting barriers, and international dynamics**: In both classrooms and workplaces, gender bias is still a reality. In India, for example, the representation of women in top-tier institutes is significantly less common. This is not just about gender; it intersects with other social inequalities, making the issue more complex. To create real change, there is a growing need for affirmative policies that take these overlapping challenges into account and ensure that opportunities in STEM are accessible to all. International efforts are helping raise awareness of the gender gap in STEM.
6. **Policies**: Policies should be implemented to provide financial incentives for schools to integrate technologies such as AI, IoT, AoIT, Metaverse, and XR, ensuring that these technologies are used equitably and safely through standardized guidelines. To address disparities, targeted funding should be allocated to underserved areas to maintain technology updates in line with current industry and ethical standards. We suggest mandating continuous professional development for educators on emerging technologies and promoting gender equity in STEM fields. This can be achieved by offering scholarships to women and implementing strict accountability measures.

Limitations

This study has several limitations. With respect to data coverage, this study employed a comprehensive search strategy in the Scopus database. However, the search criteria we used may not have covered some relevant articles published in other databases. Future research could extend the search from Scopus to other well-known databases, such as the Web of Science, to broaden the understanding of the field. Second, while BERTopic modeling identifies key topics, it may not capture interactions between these technologies and specific pedagogical outcomes owing to the abstract nature of topic modeling. Future research could add qualitative analyses to the literature review to gain a deeper understanding of the interplay between technology and outcomes.

Conclusion

This study highlights the critical role of emerging technologies—robotics, artificial intelligence (AI), extended reality (ER), and interconnected smart systems—in advancing STEM education. It emphasizes the persistent challenge of gender equity in these fields. Culturally relevant, cost-effective access to these technologies is essential. Workshops and competitions can help foster an inclusive environment. Our findings reveal the potential to equip students with crucial skills for today's workforce through immersive, practical experiences aligning with SDG4.4.

The evolution of AI, particularly through generative AI, has begun to enhance personalized learning and prediction capabilities by generating real-time, multilingual, and context-specific educational content, feedback, and interactions. The potential incorporation of brain-inspired artificial general intelligence (AGI) into STEM education could drastically change the educational landscape by offering advanced and intuitive tutoring across various subjects (Raman et al., 2025). This would allow for a dynamic adaptation to the unique needs of each student without the limitations of preset programming, thereby facilitating highly personalized and effective learning experiences. Additionally, leveraging metaverse technology could create a more interconnected and persistent virtual learning environment that promotes collaborative learning.

However, the study identifies a significant gap in the integration and adaptation of educational theories with these technologies, which currently hinders the full realization of learning outcomes. While these technologies present substantial opportunities for more inclusive education, addressing challenges such as high operational costs, the need for specialized training and ethical concerns remains crucial. Strategic policy interventions and targeted professional development are essential to overcome these challenges and fully harness the potential of emerging technologies in educational settings.

Future Work

Future work in transitioning STEM education to metaverse STEM education should focus on enhancing and expanding upon the capabilities of extended reality (XR). Research could compare the effectiveness of metaverse environments with traditional XR setups in fostering engagement, understanding, and practical skills in STEM subjects. Learning systems should incorporate generative AI and artificial general intelligence to innovate multilingual content creation and decision-making and provide intelligent and interactive personalized learning.

As educational technologies evolve, research must focus on their scalability and adaptation across various educational settings to ensure educational equity. This includes examining the challenges and barriers to access, aiming to make these technologies available and beneficial to a broader demographic. Additionally, with the increasing prevalence of online and remote learning environments, both scalability and security are needed for educational integrity and reliability.

The integration of established learning theories with emerging technologies could explore how cross-disciplinary project-based learning can influence students' preparedness for the industry and affect their career trajectories. Research should also aim to adapt and optimize the use of learning theories in conjunction with modern technologies.

Future research on technology-enhanced learning should prioritize longitudinal studies to better understand the sustained impacts of such educational interventions on students' academic performance and career progression. Future work should scrutinize the potential of applying AI learning systems to reinforce biases or inequalities inadvertently. Research and solutions must be sensitive to gender and disability. In conjunction, the greater ethical risks involved in using these technologies will need to be mitigated through policy and research.

Data Availability:

The PRISMA flow chart is available as a supplementary file. The final dataset derived from the PRISMA process is included as a dataset.

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Acknowledgments:

The authors from Amrita University express their profound gratitude to Sri Mata Amritanandamayi Devi, humanitarian leader and Chancellor of Amrita Vishwa Vidyapeetham, for her visionary guidance. There is no external grant associated with this research.

Author contributions

PN and RR conceptualized the study. PN and RR carried out the data collection, analysis, and visualization. PN, MT, GV, KT and RR wrote and revised the manuscript and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

Supplementary information: The data used in the study are uploaded as supplementary material.

Annexure

Table 1: Topic wise articles on Emerging Technologies

Articles	Emerging Technology	Algorithms or Tools	Theory
Robotics in STEM			
Darmawansah et al., (2023)	Robotics-based STEM	Arduino, Bee-bot, Robo-robo, Kiwi Kits, IRobot Create, LEGO (Mindstorms, bricks, wedo)	Project-based learning, problem-based learning, constructivism
Zhong et al. (2020)	Virtual and Physical Robotics	IRobotQ3D platform	Engineering Design, Cognitive Load Reduction
Mangina et al. (2024)	Educational Robotics Computational Thinking	Various tools, methods, and robotic kits	Spatial Ability Learning
AI in STEM Education			
Xu and Ouyang (2022)	Empirical AI-STEM studies	Learning prediction, Intelligent tutoring system, Student behavior detection, Automation	Lecture Project-based learning Problem-based learning Game-based learning Collaborative learning Self-learning
Lee and Perret (2022)	AI Methods in Data Science (DS) curriculum	Hands-on activities, interactive tools, and coding exercises	Experiential Learning, Interactive Learning, Practical Hands-On Learning
Yang (2022)	AI for early childhood education (ECE)	Curriculum "AI for Kids"	AI Literacy Learning, Computational Thinking Learning, Experiential Learning
Extended Realities for STEM Learning			
Goff et al. (2018)	Augmented Reality/Virtual Reality (AR/VR)	Collaborative Game Design, Narrative Mapping, Environmental Simulations	Engagement Theory Experiential Learning Theory Situated Learning
Pellas et al. (2020)	Virtual Reality (VR)	Use of VR Head-Mounted Displays	Experiential Learning
Sırakaya and Sırakaya (2022)	Augmented Reality (AR)	Content Analysis Method	Experiential Learning Theory Constructivist Learning Theory Cognitive Load Theory Situated Learning Theory Social Learning Theory Inquiry-Based Learning
Smart Connected Systems for STEM			
Abichandani et al. (2022)	Internet-of-Things (IoT) Technology	Not Specified	Active Learning-Based Instructional Approaches
Cornetta et al. (2020)	Internet of Things (IoT) Technology	Deployment Scenarios for Fabrication-as-a-Service (FaaS) Architecture	Digital Fabrication Learning, Remote Education Learning, Machine-to-Machine Communication Learning
Benita et al. (2021)	Internet of Things (IoT) Technology	NSE smart learning initiative, SENSg, cloud computing, ParticipAct	Data-driven thinking, Experiential learning.

Table 2: Learning Theory Articles.

Articles	Learning Theory	Insights
Cognitive and Psychological Theories		
Johnson-Glenberg et al., 2018	Embodied Learning	VR enhances physical interaction and understanding through embodiment in learning.
Kewalramani et al., 2020	Embodied Cognition	Robotics and blocks enhance children's design thinking and engineering skills through play-based learning.
Klingenberg et al., 2023	Cognitive Theory	Investigates the effectiveness of learning strategies within immersive VR environments.
Yoel & Dori, 2022	Social Cognitive Theory	Examines the influence of FIRST robotics on career choices through social cognitive perspectives.
Yoel et al., 2020	Social Cognitive Theory	Evaluates the impact of the FIRST robotics program on graduates' interpersonal skills and career choices.
Rocker Yoel et al., 2023	Social Cognitive Theory	Examines the impact of mentor types on interpersonal skills and career choices in STEM.
Quesada-Real et al., 2024	Multiple Intelligences	Uses active learning strategies and robotics to enhance learning through contextual applications.
Thompson et al., 2018	Embodied Learning	VR games promote learning through authentic, interactive, and collaborative environments.
Instructional Design and Learning Models		
Nasri et al., 2021	Universal Design for Learning	Empirical evidence supports UDL and MI in enhancing inclusive education.
Chen et al., 2020	Design-Based Learning	Proposes a STEM teaching model that combines theory, practice, and innovation for IoT education.
Petrović et al., 2022	Game-Based Learning	Uses gamification and virtual tools to teach fundamentals of agent theory, enhancing learner engagement.
Budiyanto et al., 2020	Kolb's Experiential Learning	Demonstrates how educational robotics can align with Kolb's experiential learning to enhance STEM education.
Zainal et al., 2018	Experiential Learning	Robotic prototypes based on Kolb's theory enhance student engagement and interest in STEM.
Kapp et al., 2022	Multimedia Learning	Introduces smart sensors and AR for enhanced, interactive electrical experiments in STEM education.
Christopoulos et al., 2023	Multimedia Learning	Compares traditional video and VR tools in enhancing learning outcomes in biology education.
Lehmann & Rossi, 2019	Enactive Learning	Combines enactive learning with social robotics to advance tutoring and interactive learning.
Social and Cultural Contexts		
Hennessy Elliott, 2020	Positioning Theory	Highlights the social dynamics and learning power structures within robotics team settings.
Jajuri et al., 2019	Social Constructivism	STEM activities based on social constructivism improve students' academic resilience.
Applied Learning Environments		
Ntemngwa & Oliver, 2018	Grounded Theory	Robotics facilitates integrated STEM learning through practical, technology-based teaching.
Marouani, 2022	Situated Learning	Uses situated learning to enhance engineering education through practical, context-based activities.
Turner et al., 2022	Technacy Genre Theory	Integrates STEM and sustainability education through practical garden-based projects.

Tanik, 2013	Knowledge-Based Engineering	Develops a framework for improving the design process of cyber-physical systems through knowledge-based engineering.
Wu et al., 2020	Framing Theory	Analyses how different question frames affect online information sharing behaviors in STEM discussions.
Xu & Ouyang, 2022	General Systems Theory	AI optimizes STEM education systems by integrating diverse techniques and educational elements.
Ateş et al., 2023	Theory of Planned Behavior	Develops a framework to understand the factors influencing teachers' adoption of robotics in STEM.

Table 3: Distribution of STEM education research related to SDG4

SDG	TARGET	No of OCCURRENCES (papers)
SDG 4	Target 4.1	24
SDG 4	Target 4.2	31
SDG 4	Target 4.3	13
SDG 4	Target 4.4	175
SDG 4	Target 4.5	26
SDG 4	Target 4.6	10
SDG 4	Target 4.7	8
SDG 4	Target 4.a	21
SDG 4	Target 4.b	27
SDG 4	Target 4.c	108