Al Kalbani *Research and Practice in Technology Enhanced Learning* (2026) 21:9
https://doi.org/10.58459/rptel.2026.21009

Research and Practice in
Technology Enhanced Learning

RESEARCH ARTICLE Free and Open Access

Scrutinizing the role of advanced robotics in educational processes: A qualitative study

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Abstract

The study aimed to evaluate the acumens of educationists concerning the benefits of robotics technology in education, motivation, challenges in executing robotics autonomy, and future suggestions. The study included 10 educationist specialists and utilized open-ended questions to collect perceptions of the subject. A current investigation produced subjects: security concerns, job substitution issues, customization, flexibility, educational inspiration, and administrative needs related to robotics innovation. The collected responses were lensed through the instructive systems, including the Technological Pedagogical Content Knowledge (TPACK) system, constructivist learning speculations, and the Frankfurt Triangle demonstrated to collect broad suggestions. This conduct found that robotics technology offers benefits such as information, common sense, inspiration, and engagement. Despite that, challenges such as innovation, sociocultural components, adaptability, security concerns, and versatility were recognized. Additionally, the study backed the idea that future progressions and administrative systems are pivotal for overcoming these challenges and improving part of robotics in education. The consideration emphasizes the need for versatile mechanical autonomy arrangements, integration with existing advances, and energetic administrative systems. Tending to work substitution concerns, security issues, and information security is fundamental to guarantee the secure use of mechanical technology in instruction. The research recommends that policymakers and teachers contribute to reasonable robotics technology units, accomplices with innovation suppliers, and funding for underserved educational institutions. Future robotics technology improvement should prioritize user-friendliness and consistent integration with existing innovations.

Keywords: Robotics Education, Educationists perceptions, Educational Frameworks, Benefits, challenges, Pedagogical Readiness

Introduction

The quick progression of robotics technology innovation has affected different divisions, with education developing as an up-and-coming field for its application. As instructive teachers worldwide struggle with the advancing demands of the 21st century, integrating advanced robotics technology into educational forms presents both transformative openings and complex challenges (McDiarmid & Zhao, 2023). The worldwide robotics education is anticipated to develop from $1.3 billion in 2021 to $2.6 billion by 2026 (Chatzichristofis, 2023). This development underscores the expanding acknowledgment of robotics as a profitable education device. Likewise, advanced robotics offers imaginative arrangements to improve learning encounters, cultivate engagement, and progress education value (Atman Uslu et al., 2023). The move towards consolidating robotics is driven by the need to adjust to the advancing instructive scene, which progressively values personalized learning, capability, and hands-on problem-solving aptitudes (Adel, 2024). In addition, robotics has developed as a device that not only underpins these instructive objectives but contributes to modern ways of upgrading student engagement and scholarly accomplishment (Kerimbayev et al., 2023).

Furthermore, robotics technology has various applications in education, from robotics kits employed in classrooms to advanced AI-driven education instruments. The robotics integration into educational programs points to making intelligent and immersive learning situations that conventional strategies regularly fail to accomplish. Robotics can support personalized learning encounters by adjusting to students' learning and needs paces. According to Tariq (2024), this personalization is achieved through robotics' ability to engage with intuitive assignments and reenactments that adjust with modern educational hypotheses emphasizing experiential learning and student-centered approaches.

Additionally, the potential of robotics's effect on educational hones is significant. Robotics can democratize quality education by overcoming obstructions related to physical inabilities, geographic segregation, and asset confinements. For instance, the World Financial Gathering (WEF) report notes that 62% of schools in low-income ranges need satisfactory assets for STEM (Science, Technology, Engineering, and Mathematics) instruction. Robotics programs have bridged this hole by giving reasonable, high-quality instructive assets (Fraumeni & Liu, 2021). Correspondingly, the arrangement of robotics with worldwide education patterns prioritizing STEM instruction is significant (Ching et al., 2019). Robotics supports the advancement of essential considering and problem-solving aptitudes and prepares understudies with innovative education fundamental for future career readiness (Yi, 2019).

Nonetheless, robotics integration into the educational landscape has its challenges. Moreover, robotics' initial costs, the requirement for continuous support, and the necessity for comprehensive educator preparation pose critical boundaries to far-reaching appropriation. Furthermore, curricular changes are required to guarantee that robotics complements conventional educational strategies instead of supplanting them (Ashraf et al., 2020). These challenges must be fundamentally inspected to examine their effect on the achievability and viability of robotics in different academic settings.

This study analyzes the role of advanced robotics in education by examining how these advances impact learning results and educational improvement. By considering both the benefits and the challenges related to robotics, this study considers points to give a nuanced understanding of how robotics can be successfully coordinated into educational frameworks to improve learning meets and bolster instructive value.

The study aims to apprehend the following objectives:

- To explore educators' perceptions of the benefits of robotics in education.
- To understand how robotics influence student motivation from the educators' viewpoint.
- To understand the challenges in implementing robotics in education.
- To identify potential future developments and implications of robotics in education.
- To relate the perceptions of the educationist with educational frameworks for a better understanding of the subject.

Literature review

Overview of robotics in education

The advancement of robotics in instruction reflects a broader, innovative direction. At first, the utilization of essential robotics to educate programming and designing gave a foundational understanding of mechanized frameworks, which was pivotal in the late 20th century (Mangina et al., 2023). However, as innovation progressed, robotics advanced altogether. The integration of progressed highlights like sensors and AI in the early 2000s changed mechanical autonomy from straightforward instructive apparatuses to advanced frameworks capable of cultivating fundamental 21st-century abilities (Ching & Hsu, 2024). According to Alam and Mohanty (2024), the positive effect on learners' engagement and learning results, bolstered by an experimental inquiry, underscores the transformative potential of robotics. In any case, this advancement also highlights a crevice in early instructive approaches that frequently needed interactivity and personalization, which cutting-edge robotics point to address, as noted by Ciceri et al. (2023).

Moreover, the current applications of mechanical technology in instruction illustrate a wide range of benefits, from personalized learning to upgraded engagement and back for understudies with incapacities. Personalized learning through robotics discourse is a critical move towards student-centered instruction, permitting custom-fitted instruction that meets personal needs (Ecker, 2023). According to Mourtzis et al. (2023), utilizing robotics to present gamification and intuitively bunch exercises addresses conventional instructive challenges related to learners' inspiration and engagement. Furthermore, robotics' role in extraordinary instruction highlights its potential to create comprehensive learning situations. However, these applications show challenges, including the requirement for noteworthy budgetary speculation and comprehensive instructor preparation. The viability of robotics in inaccessible and cross-breed learning situations, especially amid worldwide challenges like the widespread COVID-19, underscores their flexibility and raises questions of almost equitable effect innovation (Kerimbayev et al., 2023).

Besides innovative educational developments, robotics have essentially upgraded their capabilities and applications. AI integration has empowered robots to give personalized learning encounters, adjusting to person understudy needs in real-time (Ng et al., 2023). This speaks to a noteworthy advancement over conventional, one-size-fits-all education approaches. Improved sensor innovation has progressed interaction and engagement, making learning more energetic and responsive (Su & Yang, 2024). The progression versatility and control capabilities have extended the run of hands-on exercises robots can back, making unique concepts more available. Considerably, network and interoperability with advanced stages guarantee that instructive robots can be coordinated consistently into existing frameworks (Chen et al., 2023). Robots' expanded solidness and reasonableness have democratized the development of these progressed instructive apparatuses. At the same time, these headways also highlight the prerequisite for continuous investigation to address potential challenges related to information security, advanced isolation, and the long-term supportability of robotics programs in differing educational settings.

Educators' perspectives on robotics

Benefits as perceived by educators

Teachers and educationist experts recognize the transformative potential of robotics in improving education and learning encounters. One of the essential benefits teachers highlight is the capacity of robots to encourage personalized learning (Tang et al., 2023). Robotics is prepared with progressed calculations that can adjust directions fabric to coordinate the pace and learning fashion of student motivation and engagement, in this way tending to differ instructive needs more viably than conventional strategies. This personalization is especially advantageous in classrooms with a wide range of capacities, as it guarantees that each student gets the fitting level of challenge and bolster (Darmawansah et al., 2023). Moreover, teachers regularly highlight the expanded student engagement and inspiration that robotics can cultivate (Yolcu & Demirer, 2023). Intelligent and hands-on learning encounters made conceivable through robotics have made theoretical concepts more substantial and reasonable. For occurrence, robots can mimic real-world issues and permit understudies to test with distinctive arrangements in a controlled environment. This rational application of hypothetical knowledge improves comprehension and develops basic considering and problem-solving aptitudes (Fridberg & Redfors, 2024).

Another noteworthy advantage is the robotics ability to back comprehensive instruction. As noted by Al Omoush and Mehigan (2023), robots can give custom-fitted bolster to learners with inabilities, advertising customized intelligence that offers assistance to create social aptitudes and communication capacities. Teachers have observed that students who might do something different encountered in conventional instructive settings can flourish with the help of automated devices like robotics. This viewpoint of robotics in instruction adjusts with broader endeavors to advance value and reach quality instruction for all students.

Challenges faced by educators

Despite the recognized benefits, teachers confront challenges in executing robotics in instructive settings. One of the most critical boundaries is the considerable introductory venture required for acquiring and keeping up automated frameworks (Tang et al., 2023). Numerous schools, especially those in underfunded areas, have to apportion the fundamental assets for these advances (Ayeni et al., 2024). This cost-related imperative can restrain the far-reaching robotics appropriation and compound existing educational disparities. Moreover, integrating robotics into educational programs requires comprehensive educator preparation and continuous proficient improvement (Mihai & Mapheto, 2024). Numerous teachers report feeling ill-equipped to successfully utilize robotics in their instruction due to a need for preparation and support. However, as prescribed by Boz and Allexsaht-Snider (2023), this crevice in information and aptitudes can ruin the viable usage of robotics programs and decrease their potential effect. Instructors must be prepared not as they were with specialized abilities but with educational methodologies to coordinate robotics efficiently in their lessons.

Also, the level of technology integration and adoption differs from educator to educator, which significantly impacts the resultant application of robotics in learning (Rao & Jalil, 2021). According to Ali et al. (2022), educators who possess adequate technological literacy can easily integrate robotics into lessons to increase its effectiveness in learning. On the other hand, educators with a low technological literacy rate have difficulty setting up the system, solving technical issues, and incorporating robotics into teaching-learning, which makes them fail to achieve the robust potential that robotics has in the teaching-learning process (Ali et al., 2022). These disparities in proficiency not only hinder the flow of implementation of robotics but also limit the extent to which students can benefit from hands-on, technology-driven learning experiences.

These challenges require curricular changes to ultimately join robotics into instructive systems (Lin & Chen, 2023). However, conventional educational programs frequently need to oblige robotics education’s intrigue and hands-on nature (Sapounidis et al., 2024). Teachers must explore the compression between assembly standard curricular prerequisites and improve with modern instructing apparatuses. This requires commitment and development of the education system as instructors endeavor to adjust existing obligations with the requests of coordination robotics into their practice.

Future developments and implications

Teachers and educationists see both openings and challenges in the future advancement of robotics in education. There is a developing acknowledgment that as robotics advances, its potential educational applications will extend. Occasionally, progressions in fake insights and machine learning may improve the resourcefulness and practicality of instructive robots (Al Hamad et al., 2024). Teachers expect future advancements will permit more personalized and immersive learning encounters (Chaka, 2023). In any case, there are also concerns about broad robotics integration. One concern is the potential for over-reliance on innovation and robotics, which may weaken the part or replacement of human interaction in education (Valluri, 2024). Teachers emphasize the significance of adjusting robotics with conventional instructing strategies to ensure learners create well-rounded aptitudes (Zhong et al., 2023). Furthermore, there is a need to address moral contemplations related to information protection and computerized separation, guaranteeing that the benefits of robotics are available to all learners, regardless of their socioeconomic foundation (Zhang et al., 2023).

Impact on student motivation

Enhancing engagement and interest

One of the most critical impacts of robotics on learners’ motivation and interest is the increment in engagement and intrigue (Sanusi et al., 2024). Robotics presents a hands-on, intuitive component to learning that conventional educating strategies frequently need. Robotics makes learning more energetic and energizing by permitting learners to lock in straightforwardly with the fabric through substantial, real-world applications (Omari et al., 2023). For instance, developing and programming a robot to unravel a particular issue can change unique hypothetical concepts into concrete errands, making learning more pertinent and curious. The studies found out students’ interest in using robotics in education and learning concepts like investigation by Erol et al. (2023), who learned students’ attitudes towards robotics education in STEM and ICT courses and appeared that this intelligent approach could boost students’ inspiration. A study by Erol et al. (2023) found that students interested in robotics-based learning exercises were more expected to express excitement for subjects like arithmetic and science, which are regularly seen as challenging. The quick input and unmistakable results from working with robots can give a sense of achievement and fulfillment, encouraging upgrading inspiration.

Robotics also plays a pivotal part in cultivating a positive attitude among students. The iterative handle of planning, building, and programming robots requires students to engage in problem-solving, basic considering, and inventive considering (Sharif et al., 2024). This handle regularly includes trial and error, where students should troubleshoot and refine their plans. Such encounters educate flexibility and diligence, strengthening the thought that exertion and persistence lead to advancement and career readiness. Teachers have noticed that students included in robotics education are more likely to embrace a development mentality, seeing challenges as openings to learn or maybe unfavorably deterrents (Fakaruddin et al., 2024). This move-in mentality is vital for long-term educational motivation and success inspiration, as it energizes students to accept unused challenges and endure hurdles.

Challenges in sustaining motivation

Despite the positive impacts, there are challenges in supporting students' motivation through robotics over time, such as the peculiarity impact, where the starting fervor of utilizing unused innovation can blur, driving engagement to diminish (Riedmann et al., 2024). To check this, teachers must ceaselessly enhance and coordinate mechanical technology into educational programs in important ways that keep learners interested. In addition, the shifting levels of earlier information and aptitudes among learners can cause incongruities in engagement (Erol et al., 2023). Students who recognize innovation and programming may discover robotics exercises simpler and more pleasant, whereas those with fewer encounters may struggle and get demotivated (Bahari, 2023). It is basic for teachers to give separate instruction and bolster to guarantee that all students can take advantage of robotics education. Additionally, value and understanding robotics functioning is vital, particularly in underfunded schools. This can decrease educational disparities, as students lacking introduction may fail to benefit from STEM skills. Schools and policymakers must guarantee financing, instructor preparation, and educational module integration.

Theoretical framework

The framework for this study is grounded in educational innovation speculations and models that look at the integration of inventive apparatuses in learning situations. It mainly utilizes the Technological Pedagogical Content Knowledge (TPACK) system, which expresses the relationship between technology's part in education and the educational and

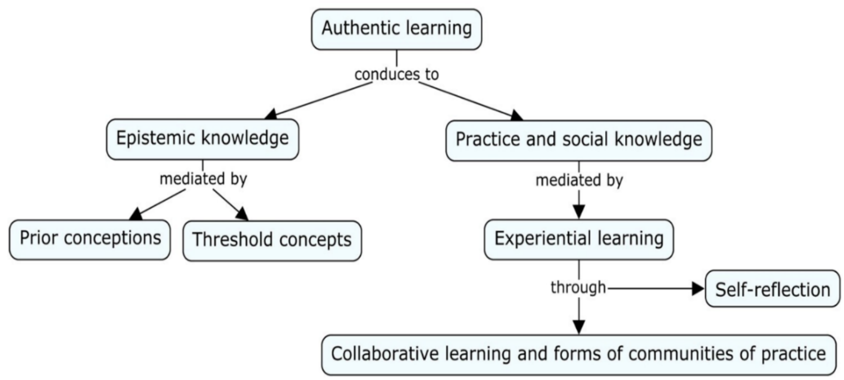

Fig. 1 Integrated learning (Class, 2024)

substance information instructors must have to coordinate innovation (da Silva Bueno & Niess, 2023) successfully (See Figure 1). Furthermore, this investigation consolidates components of constructivist learning thoughts, which encourage learners to build information effectively, primarily through engaging and hands-on encounters that progressed education can extraordinarily contribute. This system will direct the investigation of how robotics impact education results and the instruments through which these advances change instructing and learning forms.

Foundational theories of learning and technology

To methodically consider the association between sociocultural and technological improvements from an educational point of view, a system demonstrating educational forms in the advanced world has been created in Germany, consolidating different disciplinary points of view of analysts in media human science, media hypothesis, informatics, and school specialists: the professed Frankfurt Triangle illustration. The center focus of the model is on inspecting advanced artifacts, e.g., social systems, fake news, rabbit gaps, and counterfeit insights applications (Thyssen et al., 2023). The idea works through these artifacts utilizing three viewpoints and related forms.

The Frankfurt Triangle, as shown in Figure 2, highlights the three perspectives of significance within education for and around digital transformation: the technological–media, the sociocultural, and the interaction perspectives (Class, 2024).

According to Thyssen et al. (2023), the technological–media viewpoint includes understanding the innovations and media driving advanced change. This point of view centers on the mechanical perspectives of digitalization and points to creating learners' information and abilities in utilizing and working with computerized devices and innovations. The forms of examination, reflection, and planning are fundamental in this viewpoint to empower learners to get the effect of innovation on their lives and society.

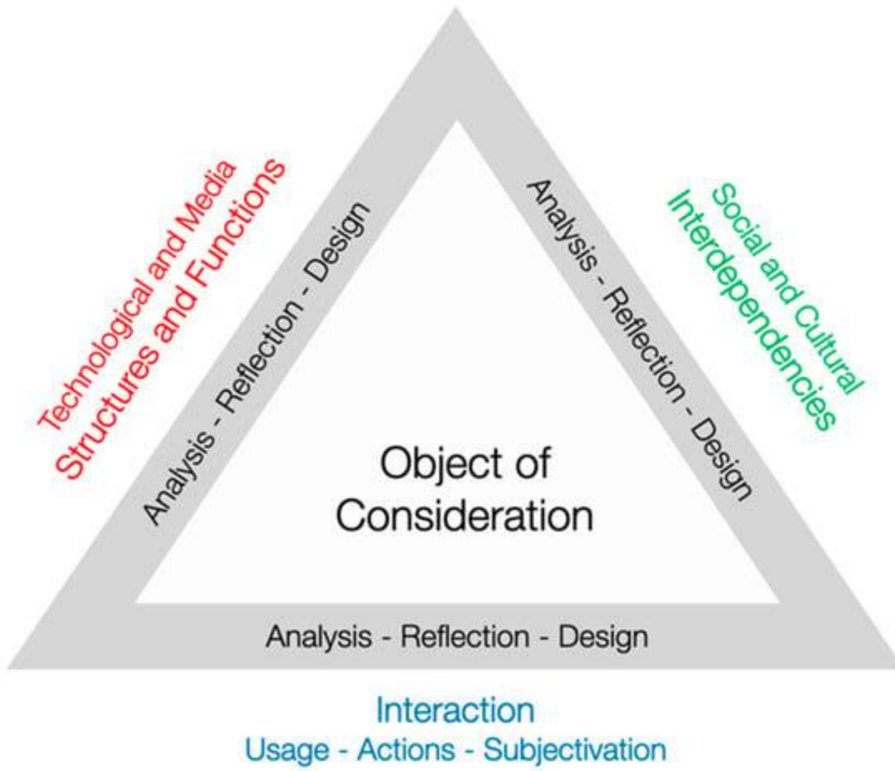

Fig. 2 The Frankfurt Triangle (Thyssen et al., 2023)

Meanwhile, the sociocultural point of view centers on the broader societal and social changes that are due to advanced change. This point of view aims to create learners' essential aptitudes and empower them to interact complexly with innovation, society, and culture. Examination, reflection, and plan forms are crucial to this point of view to permit learners to recognize and get computerized transformation's social and social implications (Thyssen et al., 2023).

Similarly, Thyssen et al. (2023) noticed that the interaction point of view centers on human-computer interaction and the plan of client interfacing. This viewpoint emphasizes people and their utilization of computerized media and frameworks, counting the reasons behind their utilization, the expected targets, the sociocultural setting inside which they work, and their level of association with computerized change. The forms of investigation, reflection, and planning are essential to this viewpoint to empower learners to provide the needs and inclinations of clients and to plan advanced items and administrations that meet their needs.

This model emphasizes the significance of considering the interaction between innovation, culture, and society in instructive concepts related to computerized media and frameworks. The model confirms that to empower support in the automated world; learners must get it not as it were the mechanical and average structures and capacities of advanced media and frameworks but the sociocultural intelligence and modes of utilize, activity, and subjectivation that shape their use.

Besides, Csikszentmihalyi's hypothesis of flow, which depicts ideal engagement through challenging, however feasible, exercises, is critical (Rathunde, 2023). Robotics can encourage this state by giving intuitively challenges that coordinate students' aptitude levels (Rosas et al., 2023). Rogers' Dissemination of Developments hypothesis clarifies the selection handle of unused advances, highlighting components such as relative advantage, compatibility, and straightforwardness that influence the spread of robotics in instruction (Maharati & Entezarian, 2023).

Comparatively, essential models like the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Acceptance Model (TAM) are pivotal in understanding technology adoption. UTAUT includes components like social impact and encouraging conditions, emphasizing the part of the organization back (Strzelecki, 2024). In comparison, TAM proposes that convenience and ease of utilization impact innovation acknowledgment (Li, 2023). Moreover, the Diffusion of Innovation (DOI) hypothesis traces how developments spread, noticing the significance of early triumphs to energize more extensive appropriation (Ayanwale & Ndlovu, 2024). The Concerns-Based Appropriation Model (CBAM) discourses individual concerns regarding innovation utilized, highlighting the requirement for proficient improvement and peer bolster to ease educators' reservations (Rotich et al., 2024).

Role of automation and robotics in educational innovation

Robotics essentially upgrade instructive effectiveness by automating scheduled errands, permitting teachers to center more on instructing. This leads to optimized asset utilization and expanded teacher fulfillment (Selwyn et al., 2023). Personalized learning encounters encouraged by robotics move forward understudy engagement and maintenance (Hu et al., 2023). Moreover, virtual and increased reality in robotics can diminish physical asset needs, taking a toll on investment funds (Guerrero-Osuna et al., 2023). By fostering necessary skills for the future workforce, robotics helps bridge the gap between educational outputs and market needs, enhancing systemic efficiency. Additionally, remote learning opportunities enabled by robotics contribute to environmental efficiency by reducing transportation and physical material use (Morze & Strutynska, 2023).

Interdisciplinary approaches to educational robotics

Robotics promote interdisciplinary learning by integrating engineering, computer science, and cognitive psychology. This holistic approach mirrors real-world problem-solving and enhances critical thinking and adaptability (Ashraf et al., 2020; Bano et al., 2024). Practical applications of theoretical knowledge through robotics increase retention and understanding (Poletti, 2023). Likewise, collaborative robotics projects foster teamwork and communication skills, which are essential for modern work environments; in the same line, robotics align well with STEM education, stimulating interest and proficiency in these crucial areas (Morze & Strutynska, 2023). Ultimately, the interdisciplinary nature of robotics prepares students for a rapidly changing technological landscape (Ashraf et al., 2020).

Similarly, robotics streamlines educational processes, reduces costs, and improves learning outcomes. Educators can focus on teaching by automating routine tasks, enhancing job satisfaction (Bahari, 2023). Moreover, virtual robotics labs offer cost-effective, high-quality educational experiences. Robotics enhances systemic efficiency and career readiness by aligning educational outputs with market needs (McDiarmid & Zhao, 2023). Remote learning opportunities facilitated by robotics reduce environmental impact, contributing to sustainability (Mourtzis et al., 2023).

Considering the above discussion, the study grounded the framework that helped to meet the prescribed objectives and listed the variables essential to this conduct. See the diagram shown in Figure 3 relating the role of Advanced Robotics in Educational Processes. The diagram visually connects the different categories of variables with relevant frameworks, helping to clarify this study's relationships and focus areas. It includes variable categories: technological, pedagogical, content knowledge, social-cultural, interaction and engagement, and outcome variables. The dashed lines within the diagram show how different variables relate to specific theoretical frameworks. TPACK framework joins with

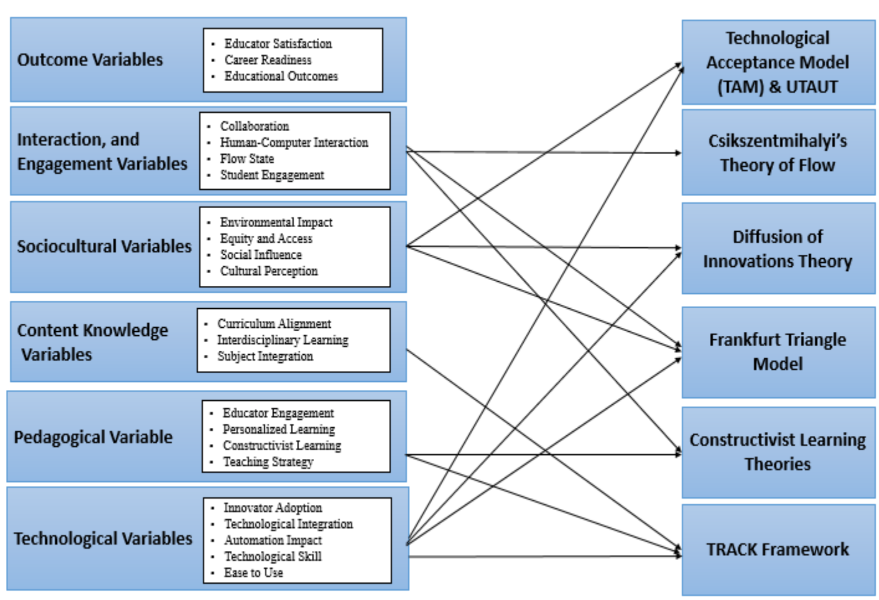

Fig. 3 Theoretical framework for robotics in education

Technological, Pedagogical, and Content Knowledge variables. Likewise, constructivist learning theories connect with Pedagogical and Interaction and Engagement variables.

Moreover, the Frankfurt Triangle Model attaches to Technological, Sociocultural, and Interaction and Engagement Variables. In contrast, the TAM and UTAUT Diffusion of Innovations Theories relate to Sociocultural and Technological Variables. Similarly, Csikszentmihalyi's Theory of Flow bonds with Interaction and Engagement Variables. This diagram helps to picture how the different components of the study's theoretical framework interrelate, guiding the conduct's qualitative analysis of the role of advanced robotics in education.

Methodology

Research design

The research adopted a qualitative approach to investigate advanced robotics in educational practices. This approach was chosen due to its reasonableness for opting in-depth instincts into the discernments and encounters of teachers concerning robotics integration in education. This technique permitted a nuanced understanding of robotics's challenges, benefits, openings, and impacts on educational processes. By centering on the essence, the study selected education experts and pointed to reveal the complex intuition between advanced robotics and educational perfects, which might need to be captured through quantitative strategies alone.

Participants

Teachers and instructors were chosen based on particular criteria to guarantee an agent test of those included in the robotics integration within education settings. The research included ten master educationists and instructors to meet the objectives of this study. The choice criteria included teachers who had reasonable encounters with robotics in their education situations and those familiar with the educational suggestions of such advances. The enrollment included coming out to schools and instructive education, which is known for utilizing advanced robotics. For that, participants' information cards were given to each participant to fill out, including participants' long time of instructing involvement, subjects taught, and level of association with robotics in their classrooms. This data made a difference in understanding the assorted viewpoints of teachers over diverse instructive settings.

Data collection

Participants' responses were collected through semi-structured interviews, outlined to permit adaptability in investigating participants' encounters, whereas a center on key investigative topics was synchronized. The interview included open-ended questions based on the study's goals, which secured points such as the benefits and challenges of utilizing robotics in education, their effect on learner motivation, and instructive effectiveness. Interviews were conducted in person or via video conferencing, recorded with participants' consent, and transcribed for analysis. The procedure ensured that a comprehensive account of each participant's views was captured, facilitating a thorough examination of their experiences with educational robotics. The following questions were adopted, aligning with the study's scope.

- What are the key benefits of robotics in education as educators perceive, and how do these benefits align with technological, pedagogical, and content knowledge practices?
- From your perspective, how does the integration of robotics influence student motivation, and what pedagogical strategies can enhance this motivation based on your experiences?
- What challenges have you encountered in implementing robotics in the classroom, particularly with technological, sociocultural, and interaction aspects?
- Can you identify any current or potential future developments in robotics that could significantly impact educational practices, and how might these developments address the challenges you have described?
- In what ways do you think the use of advanced robotics could evolve to meet educational needs better, and what are the implications for educators and students?

Data analysis

The transcribed interviews were analyzed using coding and thematic analysis methods. Initially, open coding was employed to identify key concepts and recurring patterns within the data. These codes were then organized into broader themes that reflected the main aspects of educators' experiences with robotics. Thematic analysis involved iteratively reviewing and refining these themes to ensure they accurately represented the data. Techniques for interpreting the qualitative data included constant comparison and triangulation (which is to collect data from interviews and comparing the perspectives with the past literature and making future recommendations related to the topic of interest), which helped in validating findings and providing a robust understanding of the role of robotics in educational processes. This systematic analysis revealed how advanced robotics influence teaching practices, student engagement, and overall educational effectiveness.

Results and interpretation

In this study, participants responded to questions about integrating robotics in education. Through coding and thematic analysis, several key themes emerged. These themes reflect various aspects of robotics in education, including benefits, challenges, and future developments. The themes identified are:

- Benefits of Robotics
- Student Motivation
- Implementation Challenges
- Future Developments (see Appendix A)

Additionally, the study also identified new themes, including:

- Pedagogical Motivation
- Sociocultural Issues
- Adaptability
- Regulatory Needs
- Job Replacement
- Security Concerns
- Customization (see Appendix B)

Generated themes

Benefits of robotics

Participants recognized that robotics significantly enhances educational experiences by making learning more engaging and interactive. Robotics supports active learning and problem-solving, which helps students understand and practically apply abstract concepts. E1 respondent said that,

"Robotics significantly enhances students' engagement and problem-solving skills."

Moreover, E2 respondents also supported that the hands-on nature of robotics provides students with tangible experiences that can reinforce theoretical knowledge, making it easier to grasp complex concepts, as stated;

"Robotics helps students grasp mathematical concepts through practical application."

According to the TPACK framework, effective technology integration in education requires a balance between technological, pedagogical, and content knowledge. The study's findings support this framework by demonstrating that robotics can enhance student engagement and understanding, as E1 and E2 participants highlighted. These experiences reflect TPACK's accentuation on the collaboration between educational and technological methods to bolster substance learning (Zhakiyanova et al., 2023). The constructivist learning hypothesis advances and sustains these discoveries by highlighting that learners build information effectively through engagement in encounters (Valtonen et al., 2023). Robotics gives such encounters, permitting students to associate with and control unique concepts. This hands-on approach adjusts with the constructivist view that dynamic learning cultivates a more profound understanding, as outlined by E2's perception of robotics, making unique numerical concepts more substantial.

Student motivation

Robotics is seen as a powerful tool for boosting student motivation. Since E1 participants mentioned that,

"Robotics can increase motivation by making learning interactive and fun."

In the same manner, when asked about the active participation, E8 participants added that,

"Robotics often motivates students by making learning interactive and relevant."

The TPACK framework also accentuates technology's role in enhancing pedagogical practices to boost student motivation (Handika et al., 2023). E1's comment and E8's observation of robotics making learning relevant underscore how robotics can create engaging learning environments. These findings align with Csikszentmihalyi's Theory of Flow, which posits that optimal engagement occurs when students are challenged at an appropriate level, a condition facilitated by robotics's interactive and customizable nature.

Implementation challenges

Participants highlighted several challenges related to the implementation of robotics in education. These include technological issues such as high costs and maintenance, sociocultural disparities resulting in unequal access to resources, and difficulties in managing diverse student skill levels. As highlighted by E1 participants,

"Technological issues include the cost and maintenance of equipment."

However, E3 respondent provided that,

"If I talk about challenges, I will include the steep learning curve for both students and teachers. Technologically, maintaining and updating equipment can be demanding. Socioculturally, there may be inequities in access and resources, and interaction challenges involve coordinating group work effectively."

The challenges recognized in the research, such as costs, support, and sociocultural aberrations, relate to the innovative and sociocultural viewpoints of the Frankfurt Triangle aspect (Thyssen et al., 2023). E1's concern approximately caused, and the keep of harness and E3's point-by-point depiction of challenges counting sociocultural imbalances reflect the need to understand both mechanical and sociocultural components in instruction. This demonstration emphasizes the significance of tending to these variables to empower viable and evenhanded integration of innovation. Moreover, the concerns of overseeing different ability levels and guaranteeing viable bunch work relate to the interaction point of view of the Frankfurt Triangle. Viable human-computer interaction, as laid out in this viewpoint, requires tending to understudies' changed needs and abilities to optimize the instructive benefits of robotics.

Future developments

Participants anticipate that future advancements in robotics technology will address current limitations and enhance educational integration. The responses from participants E5 and E2, respectively were,

"Future developments such as more affordable and versatile robotics kits could improve access. Enhanced educational software that supports diverse learning styles might also address interaction and curriculum integration issues." (E5)

Likewise, E2 is summarized as,

"Advances in cloud-based robotics could alleviate software issues." (E2)

Furthermore, the participants also provided the concept and future of robots like as from the E4 participant statement,

"Yes, I see the future of robots, and I would say that robots that are more user-friendly and require less maintenance could alleviate some technological challenges."

As robotics technology advances, it will become more user-friendly and require less maintenance, addressing some current technological challenges. On this E6 respondent supported that,

"Future robotics could offer more adaptive learning experiences and better integration."

As discussed by E5 and E2, future advancements in robotics align with the TPACK framework's focus on evolving technological tools to better support educational goals. E5's expectation of more affordable and versatile robotics kits and E2's reference to cloud-based solutions reflect the ongoing need to enhance technological tools to improve integration and accessibility (Mangina et al., 2023). The Frankfurt Triangle model also highlights the importance of keeping pace with technological developments to address educational needs (Thyssen et al., 2023). This model supports the idea that as robotics technology evolves, it must continue to meet the demands of academic environments, ensuring that advancements are incorporated in ways that enhance teaching and learning.

Emerged themes

Pedagogical motivation

This theme emerged during the process and underscores the role of robotics in enhancing student motivation through interactive learning and gamification. As proclaimed by the E2 participant,

"Robotics can help boost motivation by making math more engaging and less abstract. Gamification of tasks and collaborative projects where students build and program robots can further drive their enthusiasm."

The emergence of pedagogical motivation as a theme reflects the TPACK framework's emphasis on integrating technology to enhance pedagogical strategies (Li & Song, 2024).

E2's point about robotics making math more engaging through gamification aligns with constructivist theories advocating for interactive learning experiences to boost motivation and understanding.

Sociocultural issues

All participants highlighted some social and cultural issues related to integrating robotics within the context of education. Challenges related to unequal access to resources and the difficulties in ensuring that all students are equally engaged with robotics were the participants' main concerns. As pointed out by an E4 participant,

"Socioculturally, there can be disparities in access to resources among students. Interaction-wise, it can be challenging to ensure that all students are equally involved and engaged."

Sociocultural issues, as highlighted by E4, reflect the need to consider the broader societal and cultural impacts of technology, as underlined by the Frankfurt Triangle model (Thyssen et al., 2023). Addressing disparities in access and ensuring equitable engagement with robotics are crucial for inclusive education.

Adaptability

During the interview, adaptability was the other theme that emerged, and participants pointed towards it since it is a critical factor in the future of robotics in education. As prescribed by the E6 participants,

"Future robotics could offer more adaptive learning experiences and better integration with existing educational technologies."

The theme of adaptability underscores the importance of flexible technological tools, aligning with the TPACK framework and the Frankfurt Triangle's technological–media perspective (Valle et al., 2024). E6's comment about adaptive learning experiences reflects the need for robotics to be adaptable to various educational contexts to maximize their effectiveness.

Regulatory needs

The need for dynamic and up-to-date regulatory frameworks is emphasized to keep pace with rapid technological advancements, and E7 respondent carries this point through the statement that,

"Today, as technology is rapidly growing, there is a need for a thorough regulatory structure that is dynamic and considers the latest developments."

The call for refitted administrative systems, as eminent by E7, adjusts with the broader requirement for arrangements that bolster innovative integration in education, also highlighted by Silva et al. (2023). This subject highlights the significance of creating directions that can suit fast, innovative headways and guarantee their viable and moral utilization in instructive settings.

Job replacement

Participants also highlighted the concerns related to job replacement and the potential effect of robotics on the part of teachers. Whereas robotics can improve learning, there are stresses around decreased human interaction and the potential for innovation to modify conventional instructing strategies that might influence students' well-being and instructive encounters. As pointed out by the E8 and E10 respondents, respectively,

"If I say that, no doubt, robots can benefit students, but as educators, sometimes we observe that these robots can replace us and that they can reduce human interaction, as we normally do in our classes with students, which can impact their physiological health."

"I also think that robots can change teachers' learning and methods, and that can become a problem in the future."

This subject relates to the interaction viewpoint of the Frankfurt Triangle, emphasizing the need to adjust innovative integration with essential human components in harmony in education (Ramachandran et al., 2024; Thyssen et al., 2023).

Security concerns

Additionally, the members tended to security concerns, which centered on potential issues related to the integration of robotics in education, including information security and framework security.

In this regard, E9 participants supported that,

"I want to add to it… ah, that there can be a security and information problem when integrating robotics in education, and we need to consider that as well."

As E9 says, security concerns are vital for guaranteeing that the integration of mechanical autonomy does not compromise information assurance or framework security. This topic reflects the need for strong measures to address potential dangers related to instructive technology.

Customization

Customization was another vital theme developed from the meet-through-handle examination, and it is crucial for adjusting mechanical technology to various instructional needs.

As proclaimed by the E10 respondent,

"Advanced robotics could become more integrated with digital learning environments and offer more personalized learning experiences. Moreover, ah, hmm…, this evolution

would make it easier for educators to implement and provide students with tailored learning opportunities."

E10 highlights customization, which relates to the TPACK framework's focus on fitting innovation to meet particular instructional needs. The capacity to customize robotics arrangements guarantees that they adapt to assorted instructional objectives and settings, improving their viability and relevance.

The study's findings, when interpreted through the focal point of the TPACK system, constructivist learning hypotheses, and the Frankfurt Triangle model, give a comprehensive understanding of robotics in education. Robotics offers noteworthy benefits in engagement, inspiration, and practical application of information, adjusting well with hypothetical standards of compelling innovation integration and constructivist learning (Li & Song, 2024). In any case, innovation, sociocultural variables, and usage challenges must be addressed to realize these benefits altogether. Future advancements in robotics and the development of supportive regulatory frameworks will be crucial for overcoming these challenges and enhancing the role of robotics in education. The recently risen topics highlighted the complex interaction between innovation, instructional methods, and societal components, underscoring the need for continuous reflection and adjustment in integrating robotics in educational settings.

The essential objective of instructive concepts related to advanced media and frameworks, agreeing to the Frankfurt Triangle model, should be to empower learners to analyze, reflect on, and plan advanced artifacts and the marvels related to them in the setting of these three viewpoints (the technological–media, the sociocultural, and the interaction points of view) (Thyssen et al., 2023). By creating these abilities, learners can better understand and judge the influence of advanced media and frameworks on people, society, and culture. This can assist them in utilizing advanced media and frameworks in more educated and moral ways and contribute to improving computerized media and frameworks that are advantageous to society. Considering these points of view, settings, and educational objectives, satisfactory information for instructors must be laid out when comparing models. These viewpoints bolster learners' and instructors' motivation and career readiness, improving educational outcomes.

Implication of the findings

For teachers and policymakers, the study's sightings offer noteworthy suggestions for viable robotics implementation in education. As the investigation highlights, robotics can considerably upgrade understudy engagement and understanding through intelligently hands-on learning encounters. Teachers should use robotics to engage more in practical learning situations, reverberating findings from Adel (2024) and Fridberg et al. (2023) that robotics can make unique concepts more substantial and fortify the motivation and encouragement of students. The study further recognizes challenges, comprising costs, maintenance issues, and sociocultural incongruities, which teachers and policymakers must address. Policymakers should prioritize subsidizing and bolstering reasonable, versatile mechanical technology arrangements to moderate these obstructions, reflecting concerns famous by Ifenthaler et al. (2024) and Ou and Chen (2024). An independent understanding of robotics technology assets is fundamental to guarantee that all learners will have an advantage from these technologies.

Moreover, the study highlights the need for versatile and user-friendly mechanical technology arrangements. Future headways ought to center on making mechanical autonomy more available and more straightforward to coordinate with existing instructive innovations, as proposed by Kim (2024). Moreover, policymakers ought to create energetic administrative systems to keep pace with quick, innovative changes and guarantee that robotics integration adjusts with instructive objectives, as backed by Huang et al. (2023). At last, tending to rising topics such as work substitution concerns and security issues is vital. Policymakers ought to consider the adjustment between innovation and human interaction to anticipate potential negative impacts on educators' parts and students' well-being. Guaranteeing strong information assurance and framework security measures will be imperative for the secure and viable use of mechanical technology in instruction, as emphasized by Neupane et al. (2024).

By addressing these considerations, educators and policymakers can better harness the potential of robotics to enhance educational outcomes while mitigating associated risks.

Limitations of the study

Although the study provided a comprehensive construction of robotics concepts in education and from the educationists' perspective, nonetheless, the study identified few limitations during this study. The study used a qualitative approach to address the study's objectives, though more in-depth analysis could have been done by involving quantitative analysis. However, the study attained the required objectives as prescribed. Additionally, regarding the participant selection, the study included fewer numbers due to time and resource constraints. However, it did not impact the study's findings as it attained the required responses from the participants.

Conclusion

The progression of instantaneous robotics technology extensively influences manifold dominions, with education developing as a principally promising area for its utilization. In identifying its importance in education, this study has explored the role of advanced robotics in education by conducting a qualitative analysis. The study aimed to evaluate the perceptions of educationists and teachers concerning the benefits of robotics in education and, similarly, to comprehend student motivation from their perspectives. Likewise, to explore the challenges in executing robotics in education and recognize prospective future implications and developments of robotics in education. The study included 10 participants and collected their views through open-ended questions. Moreover, the collected responses were analyzed using thematic analysis by coding and generating themes. Themes were generated, and new themes emerged, including security concerns, job replacement issues, customization, adaptability, pedagogical motivation, and regulatory needs related to robotics technology. The study also compared and interpreted the educationists' responses through the lens of the TPACK framework, constructivist learning theories, and the Frankfurt Triangle model, which provided a comprehensive understanding of the integration of robotics in education. The study found and perceived that robotics offers benefits in education, including knowledge practicality, motivation, and engagement. Nevertheless, the study also identified the challenges related to robotics implementation, such as technology, sociocultural factors, cost, maintenance, security concerns, adaptability, and others that must be addressed. The study emphasizes the need for future advancements and regulatory frameworks to enhance robotics' role in education. It calls for adaptable solutions, integration with existing technologies, and addressing job replacement, security, and data protection concerns.

Future recommendations

Based on its findings, this study provides some potential recommendations for policymakers and educationists to advance robotics implementation in education for better-personalized learning. To promote robotics education, educators and policymakers should invest in affordable kits, partner with technology providers, and provide grants for underserved schools. Future robotics development should prioritize user-friendliness and seamless integration with existing technologies. It is essential to perceive and combat sociocultural disparities and implement dynamic regulations. Technology should complement human educators, protect data, and promote customizable solutions. Also, a comprehensive framework is required to resolve challenges such as job security and job replacement. This entails data protection measures such as strict compliance with privacy laws, secure cloud storage for student data, encryption technologies to safeguard sensitive information, human-robot interaction to complement educators instead of replacing them, and means to discourage strengthening socioeconomic inequalities.

Moreover, there is a requirement for targeted professional developmental programs for educators. These should enhance educators' technological skills for integrating robotics into the classroom. The teachers can attend peer mentoring, numerous group workshops, and similar continuous learning situations to update their skills and cover the gap in technological know-how, which would, in turn, facilitate more effective deployment of robotics to enhance the learning experience and achievements of the students as learners. Lastly, educators can utilize different approaches such as pre-and post-assessment, surveys, observational data, and longitudinal studies to evaluate the long-term impact of robotics on students' participation and learning across different age groups and subjects.

Abbreviations

CBAM: Concerns-Based Appropriation Model; DOI: Diffusion of Innovation; STEM: Science, Technology, Engineering, and Mathematics; TAM: Technology Acceptance Model; TPACK: Technological Pedagogical Content Knowledge; UTAUT: Unified Theory of Acceptance and Use of Technology; WEF: World Financial Gathering.

Acknowledgments

I thank Mohamed Bin Zayed University for Humanities, Abu Dhabi, United Arab Emirates, for their encouragement throughout the research.

Author's contributions

M.A.K. did the whole research solely.

Author's information

M.A.K. holds a Ph.D. in educational technology and specializes in integrating advanced technologies into educational settings. She has extensive experience in leading research initiatives focused on innovation in education at Mohamed Bin Zayed University for Humanities.

Funding

Not applicable.

Availability of data and materials

The data supporting this study's findings are not publicly available due to the need to maintain respondent confidentiality.

Declarations

Competing interests

The author declares that she has no competing interests.

Received: 13 August 2024 Accepted: 29 November 2024
Published online: 1 January 2026 (Online First: 8 May 2025)

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