Adaptive Learning in Digital Technology-Based Mathematics Education: A Study Systematic Literature Review

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Abstract

Adaptive learning based on digital technology is becoming an increasingly relevant approach in mathematics education, especially since most teachers still rely on conventional learning methods that tend to be less responsive to differences in student abilities. This study aims to explore the concept and implementation of Adaptive Learning in Digital Technology-Based Mathematics Education through a Systematic Literature Review (SLR) approach. Data were collected from books and scientific articles obtained through the Google Scholar and Scopus databases. The data analysis process used a thematic approach to identify main ideas, recurring patterns, and important issues that emerged from the selected literature. The research findings indicate that the application of adaptive learning enabled by digital technology has great potential to improve understanding of mathematical concepts through personalized learning, automated feedback, and material adjustments tailored to individual needs. The adaptive approach is recommended to be combined with conventional methods to make the learning process more flexible, creative, and relevant to students' needs in the digital era.

Keywords: Adaptive learning; Mathematics; Digital Learning, Technology

Introduction

The rapid development of digital technology in recent years has brought significant changes to education, including mathematics education (Fadli, 2024). While previously mathematics learning relied heavily on lectures, textbooks, and conventional exercises, the learning process now increasingly involves digital platforms, interactive applications, and data-driven systems. These changes not only affect how students learn but also how teachers design learning strategies that are more engaging, relevant, and tailored to students' needs in the digital age (Crowley, 2018).

Many teachers still tend to use traditional, uninnovative, and repetitive methods in mathematics teaching. This makes learning feel distant from students' experiences and less able to help them understand concepts deeply (Wang et al., 2023). As a result, mathematical thinking processes are not developed optimally, and the material taught struggles to stick with students' understanding. Without a relevant, contextual learning approach, mathematics is often perceived as abstract, rigid, and disconnected from everyday life (Oladele et al., 2022). This perception contributes to the emergence of math anxiety, where students feel afraid, worried, or lack confidence when faced with mathematics. Learning approaches exist to address these challenges, as a more personalized, flexible, and modern approach is urgently needed. One appropriate approach is adaptive learning enabled by digital technology (Simon & Zeng, 2024). This approach allows the material, difficulty level, and exercise format to be tailored to each student's abilities and needs. With increasingly advanced technology integration, adaptive learning not only increases student motivation and confidence but also positions mathematics as a more human, interactive, and meaningful learning experience.

Previous studies (Nurhaswinda et al., 2025; Su, 2017) have shown that the application of adaptive learning in mathematics instruction remains relatively low, especially at the elementary school level. Many teachers still rely on traditional teaching methods that apply uniformly to all students, without considering differences in student abilities, learning rhythms, or learning styles. This condition causes some students to struggle to understand mathematical concepts deeply because the material presented does not always align with their learning readiness. At elementary school age—when cognitive abilities, abstract understanding, and learning experiences are still developing—the lack of adaptive learning can widen the gap in learning outcomes and decrease student interest in mathematics.

This research explores Adaptive Learning in Digital Technology-Based Mathematics Education as an alternative approach with the potential to enhance the effectiveness of mathematics

instruction. This approach is still rarely utilized by teachers, even though several studies show that adaptive learning can help students learn in a more structured, personalized, and individualized way. By leveraging digital technology, adaptive systems can modify difficulty levels, provide immediate feedback, and offer differentiated learning paths tailored to each student's abilities. Therefore, the purpose of this study is to analyze how a digital technology-based adaptive learning approach is applied in mathematics education and to assess its opportunities, challenges, and implications for learning practices in elementary and secondary schools.

Research Methods

This research employed a Systematic Literature Review (SLR) approach as the primary method (Cabrera & Cabrera, 2023). This approach was chosen because it allows researchers to systematically examine various sources to obtain a comprehensive overview of Adaptive Learning in Digital Technology-Based Mathematics Education. The research focused on reviewing scientific works, including reference books, journal articles, and other relevant academic publications (Fadli, 2021). These sources were obtained through credible databases, primarily Google Scholar and Scopus, ensuring the information analyzed maintains academic validity and quality. Through a multi-layered selection and filtering process, only literature that met the criteria of relevance, novelty, and contextual appropriateness was retained for analysis.

Thematic analysis was used to analyze the research data. This technique involves identifying core ideas, recurring patterns, and key issues emerging from the literature data set (Palomino et al., 2019). This process involves not only recording findings but also in-depth interpretation to understand the relationships between themes and how each theme illustrates the development of adaptive learning implementation in digital technology-based mathematics education. This analysis produces a more focused synthesis of knowledge, enabling it to be used to map research trends, implementation challenges, and opportunities for developing adaptive learning in the context of mathematics education in the digital era.

Results and Discussion

Adaptive learning has emerged as an approach with significant potential to improve the quality of digital technology-based mathematics learning. This approach not only offers a more personalised learning experience but also adapts the material, difficulty level, and learning pace to suit each student's individual needs. Thus, adaptive learning helps students gradually grasp complex concepts while also providing further challenges for students with higher abilities. The results of this study were then further analysed to examine the implementation strategy, system design, student responses, and its effectiveness in improving mathematical understanding. The discussion presented provides a comprehensive overview of the opportunities, challenges, and recommendations for implementing adaptive learning in future digital mathematics education.

The Role of Digital Technology in Supporting Personalised Learning

New digital technologies have changed how learning happens, moving from a one-way, same-for-everyone approach to a more flexible, interactive, and responsive experience that fits each person's needs (Fadli et al., 2025). Using digital technology in math learning allows lessons to be created that do not depend on the speed of the whole class or the average ability of students. Instead, each student can follow a learning path that matches their own style, pace, and understanding of the ideas. This is what personalised learning is all about—making sure each student learns as well as they can.

Personalised learning is implemented through an adaptive learning system, an algorithm- or artificial intelligence-based platform that analyses student learning activities in real time. This system then adjusts the material, provides exercise recommendations, and provides automatic feedback based on student performance (Cho & Kim 2025). Unlike conventional learning, which provides the same material and assessments for all students, adaptive learning selects different learning paths for students who grasp the material quickly versus those who need to repeat concepts. This way, no student feels left behind, and no student finds it too easy.

Digital technology also enables additional features, such as turning lessons into games, presenting ideas with pictures or animations, and tracking how students learn. These features help make math lessons more interesting and useful, especially for students who often find math hard and confusing (Naidoo, 2022). When math concepts are presented through animations, games, or interactive models, students feel more motivated and engaged in learning. Also, teachers can use the

data to see how students are learning, determine what support they need, and provide better guidance.

While digital technology has many benefits for personalised learning, using it well requires teachers to be ready, schools to have the right equipment, and lessons to align with learning goals. Technology does not replace teachers, but it helps them deliver better, more flexible lessons to all students. With training, good education policies, and help in using digital tools, personalised learning can become a fairer and more effective way for all students to learn in the future.

Adaptive Learning Based on Digital Technology to Improve Mathematical Understanding

The growth of digital technology has led to big changes in education, especially in how math is taught. One new approach is adaptive learning, a system that adjusts the material, how it is taught, and the difficulty of the problems based on each student's skills and learning speed. Unlike traditional learning, which is the same for everyone, adaptive learning offers each child a more personalized, flexible, and focused way to learn that fits their needs. This innovation can be particularly relevant in elementary schools (Gallagher et al., 2022).

This new way of learning can be especially helpful in elementary schools. Many students struggle to understand concepts such as fractions, place value, and basic operations. With tools like smart math apps, interactive websites, and computer programs that adjust to each student, kids can learn math through pictures, hands-on activities, simple examples, and practice that moves at their own speed (Shoaib et al., 2023). This makes learning more interesting and less scary for children. The following table shows how math learning changes when adaptive learning is used in elementary and secondary schools.

Table 1. Adaptive Learning Pattern Using Digital Technology in Mathematics for Primary School

Level	Adaptive Learning Stage	Technology Support	Example Math Topic	Example of Adaptation
Primary School (Elementary)	Initial Diagnostic	Digital pre-test, automatic quiz, placement test	Addition–subtraction, number sense, fractions	System identifies student ability and assigns an appropriate starting level
	Personalized Content Delivery	Interactive videos, animations, visual simulations	Fractions using images (pizza, blocks), place value with base-ten visuals	Students who struggle receive more visual explanations, advanced learners continue to abstract concepts
	Adaptive Practice	Auto-adjusting question difficulty	Multiplication and division basics, simple patterns	Wrong answers → easier scaffolded questions; correct answers → gradual increase in difficulty
	Instant Feedback	Auto-correction, hints, audio feedback	Basic geometry shapes, perimeter and simple area	System gives clues (e.g., *"Count the sides first"*) or step-by-step guided examples
	Remediation & Enrichment	Math games, reward system, digital enrichment modules	Fraction games, multiplication challenges	Higher-ability learners unlock challenge levels; others repeat content with a different learning mode (visual/auditory/game-based)

Table 2. Adaptive Learning Pattern Using Digital Technology in Mathematics for Secondary Schools

Level	Adaptive Learning Stage	Technology Support	Example Math Topic	Example of Adaptation
Secondary School (Middle–High School)	Initial Diagnostic	Adaptive test, learning analytics	Algebra, linear equations, functions	System maps student skills and recommends prerequisite or advanced modules
	Personalized Content Delivery	Interactive modules, graphing simulations, virtual math lab	System of linear equations, quadratic functions, trigonometry	Struggling students receive visual or step-by-step guidance; advanced students explore generalized forms
	AI-Based Adaptive Practice	Auto-generated questions, AI error analysis	Exponents, logarithms, probability, 3D geometry	System adjusts: *basic* → *moderate* → *advanced* depending on learner performance
	Feedback and Progress Tracking	Analytics dashboard, automated progress report	Square roots, basic limits, derivatives	System identifies weak areas and recommends targeted review activities
	Extension and Concept Application	STEAM simulations, digital project-based learning, logic challenges	Applying functions in real-life contexts, mathematical modeling	High-performing students complete projects (e.g., function graph simulation based on real-world data)

Tables 1 and 2 show that an adaptive learning approach in math can be much more effective and engaging when well-planned and using the right technology. By following clear steps—like finding out what students already know, giving them material that fits their needs, offering exercises that adjust to their level, and giving instant feedback—learning is no longer the same for everyone; it is tailored to each student's needs. This lets students learn at a pace that suits them, take on challenges that match their skills, and have a more interactive and meaningful learning experience (Ahmed & Ibrahim, 2023). With good planning, teachers can use learning data to provide more targeted support, so adaptive learning not only helps students understand math better but also boosts their motivation, interest, and confidence in solving problems.

Adaptive learning lets teachers get up-to-date information, such as which questions students often get wrong, how long they spend on tasks, and which topics they already understand. This information helps teachers make better choices, such as providing the right extra help rather than repeating everything (Isaeva et al., 2025). Learning is no longer just about teaching the material, but also about helping each child reach their goals in the way and at the speed that works best for them.

Digital technology in adaptive learning also helps students feel more motivated to learn math. Many platforms use game-like features, online rewards, different levels, and instant feedback (Wullschleger et al., 2023). These features have been shown to help students feel less worried about

math and slowly build their confidence (Pinatil & Ramos, 2023). Children who usually feel left out can enjoy learning more, while students who are already good at math can keep improving with harder problems. Overall, adaptive learning is not just about using technology in the classroom. It is a teaching approach that supports diverse student abilities, helps students understand more deeply, and makes math learning more personal and meaningful (Tretow-Fish & Khalid, 2023). Adaptive learning gives elementary schools the chance to move away from one-size-fits-all teaching and focus on what works best for each child.

Challenges and Implications in Adaptive Learning

Using adaptive learning in digital math education creates big opportunities to make learning more personal and flexible for each student. However, there are some challenges that need to be addressed for it to work well. One big challenge is the difference in technology available. Not all schools have digital devices, reliable internet, or enough support to use adaptive learning tools (Masruroh et al., 2025). This causes differences in how students learn between schools that are ready for digital learning and those that are not.

Another challenge is whether teachers are ready. Many teachers do not fully understand how adaptive technology works or how to use the learning data it provides to improve their teaching. Some teachers are accustomed to traditional methods and find adaptive technology too complicated or time-consuming to incorporate into in-class instruction. Because of this, training and support are important to help teachers move from just presenting material to using data to guide student learning (Mukhamadiyeva & Hernández-Torrano, 2024). Another challenge is ensuring that adaptive learning aligns with the national curriculum and tests. Adaptive learning focuses on personalising lessons, but national curricula are usually the same for everyone and expect students to reach certain goals at the same time (Wong, 2021). This timing difference can make it hard to decide on learning goals, tests, and how to manage class time. Because of this, curricula need to be more flexible, and teachers need space to try new ideas so that learning can be adapted without breaking any rules.

Despite these challenges, there are significant positive implications for the future of education, particularly in mathematics. With a system capable of reading student learning patterns, providing automatic feedback, and identifying weaknesses or misconceptions in real time, adaptive learning helps students learn at their own pace (Qurrotu'ain & Fadli, 2024). This not only improves academic outcomes but also fosters confidence, curiosity, and intrinsic motivation in mathematics. The adaptive approach also enables inclusive learning: slow learners are not left behind, and fast learners are not held back.

The long-term implication of implementing adaptive learning is the emergence of a data-driven learning ecosystem that can help schools, teachers, and leaders. In the long run, using adaptive learning can create a system where schools, teachers, and leaders use data to better understand how students are doing (Lin et al., 2025). This helps them make better decisions, like changing the curriculum, training teachers, or planning national learning strategies based on what students really need. If the challenges can be solved over time, adaptive learning could become the basis for a more personal, effective, and caring way of learning in the future.

Conclusion

Adaptive learning in digital technology-based mathematics education has strong potential to improve learning by offering personalized experiences, reinforcing concepts, and providing feedback based on data. Schools should start thinking about policies and how to integrate adaptive learning systems, so teachers can use them effectively in their classrooms. This method helps students understand math concepts better and makes learning more flexible, relevant, and tailored to each student. The results of this review offer a solid foundation and clearer direction for future research, especially on how to implement adaptive learning, prepare infrastructure, and support teachers, so it can be used successfully at different education levels. From a scientific perspective, this review contributes to the literature by providing a structured synthesis of adaptive learning in digital technology–based mathematics education, highlighting its pedagogical value beyond technical implementation. However, this study is limited by the scope of the systematic literature review, including reliance on selected databases, publication time frames, and variations in research designs across the reviewed studies. Therefore, future research is recommended to conduct empirical, longitudinal studies examining adaptive learning implementation across different educational levels, with particular attention to infrastructure readiness, teacher professional development, and policy support to ensure sustainable and effective integration.

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References

Ahmed, A., & Ibrahim, A. A. (2023). The effectiveness of adaptive learning methods in mathematics compared to flipped learning analyzed by ANN and IoT. *Wireless Personal Communications*, 1-21. https://doi.org/10.1007/s11277-023-10500-6

Cabrera, D., & Cabrera, L. L. (2023). The steps to doing a systems literature review (SLR). *Journal of Systems Thinking Preprints*.

Crowley, K. (2018). *The Impact of Adaptive Learning on Mathematics Achievement*. New Jersey City University.

Fadli, M. R. (2021). Memahami desain metode penelitian kualitatif. *Humanika: Kajian Ilmiah Mata Kuliah Umum*, *21*(1), 33-54. https://doi.org/10.21831/hum.v21i1.38075

Fadli, M. R. (2024). Digital Pedagogy Philosophy: Building Critical Awareness of The Role of Technology in Education. *Jurnal Filsafat*, *34*(2), 307-334. https://doi.org/10.22146/jf.93321

Fadli, M. R., Santosa, I., Alfian, A., Syofyan, H., & Fatonah, K. (2025). Optimizing the use of ai in elementary school learning: For teachers in the digital era: English. *Jurnal Pembelajaran Pemberdayaan Masyarakat (JP2M)*, *6*(1), 251-259. https://doi.org/10.33474/jp2m.v6i1.23358

Gallagher, M. A., Parsons, S. A., & Vaughn, M. (2022). Adaptive teaching in mathematics: A review of the literature. *Educational Review*, *74*(2), 298-320. https://doi.org/10.1080/00131911.2020.1722065

Cho, M. K., & Kim, S. (2025). Analyzing AI-based educational platforms for supporting personalized mathematics learning. *International Electronic Journal of Mathematics Education*, *20*(4), em0847. https://doi.org/10.29333/iejme/16664

Isaeva, R., Karasartova, N., Dznunusnalieva, K., Mirzoeva, K., & Mokliuk, M. (2025). Enhancing learning effectiveness through adaptive learning platforms and emerging computer technologies in education. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(1), 144-160. https://doi.org/10.22437/jiituj.v9i1.37967

Lin, C. H., Kuo, B. C., & Chang, F. T. Y. (2025). The impact of Taiwan adaptive learning platform (TALP) on self-regulated learning and mathematics achievement. *Educational Psychology*, 1-22. https://doi.org/10.1080/01443410.2025.2561028

Masruroh, U., Firdaus, R., Fitriawan, H., & Yulianti, D. (2024). Development Study of Technology-Based Adaptive Learning Modules for Students with Special Needs. *Jurnal Teknologi Pendidikan : Jurnal Penelitian Dan Pengembangan Pembelajaran*, *9*(3), 526–533. https://doi.org/10.33394/jtp.v9i3.12250

Mukhamadiyeva, S., & Hernández-Torrano, D. (2024). Adaptive learning to maximize gifted education: Teacher perceptions, practices, and experiences. *Journal of Advanced Academics*, *35*(4), 652-670. https://doi.org/10.1177/1932202X241253166

Naidoo, J. (2022). Technology-based pedagogy for mathematics education in South Africa: Sustainable development of Mathematics Education post Covid-19. *Sustainability*, *14*(17), 10735. https://doi.org/10.3390/su141710735

Nurhaswinda, N., Pebriana, P. H., & Nurmalina, N. (2025). The Impact of Technology-Driven Adaptive Learning on Mathematical Conceptual Mastery in Primary Education. *G-Couns: Jurnal Bimbingan dan Konseling*, *9*(3), 2383-2397. https://doi.org/10.31316/g-couns.v9i3.8388

Oladele, J.I., Ndlovu, M., Ayanwale, M.A. (2022). Computer Adaptive-Based Learning and Assessment for Enhancing STEM Education in Africa: A Fourth Industrial Revolution Possibility. In: Chirinda, B., Luneta, K., Uworwabayeho, A. (eds) Mathematics Education in Africa. Springer, Cham. https://doi.org/10.1007/978-3-031-13927-7_8

Palomino, M., Dávila, A., & Melendez, K. (2019). Methodologies, methods, techniques and tools used on SLR elaboration: a mapping study. In *International Conference on Software Process Improvement* (pp. 14-30). Springer, Cham.

Pinatil, L., & Ramos, A. (2023). Theory of adaptation of educators teaching technology-based courses. *Recoletos Multidisciplinary Research Journal*, *11*(1), 103-118. https://doi.org/10.32871/rmrj2311.01.08

Qurrotu'ain, R., & Fadli, M. R. (2024). The Effect of Mathematics Anxiety on Students' Learning Achievement: An Ex Post Facto Study. In *Proceeding of the International Conference on Mathematical Sciences, Natural Sciences, and Computing* (Vol. 1, No. 2, pp. 01-14).

Shoaib, M., Fitzpatrick, D., & Pitt, I. (2023). Assistive technology-based solutions in learning mathematics for visually-impaired people: exploring issues, challenges and opportunities. *Multimedia Tools and Applications*, *82*(29), 46153-46184. https://doi.org/10.1007/s11042-023-17409-z

Simon, P. D., & Zeng, L. M. (2024). Behind the Scenes of Adaptive Learning: A Scoping Review of Teachers' Perspectives on the Use of Adaptive Learning Technologies. *Education Sciences*, *14*(12), 1413. https://doi.org/10.3390/educsci14121413

Su, C. (2017). Designing and developing a novel hybrid adaptive learning path recommendation system (ALPRS) for gamification mathematics geometry course. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 2275-2298. https://doi.org/10.12973/eurasia.2017.01225a

Tretow-Fish, T. A. B., & Khalid, M. S. (2023). Methods for evaluating learning analytics and learning analytics dashboards in adaptive learning platforms: A systematic review. *Electronic Journal of e-Learning*, *21*(5), 430-449. https://doi.org/10.34190/ejel.21.5.3088

Wang, S., Christensen, C., Cui, W., Tong, R., Yarnall, L., Shear, L., & Feng, M. (2023). When adaptive learning is effective learning: comparison of an adaptive learning system to teacher-led instruction. *Interactive Learning Environments*, *31*(2), 793-803. https://doi.org/10.1080/10494820.2020.1808794

Wong, S. L. (2021). Effects of Motivational Adaptive Instruction on Student Motivation Towards Mathematics in a Technology-Enhanced Learning Classroom. *Contemporary Educational Technology, 13*(4), ep326. https://doi.org/10.30935/cedtech/11199

Wullschleger, A., Lindmeier, A., Heinze, A., Meier-Wyder, A., Leuchter, M., Vogt, F., & Moser Opitz, E. (2023). Improving the quality of adaptive learning support provided by kindergarten teachers in play-based mathematical learning situations. *European Early Childhood Education Research Journal*, *31*(2), 225-242. https://doi.org/10.1080/1350293X.2022.2081348