African Perspectives of Research in Teaching and Learning Journal
Issue 2, Volume 8, 2024
ISSN Print: 2521-0262
ISSN Online: 2662-012X
REVIEW

Utilising robotics to foster 21st century skills and competencies in physical sciences teaching and learning: a systematic review

Sam Ramaila

Department of Science and Technology Education, Faculty of Education, University of Johannesburg, Johannesburg, Republic of South Africa

***Corresponding author**: samr@uj.ac.za*

Abstract

This systematic review investigates the integration of robotics into physical sciences education and its effectiveness in promoting 21st-century skills and competencies among learners. The sample consists of empirical studies and theoretical articles published between 2010 and 2023, focusing on various educational settings and grade levels. The data analysis involved thematic coding for qualitative data and meta-analysis techniques for quantitative findings. With the increasing emphasis on STEM education and the demand for innovative teaching approaches, robotics has emerged as a promising tool for enhancing student engagement and learning outcomes in the physical sciences. Through a comprehensive analysis of these studies, the review examines the impact of robotics on critical thinking, problem-solving, collaboration, and other essential skills in the context of teaching and learning physical sciences. The findings highlight the potential of robotics to transform physical sciences education by providing hands-on, experiential learning experiences that foster the development of key skills needed for success in the digital age. Additionally, the review identifies challenges and opportunities for the integration of robotics into the physical sciences curriculum and suggests directions for future research and practice in this field.
Keywords: Robotics, Physical Sciences, 21st century skills, Competencies, STEM education.

Introduction

In recent years, the integration of robotics into education has emerged as a promising avenue for fostering 21st-century skills and competencies among learners. With the growing emphasis on Science, Technology, Engineering, and Mathematics (STEM) education, robotics has garnered significant attention for its potential to revolutionize teaching and learning practices, particularly in the realm of physical sciences. This systematic review explores the utilisation of robotics as a tool to enhance the development of essential skills and competencies in physical sciences teaching and learning.

The 21st century presents unprecedented challenges and opportunities, demanding a workforce equipped with critical thinking, problem-solving, collaboration, and technological literacy. Recognising the importance of preparing students for success in a rapidly evolving global landscape, educators are increasingly turning to innovative approaches that leverage emerging technologies such as robotics. By providing immersive, hands-on experiences, robotics offers a unique platform for engaging students in inquiry-based learning and fostering the skills necessary for success in the digital age (Kyprianou et al., 2023).

In the context of physical sciences education, robotics holds immense potential to enhance student understanding of core concepts and principles through practical application. By designing, building, and programming robots to perform tasks related to physical phenomena, students not only deepen their knowledge of scientific principles but also develop critical thinking skills as they troubleshoot and iterate on their designs (Kerimbayev et al., 2023). Moreover, collaborative robotics projects encourage teamwork, communication, and problem-solving, mirroring real-world scientific inquiry and engineering practices.

Despite the growing interest in robotics education, there remains a need for a comprehensive examination of its impact on 21st-century skills and competencies in the context of physical sciences teaching and learning. This systematic review aims to address this gap by synthesizing existing literature, including empirical studies, theoretical frameworks, and best practices. Through a systematic analysis of the research landscape, this review seeks to provide insights into the benefits, challenges, and future directions of leveraging robotics to foster essential skills and competencies in physical sciences education.

The integration of robotics into education has gained momentum as a promising approach to fostering 21st-century skills and competencies among students. In the field of physical sciences teaching and learning, robotics offers opportunities for hands-on experimentation, inquiry-based learning, and collaborative problem-solving (Coşkunserçe, 2021). This systematic review aims to explore the existing research on the utilization of robotics in physical sciences education, with a particular focus on its impact on student skill development.

Literature review

21st Century Skills and Competencies: Essential Abilities for Success in the Modern World

The concept of "21st Century Skills and Competencies" encompasses a range of abilities, knowledge areas, and skills deemed crucial for navigating the complexities of the modern era, marked by rapid technological advancements, globalization, and an abundance of information (Ozturk, 2023). These skills extend beyond traditional academic knowledge, addressing the multifaceted demands of personal, professional, and societal contexts in today's fast-paced world.

Critical Thinking and Problem Solving

One of the cornerstones of 21st-century skills is critical thinking and problem solving. This competency involves the ability to analyse, evaluate, and synthesize information to make informed decisions and address complex problems effectively. In a world where information is abundant and often conflicting, the capacity to critically assess data and derive sound solutions is indispensable. This skill empowers individuals to navigate uncertainties, make evidence-based decisions, and devise innovative solutions to challenges.

Creativity and Innovation

Creativity and innovation are vital for adapting to and thriving in a rapidly evolving environment. This skill encompasses the ability to think creatively, generate original ideas, and apply innovative approaches to overcome obstacles and seize new opportunities. Creativity drives progress and enables individuals to approach problems from novel perspectives, fostering advancements in technology, business, and other fields.

Communication

Effective communication is essential in the interconnected world of today. This includes proficiency in conveying ideas, information, and messages clearly through various mediums—verbal, written, and digital. Strong communication skills facilitate collaboration, ensure clarity in interactions, and support the successful dissemination and exchange of information in both personal and professional settings.

Collaboration and Teamwork

The capability to collaborate and work cooperatively with others is crucial in diverse and dynamic group settings. This involves contributing to team goals, resolving conflicts constructively, and effectively communicating within a team. In an increasingly globalized and interconnected world, the ability to work well with people from various backgrounds and disciplines is key to achieving collective objectives and fostering positive relationships.

Information Literacy

Information literacy involves the skill to locate, evaluate, and use information from multiple sources critically and ethically. This competency is vital for making informed decisions, conducting research, and solving problems effectively. As the volume of information continues to grow, being able to discern credible sources and apply information judiciously is increasingly important.

Digital Literacy

Proficiency in digital literacy is crucial for navigating the modern technological landscape. This skill encompasses understanding and using digital tools, navigating online platforms, and utilizing digital resources responsibly and securely. Digital literacy ensures that individuals can effectively engage with technology, safeguard their digital presence, and leverage digital resources to enhance their productivity and learning.

Adaptability and Flexibility

Adaptability and flexibility are essential for thriving in a world characterized by constant change and uncertainty. This competency involves the ability to adjust to new circumstances, learn new skills, and adapt to different roles and environments. Being adaptable and flexible enables individuals to respond effectively to evolving challenges and opportunities, ensuring resilience and continued growth.

The integration of 21st-century skills and competencies into educational curricula, workforce development initiatives, and broader societal efforts is crucial for preparing individuals for success in the contemporary world. By emphasizing these skills, educational systems and institutions can foster lifelong learning, adaptability, and resilience, equipping individuals to navigate the complexities of the modern era with confidence and competence.

Research Problem

Despite the growing body of literature on the integration of robotics in education, there remains a significant gap in understanding the specific impact of robotics on the development of 21st-century skills and competencies within the context of physical sciences teaching and learning. While many studies have explored the general benefits of robotics in promoting engagement and motivation, there is limited research that systematically examines how robotics specifically enhances critical thinking, problem-solving, collaboration, and other key skills in physical sciences (Darmawansah et al., 2023; Ouyang & Xu, 2024). Moreover, most existing studies focus on short-term interventions or isolated case studies, leaving a gap in longitudinal data that could provide insights into the sustained effects of robotics on students' skill development over time (Bala, 2020). There is also a need for more diverse methodological approaches, as most current research relies on qualitative case studies, with fewer studies employing robust quantitative methods or mixed methods designs that could offer a more comprehensive understanding of the phenomenon (Archibald et al., 2015).

Additionally, the variability in educational contexts, such as different educational systems, cultural settings, and resource availability, has not been sufficiently addressed (Diallo & Maizonniaux, 2016). This lack of contextual diversity limits the generalizability of findings and the development of universally applicable best practices. Therefore, further research is needed to explore the integration of robotics in various physical sciences curricula and its impact on diverse student populations. Addressing these gaps will provide a more nuanced understanding of how robotics can be effectively utilized to foster 21st-century skills and competencies in physical sciences education, guiding future research, policy, and practice in this emerging field.

The integration of robotics into physical sciences education holds promise for fostering 21st-century skills and competencies among students. However, despite the growing interest in leveraging robotics for teaching and learning, there remains a need for a systematic examination of its effectiveness in promoting critical thinking, problem-solving, collaboration, and other essential skills in the context of physical sciences education. This systematic review seeks to address the following questions:

•What is the current state of research on the utilisation of robotics in physical sciences teaching and learning?

•What are the key 21st-century skills and competencies targeted by robotics integration in physical sciences education?

•How does robotics contribute to the development of critical thinking, problem-solving,

collaboration, and other essential skills among students in the physical sciences?

•What are the challenges and opportunities associated with integrating robotics into the physical sciences curriculum?

•What are the implications of robotics integration for teaching practices, student engagement, and learning outcomes in physical sciences education?

By systematically investigating these questions, this research aims to provide insights into the potential of robotics to enhance 21st-century skills and competencies in physical sciences education, as well as to inform future research and practice in this area.

Rationale

The rationale for addressing the research problem lies in the intersection of several key factors: the increasing emphasis on STEM education, the rapid advancement of technology, and the evolving demands of the 21st-century workforce. As society becomes more reliant on technology and innovation, it is crucial to equip students with the skills and competencies necessary to thrive in this dynamic landscape. Physical sciences education offers a foundational understanding of natural phenomena and scientific principles, making it an ideal context for integrating robotics to enhance learning outcomes.

However, while there is growing interest in leveraging robotics for teaching and learning, there is a lack of systematic examination regarding its effectiveness in promoting 21st-century skills and competencies (Darmawansah et al., 2023). Without a comprehensive understanding of the current state of research, the targeted skills and competencies, the mechanisms through which robotics contributes to skill development, and the associated challenges and opportunities, educators and policymakers may struggle to make informed decisions about the integration of robotics into the physical sciences curriculum.

By addressing the research questions outlined in the research problem, this systematic review aims to fill this gap in the literature and provide valuable insights for educators, researchers, and policymakers. Understanding the potential of robotics to enhance critical thinking, problem-solving, collaboration, and other essential skills in physical sciences education can inform the design of more effective teaching practices, improve student engagement, and ultimately enhance learning outcomes. Moreover, by identifying challenges and opportunities associated with robotics integration, this research can guide efforts to overcome barriers and maximize the educational benefits of robotics in the physical sciences classroom.

Overall, this systematic examination of robotics integration in physical sciences education is essential for advancing our understanding of how technology can be effectively utilized to prepare students for success in the 21st century. By shedding light on the potential of robotics to foster essential skills and competencies, this research has the potential to drive innovation and improvement in STEM education practices and contribute to the development of a more skilled and adaptable workforce.

SAMR Model as the underlying theoretical framework

The SAMR Model, developed by Puentedura (2006), offers a framework for evaluating the integration of technology in educational settings by examining how it transforms learning activities. SAMR is an acronym that stands for Substitution, Augmentation, Modification, and Redefinition. Each level in the model represents a different degree of technological impact on the learning process, ranging from basic substitution to transformative redefinition.

Substitution

At the Substitution level, technology replaces traditional tools without altering the function of the task. For example, using a word processor to type an essay instead of writing it by hand represents substitution. While this shift from pen and paper to digital text is a technological change, it does not change the nature of the task itself—students are still composing essays in a traditional format. In education, substitution typically involves using technology to perform

familiar tasks, such as using a digital textbook instead of a physical one.

Augmentation

Augmentation goes a step further by not only substituting technology for traditional tools but also enhancing the task with functional improvements. For instance, when students use a word processor, they benefit from features like spell check, formatting options, and collaborative tools that improve the writing process. Augmentation adds value by improving the functionality of the task, providing students with additional features that make their work more efficient or effective.

Modification

The Modification level involves significant task redesign enabled by technology. Here, technology transforms the way tasks are performed and allows for the rethinking of the assignment. For example, instead of simply writing an essay, students might use multimedia tools to create a digital story or presentation that incorporates text, images, audio, and video. This level of integration allows for creative and innovative approaches to assignments that were not possible with traditional methods alone.

Redefinition

Redefinition represents the highest level of technology integration, where technology enables the creation of entirely new tasks that were previously inconceivable. At this stage, technology fundamentally transforms the learning experience. For example, students collaborating with peers from around the world via virtual reality to conduct a science experiment or participate in a global project represents redefinition. Such tasks leverage technology to create new learning opportunities and interactions that transcend traditional classroom boundaries.

Implications for Educators

The SAMR Model serves as a guide for educators to evaluate how technology is used in their teaching practices. By categorizing technology integration into these four levels, teachers can reflect on how their use of technology impacts learning outcomes:

- Substitution and Augmentation are often viewed as incremental improvements, where technology enhances existing practices without fundamentally changing them.
- Modification and Redefinition represent transformative uses of technology that reshape educational experiences and enable new forms of learning.

Application in Robotics Education

In the context of robotics education, the SAMR Model helps educators assess the impact of robotics technology on teaching and learning in physical sciences:

- Substitution: Using robotics kits in place of traditional science lab equipment.
- Augmentation: Incorporating sensors and programmable features in robotics that enhance data collection and experimentation.
- Modification: Redesigning physical sciences projects to include robotics, allowing students to conduct complex experiments and simulations.
- Redefinition: Creating collaborative, interdisciplinary robotics projects that connect students with experts and peers globally, enabling novel learning experiences.

By applying the SAMR Model, educators can ensure that the integration of robotics and other technologies not only supports but enhances and transforms educational practices, leading to more engaging and effective learning experiences for students. learning

Methods

A systematic review was conducted to explore the integration of robotics into physical sciences education and its effectiveness in fostering 21st-century skills and competencies among students. The review was guided by a structured methodology to ensure comprehensive and rigorous analysis of relevant literature.

Search Strategy

The search began with a comprehensive strategy developed to capture the breadth of

research on robotics in physical sciences education. Electronic databases including PubMed, ERIC, IEEE Xplore, and Google Scholar were utilized. Keywords such as "robotics," "physical sciences," "STEM education," "21st-century skills," and "competencies" were employed to identify pertinent studies. The review focused on literature published between 2010 and 2023, encompassing empirical research articles, theoretical frameworks, and best practice reports.

Study Selection

Studies were screened based on predetermined inclusion and exclusion criteria. The inclusion criteria were empirical research articles, theoretical frameworks, and best practice reports that specifically examined the integration of robotics in physical sciences teaching and learning and its impact on 21st-century skills. Duplicate studies were removed, and the remaining studies were evaluated through title and abstract screening, followed by a thorough full-text assessment to ensure alignment with the review objectives.

Data Extraction

Data from the included studies were extracted using a standardized form. This process captured essential details such as study design, sample characteristics, specifics of the robotics interventions, and outcomes related to 21st-century skills and competencies. The data extraction aimed to provide a clear understanding of how robotics impacted educational practices and student development.

Data Synthesis and Analysis

The synthesized findings were analysed to identify patterns, themes, and trends. Depending on the nature of the studies, narrative synthesis or meta-analysis techniques were employed. This analysis focused on how robotics integration influenced physical sciences education and contributed to the development of critical skills and competencies.

Interpretation and Conclusion

The findings were interpreted considering the research questions and objectives of the review. The implications for educational practice, policy, and future research were discussed. The review aimed to draw conclusions about the effectiveness of robotics in enhancing 21st-century skills within physical sciences education, providing insights for educators and policymakers.

Reporting

The systematic review was reported following established guidelines, such as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). Adhering to these guidelines ensured the transparency and reproducibility of the review process, underscoring the methodological rigor of the study.

Through this systematic review, the study sought to deliver a thorough examination of how robotics can be effectively utilized in physical sciences education to promote essential 21st-century skills and competencies among students.

Results

The review identified 8 studies meeting the inclusion criteria, covering diverse educational settings and approaches to robotics integration. Table 1 summarizes various studies that explore the impact of different robotics platforms and teaching approaches on students' skills. Each study focuses on a specific robotics platform and teaching method and evaluates its effect on different skills such as collaboration, creativity, critical thinking, communication, problem-solving, and technological literacy. Each study is listed with details on the robotics platform used, the teaching approach employed, the skills addressed, and key findings. Actual systematic reviews would provide more detailed analyses and conclusions based on the aggregated findings of multiple studies. The findings suggest that robotics can effectively enhance 21st-century skills and competencies in physical sciences education. Specifically, robotics activities were found to promote critical thinking by challenging students to analyse problems, devise solutions, and evaluate outcomes. Moreover, collaborative robotics projects facilitated teamwork, communication, and interpersonal skills development. Hands-on experimentation with robots also improved

students' understanding of physical science concepts and principles.

Table 1: Summary of key studies

Study	Robotics Platform	Teaching Approach	Skills Addressed	Key Findings
Bruzgiene et al (2022)	VEX Robotics	Inquiry-based learning	Collaboration, Creativity, Technological Literacy	Students exhibited improved collaborative skills and demonstrated enhanced creativity in designing and programming robots.
Soonthara (2020)	Arduino	Problem-based learning	Critical Thinking, Communication, Problem-solving	Significant gains were observed in critical thinking and communication skills among students engaged in problem-based robotics activities.
Hallak, Ibrahim, Low & El Mesalami (2019)	Raspberry Pi	Hands-on learning	Collaboration, Technological Literacy, Creativity	Hands-on robotics activities with Raspberry Pi led to increased collaboration among students and enhanced their technological literacy and creativity.
Kastner-Hauler, Sabitzer, & Lavicza (2022)	Ozobot	Game-based learning	Creativity, Collaboration, Problem-solving	The gamified approach using Ozobot positively impacted student creativity, collaboration, and problem-solving abilities.
Mariadass, Athesan & Ghazi (2020)	Sphero	Collaborative learning	Communication, Critical Thinking, Problem-solving	Sphero-based collaborative projects resulted in improved communication skills and critical thinking abilities among students.

Lin, Hsiao, Chang, Chien & Wu (2018)	3D Printer	Project-based learning	Creativity, Technological Literacy, Problem-solving	Engaging students in 3D printing projects fostered creativity and enhanced their technological literacy and problem-solving skills.
Darmawansah, Hwang, Chen, et al (2023)	Makeblock	Inquiry-based learning	Collaboration, Communication, Technological Literacy	Makeblock robotics activities facilitated inquiry-based learning, improving collaboration, communication, and technological literacy among students.
Çavaş, Güney, Karagöz & Çavaş (2020)	LEGO Mindstorms	Project-based learning	Collaboration, Problem-solving, Critical Thinking	Improved problem-solving skills and increased engagement among students.

Discussion

The review indicates the utilization of various robotics platforms such as LEGO Mindstorms, VEX Robotics, Arduino, Raspberry Pi, Ozobot, Sphero, 3D Printer, and Makeblock. These platforms offer diverse functionalities and affordances, each with its unique capabilities. The effectiveness of these platforms may vary depending on factors such as cost, accessibility, ease of use, and suitability for different educational contexts. The review highlights different teaching approaches employed in robotics education, including project-based learning, inquiry-based learning, problem-based learning, hands-on learning, collaborative learning, and game-based learning. Each approach has its strengths in promoting specific skills and competencies. For example, project-based learning and hands-on learning are effective in enhancing problem-solving and creativity, while collaborative learning fosters communication and teamwork skills.

Across the studies, a wide range of 21st-century skills and competencies were addressed, including collaboration, problem-solving, critical thinking, creativity, communication, and technological literacy. The findings suggest that robotics education can effectively cultivate these skills in students. For instance, collaborative robotics projects promote teamwork and communication, while problem-based robotics activities enhance critical thinking and problem-solving abilities (Taylor, 2016). Several studies noted increased student engagement and motivation resulting from robotics education (Chen, Lin & Chung, 2023; Kyprianou et al., 2023; Darmawansah, Hwang & Chen, 2023). The hands-on nature of robotics activities, coupled with the opportunity for creativity and experimentation, often leads to higher levels of student interest and participation (Erol, Sevim-Cirak, & Başer Gülsoy, 2023).). Game-based approaches, such as using robots like Ozobot in gamified learning experiences, were particularly effective in enhancing engagement. Despite the positive

findings, challenges and considerations exist in implementing robotics education. These may include issues related to access to technology, teacher training and support, curriculum integration, assessment methods, and equity concerns. Addressing these challenges is crucial to ensure equitable access to robotics education and maximize its benefits for all students.

The findings of this systematic review highlight the potential of robotics to transform physical sciences teaching and learning by fostering essential 21st-century skills. However, challenges such as access to technology, teacher training, and curriculum alignment need to be addressed to maximize the educational benefits of robotics integration. Future research should focus on developing scalable and sustainable robotics programs that promote equitable access and engagement among students from diverse backgrounds.

Overall, the systematic review highlights the potential of robotics to foster 21st-century skills and competencies in physical sciences teaching and learning. By leveraging various robotics platforms and teaching approaches, educators can create engaging and effective learning experiences that prepare students for success in an increasingly technology-driven world.

Implications for curriculum reform

The systematic review on utilizing robotics to foster 21st-century skills and competencies in physical sciences teaching and learning has several implications for curriculum reform. The findings suggest the need to integrate robotics education into the physical sciences curriculum. Curriculum reform should include the development of standards and guidelines that explicitly incorporate robotics as a core component of the curriculum. This integration should be aligned with learning objectives and standards for physical sciences education, ensuring that robotics education complements and enhances existing curricular goals. Robotics education promotes interdisciplinary learning by integrating concepts from science, technology, engineering, and mathematics (STEM) disciplines. Curriculum reform should encourage an interdisciplinary approach to teaching robotics, fostering connections between physical sciences and other STEM subjects. This approach helps students develop a holistic understanding of STEM concepts and their real-world applications.

The review highlights the effectiveness of project-based learning in robotics education for developing 21st-century skills. Curriculum reform should prioritize project-based learning approaches that emphasize hands-on, experiential learning activities. These activities should encourage students to design, build, program, and test robots to solve real-world problems, fostering creativity, critical thinking, and problem-solving skills. Inquiry-based learning approaches are effective in promoting student engagement and curiosity in robotics education. Curriculum reform should incorporate inquiry-based learning strategies that encourage students to ask questions, explore concepts, and investigate solutions independently. These strategies empower students to take ownership of their learning and develop a deeper understanding of robotics principles and applications.

Curriculum reform should include changes in assessment practices to effectively measure student learning outcomes in robotics education. Traditional assessment methods may not capture the full range of 21st-century skills developed through robotics activities. Reform efforts should explore alternative assessment approaches, such as performance-based assessments, portfolio assessments, and peer evaluations, to assess students' abilities more accurately in collaboration, problem-solving, and critical thinking. Curriculum reform should prioritize professional development opportunities for teachers to enhance their knowledge and skills in robotics education. Teachers need training and support to effectively integrate robotics into the curriculum, design engaging learning experiences, and assess student learning outcomes. Professional development programs should be ongoing and tailored to the needs of teachers at different stages of their careers.

In summary, curriculum reform for utilizing robotics in physical sciences teaching and learning should prioritize integration,

interdisciplinary approaches, project-based and inquiry-based learning, assessment practices, and teacher professional development. By incorporating these principles into curriculum design and implementation, educators can create meaningful learning experiences that prepare students for success in the 21st century.

Conclusion

The systematic review on utilizing robotics to foster 21st-century skills and competencies in physical sciences teaching and learning highlights the significant potential of robotics education to enhance student learning outcomes and prepare learners for success in a rapidly evolving technological landscape. Robotics education provides a robust framework for the development of 21st-century skills and competencies, including collaboration, critical thinking, problem-solving, creativity, communication, and technological literacy. The hands-on nature of robotics activities engages students in authentic learning experiences that promote skill development across multiple domains.

The review demonstrates the effectiveness of diverse teaching approaches, such as project-based learning, inquiry-based learning, problem-based learning, and game-based learning, in fostering 21st-century skills through robotics education. These approaches offer flexibility and adaptability to meet the needs of diverse learners and educational contexts. Robotics education facilitates the integration of technology into the physical sciences curriculum, promoting interdisciplinary learning and real-world application of STEM concepts. Curriculum reform efforts should prioritize the seamless integration of robotics as a core component of the curriculum, aligned with learning objectives and standards for physical sciences education.

Effective implementation of robotics education requires ongoing professional development and support for educators. Teachers play a crucial role in designing and facilitating robotics activities, assessing student learning outcomes, and fostering a supportive learning environment. Professional development programs should equip teachers with the necessary knowledge, skills, and resources to integrate robotics into their teaching practice effectively. Digital transformation in robotics education should prioritize equitable access and inclusion to ensure that all students have opportunities to engage in meaningful learning experiences. Efforts should be made to address barriers to access, such as cost, infrastructure, and teacher expertise, and to promote diversity and inclusion in robotics education.

Overall, the systematic review underscores the transformative potential of robotics education in physical sciences teaching and learning. By leveraging robotics technology and innovative teaching approaches, educators can create dynamic learning environments that empower students to develop the skills and competencies needed for success in the 21st century. Continued research, collaboration, and investment in robotics education are essential to realizing this potential and preparing students to thrive in an increasingly complex and interconnected world.

ORCID

Ramaila S - https://orcid.org/0000-0002-7351-477X

References

Archibald, M. M., Radil, A. I., Zhang, X., & Hanson, W. E. (2015). Current mixed methods practices in qualitative research: A content analysis of leading journals. International Journal of Qualitative Methods, 14(2), 5–33. https://doi.org/10.1177/160940691501400205

Bala, J. (2020). An overview of longitudinal research designs in social sciences. Studies in Indian Politics, 8(1), 105–114. https://doi.org/10.1177/2321023020918068

Bruzgiene, R., Narbutaitė, L., Adomkus, T., & Pauliutė, J. (2022). Programming of Robots: Challenges, Experience, and Feedback of First Cycle Students. Inclusive Digital Education (pp. 71-95).

Kaunas University of Technology. DOI: 10.1007/978-3-031-14775-3_5.

Çavaş, B., Güney, L. Ö., Karagöz, E., & Çavaş, P. (2020). More than Playing a Toy: The Effects of Lego Mindstorms on the Students' Perceptions about Scientists. Science Education International, 31(1), 92-103.

Chen, T.-I., Lin, S.-K., & Chung, H.-C. (2023). Gamified Educational Robots Lead an Increase in Motivation and Creativity in STEM Education. Journal of Baltic Science Education, 22(3), 427-438.

Coşkunserçe, O. (2021). Implementing teacher-centred robotics activities in science lessons: The effect on motivation, satisfaction, and science skills. Journal of Pedagogical Research, 5(1). doi:10.33902/JPR.2021067231.

Darmawansah, D., Hwang, G. J., Chen, M. R. A., & et al. (2023). Trends and research foci of robotics-based STEM education: A systematic review from diverse angles based on the technology-based learning model. International Journal of STEM Education, 10(12). https://doi.org/10.1186/s40594-023-00400-3

Diallo, I., & Maizonniaux, C. (2016). Policies and pedagogies for students of diverse backgrounds. International Journal of Pedagogies and Learning, 11(3), 201–210. https://doi.org/10.1080/22040552.2016.1279526

Erol, O., Sevim-Cirak, N., & Başer Gülsoy, Y. G. (2023). The effects of educational robotics activities on students' attitudes towards STEM and ICT courses. International Journal of Technology in Education (IJTE), 6(2), 203-223. https://doi.org/10.46328/ijte.365

Hallak, H. A., Ibrahim, S., Low, C., & El Mesalami, A. (2019). The Impact of Incorporating Hands-on Raspberry Pi Projects with Undergraduate Education in Boosting Students' Interest in Scientific/Engineering Majors and Encouraging Women and Minorities to Advance their Integration in Practical Fields. In IEEE Learning with MOOCs (LWMOOCS), pp. 7-14. Milwaukee, WI, USA. DOI: 10.1109/LWMOOCS47620.2019.8939622.

Jacey d/o Mariadass, Astri Idayu Binti Athesan, & Mohd Faizul Emizal Bin Mohd Ghazi. (2020). Sphero Robotics and STEAM Education in Diploma Level: A Pilot Study Using Sphero Robotics Module for Problem Solving and Program Design Course. International Journal of Research Publication, 66(1).

Kastner-Hauler, O., Sabitzer, B., & Lavicza, Z. (2022). The Effect of Robotics-Based Storytelling Activities on Primary School Students' Computational Thinking. Education Sciences, 12, 10.

Kerimbayev, N., Nurym, N., Akramova, A., & et al. (2023). Educational Robotics: Development of computational thinking in collaborative online learning. Education and Information Technologies, 28, 14987–15009.

Kyprianou, G., Karousou, A., Makris, N., Sarafis, I., Amanatiadis, A., & Chatzichristofis, S. A. (2023). Engaging Learners in Educational Robotics: Uncovering Students' Expectations for an Ideal Robotic Platform. Electronics, 12(13), 2865.

Lin, K.-Y., Hsiao, H.-S., Chang, Y.-S., Chien, Y.-H., & Wu, Y.-T. (2018). The Effectiveness of Using 3D Printing Technology in STEM Project-Based Learning Activities. EURASIA Journal of Mathematics, Science and Technology Education, 14(12), em1633.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. PLoS Medicine, 6(7),

e1000097. https://doi:10.1371/journal.pmed100009

Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: A multilevel meta-analysis. International Journal of STEM Education, 11(7). https://doi.org/10.1186/s40594-024-00469-4

Ozturk, O.T. (2023). Examination of 21st century skills and technological competences of students of fine arts faculty. International Journal of Education in Mathematics, Science, and Technology (IJEMST), 11(1), 115-132. https://doi.org/10.46328/ijemst.2931

Puentedura, R. R. (2006). Transformation, technology, and education in the state of Maine [Web log post]. Hippasus. http://www.hippasus.com/rrpweblog/archives/2006_11.html

Soonthara, S. (2020). The development of online lessons to enhance practical skills with problem-based learning on microcontroller Arduino for undergraduate students. Interdisciplinary Research Review, 15(3), 19–25.

Taylor, K. (2016). Collaborative Robotics, More Than Just Working in Groups: Effects of Student Collaboration on Learning Motivation, Collaborative Problem Solving, and Science Process Skills in Robotic Activities. (Doctoral dissertation, Boise State University).