International Journal of Academic Pedagogical Research (IJAPR)
ISSN: 2643-9123
Vol. 8 Issue 5 May - 2024, Pages: 43-47

AI-Powered Pedagogies in Mathematics Education: A Systematic Review

Jay Fie P. Luzano, PhD

Assistant Professor IV, Bukidnon State University
Malaybalay City, Bukidnon, Philippines
jayfieluzano@buksu.edu.ph

Abstract: *Artificial Intelligence (AI) is revolutionizing education, particularly in mathematics, by offering personalized learning, adaptive assessments, and intelligent tutoring, though its potential is still underexplored in scholarly literature. This study employed a systematic review approach, as outlined by Strech and Sofaer (2011), to investigate AI-powered pedagogies in mathematics education. Results showed five (5) emerging themes on AI-powered pedagogies in mathematics education, namely; (1) Personalized Learning; (2) Enhanced Assessment and Feedback; (3) Gamification and Engagement; (4) Data-Driven Instructional Strategies; and (5) Equity and Accessibility. AI-powered pedagogies in mathematics education enhance personalized learning, assessment, student engagement, data-driven instruction, and educational equity, collectively transforming education and improving student outcomes. To leverage AI-powered pedagogies in mathematics education, educational institutions, and policymakers may invest in adaptive learning systems, continuous professional development for educators, and robust technological infrastructure to enhance personalized learning, real-time feedback, and equitable access to AI resources.*

Keywords—AI-Powered Pedagogies; Mathematics Education; Systematic Review

1. INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative force in various fields, including education, where its potential to revolutionize teaching and learning practices is increasingly recognized (Chen, L., Chen, P., & Lin, Z., 2020). This systematic review focuses on AI-powered pedagogies in mathematics education, an area ripe with opportunities yet still underexplored in scholarly literature. As educators seek innovative ways to enhance student learning and engagement, AI technologies promise personalized learning experiences, adaptive assessments, and intelligent tutoring systems (Akavova, Temirkhanova, & Lorsanova, 2023). However, despite these promising developments, significant gaps persist in understanding the full impact and optimal implementation of AI in mathematics education.

One major gap in the current literature is the lack of comprehensive studies that examine the long-term effects of AI-powered pedagogies on student outcomes in mathematics (Qiu, Pan, & Ishak, 2022). While several short-term studies have demonstrated improvements in student performance and engagement, there is limited evidence on how these benefits are sustained over time (Aranzo et al., 2023). Moreover, the majority of existing research tends to focus on immediate academic gains, often neglecting the broader educational impacts such as critical thinking, problem-solving skills, and student motivation (Yu, Gao, & Wang, 2020). This review aims to address these gaps by synthesizing findings from various studies and providing a more holistic view of AI's role in mathematics education.

Another critical area where the literature falls short is in understanding the differential impacts of AI-powered pedagogies across diverse student populations. Most studies tend to generalize findings without considering variations in student backgrounds, learning styles, and socio-economic factors (Zhan, Shen, & Lin, 2022). Consequently, there is a pressing need for research that explores how AI can be tailored to meet the unique needs of diverse learners, particularly those from underrepresented or disadvantaged groups (Woolf et al., 2013). By highlighting these disparities, this review seeks to encourage more inclusive and equitable approaches to integrating AI into mathematics education.

Furthermore, the literature lacks in-depth analyses of the challenges and barriers associated with implementing AI technologies in educational settings (Chan & Zary, 2019). Issues such as data privacy, ethical concerns, teacher preparedness, and infrastructure limitations are often mentioned but not thoroughly investigated (Szcyrek & Stewart, 2022). Understanding these challenges is crucial for developing effective strategies and policies that support the seamless integration of AI in classrooms (Younas et al., 2023). This review not only identifies the existing challenges but also discusses potential solutions and best practices drawn from successful case studies, aiming to provide practical insights for educators and policymakers.

2. METHODS

This study employed a systematic review approach, as outlined by Strech and Sofaer (2011), to investigate AI-powered pedagogies in mathematics education. A comprehensive search strategy was implemented, utilizing various databases, academic journals, and books. The search terms were centered on "AI-powered pedagogies in Mathematics Education," and the review focused on peer-reviewed English publications from 2020-2024.

The initial search yielded a large number of articles, which were then screened based on titles and abstracts, narrowing the

selection to thirty-four (34) articles for detailed review. This meticulous examination uncovered common themes and patterns, providing a thorough understanding of AI-powered pedagogies in mathematics education.

By integrating diverse research, this systematic approach offered a well-rounded perspective on the subject. Specific articles provided valuable insights, particularly in identifying effective strategies for fostering accountability in AI applications. The common themes identified in the review aim to inform future research, discussions, and strategic decisions related to AI-powered pedagogies in mathematics education.

Overall, this study contributes to the field by synthesizing existing research, highlighting effective practices, and identifying areas for further exploration. It offers a foundation for educators, researchers, and policymakers to develop and implement AI technologies that enhance mathematics education.

3. RESULTS AND DISCUSSION

AI-Powered Pedagogies in Mathematics Education

Theme 1: Personalized Learning

One of the foremost themes emerging from the literature on AI-powered pedagogies in mathematics education is the potential for personalized learning (Tapalova, Zhiyenbayeva, & Gura, 2022). AI technologies, through adaptive learning systems, can tailor educational content to meet individual students' needs, providing customized feedback and exercises that match their specific learning pace and style (Hashim et al., 2022). This personalized approach allows for differentiated instruction, enabling students to engage with material that is neither too easy nor too difficult, thus maintaining optimal learning engagement and minimizing frustration (Prain et al., 2012).

Studies have shown that personalized learning facilitated by AI can significantly improve students' understanding and retention of mathematical concepts (Luzano, 2024). By continuously analyzing student performance data, AI systems can identify learning gaps and misconceptions in real time, adjusting the instruction accordingly. This dynamic adaptability helps address the diverse learning needs within a classroom, ensuring that each student receives the appropriate level of challenge and support (Chen et al., 2020). Consequently, personalized AI-driven pedagogies can lead to more efficient and effective learning experiences, fostering better academic outcomes in mathematics education (Ku et al., 2007).

Theme 2: Enhanced Assessment and Feedback

AI-powered pedagogies in mathematics education also enhance assessment and feedback mechanisms (Hooda et al., 2022). Traditional assessment methods often rely on periodic testing, which provides limited insights into a student's ongoing learning process (McCarthy, Niederjohn, & Bosack, 2011). In contrast, AI technologies enable continuous formative assessment through real-time data collection and analysis. This allows educators to monitor student progress more closely and intervene promptly when issues arise, facilitating a more proactive approach to education (Pang-an et al., 2022).

Moreover, AI systems can generate detailed feedback that is both immediate and specific, helping students understand their mistakes and learn from them. Automated grading tools not only save teachers time but also ensure consistent and unbiased evaluation (Heap, Hudson, & Archibald, 2020). The immediacy and precision of AI-generated feedback can significantly improve students' learning outcomes by helping them address errors and misconceptions quickly (Sutherland et al., 2023). This continuous assessment and feedback loop are crucial in mathematics education, where cumulative knowledge and skills build upon one another (Luzano & Ubalde, 2023).

Theme 3: Gamification and Engagement

The integration of AI in mathematics education has also popularized the use of gamification to enhance student engagement (Daghestani et al., 2020). Gamification leverages game-design elements such as rewards, challenges, and leaderboards to make learning more interactive and enjoyable (Luzano, 2023). AI systems can adapt these elements to individual student preferences and performance levels, ensuring that the gamified experience remains both challenging and rewarding for all learners (Gligorea et al., 2023).

Research indicates that gamification can significantly increase motivation and participation in mathematics learning (Casanova et al., 2023). By transforming traditional exercises into engaging activities, students are more likely to invest time and effort into their studies (Luzano, 2020). AI-driven gamification also promotes a sense of achievement and progress, which can boost students' confidence and interest in mathematics (Luzano, 2024). This heightened engagement not only makes learning more enjoyable but also helps students develop a deeper understanding of mathematical concepts through sustained and active participation (Nallada et al., 2024).

Theme 4: Data-Driven Instructional Strategies

Another critical theme is the use of data-driven instructional strategies enabled by AI technologies (Amer-Yahia, 2022). AI systems can analyze vast amounts of educational data to identify trends, patterns, and correlations that are not immediately apparent to educators. This data-driven insight can inform instructional strategies, helping teachers adopt more effective teaching practices tailored to their students' needs (Dogan, M., Dogan, T., & Bozkurt, A., 2023).

For instance, AI can identify which teaching methods are most effective for different types of learners and recommend personalized instructional approaches (Luzano, 2024). It can

also predict student performance and identify those at risk of falling behind, allowing for timely interventions. By leveraging data analytics, educators can make informed decisions that enhance teaching efficacy and student learning outcomes (Romorosa et al., 2023). This data-centric approach represents a significant shift from traditional intuition-based teaching methods, promising a more scientific and evidence-based paradigm in mathematics education (Popova et al., 2022).

Theme 5: Equity and Accessibility

Equity and accessibility are emerging themes in the context of AI-powered pedagogies in mathematics education. AI has the potential to bridge educational gaps by providing high-quality learning resources to students regardless of their geographic or socioeconomic status (Supriyadi & Kuncoro, 2023). Online AI-driven platforms can offer personalized and scalable learning opportunities to students in underserved or remote areas, democratizing access to quality education (Pardamean et al., 2022).

Additionally, AI can cater to diverse learning needs, including those of students with disabilities (Nganji & Brayshaw, 2017). For example, AI-powered tools can provide alternative representations of mathematical concepts, such as visual aids or auditory explanations, making learning more accessible (Tortola, 2021; Tortola, 2024). By addressing individual learning barriers and providing tailored support, AI technologies can promote a more inclusive educational environment (Luzano, 2024). Ensuring that all students have access to these advanced learning tools is crucial for fostering equity in education and enabling every student to achieve their full potential in mathematics.

4. CONCLUSION AND RECOMMENDATION

The integration of AI-powered pedagogies in mathematics education presents significant opportunities for enhancing personalized learning, assessment and feedback mechanisms, student engagement through gamification, data-driven instructional strategies, and educational equity and accessibility. Personalized learning through AI tailors educational content to individual student needs, improving comprehension and retention. Enhanced assessment and feedback provide immediate, detailed insights, facilitating timely interventions and continuous improvement. Gamification increases motivation and participation, making learning more engaging and effective. Data-driven instructional strategies enable teachers to make informed decisions based on comprehensive analytics, optimizing teaching practices. Furthermore, AI's ability to democratize access to quality education and cater to diverse learning needs promotes greater equity and inclusivity. Collectively, these AI-driven innovations can transform mathematics education, fostering improved academic outcomes and ensuring that all students have the opportunity to succeed.

To fully leverage the potential of AI-powered pedagogies in mathematics education, it is recommended that educational institutions and policymakers invest in the development and implementation of adaptive learning systems, continuous professional development for educators, and robust technological infrastructure. Schools may adopt AI tools that offer personalized learning paths and real-time feedback to address individual student needs effectively. Training programs for teachers may be enhanced to equip them with the skills to integrate AI technologies into their instructional strategies and utilize data-driven insights. Additionally, significant investments in technological infrastructure are also recommended to ensure equitable access to AI resources across all regions, particularly in underserved and remote areas to improve learning outcomes, engagement, and equity in mathematics education.

5. REFERENCES

[1] Akavova, A., Temirkhanova, Z., & Lorsanova, Z. (2023). Adaptive learning and artificial intelligence in the educational space. E3S Web of Conferences. https://doi.org/10.1051/e3sconf/202345106011.

[2] Amer-Yahia, S. (2022). Towards AI-Powered Data-Driven Education. Proc. VLDB Endow., 15, 3798-3806. https://doi.org/10.14778/3554821.3554900.

[3] Aranzo, R., Damicog, M., Macahito, C., Reyes, A. Tancio, K., & Luzano, J. (2023). A Case Analysis of the Strategies of Students in Learning Mathematics amidst Academic Disruption. International Journal of Multidisciplinary Approach and Studies, 10(2), 1-15.

[4] Casanova, E., Octaviano, D., Okit, R., Tactacon, J., Arcaya, J. & Luzano, J. (2023). Enhancing Academic Performance via Web-Based Learning Material Development in Mathematics. International Journal of Arts, Humanities and Management Studies, 9 (5), 1-11.

[5] Chan, K., & Zary, N. (2019). Applications and Challenges of Implementing Artificial Intelligence in Medical Education: Integrative Review. JMIR Medical Education, 5. https://doi.org/10.2196/13930.

[6] Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. IEEE Access, 8, 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510.

[7] Chen, X., Xie, H., Zou, D., & Hwang, G. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. Comput. Educ. Artif. Intell., 1, 100002. https://doi.org/10.1016/j.caeai.2020.100002.

[8] Daghestani, L., Ibrahim, L., Al-Towirgi, R., & Salman, H. (2020). Adapting gamified learning systems using educational data mining techniques. Computer Applications in Engineering Education, 28, 568 - 589. https://doi.org/10.1002/cae.22227.

[9] Dogan, M., Dogan, T., & Bozkurt, A. (2023). The Use of Artificial Intelligence (AI) in Online Learning and Distance Education Processes: A Systematic Review of Empirical Studies. Applied Sciences. https://doi.org/10.3390/app13053056.

[10] Gligorea, I., Cioca, M., Oancea, R., Gorski, A., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. Education Sciences. https://doi.org/10.3390/educsci13121216.

[11] Hashim, S., Omar, M., Jalil, H., & Sharef, N. (2022). Trends on Technologies and Artificial Intelligence in Education for Personalized Learning: Systematic Literature Review. International Journal of Academic Research in Progressive Education and Development. https://doi.org/10.6007/ijarped/v11-i1/12230.

[12] Heap, T., Hudson, C., & Archibald, A. (2020). Investigating the Impact of an AI-driven Discussion Platform on Educator Perceptions and Feedback. , 127-136. https://doi.org/10.38069/EDENCONF-2020-AC0010.

[13] Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. (2022). Artificial Intelligence for Assessment and Feedback to Enhance Student Success in Higher Education. Mathematical Problems in Engineering. https://doi.org/10.1155/2022/5215722.

[14] Ku, H., Harter, C., Liu, P., Thompson, L., & Cheng, Y. (2007). The effects of individually personalized computer-based instructional program on solving mathematics problems. Comput. Hum. Behav., 23, 1195-1210. https://doi.org/10.1016/j.chb.2004.11.017.

[15] Luzano, J. F. (2020). Development and Validation of Strategic Intervention Materials (SIMs) of the Selected Topics in Trigonometry of Precalculus Discipline in Senior High School. Journal of Mathematics and Statistics Studies, 1(2), 26–37.

[16] Luzano, J. & Ubalde, M. (2023). Notable Accounts of the Professional Practice of Tertiary Mathematics Teachers in the Philippines. Science International (Lahore), 35(2), 129-133.

[17] Luzano, J. (2023). The Interplay of Conceptual Understanding and Problem-Solving Competence in Mathematics. International Journal of Multidisciplinary Approach and Studies, 10(2), 89-97.

[18] Luzano, J. (2023). An ADDIE Model Analysis on the Engineering of Contextualized Intervention Materials (CIMs) and Students' Achievement in Mathematics. International Journal of Multidisciplinary Approach and Studies, 10 (6), 25-47.

[19] Luzano, J. (2023). Revolutionizing Calculus Education on Flexible Learning: A Tale of Students in a State University. International Journal of Arts, Humanities and Management Studies, 9(11), 30-37.

[20] Luzano, J. (2024). Assessment in Mathematics Education in the Sphere of Artificial Intelligence: A Systematic Review on Its Threats and Opportunities. International Journal of Academic Multidisciplinary Research, 8(2), 100-104.

[21] Luzano, J. (2024). Robustness of Quantitative Research Methods in Mathematics Education. International Journal of Academic and Applied Research, 8(3), 55-58.

[22] Luzano, J. (2024). Exploring Gender-Inclusive Pedagogical Strategies in Mathematics. International Journal of Academic Pedagogical Research, 8(3), 39-42.

[23] Luzano, J. (2024). Dichotomies of Mathematics Classroom Discourses in Higher Education: A Systematic Review. International Journal of Academic Multidisciplinary Research, 8(3), 84-87.

[24] Luzano, J. (2024). A Scoping Review of the Professional Practices and Standards in Mathematics in Higher Education. Journal of Harbin Engineering University, 45(3), 1 – 6.

[25] Luzano, J., Binayao, B., & Peligrino, M. (2024). Empowering Child Development Workers in Classroom Management and Pedagogy Extension Project: An Impact Study. International Journal of Academic Multidisciplinary Research, 8(4), 256-263.

[26] Luzano, J. (2024). Strategic Foresight in Mathematics Education: A Post-COVID Integrative Assessment. International Journal of Academic and Applied Research, 8(4), 138-144.

[27] Luzano, J. (2024). An Integrative Review of AI-Powered STEM Education. International Journal of Academic Pedagogical Research, 8(4), 113-118.

[28] Luzano, J. (2024). Pedagogical Influence of an AI Chatbot Gemini in Mathematics Education. International Journal of Academic Pedagogical Research, 8(4), 107-112.

[29] Luzano, J. (2024). Transformational Learning Experiences on Productive-Failure Approach in Mathematics. International Journal of Academic Pedagogical Research, 8(4), 54-58.

[30] Luzano, J. (2024). Success Initiatives of Mathematics Educators as Inspired by Taylor Swift's Commencement Address at New York University. International Journal of Academic Multidisciplinary Research, 8(4), 14-20.

[31] Luzano, J. (2024). Physical and Psychological Well-being of Higher Education Students in Mathematics Context. International Journal of Academic Multidisciplinary Research, 8(4), 10-13.

[32] McCarthy, M., Niederjohn, D., & Bosack, T. (2011). Embedded Assessment. Teaching of Psychology, 38, 78 - 82. https://doi.org/10.1177/0098628311401590.

[33] Nallada, J., Hulagpos, D., Damasco, J., & Luzano, J. (2024). Unveiling the Power of Educational Mathematics Applications as Formative Assessment Tools: A Multiple Case Study. International Journal of Research in STEM Education, 6(1), 15–35. https://doi.org/10.33830/ijrse.v6i1.1657

[34] Nganji, J., & Brayshaw, M. (2017). Disability-aware adaptive and personalised learning for students with multiple disabilities. International Journal of Information

and Learning Technology, 34, 307-321. https://doi.org/10.1108/IJILT-08-2016-0027.

[35] Pang-an, A., Arceno, J., Tantog, A. Alayon, M., & Luzano, J. (2022). Learning Experiences of College Students in Mathematics in the Modern World during Synchronous Classes. International Journal of Academic Multidisciplinary Research, 6(10), 89-97.

[36] Pardamean, B., Suparyanto, T., Cenggoro, T., Sudigyo, D., & Anugrahana, A. (2022). AI-Based Learning Style Prediction in Online Learning for Primary Education. IEEE Access, PP, 1-1. https://doi.org/10.1109/ACCESS.2022.3160177.

[37] Popova, Y., Abdualiyeva, M., Torebek, Y., Yelshibekov, N., & Omashova, G. (2022). Improving the effectiveness of senior graders' education based on the development of mathematical intuition and logic: Kazakhstan's experience. , 7. https://doi.org/10.3389/feduc.2022.986093.

[38] Prain, V., Cox, P., Deed, C., Dorman, J., Edwards, D., Farrelly, C., Keeffe, M., Lovejoy, V., Mow, L., Sellings, P., Waldrip, B., & Yager, Z. (2012). Personalised learning: lessons to be learnt. British Educational Research Journal, 39, 654-676. https://doi.org/10.1080/01411926.2012.669747.

[39] Qiu, Y., Pan, J., & Ishak, N. (2022). Effectiveness of Artificial Intelligence (AI) in Improving Pupils' Deep Learning in Primary School Mathematics Teaching in Fujian Province. Computational Intelligence and Neuroscience, 2022. https://doi.org/10.1155/2022/1362996.

[40] Romorosa, Q., Dahe, K., Colanggo, M., Resabal, D., Anlicao, R., Boquia, R., Acot, C., Luzano, J. (2023). Improving Students' Achievement of Learning Competencies in Mathematics through Micro-Lecture via ED Puzzle. International Journal of Multidisciplinary Approach and Studies, 10(4), 120-133.

[41] Strech, D., & Sofaer, N. (2011). How to write a systematic review of reasons. Journal of Medical Ethics, 38, 121 - 126. https://doi.org/10.1136/medethics-2011-100096.

[42] Supriyadi, E., & Kuncoro, K. (2023). Exploring the future of mathematics teaching: Insight with ChatGPT. Union: Jurnal Ilmiah Pendidikan Matematika. https://doi.org/10.30738/union.v11i2.14898.

[43] Sutherland, S., Machado, T., Mahajan, S., Mohaddesi, O., Matuk, C., Smith, G., & Harteveld, C. (2023). Exploring the Role of AI-Generated Feedback Tangential to Learning Outcomes. 2023 IEEE Conference on Games (CoG), 1-8. https://doi.org/10.1109/CoG57401.2023.10333239.

[44] Szcyrek, S., & Stewart, B. (2022). Surveillance in the System: Data as Critical Change in Higher Education. The Open/Technology in Education, Society, and Scholarship Association Journal. https://doi.org/10.18357/otessaj.2022.2.2.34.

[45] Tapalova, O., Zhiyenbayeva, N., & Gura, D. (2022). Artificial Intelligence in Education: AIEd for Personalised Learning Pathways. Electronic Journal of e-Learning. https://doi.org/10.34190/ejel.20.5.2597.

[46] Tortola, R. (2021). Is Mother Tongue Based Worth Continuing? A Policy Brief. International Journal of Multidisciplinary Approach and Studies, Volume: 8, Sep-Oct 2021(No: 5), 1–10.

[47] Tortola, R. (2021). Voices of Teachers in Teaching Mathematics using Mother Tongue-Based Multilingual Education. International Journal of Multidisciplinary Approach and Studies, 4. https://doi.org/10.13140/RG.2.2.10949.01769

[48] Tortola, R.(2024) Ethical Decision-Making in the Context of Education: A Systematic Literature Review. International Journal of Multidisciplinary Approach and Studies. 11(2), 19-73.

[49] Woolf, B., Lane, H., Chaudhri, V., & Kolodner, J. (2013). AI Grand Challenges for Education. AI Mag., 34, 9-. https://doi.org/10.1609/aimag.v34i4.2490.

[50] Younas, A., Subramanian, K., Haziazi, M., Hussainy, S., & Kindi, A. (2023). A Review on Implementation of Artificial Intelligence in Education. International Journal of Research and Innovation in Social Science. https://doi.org/10.47772/ijriss.2023.7886.

[51] Yu, Z., Gao, M., & Wang, L. (2020). The Effect of Educational Games on Learning Outcomes, Student Motivation, Engagement and Satisfaction. Journal of Educational Computing Research, 59, 522 - 546. https://doi.org/10.1177/0735633120969214.

[52] Zhan, Z., Shen, W., & Lin, W. (2022). Effect of product-based pedagogy on students' project management skills, learning achievement, creativity, and innovative thinking in a high-school artificial intelligence course. Frontiers in Psychology, 13. https://doi.org/10.3389/fpsyg.2022.849842.