Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education.
Asia-Pacific Society for Computers in Education

AI-Driven Feedback for Enhancing Students' Mathematical Problem-Solving: The ScaffoldiaMyMaths System

Daner SUN[a*], Jingyun WANG[b], Lan YANG[c], Kee-lee CHOU[d], Zhixuan SONG[a] & Zhizi ZHENG[a]

[a]*Department of Mathematics and Information Technology, The Education University of Hong Kong*

[b]*Department of Computer Science, Durham University, UK*

[c]*Department of Curriculum and Instruction, The Education University of Hong Kong*

[d]*Department of Asian and Policy Studies, The Education University of Hong Kong*

*dsun@eduhk.hk

Abstract: As online learning becomes increasingly prevalent, it is essential to understand students' perspectives and address the challenges they encounter. The developing system, ScaffoldiaMyMaths, aims to support the mathematics learning of underprivileged and lower-ability primary school students. This system integrates context-specific and dynamic scaffolding to provide personalized support, particularly in the study of fractions. In addition to standard learning management features, ScaffoldiaMyMaths offers dynamic virtual manipulative representations and adaptive scaffolding for problem-solving, complemented by AI-based real-time feedback. The AI-generated feedback enhances the learning experience by delivering immediate, tailored responses to students' queries. It analyzes students' inputs to offer precise guidance, suggest alternative problem-solving strategies, and identify areas needing further practice. By utilizing AI, ScaffoldiaMyMaths ensures that feedback is both prompt and customized, effectively addressing individual learning gaps and fostering a deeper understanding of mathematical concepts.

Keywords: ScaffoldiaMyMaths, AI feedback, Mathematical Problem Solving, adaptive scaffoldings

1. Introduction

Amidst rapid advancements in artificial intelligence (AI), its integration into educational feedback mechanisms has become increasingly significant (Escalante, 2023). AI-driven systems present opportunities for personalized learning and adaptive feedback (Jia, Sun, & Looi, 2024). However, there is a notable scarcity of mathematics learning systems specifically tailored for primary school students in Hong Kong, especially those from low-resource families. To address this gap and improve educational equity, we have designed and developed ScaffoldiaMyMaths, a mathematics learning system for Hong Kong primary students. As a learning management system, ScaffoldiaMyMaths offers adaptive scaffolding while leveraging AI to provide real-time, customized feedback. This innovative approach enables students to enhance their problem-solving strategies and effectively manage their learning processes (Wu et al., 2017). By fostering self-directed learning and utilizing cutting-edge AI technologies, ScaffoldiaMyMaths aims to improve the efficacy of mathematics education, supporting students in achieving academic success despite limited resources.

2. Literature Review

Scaffolding in open-ended learning environments is a vital process that supports students as they navigate complex tasks (Sun et al., 2024). This scaffolding framework can be categorized into four primary types based on their functions: conceptual, metacognitive, procedural, and strategic (Hannafin et al., 1999). Conceptual scaffolds help learners focus on relevant aspects of a defined problem or task, while metacognitive scaffolds encourage exploration of different problem-solving strategies. Procedural scaffolds guide the effective use of tools and features within the learning environment, and strategic scaffolds provide guidance on how to approach and tackle tasks effectively. Yelland and Masters (2007) expanded this framework by introducing 'cognitive scaffolding,' which encompasses tools and techniques that support both conceptual and procedural understanding. This framework further divides scaffolding into technical and affective categories. Technical scaffolding includes features that mediate and influence learning outcomes, whereas affective scaffolding focuses on motivating and sustaining student engagement. Scaffolds also vary in delivery modes, including embedded versus non-embedded, fixed versus adaptive, and hard versus soft forms. Hard scaffolds are static and technology-mediated, providing fixed support structures, while soft scaffolds are more flexible and often provided by experts, allowing for customization (Saye & Brush, 2002; Sharma & Hannafin, 2007). Additionally, dynamic scaffolds offer real-time assessments based on learner needs, while static scaffolds consist of fixed guidelines (Kim & Hannafin, 2010). Scaffolding can be embedded directly into the learning environment or presented in non-embedded forms requiring student initiative**.** Despite the classifications, the interplay of various scaffolding mechanisms reveals the complexity of distinguishing these types in educational research (Jiang & Elen, 2010).

3. The Structure and features of ScaffoldiaMyMaths

ScaffoldiaMyMaths (as shown in Figure 1.) is an innovative web-based learning management system designed to support primary mathematics education in Hong Kong, especially for low-resource families. It features dynamic scaffolding principles and structures lessons into five sets of fraction problems. Each set includes ten tasks with tailored scaffolding, such as explanation prompts and hints, visually adapted to the nature of each task. **A. Fixed Backward Fading Scaffolding Condition:** In this condition, participants begin with full support for problem-solving. For the first task, all four solution steps are sequentially presented, with each step revealed by clicking the “next step” button. By the final step, all solution steps are shown simultaneously. Scaffolding is gradually reduced in subsequent tasks. In the second task, the presentation remains unchanged. For the third task, the final step is omitted, requiring participants to input it themselves; if incorrect, feedback is provided. This pattern continues, with the fourth task mirroring the third, and further reductions occur in the fifth through tenth tasks, ultimately providing no scaffolding. **B. Fixed Fading and Adding Scaffolding Condition:** This condition incorporates both fading and adding scaffolding. Initially, full support is provided in the first task, gradually decreasing across tasks. In the first and tenth tasks, all steps are shown; in the second and ninth, the first three steps are displayed; in the third and eighth, only the first two steps are visible. Scaffolding is removed in tasks five and six, then reintroduced with increasing support from tasks seven to ten. **C. Performance-Based Fading Scaffolding:** This condition also follows the fixed backward fading approach, but with performance-based adjustments. If a participant answers a task incorrectly, the fading of scaffolding is paused until the participant successfully completes two consecutive tasks. Once this is achieved, the fading schedule resumes. This adjustment ensures that scaffolding is adapted to individual performance levels. **D. Performance-Based Fading and Adding Scaffolding:** In this condition, scaffolding adjustments are dynamic. Initially following a fixed backward fading approach, support remains unchanged if participants fail the first or second tasks until they complete two consecutive tasks correctly. Incorrect answers after fading prompts reintroduce scaffolding, restoring all steps until consistent correct answers allow fading to resume. In addition to foundational elements, ScaffoldiaMyMaths includes several key innovations. The system uses AI-powered scaffolding to provide instant, personalized feedback and recommendations, enhancing self-assessment and self-directed learning. It features dynamic difficulty adjustments based on student performance and supports gradual fading of scaffolding. Additionally, comprehensive analytics, student-centered pedagogical approaches, and multimodal content cater to diverse learning styles, while improved accessibility allows engagement across various devices, fostering an inclusive learning environment.

4. Conclusion and Future Study

ScaffoldiaMyMaths represents a significant advancement in technology-supported mathematics education for primary students from low-resource families by integrating dynamic scaffolding and AI-powered feedback. Its diverse approaches, from fixed backward fading to performance-based adjustments, enhance problem-solving skills and foster independent learning. Future research will include longitudinal studies, comparative analyses with traditional methods, and user feedback to refine and expand the application of this innovative system across different educational contexts.

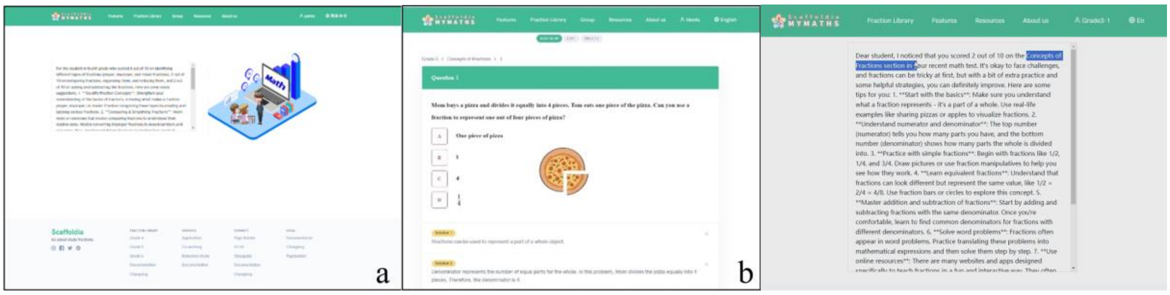

Figure 1. The interface of adaptive scaffolding in ScaffodiaMyMaths and AI generated feedback

Acknowledgments

The research is funded by General Research Fund: 18609221 Preparation for Post Pandemic Society: Providing Technology-Supported Adaptive Scaffoldings for Students with Mathematics Learning Difficulties in Hong Kong Primary Schools.

References

Escalante, J. (2023). Ai-generated feedback on writing: insights into efficacy and enl student preference. International Journal of Educational Technology in Higher Education, 20(1). https://doi.org/10.1186/s41239-023-00425-2

Hannafin, M., Land, S., & Oliver, K. (1999). Open-ended learning environments: Foundations, methods, and models. In C. M. Reigeluth (Ed.), Instructional design theories and models (Vol. II, pp. 115–140)., A new paradigm of instructional theory Mahwah, NJ: Lawrence Erlbaum

Jia, F., Sun, D*. & Looi, C.K. (2023). Artificial Intelligence in Science Education (2013-2023): Research Trends in Ten Years. *Journal of Science Education and Technology*, https://doi.org/10.1007/s10956-023-10077-6

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education*, *56*(2), 403-417. https://doi.org/10.1016/j.compedu.2010.08.024

Saye, J. and Brush, T. (2002) Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, 50, 77-96. http://dx.doi.org/10.1007/BF02505026

Sharma, P., Hannafin, M.J., 2007. Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments*, 15, 27–46.. https://doi.org/10.1080/10494820600996972

Sun, D., Chou, K.L., Yang, L., & Yang, Y. (accepted) (2024). A Systematic Review of Technology-Supported Scaffoldings in Empirical Studies from 2017-2022: Trends, Scaffolding Design Features and Learning Outcome. *Educational Technology & Society*, *27(3)*, 185-203. https://doi.org/10.30191/ETS.202407_27(3).RP11

Wu, X., Kollar, I., & Stegmann, K. (2017). Adaptable scripting to foster regulation processes and skills in computer-supported collaborative learning. *International Journal of Computer-Supported Collaborative Learning,* 12(2), 153-172.

Yelland, N., & Masters, J. (2007). Rethinking scaffolding in the information age. *Computers & Education, 48*(3), 362–382. https://doi.org/10.1016/j.compedu.2005.01.010