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A Review of Use of Artificial Intelligence in Teaching and Learning of Mathematics

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Abstract

This systematic review examines the integration of artificial intelligence (AI) in mathematics education, analyzing 60 research studies from 2017 to 2021. The findings highlight AI's transformative potential in enhancing teaching methodologies, improving student engagement, and facilitating the understanding of complex mathematical concepts. Key AI technologies explored include intelligent tutoring systems, robotics, and generative AI models such as ChatGPT. These tools enable personalized learning experiences, real-time feedback, and interactive problem-solving environments, addressing traditional challenges in mathematics instruction. However, the review also identifies limitations, including ethical considerations, implementation barriers, and contextual constraints in diverse educational settings. The study underscores the importance of a balanced approach that combines technological innovation with effective pedagogical practices, aiming to maximize the benefits of AI in mathematics education while mitigating its challenges. This comprehensive analysis provides a foundation for future research and practical applications, particularly in underrepresented regions, to advance the global adoption of AI in educational contexts.

Kewords: Artificial Intelligence (AI), Mathematics Education, Intelligent Tutoring Systems, Educational Robotics, Personalized Learning, Generative AI, Teaching Methodologies

Introduction:

Artificial intelligence (AI) is revolutionizing various sectors, including education, where it offers transformative possibilities for enhancing teaching and learning processes. Mathematics education, a field traditionally perceived as challenging, has significantly benefited from AI technologies. These innovations support educators in creating personalized, interactive, and engaging learning environments while enabling students to develop critical problem-solving skills. This paper explores the application of AI in mathematics education, focusing on its potential to address long-standing instructional challenges and improve academic outcomes. By leveraging tools such as intelligent tutoring systems, robotics, and generative AI models like ChatGPT, educators can provide customized learning experiences that cater to diverse student needs. However, the adoption of AI also presents challenges, including ethical considerations, resource disparities, and varying levels of technological proficiency among educators and students. Through a systematic review of 60 research publications from 2017 to 2021, this study aims to evaluate the effectiveness, benefits, and limitations of AI in mathematics education. The findings

offer valuable insights for educators, policymakers, and researchers seeking to integrate AI into teaching practices responsibly and effectively, ultimately transforming the educational landscape. We have divided the papers broadly into two categories: use of ChatGPT in teatching and learning of Mathematics and use of AI in teaching and learning of Mathematics. The first category exclusively discusses the use of ChatGPT whereas the second category includes any type of AI tool in teaching and learning of Mathematics.

ChatGPT for Teaching and Learning mathematics:

The advanced natural language processing (NLP) system, ChatGPT introduced in 2022, has not only been discussed in traditional and digital media but also sparked intense debates about its transformative potential and challenges. This technological innovation, hailed as a potential black swan event, has revived discussions on the societal implications of artificial intelligence (AI), particularly in education and academia. While some celebrate ChatGPT's accessibility and versatility, others express concerns over its unpredictable behaviors and possible misuse (Hidayat et al., 2021; Tashtoush et al., 2023). ChatGPT, an innovative natural language processing (NLP) tool launched in 2022, has become a focal point of both traditional and digital media. Its unpredictable capabilities have sparked debates, with some viewing it as a black swan event. Despite prior discussions around artificial intelligence (AI), ChatGPT's emergence has reignited public discourse on the technology's potential benefits and risks to society. While some innovators and early adopters commend its accessibility and utility, others express concerns reminiscent of dystopian portrayals, such as in the *Terminator* films. Among the diverse applications of ChatGPT, its implications for education and academia have been particularly significant, as its ability to produce human-like written content raises critical questions about its role in teaching and learning.

The evolution of AI from a perceived novelty to a transformative technology underscores its disruptive potential. The adoption of tools like ChatGPT is inevitable, making it essential to understand their advantages, limitations, and ethical considerations (Hidayat et al., 2021; Tashtoush et al., 2023). Particularly in education, evaluating ChatGPT's impact can help educators develop strategies to maximize its benefits while mitigating potential drawbacks (Firat, 2023; Tashtoush et al., 2022a). As stakeholders acclimate to this technology, resistance to change often dissipates, paving the way for its integration into everyday life (Alkaissi & McFarlane, 2023; De Winter, 2023; Deng et al., 2018; Tashtoush et al., 2022b; Thorp, 2023).

AI, a rapidly expanding field of computer science, encompasses applications from medical diagnostics to self-driving cars and educational tools. Combining AI with emerging technologies like the Internet of Things (IoT) has given rise to Artificial Intelligence of Things (AIoT), enabling further advancements (Deng et al., 2019; Tashtoush et al., 2023). ChatGPT stands out as a promising example, leveraging NLP and deep learning (DL) to simulate human-like interactions and address a broad range of subjects (Lin et al., 2023).

The global AI industry, predicted to surpass $450 billion in value by 2023 (Jyoti & Kuppuswamy, 2022), has seen significant strides across fields such as law (Arrabal Platero, 2022), finance (El Fallahi et al., 2022), medicine (García-Peñalvo et al., 2021), and education (Qu et al., 2022). ChatGPT

exemplifies this progress, using large language models to enhance user interaction, yet it also highlights the so-called "AI effect," where advanced AI capabilities are underestimated due to their perceived simplicity (Walker & Noorden, 2023; Bitzenbauer, 2023).

In education, AI technologies like ChatGPT are reshaping teaching methodologies. Generative Artificial Intelligence (GAI), powered by machine learning frameworks such as Generative Adversarial Networks (GANs) and Generative Pre-trained Transformers (GPTs), enables the creation of synthetic content for diverse applications (Abukmeil et al., 2021; Brown et al., 2020; Guo et al., 2023; Hu, 2022; Wardat, 2023). While GANs specialize in generating realistic data through adversarial training (Rudolph et al., 2023; Han & Kamber, 2011), GPT models like ChatGPT excel at generating coherent and contextually appropriate text for education, customer service, and more (Guo et al., 2023; Rudolph et al., 2023).

ChatGPT's potential in education, particularly mathematics, is vast. It supports educators by generating personalized content, facilitating problem-solving, and enhancing student engagement (Guo et al., 2023). Moreover, ChatGPT's ability to assist with assessments and feedback further underscores its value (Crust, 2023; De Winter, 2023). Students benefit from its intuitive interface, which enables easy comprehension of complex mathematical concepts. However, as with any tool, ChatGPT has limitations, including occasional inaccuracies and an inability to fully grasp contextual subtleties (Tenhundfeld & ChatGPT, 2023). Thus, its use must complement, rather than replace, traditional teaching methods. There are research suggestions for the responsible integration of ChatGPT into educational settings, ensuring its benefits are maximized while its risks are minimized (Pardos & Bhandari, 2023; Shahriar & Hayawi, 2023).

AI, a rapidly advancing field in computer science, focuses on creating intelligent systems capable of performing tasks typically associated with human cognition. This includes applications ranging from medical diagnostics to autonomous vehicles and educational tools (Deng et al., 2019; Lin et al., 2023). ChatGPT, specifically, represents a breakthrough in AI-powered chatbots, offering conversational capabilities that simulate human interaction. Built on the GPT-3 framework, ChatGPT's vast 175 billion parameters enable it to generate human-like responses, making it a promising tool for diverse applications, including mathematics education (Guo et al., 2023; Rudolph et al., 2023).

The integration of AI technologies such as ChatGPT into education has revolutionized teaching and learning processes. By enabling personalized learning experiences, providing instant feedback, and facilitating access to complex mathematical concepts, ChatGPT has the potential to enhance student engagement and academic achievement (Guo et al., 2023; Firat, 2023). However, its adoption is not without challenges. Limitations in accuracy, contextual understanding, and the ethical implications of its use necessitate a balanced approach that combines technological innovation with human oversight (Pardos & Bhandari, 2023; Shahriar & Hayawi, 2023). ChatGPT can be responsibly integrated into educational settings while maximizing its benefits and addressing its challenges (Frieder et al., 2023; Shakarian et al., 2023).

AI in Mathematics Teaching and Learning

The integration of artificial intelligence (AI) into education has gained significant attention in recent years, transforming teaching and learning practices across various disciplines, including mathematics. AI represents a leap forward in leveraging advanced technologies to enhance educational outcomes. Recent studies emphasize the profound potential of AI in facilitating better cognitive and mathematical skill development for students at all levels (Chen et al., 2020a; Cope et al., 2020; He et al., 2019; Schiff, 2021; Vaishya et al., 2020). By leveraging innovative tools, AI enables faster access to information and supports independent learning, empowering students to acquire knowledge beyond traditional classroom boundaries (Popenici & Kerr, 2017; Gao, 2020).

The role of AI in education is not limited to aiding students. It also augments teachers' efforts by introducing tools like teachable agents and robotics, which create dynamic and engaging learning environments (Song, 2017; Voskoglou & Salem, 2020). While AI enhances educational efficiency, it does not replace educators but instead complements their work by overcoming traditional teaching challenges (Cope et al., 2020). Despite these advantages, deploying AI technologies in education presents challenges such as resource requirements, ethical concerns, and public perception issues (Neri & Cozman, 2019; Popenici & Kerr, 2017).

The application of AI in mathematics education specifically offers unique benefits, such as improving problem-solving and conceptual understanding through tools like robotics and machine learning algorithms (Casler-Failing, 2018; Harper et al., 2021). However, existing research has predominantly focused on STEM and engineering contexts, leaving significant opportunities to explore AI's broader impact in mathematics education (Chen et al., 2020a; Zawacki-Richter et al., 2019). This systematic literature review aims to address these gaps by providing a comprehensive analysis of AI’s role in mathematics education, emphasizing its advantages, methodologies, and thematic trends. The findings contribute to understanding how AI can transform educational practices and inspire future research in this field.

In 1956, Marvin Minsky and John McCarthy organized the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI), a groundbreaking eight-week-long event that officially introduced the term "artificial intelligence" (AI). Since then, AI has been explored through various conceptual frameworks. A key challenge in defining AI, as discussed by Poole et al. (1998), lies in determining the parameters of artificiality and how computer intelligence fundamentally differs from human cognition (Cope et al., 2020). Broadly, AI represents a convergence of advancements in computer science, machine learning, and information communication technologies, enabling machines to perform tasks that mimic human capabilities (Chen et al., 2020b). Baker and Smith (2019) define AI as systems capable of executing cognitive functions such as problem-solving (PS) and learning, traditionally associated with human intelligence. Examples of AI technologies include data mining, natural language processing, neural networks, and algorithms, all of which have significant implications for decision-making in educational contexts (Hwang et al., 2020).

In mathematics education, AI fosters an innovative approach by integrating tools and methods that support the development of students’ cognitive and problem-solving skills. By employing animation and

software tools, students can enhance their imagination and critical thinking abilities (Voskoglou & Salem, 2020). AI technologies, including intelligent tutoring systems and robotics, have transformed classrooms into environments that facilitate dynamic and interactive learning experiences, thereby improving teaching methodologies. These technologies also address the long-standing goal of AI researchers: to replicate human-like reasoning, emotion, and problem-solving in machines while continuously pushing the boundaries of machine autonomy (Chesani et al., 2017).

The role of robotics, a prominent AI application, is particularly notable in mathematics education. Robotics has expanded across various domains, offering significant advantages for student engagement and motivation. For instance, tools like LEGO robotics, including the EV3 Mindstorms, provide students with hands-on opportunities to explore mathematical concepts interactively. Studies have shown that robotics can enrich middle school math instruction by fostering deeper engagement compared to traditional teaching methods (Casler-Failing, 2021). Despite these benefits, practical challenges such as classroom space and teacher-to-student ratios hinder the widespread adoption of robotics in early education (Seckel et al., 2021).

AI also promotes the development of personalized learning pathways. Models like Ouyang and Jiao's (2021) framework categorize AI's educational roles as AI-directed (learner-as-recipient), AI-supported (learner-as-collaborator), and AI-empowered (learner-as-leader). This framework underpins many AI applications, emphasizing their potential to adapt to diverse learning needs and enhance student outcomes.

Recent studies affirm the positive impact of AI on students' academic performance, creative problem-solving skills, and learning attitudes (Min et al., 2021; Kim & Han, 2021; Liao & Gu, 2022). From kindergarten to higher education, AI tools such as virtual assistants and AI-powered classroom environments have demonstrated their value in fostering conceptual understanding and integrating advanced pedagogical approaches (Chen et al., 2020b; Ma & Siau, 2018). In early education, for example, AI can transform classrooms into "wisdom classrooms," where students benefit from customized learning experiences tailored to their developmental stages.

Robotics is the most widely used approach to integrating artificial intelligence (AI) in mathematics education, surpassing other methods such as systems, tools, teachable agents, autonomous agents, and comprehensive approaches. This aligns with Zhong and Xia (2020), who identified the potential for rapid, evidence-based research in teaching mathematical content knowledge through robotics. With nine studies highlighting the use of robotics, research indicates a predominantly positive impact, as also observed by Seckel et al. (2021), who found that primary school teachers hold favorable views toward the inclusion of robots in mathematics instruction.

Systems and tools represent the second most common AI approaches in mathematics education. Various systems, such as R and MATLAB, have been applied in research (Duzhin & Gustafsson, 2018). Other examples include intelligent tutoring systems, designed to simulate the behavior of human educators (Hasanein & Abu-Naser, 2018), and integrated systems combining microworlds with intelligent support mechanisms. However, integrated systems remain limited in scope, as noted by Rojano and Garcia-

Campos (2017), who found that such systems sometimes fail to accommodate diverse student responses, particularly in algebraic or numerical contexts.

The comprehensive approach to AI in mathematics education has also demonstrated positive outcomes. Wu (2021) concluded that AI-assisted teaching significantly enhances foundational mathematics education, a finding supported by Zawacki-Richter et al. (2019), who noted AI's potential to advance learning analytics. However, challenges such as privacy concerns and the extensive data required for these systems persist, emphasizing the need for caution in their implementation. Given these findings, future research should focus on exploring robotics' full potential in mathematics education.

Geographically, the majority of reviewed studies were conducted in the United States and Mexico, with limited representation from countries such as the United Kingdom, Sweden, and China (Casler-Failing, 2018; Harper et al., 2021; Mills, 2021). Some countries, such as Norway, have integrated programming into mathematics curricula, which complements the use of robotics (Forsström & Afdal, 2019). Nevertheless, more intercultural research is needed to understand the varying impacts of AI on mathematics education across diverse contexts, particularly in underrepresented regions like Asia.

AI has shown potential to significantly enhance students' educational experiences by improving accessibility, fostering teacher-student communication, and allowing for personalized learning pathways. Wu (2021) found that AI-assisted teaching improved mathematics scores by 30% compared to traditional methods while fostering greater collaboration among students. These findings highlight the growing importance of incorporating AI into national education strategies, with Forsström and Afdal (2019) emphasizing the integration of programming and technology into curricula as a means to boost mathematics performance.

Methodologically, our review identified three research approaches: quantitative, qualitative, and mixed methods. Quantitative methods, which prioritize statistical and numerical data, were slightly more prevalent, with eight studies using this approach (e.g., Duzhin & Gustafsson, 2017; Gulz et al., 2020). Qualitative methods, employed in seven studies, were particularly effective in exploring behavioral and observational data, such as the use of LEGO robotics in classrooms (Casler-Failing, 2021). Mixed-method studies, though less common, provided valuable insights by reconciling quantitative and qualitative findings to enrich the understanding of AI's impact (Salas-Rueda et al., 2020).

Regarding publication trends, 2021 saw the highest number of AI-related studies, particularly from European authors. These studies often explored the role of robotics in enhancing active learning and engagement in mathematics (Lopez-Caudana et al., 2020). The findings suggest that educators are increasingly recognizing the benefits of robotics for fostering creativity, problem-solving, and mathematical thinking in students (Rico-Bautista et al., 2019).

Effectiveness emerged as the most researched theme in AI studies, underscoring its significant impact on mathematics education. Robotics, for instance, has been shown to promote deeper student engagement and understanding compared to traditional teaching methods (Casler-Failing, 2018). However, effective implementation requires careful planning and appropriate strategies, as highlighted by Lopez-Caudana et al. (2020).

Additionally, studies have explored strategies, roles, and conceptual understandings related to AI in education. Teachers' programming skills, for example, are crucial for effectively integrating AI tools into classrooms (Forsström & Afdal, 2020). Educators must also cultivate a strong conceptual grasp of AI to deliver meaningful and interactive learning experiences. The incorporation of AI not only enhances student creativity and critical thinking but also prepares them for a technologically advanced future (Seckel et al., 2021).

Artificial intelligence (AI) is the simulation of human intelligence within machines, designed to think and perform tasks typically requiring human input. AI systems rely on data and experience to function effectively, learning and improving autonomously through usage. In mathematics education, AI offers numerous advantages. It fosters critical thinking and responsibility in students, enhances their understanding of fundamental concepts in geometry, mathematics, and statistics, and improves interpersonal skills and social interactions. By creating dynamic learning environments, AI facilitates effective knowledge acquisition and a deeper engagement with mathematical concepts.

The findings of bin Mohamed et at. highlight various AI implementation approaches, including systems, teachable agents, autonomous agents, machine learning models, digital technology tools, and comprehensive frameworks. Among these, robotics emerges as the most commonly used method by students, teachers, and researchers due to its hands-on and engaging applications.

AI’s integration into mathematics teaching and learning has gained traction globally. Many countries have adopted AI to enhance education quality, with the United States leading in research publications over the past five years, followed by nations like Mexico and Canada. While various aspects of AI—such as advantages, limitations, and implementation strategies—are explored, its effectiveness remains the most frequently studied topic. Understanding this effectiveness is vital to expanding AI’s role in education. When proven successful, AI can be applied more broadly to revolutionize learning experiences.

Robotics, in particular, holds significant educational potential, enabling students and educators to explore mathematical concepts interactively. However, its implementation must be carefully managed to avoid adding unnecessary complexity to students’ workloads. Rather than relying on robotics as the sole tool, educators and students should leverage its capabilities to enhance mathematical understanding and focus on core concepts.

In summary, AI transforms teaching and learning into more engaging, creative, and efficient processes, simplifying complex subjects and enhancing students’ comprehension. With further exploration and thoughtful application, AI has the potential to redefine mathematics education and inspire broader adoption in classrooms worldwide.

Conclusion

This systematic review underscores the transformative potential of artificial intelligence (AI) in mathematics education, revealing its capacity to enhance teaching methodologies, foster personalized learning, and improve student engagement. By integrating tools such as intelligent tutoring systems,

robotics, and generative AI models like ChatGPT, educators can address traditional challenges and create dynamic, interactive learning environments that cater to diverse student needs. However, the study also highlights critical challenges, including ethical concerns, resource constraints, and varying levels of technological proficiency among stakeholders. These limitations emphasize the need for a balanced approach that combines innovative AI applications with robust pedagogical frameworks and ethical safeguards. The findings contribute to the growing body of research on AI in education, offering practical insights for policymakers, educators, and researchers. Future efforts should focus on addressing contextual and cultural disparities, exploring scalable solutions, and fostering interdisciplinary collaboration to ensure that AI technologies are harnessed responsibly and equitably. By doing so, AI can become a powerful ally in transforming mathematics education and advancing global educational goals.

References:

1. Abukmeil, M., Ferrari, S., Genovese, A., Piuri, V., & Scotti, F. (2021). A survey of unsupervised generative models for exploratory data analysis and representation learning. *ACM Computing Surveys, 54*(5), 1-40. https://doi.org/10.1145/ 3450963
2. Alkaissi, H., & McFarlane, S. (2023). Artificial Hallucinations in ChatGPT: Implications in scientific writing, *Cureus, 15*(2), pe35179. https://doi.org/10.7759/cureus.35179
3. Arrabal Platero, P. (2022). *Los objetivos de desarrollo sostenible y la inteligencia artificial en el proceso judicial* [*The sustainable development goals and artificial intelligence in the judicial process*]. Tirant lo Blanch.
4. Baker, T., & Smith, L. (2019). Educ-AI-tion rebooted? Exploring the future of artificial intelligence in schools and colleges. *Nesta*. https://media.nesta.org.uk/documents/Future_of_AI_and_education_v5_WEB.pdf
5. Bitzenbauer, P. (2023). ChatGPT in physics education: A pilot study on easy-to-implement activities. *Contemporary Educational Technology, 15*(3), ep430. https://doi.org/10.30935/cedtech/13176
6. Brown, T. B., Mann, B., Ryder, N., Subbiah, M., Kaplan, J., Dhariwal, P., & Amodei, D. (2020). Language models are few-shot learners. *arXiv*. https://doi.org/10.48550/arXiv.2005.14165
7. Casler-Failing, S. L. (2018). Robotics and math: Using action research to study growth problems. *Canadian Journal of Action Research, 19*(2), 4-25. https://doi.org/10.33524/cjar.v19i2.383
8. Casler-Failing, S.L. (2021). Learning to teach mathematics with robots: Developing the 't' in technological pedagogical content knowledge. *Research in Learning Technology, 29*. https://doi.org/10.25304/rlt.v29.2555
9. Chen, L., Chen, P., & Lin, Z. (2020a). Artificial intelligence in education: A review. *IEEE Access, 8*, 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510
10. Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020b). Application and theory gaps during the rise of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 1*, 100002. https://doi.org/10.1016/j.caeai.2020.100002
11. Chesani, F., Mello, P., & Milano, M. (2017). Solving mathematical puzzles: A challenging competition for AI. *Association for the Advancement of Artificial Intelligence, 38*(3), 83-96. https://doi.org/10.1609/aimag.v38i3.2736

12. Cope, B., Kalantzis, M., & Searsmith, D. (2020). Artificial intelligence for education: Knowledge and its assessment in AI-enabled learning ecologies. *Educational Philosophy and Theory*, *53*(12), 1229-1245. https://doi.org/10.1080/00131857.2020.1728732
13. Crust, G. (2023). *ChatGPT employability study skills and curriculum development*. https://doi.org/10.13140/ RG.2.2.35643.28960
14. De Winter, J. (2023). *Can ChatGPT pass high school exams on English language comprehension?* https://www.researchgate.net/publication/366659237_Can_ChatGPT_pass_high_school_exams_on_English_Language_Comprehension
15. De Winter, J. (2023). *Can ChatGPT pass high school exams on English language comprehension?* https://www.researchgate.net/publication/366659237_Can_ChatGPT_pass_high_school_exams_on_English_Language_Comprehension
16. Deng, J., Lam, C., Wong, M., Sin, S., & Martins, R. (2019). Instantaneous power quality indices detection under frequency deviated environment. *IET Science, Measurement & Technology*, *13*(8), 1111-1121. https://doi.org/10.1049/iet-smt.2018.5123
17. Deng, J., Lam, C., Wong, M., Wang, L., Sin, S., & Martins, R. (2018). A power quality indexes measurement system platform with remote alarm notification. In *Proceedings of the IECON 2018–44th Annual Conference of the IEEE Industrial Electronics Society* (pp. 3461-3465). https://doi.org/10.1109/IECON. 2018.8591375
18. Duzhin, F., & Gustafsson, A. (2018). Machine learning-based app for self-evaluation of teacher-specific instructional style and tools. *Education Sciences*, *8*(1), 7-21. https://doi.org/10.3390/educsci8010007
19. El Fallahi, F., Ibenrissoul, A., & Adil, E. L. (2022). Does innovation play a role in the relationship between corporate social and financial performance? A systematic literature review. *International Journal of Financial, Accounting, and Management*, *4*(3), 315-334. https://doi.org/10.35912/ijfam.v4i3.1146
20. Firat, M. (2023). *How chat GPT can transform autodidactic experiences and open education?* https://doi.org/ 10.31219/osf.io/9ge8m
21. Forsström, S.E., Afdal, G. (2020). Learning mathematics through activities with robots. *Digital Experiences in Mathematics Education*, *6*(1), 30-50. https://doi.org/10.1007/s40751-019-00057-0
22. Frieder, S., Pinchettil, L., Griffiths, R., Salvatori, T., Lukasiewicz, T., Petersen, P., Chevalier, A., & Berner, J. (2023). Mathematical capabilities of ChatGPT. *arXiv*. https://doi.org/10.48550/arXiv.2301.13867
23. García-Peñalvo, F., Vázquez-Ingelmo, A., García-Holgado, A., Sampedro-Gómez, J., Sánchez-Puente, A., Vicente-Palacios, V., Dorado-Diaz, P. I., & Sánchez, P. L. (2021). Application of artificial intelligence algorithms within the medical context for non-specialized users: The CARTIER-IA platform. *International Journal of Interactive Multimedia and Artificial Intelligence*, *6*(6), 46-53. https://doi.org/10.9781/ijimai.2021.05.005
24. Gulz, A., Londos, L., & Haake, M. (2020). Preschoolers' understanding of a teachable agent-based game in early mathematics as reflected in their gaze behaviors–An experimental study. *International Journal of Artificial Intelligence in Education*, *30*(7), 38-73. https://doi.org/10.1007/s40593-020-00193-4

25. Guo, B., Zhang, X., Wang, Z., Jiang, M., Nie, J., Ding, Y., Yue, J., & Wu, Y. (2023). How close is ChatGPT to human experts? Comparison corpus, evaluation, and detection. *arXiv*. https://doi.org/10.48550/ arXiv.2301.07597
26. Harper, F., Stumbo, Z., & Kim, N. (2021). When Robots invade the neighborhood: Learning to teach prek-5 mathematics leveraging both technology and community knowledge. *Contemporary Issues in Technology and Teacher Education*, *21*(1), 19-52.
27. Hasanein, H. A. A., & Abu-Naser, S. S. (2018). Developing education in Israa University using intelligent tutoring system. *International Journal of Academic Pedagogical Research*, *2*(5), 1-16.
28. Hidayat, R., Syed Zamri, S. N. A., Zulnaidi, H., Abdullah, M. F. N. L., & Adnan, M. (2021). The interrelationships between metacognition and modeling competency: The moderating role of the academic year. *European Journal of Educational Research*, *10*(4), 1853-1866. https://doi.org/10.12973/eu-jer.10.4.1853
29. Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, *1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001
30. Jyoti, R., & Kuppuswamy, R. (2022). *Worldwide artificial intelligence software forecast, 2022-2026 (US49571222)*. IDC.
31. Kim, K. J., & Han, H. J. (2021). A design and effect of maker education using educational artificial intelligence tools in elementary online environment. *Journal of Digital Convergence*, *19*(6), 61-71. https://doi.org/10.14400/JDC.2021.19.6.061
32. Liao, L., & Gu, F. (2022). 5G and artificial intelligence interactive technology applied in preschool education courses. *Wireless Communications and Mobile Computing*, *2022*, 7629354. https://doi.org/10.1155/2022/7629354
33. Lin, C., Huang, A., & Yang, S. (2023). Review of AI-driven conversational chatbots implementation methodologies and challenges (1999-2022). *Sustainability*, *15*, 4012. https://doi.org/10.3390/su15054012
34. Lopez-Caudana, E., Ramirez-Montoya, M. S., Martínez-Pérez, S., & Rodríguez-Abitia, G. (2020). Using robotics to enhance active learning in mathematics: A multi-scenario study. *Mathematics*, *8*(12), 2163. https://doi.org/10.3390/math8122163
35. Lopez-Caudana, E., Ramirez-Montoya, M. S., Martínez-Pérez, S., & Rodríguez-Abitia, G. (2020). Using robotics to enhance active learning in mathematics: A multi-scenario study. *Mathematics*, *8*(12), 2163. https://doi.org/10.3390/math8122163
36. Ma, Y., & Siau, K. L. (2018). Artificial intelligence impacts on higher education. *MWAIS Proceedings*, *42*(5), 1-5.
37. Mills, N. J. D. (2021). ALEKS constructs as predictors of high school mathematics achievement for struggling students. *Heliyon*, *7*(6), e07345. https://doi.org/10.1016/j.heliyon.2021.e07345
38. Min, S. A., Jeon, I. S., & Song, K. S. (2021). The effects of artificial intelligence convergence education using machine learning platform on STEAM literacy and learning flow. *Journal of the Korea Society of Computer and Information*, *26*(10), 199-208. https://doi.org/10.9708/jksci.2021.26.10.199
39. Neri, H., & Cozman, F. (2019). The role of experts in the public perception of risk of artificial intelligence. *AI & Society*, *35*, 663-673. https://doi.org/10.1007/s00146-019-00924-9

40. Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence, 2*, 100020. https://doi.org/10.1016/j.caeai.2021.100020
41. Pardos, Z., & Bhandari, S. (2023). Learning gain differences between ChatGPT and human tutor generated algebra hints. *arXiv*. https://doi.org/ 10.48550/arXiv.2302.06871
42. Poole, D. L., Mackworth, A. K., & Goebel, R. (1998). *Computational intelligence: A logical approach*. Oxford University Press.
43. Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, *12*(22), 1-13. https://doi.org/10.1186/s41039-017-0062-8
44. Qu, J., Zhao, Y., & Xie, Y. (2022). Artificial intelligence leads the reform of education models. *Systems Research and Behavioral Science, 39*(3), 581-588. https://doi.org/10.1002/sres.2864
45. Rico-Bautista, N. A., Rico-Bautista, D. W., & Medina-Cárdenas, Y. C. (2019). Collaborative work as a learning strategy to teach mathematics incorporating robotics using led godt education system and fischertechnik in seventh graders at the school isidro caballero delgado in Floridablanca Santander Colombia. *Journal of Physics: Conference Series, 1386*, 012146. https://doi.org/10.1088/1742-6596/1386/1/012146
46. Rojano, T., & García-Campos, M. (2017). Teaching mathematics with intelligent support in natural language. Tertiary education students working with parametrized modelling activities. *Teaching Mathematics and its Applications: An International Journal of the IMA, 36*(1), 18-30. https://doi.org/10.1093/teamat/hrw009
47. Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewed or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching, 6*, 1. https://doi.org/10.37074/jalt.2023.6. 1.9
48. Salas-Rueda, R. A., Salas-Rueda, E. P., & Salas-Rueda, R. D. (2020). Analysis and design of the web game on descriptive statistics through the ADDIE model, data science and machine learning. *International Journal of Education in Mathematics, Science and Technology*, *8*(3), 245-260. https://doi.org/10.46328/ijemst.v8i3.759
49. Seckel, M. J., Breda, A., Font, V., & Vásquez, C. (2021). Primary school teachers' conceptions about the use of robotics in mathematics. *Mathematics, 9*, 3181. https://doi.org/10.3390/math9243186
50. Shahriar, S., & Hayawi, K. (2023). Let's have a chat! A conversation with ChatGPT: Technology, applications, and limitations. *arXiv*. https://doi.org/10.48550/arXiv.2302.13817
51. Shakarian, P., Koyyalamudi, A., Ngu, N., & Mareedu, L. (2023). An independent evaluation of ChatGPT on mathematical word problems. *arXiv*. https://doi.org/10.48550/arXiv.2302.13814
52. Song, D. (2017). Designing a teachable agent system for mathematics learning. *Contemporary Educational Technology, 8*(2), 176-190. https://doi.org/10.30935/cedtech/6194
53. Tashtoush, M., Wardat, Y., & Elsayed, A. (2023). Mathematics distance learning and learning loss during COVID-19 pandemic: Teachers' perspectives. *Journal of Higher Education Theory and Practice, 23*(5), 162-174. https://doi.org/10.33423/ jhetp.v23i5.5933
54. Tashtoush, M., Wardat, Y., Aloufi, F., & Taani, O. (2022a). The effect of a training program based on (TIMSS) to developing the levels of habits of mind and mathematical reasoning skills among pre-service mathematics teachers. *EURASIA Journal of Mathematics, Science and Technology Education, 18*(11), em2182. https://doi.org/10.29333/ejmste/ 12557

55. Tashtoush, M., Wardat, Y., Aloufi, F., & Taani, O. (2022b). The effectiveness of teaching method based on the components of concept-rich instruction approach in students achievement on linear algebra course and their attitudes towards. *Journal of Higher Education Theory and Practice, 22*(7), 41-57. https://doi.org/10.33423/jhetp.v22i7.5269
56. Tenhundfeld, N., & ChatGPT (2023). *Two birds with one stone: Writing a paper entitled "ChatGPT as a tool for studying human-AI interaction in the wild" with ChatGPT*. https://doi.org/10.13140/RG.2.2.25319. 73123
57. Voskoglou, M. G., & Salem, A.-B. M. (2020). Benefits and limitations of the artificial with respect to the traditional learning of mathematics. *Mathematics, 8*(4), 611. https://doi.org/10.3390/math8040611
58. Walker, C., & Noorden, R. (2023). What ChatGPT and generative AI mean for science. *Nature, 614*(7947), 214-216. https://doi.org/10.1038/d41586-023-00340-6
59. Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? *International Journal of Educational Technology in Higher Education, 16*(1), 1-27. https://doi.org/10.1186/s41239-019-0171-0
60. Zhong, B., & Xia, L. (2020). A systematic review on exploring the potential of educational robotics in mathematics education. *International Journal of Science and Mathematics Education, 18*(1), 79-101. https://doi.org/10.1007/s10763-018-09939-y