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Transforming mathematics education with AI: Innovations, implementations, and insights

Sheunghyun Yeo[1]*, Jewoong Moon[2], Dong-Joong Kim[3]

[1]Professor, Daegu National University of Education
[2]Professor, The University of Alabama
[3]Professor, Korea University

ABSTRACT

The use of artificial intelligence (AI) in mathematics education has advanced as a means for promoting understanding of mathematical concepts, academic achievement, computational thinking, and problem-solving. From a total of 13 studies in this special issue, this editorial reveals threads of potential and future directions to advance mathematics education with the integration of AI. We generated five themes as follows: (1) using ChatGPT for learning mathematical content, (2) automated grading systems, (3) statistical literacy and computational thinking, (4) integration of AI and digital technology into mathematics lessons and resources, and (5) teachers' perceptions of AI education. These themes elaborate on the benefits and opportunities of integrating AI in teaching and learning mathematics. In addition, the themes suggest practical implementations of AI for developing students' computational thinking and teachers' expertise.

Keywords Artificial intelligence, Mathematics education

Introduction

The application of artificial intelligence (AI) in education is paving the way to change the methods of teaching and learning mathematics because it brings innovative approaches that were not possible before. Appreciated in mathematics education, AI finds its uses in intelligent tutoring systems, computer grading, adaptive learning systems, and data analysis (Hwang & Tu, 2021; Moore et al., 2023). Such AI applications in mathematics education do not only contribute to the development of learner-centered educational systems but also enable educators to effectively monitor students' learning profiles and adaptively support learning experiences. Using this technological support, it is easier for teachers to identify specific individuals who require guidance through the process or motivated and encouraged to do more within a classroom setting, and AI can help to achieve this goal (Crompton et al., 2024).

In this special issue, we present how various aspects of AI are being used, can be used, or can potentially be adopted in theoretical studies as well as practical implementations. The featured 13 articles of this

***Corresponding author** Sheunghyun Yeo
E-mail shyeo@dnue.ac.kr
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special issue cut across important fields of utilizing AI techniques in mathematics education and enhancing teaching learning processes with the help of technologies. We generated five themes addressing different aspects of AI applications in mathematics education focusing on several fundamental issues: ChatGPT for learning mathematical content, automated grading systems, statistical literacy and computational thinking, integration of AI and digital technology into mathematics lessons and resources, and teachers' perceptions of AI education.

Using ChatGPT for Learning Mathematical Content

Establishing virtual teaching agents nurtures the enablement of understanding of knowledge through the application of AI chatbots such as ChatGPT. Such tools enable students to pose inquiries, share information, and attain timely feedback to improve their comprehension of the subject areas. The feedback loop cycle allows students to elaborate their mathematical knowledge and enhance their performance at later times.

Lee et al. (2024b) utilized OpenAI's ChatGPT to teach the course "Introductory Mathematics for Artificial Intelligence (Math4AI)" conducted at a university, exploring how to apply ChatGPT to the course delivery and student learning. They trained ChatGPT and created their own chatbot, introducing a learning model in which students use this chatbot to enrich their understanding. Their proposed approach aims at delivering individualized learning experiences not only in the Math4AI course but in other college mathematics courses as well.

Park and Manley (2024) explored whether ChatGPT could assist students with proof-based learning activities, and compared it with other proof technologies to gather useful information on the optimal use of such instruments in educational models. They recommended applications of ChatGPT in various aspects, particularly in enhancing students' logical skills in proving hypotheses. They highlighted the importance of comparing AI tools with other technologies to establish a comprehensive mathematical understanding and to address existing implementation challenges.

Automated Grading Systems

Automated grading systems, supported by AI, are still emerging but hold promise for analyzing descriptive evaluations in educational settings. These systems employ advanced text processing techniques and feature representations to enhance personalized and automatic grading procedures.

Choi et al. (2024) investigated the effects of an automated grading system on teaching and learning, advocating for their integration to reduce instructors' workloads and provide students with prompt results. Their findings indicate that an automated system can effectively manage large volumes of student data and provide uniform grading, which is particularly beneficial in large classrooms, which contributes to scalable assessment.

Shin et al. (2024) explored the practicality of utilizing ChatGPT's conversational capabilities to evaluate descriptive assessment items. They compared predictions and scoring results between teachers and ChatGPT. The study aims at three descriptive tasks related to permutations and combinations for first-year high school students. The results showed a high degree of consistency between the scores given by teachers and ChatGPT, suggesting the AI's scoring capability. They presented Few-Shot-CoT, structured, and iterative prompts, presenting that prompt engineering methods can achieve high accuracy in automated scoring.

Enhancing Statistical Literacy and Computational Thinking

The integration of AI in teaching statistics has revealed various benefits, especially in enhancing students' understanding of statistical concepts and computational abilities. AI helps students grasp data variations, draw conclusions from gathered data, and improve problem-solving skills. Using real-life data sets and problems, subject-specific teaching strategies promote a better comprehension of statistical concepts and skills.

Jin and Suh (2024) established a statistics education program embracing deep learning predictions of high school mathematics. They noted that students' perception of the role of context enhanced after touching on how data was produced and obtained. Furthermore, the students were able to improve their understanding of data variability in addition to analyzing various data sets. They also showed that they can use critical thinking skills in order to all the data during their process of its validation of its relevance.

Saralar-Aras and Cicek Schoenberg (2024) further stressed on adoption of coding and AI in mathematics education as a tool for developing computational thinking and problem-solving skills. They conducted a double-scoping review of 38 peer-reviewed articles published in the last 20 years and pointed out that AI has played a huge role in enhancing mathematics education. The rationale of the study lays in enhancing analytical and problem-solving abilities through the integration of AI specifically within data-based processes. The integration of AI in cognition is explained with arguments on how the AI should augment individuals' cognition and encourage them to contemplate the algorithmic base.

Kim and Chang (2024) explored how the elements of AI Big Ideas fit within the context of elementary mathematics education to develop AI thinking skills. Using the AI4K12 Framework, they designed and taught four mathematics lessons to 5th and 6th graders. Their research assessed students' AI thinking through a framework combining computational thinking taxonomy and AI components. The results indicated that AI Big Ideas increased students' knowledge and comprehension of AI and mathematics issues, as well as problem-solving abilities. The study underscores the potential for implementing AI teaching in elementary schools and the advantages of integrating AI elements into mathematics lessons.

Integrating AI and Digital Technology into Mathematics Lessons and Resources

AI and digital technology can be harnessed to improve mathematical education, offering comprehensive and highly-interactive learning platforms. The following studies collectively illustrate understanding of how to utilize advanced learning technology platforms, such as AI and Immersive Virtual Reality (IVR) to enhance students' mathematical competencies and achievement.

Yuk et al. (2024) explored the use of 'Sussam' application in integrating educational technology in mathematics education. The study focuses on effective task management strategies for students in supplementary learning activities. The Sussam application proposed to address the need to improve the problem-solving skills of students through better task management, as far as it is related to the assignment of tasks by the teacher. The study also reveals that through the 'Sussam,' the students' problem-solving skills are also enhanced through provided assignments based on the level of the class while emphasizing the importance of the teachers in a world that is gradually shifting to the use of technological gadgets in teaching and learning.

Awoyemi et al. (2024) conducted a narrative review on studies using IVR to teach high school students and specifically improve content knowledge according to the TPACK model. The findings highlight the benefits of utilizing IVR in mathematics education, including enhanced engagement and motivation, and improved spatial visualization abilities. The study stresses the importance of enhancing teacher training and faculty

development to fully realize the potential of IVR in mathematics education. They assert that more studies should be conducted to overcome technology constraints (i.e., accessibility and course modifications) to expand more opportunities for IVR in mathematics education.

Oh and Kim (2024) examined the use of concrete objects in the optimization contents of high school AI mathematics textbooks. They developed a framework for analyzing the discursive constructs operations of AI-based mathematical objects. The authors examined how specific objects are performed through naming and discursive practices, and knowledge could be useful to be integrated into the curriculum. They provide not only practical suggestions for how to develop AI-based mathematical discourse in an exploratory way, but also implications for the development of effective discursive construction processes and written curricula for AI-based mathematical objects.

Teachers' Perceptions of AI in Education

Integrating AI into mathematics teaching is a promising approach that can enhance both teaching and learning processes. To maximize these benefits and promote implementation, it is vital to consider the benefits and perceptions of both in-service and pre-service teachers. Promoting positive attitudes toward AI, supported by clear and effective professional development, can significantly enhance the successful integration of AI applications in education, thereby improving mathematics education both now and in the future.

Lee et al. (2024a) paid particular attention to the factors influencing teachers' intentions to incorporate the AI mathematics learning system, TocToc-Math, into an elementary school classroom. Using the technology acceptance model, they studied the perceived usefulness, perceived ease of use, and attitude towards using AI as key variables. They also established that perceived usefulness and ease of use of AI positively impacted the teachers' overall perceptions of the value of AI Math learning systems and, thus, the use intention. This investigation reveals that there is a need to improve the attitudes toward AI both as a tool for mathematics instruction and as a holistic technological platform among teachers to support the intended implementation of AI-based mathematics education tools.

Kim (2024) investigated the perceptions and concerns of 52 elementary and secondary mathematics teachers regarding the implementation of AI in their classrooms. The study also revealed a generally negative attitude towards AI, especially among secondary school teachers. This underlines the need for targeted professional development to increase teachers' readiness and skills for effectively employing AI technologies in their teaching.

Yeo et al. (2024) examined preservice teachers' beliefs about AI-based mathematics educational support systems, TocToc-Math. The study found that preservice teachers had a positive perception of the content and educational merits of AI support systems. Using an evaluation framework derived from a literature review and key criteria identification, preservice teachers assessed TocToc-Math in terms of its content, implementation method, use of technology, and curriculum alignment. The authors emphasize the significance of preparing preservice teachers to become critical consumers of digital tools and AI in mathematics education. They suggest that preservice teacher education and professional development should focus on improving these capabilities.

Conclusion

This special issue presents a series of articles that illustrate how AI is transforming the mathematics teaching and learning process, enhancing both formative and summative assessments, and promoting computational thinking among students. The collection of studies in this editorial marks an initial effort to understand the consequences of integrating AI into mathematics classrooms. These studies collectively highlight the potential of AI and digital technologies to offer comprehensive, interactive learning platforms that can significantly improve mathematical competencies and achievement. As we reflect on the findings presented in this special issue, it is clear that AI has the potential to revolutionize mathematics education.

Next Steps

Unlike the system of mathematics education that relies on language and symbols as tools, the introduction of AI as a tool for mathematical thinking, learning, and teaching is likely to change the nature of teaching and learning mathematics like never before, affecting learning theory, psychology, and teaching and professional development (Mariotti, 2019; Vygotsky, 1986). For instance, AI-driven simulations and interactive platforms have the potential to change the nature of student learning and therefore need to be studied in conjunction with other areas of affective domains to develop learning principles and the psychology of mathematics education (Lee & Yeo, 2022; Son et al., 2024).

We also need to develop comprehensive professional development programs that equip teachers with the skills to integrate AI effectively into their teaching such as how to use AI tools, understanding their pedagogical implications, and fostering a growth mindset towards AI adoption. In addition, there is a need for ongoing research to determine the long-term impact of various advanced AI technologies on student and instructional performance. Future studies should explore the effects of virtual tools, media, and communication methods to develop more engaging and relevant teaching tools that address current societal and global educational challenges.

By incorporating these aspects, future research will be able to provide a more holistic view of the potential and challenges of integrating AI in mathematics education. Addressing these areas will not only enhance the theoretical grounding of mathematics education but also offer practical insights for educators, researchers, and policymakers to optimize the use of AI in educational settings. The editors of this special issue are pleased to offer this editorial as a starting point for reflections on AI in mathematics education. We hope that the insights and findings presented here will foster growth and research in this promising field, ultimately contributing to the development of more effective and innovative educational practices in mathematics education. By continuing to explore the integration of AI in mathematics education, we can work towards providing students with the skills and knowledge they need to succeed in an increasingly digital world.

References

Awoyemi, I. D., Mercado, F. M. S., & Moon, J. (2024). A narrative review on immersive virtual reality in enhancing high school students' mathematics competence: From TPACK perspective. *The Mathematical Education, 63*(2), 295–318.

Choi, I. Y., Kim, H. G., Jung, I. W., & Song, M. H. (2024). Automatic scoring of mathematics descriptive assessment using random forest algorithm. *The Mathematical Education, 63*(2), 165–186.

Crompton, H., Jones, M. V., & Burke, D. (2024). Affordances and challenges of artificial intelligence in K–12 education: A systematic review. *Journal of Research on Technology in Education, 56*(3), 248–268. https://doi.org/10.1080/15391523.2022.2121344

Hwang, G. J., & Tu, Y. F. (2021). Roles and research trends of artificial intelligence in mathematics education: A bibliometric mapping analysis and systematic review. *Mathematics, 9*(6), 584. https://doi.org/10.3390/math9060584

Jin, H. S., & Suh, B. (2024). Research on a statistics education program utilizing deep learning predictions in high school mathematics. *The Mathematical Education, 63*(2), 209–231.

Kim, C., & Chang, H. (2024). A case study of elementary school mathematics-integrated classes based on AI Big Ideas for fostering AI thinking. *The Mathematical Education, 63*(2), 255–272.

Kim, J. (2024). An analysis of perceptions of elementary teachers and secondary mathematics teachers on the use of artificial intelligence (AI) in mathematics education. *The Mathematical Education, 63*(2), 351–368.

Lee, D., & Yeo, S. (2022). Developing an AI-based chatbot for practicing responsive teaching in mathematics. *Computers & Education, 191*, 104646. https://doi.org/10.1016/j.compedu.2022.104646

Lee, K. H., Yeo, S., Tak, B., Choi, J. H., Son, T., & Ock, J. (2024a). A study on the factors of elementary school teachers' intentions to use AI math learning system: Focusing on the case of TocToc-Math. *The Mathematical Education, 63*(2), 335–350.

Lee, S. G., Park, D., Lee, J. Y., Lim, D. S., & Lee, J. H. (2024b). Use of ChatGPT in college mathematics education. *The Mathematical Education, 63*(2), 123–138.

Mariotti, M. A. (2019). The contribution of information and communication technology to the teaching of proof. In G. Hanna, D. A. Reid, & M. de Villiers (Eds.), *Proof Technology in mathematics Research and Teaching* (pp. 173–195). Springer. https://doi.org/10.1007/978-3-030-28483-1_8

Moore, R. L., Jiang, S., & Abramowitz, B. (2023). What would the matrix do?: A systematic review of K-12 AI learning contexts and learner-interface interactions. *Journal of Research on Technology in Education, 55*(1), 7–20.

Oh, Y. S., & Kim, D. J. (2024). An analysis of discursive constructs of AI-based mathematical objects used in the optimization content of AI mathematics textbooks. *The Mathematical Education, 63*(2), 319–334.

Park, H. J., & Manley, S. (2024). Using ChatGPT as a proof assistant in a mathematics pathways course. *The Mathematical Education, 63*(2), 139–163.

Saralar-Aras, I., & Cicek Schoenberg, Y. (2024). Unveiling the synergistic nexus: AI-driven coding integration in mathematics education for enhanced computational thinking and problem-solving. *The Mathematical Education, 63*(2), 233–254.

Shin, B., Lee, J., & Yoo, Y. (2024). Exploring automatic scoring of mathematical descriptive assessment using prompt engineering with the GPT-4 model: Focused on permutations and combinations. *The Mathematical Education, 63*(2), 187–207.

Son, T., Yeo, S., & Lee, D. (2024). Exploring elementary preservice teachers' responsive teaching in mathematics through an artificial intelligence-based Chatbot. *Teaching and Teacher Education, 146*, 104640. https://doi.org/10.1016/j.tate.2024.104640

Vygotsky, L. S. (1986). *Thought and language*. MIT Press.

Yeo, J., Son, T., & Song, Y. (2024). Preservice teachers' evaluation of artificial intelligence-based math support system: Focusing on TocToc-Math. *The Mathematical Education, 63*(2), 369–385.

Yuk, J., Huh, N., & Ko, H. (2024). A case study on middle school classes utilizing the math learning application 'Sussam'. *The Mathematical Education, 63*(2), 273–294.