AKSIOMA EDUCATION JOURNAL
Aksioma: Jurnal Matematika
https://nawalaeducation.com/index.php/AEJ/index
Volume 2 Nomor 4, December 2025
e-ISSN : 3047-3187
DOI : https://doi.org/10.62872/1v2c2209

Over-Scaffolding in Mathematics Education and Its Impact on Students' Cognitive Autonomy

Nur Wahyuni✉
Universitas Ahmad Dahlan

e-mail: 2207050016@webmail.uad.ac.id

INFO ARTICLE

Accepted : November 10, 2025
Revised : December 10, 2025
Approved : November 20, 2025
Published: December 31, 2025

Keywords:
Mathematics Education; Instructional Scaffolding; Artificial Intelligence in Education; Productive Struggle; Learner Autonomy; Sustainable Learning.

ABSTRACT

The increasing integration of digital technology and artificial intelligence (AI) into mathematics education has transformed instructional practices, offering new possibilities for personalized learning while simultaneously introducing risks related to cognitive dependency and declining learner autonomy. This study investigates how instructional scaffolding and AI-supported learning influence the sustainability of students' mathematical competence. Employing a qualitative systematic literature review, this research analyzed 26 peer-reviewed studies published between 2012 and 2025 that address scaffolding, productive struggle, teacher competence, fading dynamics, and AI-mediated instruction. Data were collected through document analysis and synthesized using thematic content analysis. The findings indicate that adaptive scaffolding significantly enhances conceptual understanding, motivation, productive struggle, and learner autonomy when guided by strong pedagogical expertise and gradual fading of support. However, excessive scaffolding and unregulated AI assistance weaken cognitive independence and long-term problem-solving resilience. This study concludes that sustainable mathematics learning requires an integrated instructional framework that positions teachers as central regulators of learning, ensures ethical and adaptive AI use, and prioritizes the systematic transfer of responsibility from external support to students' internal self-regulation.

INTRODUCTION

Recent international studies indicate that despite massive investment in digital learning technologies, students' mathematical reasoning, autonomy, and problem-solving persistence remain fragile across educational levels. Sugiati et al. (2025) demonstrate that although structured teacher assistance significantly improves conceptual understanding in mathematics, improper calibration of support often leads to dependency rather than independence. Similarly, Klingensmith (2025) reports that many mathematics intervention programs still struggle to cultivate sustainable learner autonomy, particularly when instructional support is not systematically faded. These findings reveal a persistent pedagogical tension: students require structured guidance to learn complex mathematical concepts, yet excessive assistance undermines the very cognitive resilience that mathematics education seeks to develop.

This tension is further intensified by the rapid expansion of artificial intelligence in instructional environments. Kostopoulos et al. (2025) document how agentic AI systems increasingly deliver personalized instructional scaffolding in real time, significantly improving short-term performance. However, emerging evidence also indicates that such systems risk weakening students' capacity for productive struggle and independent reasoning when assistance is over-automated (Kulesa et al., 2025). Bierer (2018) previously characterized this phenomenon as everscaffolding, in which continuous support suppresses the development of self-regulated learning. These converging findings suggest that the core challenge in contemporary mathematics education is no longer access to support, but the pedagogical regulation of support.

At the classroom level, the effectiveness of scaffolding is strongly shaped by teacher competence and beliefs. Blakeslee (2024) demonstrates that teachers' pedagogical content knowledge and expectancy beliefs significantly influence how scaffolding is enacted in mathematics interventions. Teachers who maintain high academic expectations and strong content understanding are more likely to provide challenging yet supportive guidance that stimulates productive struggle, a process shown to strengthen students' mathematical mindset and perseverance (Muharram et al., 2025). Conversely, Li (2025) reveals that poorly timed fading of teacher support can either confuse learners or inhibit their independence, indicating that scaffolding is not a static strategy but a dynamic pedagogical process requiring high professional judgment.

Although extensive research has examined scaffolding strategies and the growing role of AI in education, these strands of research remain largely fragmented. Studies on scaffolding rarely incorporate the influence of AI-based instructional systems, while AI research frequently prioritizes performance gains over long-term learner autonomy and cognitive development (Xu et al., 2025; Peterson, 2024). Consequently, there is limited integrative understanding of how teacher-guided scaffolding and AI-mediated support interact to shape sustainable mathematics learning.

To address this gap, the present study aims to synthesize contemporary research on scaffolding, teacher competence, and AI-supported instruction in mathematics education in order to construct a coherent pedagogical framework for sustainable learning. The novelty of this research lies in the formulation of an Adaptive Fading Scaffolding Model, which reconceptualizes instructional support as a dynamically regulated process balancing guidance, productive struggle, learner autonomy, and ethical AI mediation. This model extends classical interpretations of Vygotsky's Zone of Proximal Development by incorporating contemporary digital and artificial intelligence contexts (Connolly, 2025).

METHODOLOGY

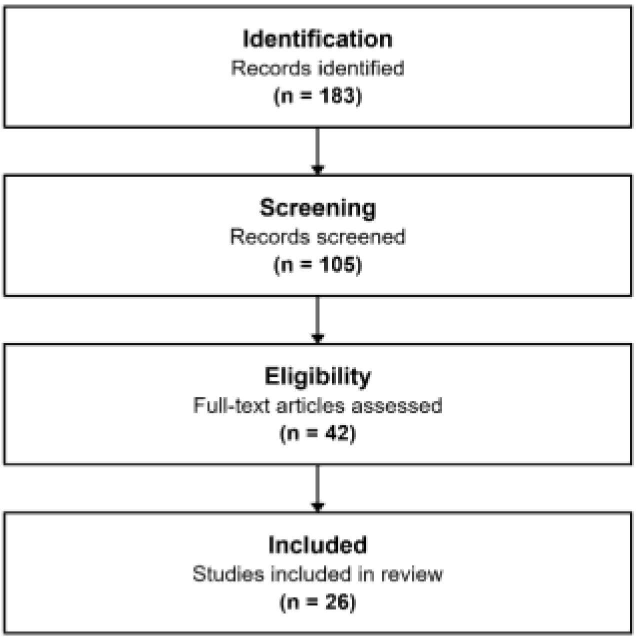
This study employed a qualitative systematic literature review design to examine the pedagogical dynamics of scaffolding and artificial intelligence in contemporary mathematics education. The qualitative approach was selected to enable an in-depth synthesis of theoretical perspectives and empirical findings related to instructional support, learner autonomy, productive struggle, and technology-mediated learning. The review was conducted following structured stages consisting of problem identification, literature search, screening and eligibility assessment, data extraction, thematic analysis, and synthesis.

The population of this study comprised peer-reviewed research articles, doctoral dissertations, and scholarly books focusing on scaffolding strategies, mathematics instruction, artificial intelligence in education, and learner development. A purposive sampling technique was used to select relevant literature published between 2012 and 2025. From an initial corpus of 183 sources identified through Scopus, ERIC, and Google Scholar databases, 26 studies were selected based on predefined inclusion criteria: relevance to mathematics learning, explicit discussion of scaffolding or AI-supported instruction, empirical or theoretical rigor, and publication in reputable academic outlets.

Data were collected through systematic document analysis. Each selected study was carefully reviewed using a structured extraction framework that captured research context, methodology, instructional approach, learning outcomes, and theoretical implications. This process ensured consistency and transparency in data handling while enabling the identification of recurring concepts and relationships across studies.

Data analysis was conducted using thematic content analysis. The researchers applied open coding to identify key patterns in instructional practices, teacher competence, learner autonomy, and AI-mediated support. These codes were subsequently organized through axial coding to establish conceptual categories and interrelationships. Finally, selective coding was employed to integrate the categories into a coherent analytical framework. This process resulted in the development of the Adaptive Fading Scaffolding Model, which conceptualizes instructional support as a dynamic balance between guidance, productive struggle, learner self-regulation, and ethical AI integration.

Below is the research procedure diagram that you can insert into the methodology section.



RESULTS AND DISCUSSION

Adaptive Scaffolding and Learning Quality

The findings indicate that adaptive scaffolding significantly enhances learning quality when instructional assistance is carefully calibrated and gradually withdrawn. Sugiati et al. (2025) demonstrate that the use of *scaffolding thresholds* enables teachers to determine the optimal timing and intensity of instructional support, ensuring that students remain within their zone of proximal development. This strategic adjustment of assistance promotes deeper conceptual understanding and prevents cognitive overload. Complementing this, Frey et al. (2023) show that systematic scaffolding followed by gradual release of responsibility strengthens learner autonomy and metacognitive control, leading to sustained engagement in mathematical tasks.

These results extend the classical interpretation of Vygotsky’s learning theory by confirming that effective learning does not emerge from constant support but from the dynamic regulation of assistance in response to learner readiness (Connolly, 2025). When support is adapted to students’ evolving competence, learners demonstrate higher persistence and improved self-regulation, indicating that adaptive scaffolding functions as a cognitive regulator that balances instructional guidance and independent learning development.

Table 1. Effects of Adaptive Scaffolding on Learning Quality

Indicator	Description of Findings	Educational Implications	Sources
Conceptual understanding	Improved significantly through calibrated assistance	Strengthens mastery of mathematical concepts	Sugiati et al., 2025
Student motivation	Increased engagement and persistence	Supports sustainable learning	Frey et al., 2023
Learning independence	Develops through gradual fading	Promotes self-regulated learning	Connolly, 2025

Table 1 provides compelling evidence that adaptive scaffolding significantly enhances the quality of mathematics learning when instructional support is delivered in a calibrated and responsive manner. The findings demonstrate that well-timed guidance strengthens conceptual understanding by helping learners bridge gaps between prior knowledge and new content. This process reduces cognitive overload and allows students to construct meaning more effectively within their zone of proximal development (Sugiati et al., 2025).

Beyond cognitive outcomes, the table highlights notable improvements in student motivation and engagement. When scaffolding is structured and progressively withdrawn, learners experience a sense of competence and control over their learning process, which reinforces intrinsic motivation and persistence (Frey et al., 2023). These motivational gains are critical for sustaining long-term engagement in mathematically demanding tasks.

The development of learning independence reflected in Table 1 indicates that adaptive scaffolding promotes self-regulated learning behaviors. Students gradually assume responsibility for planning, monitoring, and evaluating their own learning, which aligns with contemporary models of autonomous learning (Connolly, 2025). This shift represents a transition from teacher-centered support toward learner-centered cognitive ownership.

Collectively, these findings confirm that effective scaffolding functions as a cognitive regulation mechanism that balances instructional assistance with autonomy development. Rather than fostering dependency, adaptive scaffolding cultivates intellectual confidence and resilience, enabling students to internalize problem-solving strategies and apply them independently across contexts.

Teacher Competence and Expectancy Beliefs

The analysis reveals that the effectiveness of scaffolding is highly dependent on teachers' pedagogical content knowledge and expectancy beliefs. Blakeslee (2024) and Klingensmith (2025) report that teachers with strong subject mastery and positive expectations toward student capability are more likely to design scaffolding that challenges learners while providing sufficient emotional and cognitive support. Such instructional practices stimulate productive struggle and strengthen students' confidence in tackling complex mathematical problems.

Moreover, Li (2025) emphasizes that the timing of fading teacher support is a critical professional skill. Improper fading either overwhelms learners or suppresses their independence, demonstrating that scaffolding is not a static technique but a dynamic pedagogical process that demands continuous diagnostic judgment from teachers.

Table 2. Role of Teacher Competence in Scaffolding Effectiveness

Indicator	**Description of Findings**	**Educational Implications**	**Sources**
Pedagogical Content Knowledge	Determines quality of scaffolding design	Enables higher-order learning	Blakeslee, 2024
Expectancy beliefs	Shape feedback and instructional challenge	Strengthen student confidence	Klingensmith, 2025
Instructional sensitivity	Influences fading timing	Preserves learner autonomy	Li, 2025

Table 2 underscores the decisive role of teacher competence and expectancy beliefs in shaping the effectiveness of scaffolding practices. Teachers with strong pedagogical content knowledge possess the disciplinary understanding necessary to design support that targets core conceptual difficulties and higher-order reasoning, rather than superficial task completion (Blakeslee, 2024).

Furthermore, expectancy beliefs strongly influence the level of cognitive challenge teachers are willing to provide. Educators who maintain high expectations for student capability are more likely to design demanding tasks and provide constructive feedback that encourages perseverance and intellectual risk-taking (Klingensmith, 2025). This environment nurtures a culture of academic confidence and achievement.

The table also reveals that instructional sensitivity is crucial for determining the timing of fading. Effective teachers continuously assess student readiness and adjust their level of support accordingly, preventing both premature withdrawal and excessive dependence (Li, 2025). This dynamic calibration requires advanced pedagogical judgment and reflective practice.

Together, these dimensions demonstrate that scaffolding quality is not primarily a function of instructional tools but of teacher expertise. Teacher competence serves as the central driver of meaningful cognitive development in scaffolded learning environments.

Productive Struggle and Mathematical Mindset

A central theme in the findings is the importance of *productive struggle* in cultivating a strong mathematical mindset. Muharram et al. (2025) find that when students are exposed to balanced cognitive challenges, they develop greater perseverance, flexibility in problem solving, and confidence in their mathematical ability. These attributes foster long-term engagement and resilience in mathematics learning.

The results align with constructivist perspectives, which view cognitive conflict as a catalyst for conceptual growth. Scaffolding therefore should not eliminate struggle but rather structure it in a manner that supports meaning-making and persistence.

Table 3. Impact of Productive Struggle on Mathematical Development

Indicator	Description of Findings	Educational Implications	Sources
Cognitive resilience	Increased perseverance	Builds learning stamina	Muharram et al., 2025
Problem-solving flexibility	Improved adaptability	Supports complex reasoning	Muharram et al., 2025
Growth mindset	Strengthened beliefs about ability	Encourages risk-taking	Muharram et al., 2025

Table 3 highlights the fundamental importance of productive struggle in cultivating a sustainable mathematical mindset. When students engage with challenging problems under structured guidance, they develop persistence and adaptability two traits essential for long-term success in mathematics (Muharram et al., 2025).

The findings indicate that exposure to controlled difficulty enhances problem-solving flexibility by requiring students to explore multiple strategies, evaluate alternatives, and revise their thinking. These cognitive behaviors foster deeper conceptual understanding and transferable reasoning skills.

Additionally, productive struggle strengthens growth-oriented beliefs about learning. Students begin to perceive mistakes and difficulty as integral components of intellectual growth rather than indicators of failure. This mindset transformation promotes confidence, resilience, and sustained engagement.

Therefore, productive struggle emerges not as an obstacle to learning but as a central mechanism through which higher-order cognition and durable mathematical competence are developed.

4. AI-Supported Scaffolding and Learner Autonomy

The integration of artificial intelligence into instructional scaffolding has produced mixed outcomes. Kostopoulos et al. (2025) and Xu et al. (2025) demonstrate that AI-supported systems enhance personalization, provide immediate feedback, and accelerate mastery learning. These systems are particularly effective in diagnosing learner needs and adjusting instructional content in real time.

However, Kulesa et al. (2025) caution that excessive reliance on AI-based support can weaken students' cognitive effort and problem-solving resilience. This evidence underscores the importance of pedagogically regulating AI use so that technology functions as a cognitive partner rather than a cognitive substitute.

Table 4. Influence of AI-Based Scaffolding on Learning

Indicator	Description of Findings	Educational Implications	Sources
Personalization	Adaptive tasks aligned with learner needs	Increases learning efficiency	Kostopoulos et al., 2025
Immediate feedback	Rapid correction of misconceptions	Supports mastery learning	Xu et al., 2025
Risk of dependency	Overuse reduces cognitive effort	Requires pedagogical control	Kulesa et al., 2025

Table 4 provides a nuanced portrayal of the complex role of artificial intelligence in mathematics learning, where technological benefits coexist with significant pedagogical risks. Empirical studies show that AI-based scaffolding systems substantially enhance instructional personalization by continuously adapting learning tasks to students' cognitive profiles and delivering immediate feedback that accelerates conceptual mastery and learning efficiency (Kostopoulos et al., 2025; Xu et al., 2025). These systems are particularly effective in identifying misconceptions and dynamically adjusting task difficulty, offering support precision that is rarely achievable through traditional classroom instruction (Nagashima et al., 2025).

However, the evidence also reveals emerging concerns regarding cognitive dependency. When AI systems provide excessive guidance or instantaneous solutions, students' engagement in productive struggle diminishes, reducing opportunities for deep cognitive processing and weakening long-term problem-solving resilience (Kulesa et al., 2025; Long & Aleven, 2017). This condition aligns with Bierer's (2018) earlier warning that continuous instructional assistance can suppress the development of learner autonomy.

Furthermore, the tension between learning efficiency and cognitive independence underscores a fundamental pedagogical dilemma. While AI optimizes short-term performance, sustainable learning depends on cultivating intellectual agency and metacognitive control. Effective integration therefore requires the deliberate design of instructional sequences in which AI-based scaffolding is progressively reduced as learners demonstrate increasing competence, consistent with adaptive fading principles (Li, 2025; Frey et al., 2023).

Crucially, Table 4 highlights the irreplaceable role of teacher judgment in mediating AI use. Although AI systems excel at data-driven personalization, they lack sensitivity to contextual factors such as student motivation, emotional wellbeing, and classroom culture. Teachers must therefore function as pedagogical regulators who determine when and how AI support is deployed to preserve the balance between instructional efficiency and learner autonomy (Peterson, 2024; Hammond, 2025).

Over-Scaffolding and Fading Dynamics

The findings confirm substantial risks associated with excessive scaffolding. Bierer (2018) identifies *everscaffolding* as a condition where continuous support inhibits learner autonomy and independent problem solving. Li (2025) further demonstrates that improper timing of support withdrawal disrupts learning development, reinforcing the importance of strategic fading.

These patterns validate the necessity of the **Adaptive Fading Scaffolding Model**, which integrates teacher expertise, learner self-regulation, and ethical AI mediation to sustain high-quality mathematics learning in digital environments.

Table 5. Risks of Excessive Scaffolding and Improper Fading

Indicator	Description of Findings	Educational Implications	Sources
Everscaffolding	Continuous support weakens autonomy	Hinders independent thinking	Bierer, 2018
Fading timing	Premature or delayed fading disrupts learning	Requires professional judgment	Li, 2025
Cognitive dependency	Overreliance on assistance	Reduces problem-solving resilience	Bierer, 2018; Kulesa et al., 2025

Table 4 provides a nuanced portrayal of the complex role of artificial intelligence in mathematics learning, where technological benefits coexist with significant pedagogical risks. Empirical studies show that AI-based scaffolding systems substantially enhance instructional personalization by continuously adapting learning tasks to students' cognitive profiles and delivering immediate feedback that accelerates conceptual mastery and learning efficiency (Kostopoulos et al., 2025; Xu et al., 2025). These systems are particularly effective in identifying misconceptions and dynamically adjusting task difficulty, offering support precision that is rarely achievable through traditional classroom instruction (Nagashima et al., 2025).

However, the evidence also reveals emerging concerns regarding cognitive dependency. When AI systems provide excessive guidance or instantaneous solutions, students' engagement in productive struggle diminishes, reducing opportunities for deep cognitive processing and weakening long-term problem-solving resilience (Kulesa et al., 2025; Long & Aleven, 2017). This condition aligns with Bierer's (2018) earlier warning that continuous instructional assistance can suppress the development of learner autonomy.

Furthermore, the tension between learning efficiency and cognitive independence underscores a fundamental pedagogical dilemma. While AI optimizes short-term performance, sustainable learning depends on cultivating intellectual agency and metacognitive control. Effective integration therefore requires the deliberate design of instructional sequences in which AI-based scaffolding is progressively reduced as learners demonstrate increasing competence, consistent with adaptive fading principles (Li, 2025; Frey et al., 2023).

Crucially, Table 4 highlights the irreplaceable role of teacher judgment in mediating AI use. Although AI systems excel at data-driven personalization, they lack sensitivity to contextual factors such as student motivation, emotional wellbeing, and classroom culture. Teachers must therefore function as pedagogical regulators who determine when and how AI support is deployed to preserve the balance between instructional efficiency and learner autonomy (Peterson, 2024; Hammond, 2025).

CONCLUSION

This study provides robust evidence that the sustainability of mathematics learning in contemporary digital environments depends on the careful orchestration of adaptive scaffolding, professional teacher judgment, and ethically regulated artificial intelligence. The findings affirm that when instructional support is dynamically calibrated and progressively faded, students develop stronger conceptual understanding, heightened motivation, productive struggle, and enduring learner autonomy. Conversely, excessive scaffolding and unregulated AI intervention undermine cognitive independence and weaken long-term problem-solving resilience. These results highlight the central role of teachers as pedagogical architects who govern the balance between support and independence while mediating the influence of intelligent technologies. The proposed framework of Adaptive Fading Scaffolding offers both a theoretical contribution and a practical roadmap for designing resilient mathematics instruction that fosters intellectual agency, cognitive flexibility, and sustainable academic growth in the digital era.

LITERATURE

Athanases, S. Z., & de Oliveira, L. C. (2014). Scaffolding versus routine support for Latina/o youth in an urban school: Tensions in building toward disciplinary literacy. Journal of Literacy Research, 46(2), 263–299. https://doi.org/10.1177/1086296X14527508

Bierer, B. (2018). When more is less: The risks of everscaffolding learning. In The use of technology in teaching and learning (pp. 46–53).

Blakeslee, D. (2024). A case study on the impact of intermediate elementary teachers' pedagogical content knowledge and expectancy beliefs of students on scaffolding practices in mathematics intervention.

Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., … Paskevicius, M. (2020). A global outlook to the interruption of education due to COVID-19 pandemic. Asian Journal of Distance Education, 15(1), 1–126.

Connolly, R. (2025). Exploring Vygotsky's zone of proximal development in preschool education (Master's thesis, University of Wyoming).

Dan, N. T., Trung, L. T., Nga, N. T. H., & Dung, T. T. (2024). Digital game-based learning in mathematics education at primary school level: A systematic literature review. Eurasia Journal of Mathematics, Science and Technology Education, 20(1). https://doi.org/10.29333/ejmste/14377

Frey, N., Fisher, D., & Almarode, J. (2023). How scaffolding works: A playbook for supporting and releasing responsibility to students. Thousand Oaks, CA: Corwin.

Fjærestad, M., & Xenofontos, C. (2025). Digital tools in mathematics classrooms: Norwegian primary teachers' experiences. in education, 30(1). https://doi.org/10.37119/ojs2025.v30i1.807
Hammond, Z. (2025). Rebuilding students' learning power: Teaching for instructional equity and cognitive justice. Thousand Oaks, CA: Corwin.
Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S., & Reiss, K. (2020). The potential of digital tools to enhance mathematics and science learning. Computers & Education, 153, 103897. https://doi.org/10.1016/j.compedu.2020.103897
Joshi, D., & Khanal, J. (2025). Digital resource engagement and mathematical achievement. Computers in Human Behavior Reports. https://doi.org/10.1016/j.chbr.2025.100782
Klingensmith, K. A. (2025). Refining and improving mathematics intervention instruction (Doctoral dissertation, University of Pittsburgh).
Komarudin, K., Suherman, S., & Vidákovich, T. (2024). The RMS teaching model with brainstorming technique and student digital literacy. Heliyon, 10. https://doi.org/10.1016/j.heliyon.2024.e33877
Kostopoulos, G., Gkamas, V., Rigou, M., & Kotsiantis, S. (2025). Agentic AI in education. IEEE Access.
Kulesa, A. C., Mission, M., Croft, M., & Wells, M. K. (2025). Productive struggle: How artificial intelligence is changing learning.
Lavidas, K., Apostolou, Z., & Papadakis, S. (2022). Challenges and opportunities of mathematics in digital times. Education Sciences, 12(7), 459. https://doi.org/10.3390/educsci12070459
Li, J. (2025). Stepping out of the conversation: Teacher fading dynamics. System, 132, 103698. https://doi.org/10.1016/j.system.2025.103698
Long, Y., & Aleven, V. (2017). Educational game and intelligent tutoring system. ACM Transactions on Computer-Human Interaction, 24(3). https://doi.org/10.1145/3057879
Muharram, M. R. W., Karlimah, D. A. M. L., Apriani, I. F., Septiani, F., & Meilani, F. (2025). Elementary teachers as catalysts for productive struggle and mathematical mindset. In Innovative and Digital Learning in Education (pp. 489–498).
Nagashima, T., Kilger, H., & Aleven, V. (2025). When less is more: Students' use of diagrams in AI tutor for algebra learning. In Proceedings of the Annual Meeting of the Cognitive Science Society (Vol. 47).
Ng, C., Chen, Y., Wu, C., & Chang, T. (2022). Evaluation of math anxiety and remediation. Brain and Behavior, 12. https://doi.org/10.1002/brb3.2557
Peterson, A. (2024). Jarvis: A cognitive memory architecture for AI-augmented learning.
Ramdhani, S., Nirmala, S., & Nurcahyono, N. (2025). Challenges in online mathematics education. Indonesian Journal of Educational Development, 6(1), 24–39. https://doi.org/10.59672/ijed.v6i1.4640
Sugiati, I., Rahayuningsih, S., & Prayitno, A. (2025). Optimizing teacher assistance in mathematics learning through scaffolding thresholds. EduMatSains, 10(2), 374–382.
Sun, L., Ruokamo, H., Siklander, P., Li, B., & Devlin, K. (2021). Students' perceptions of scaffolding in digital game-based learning. Learning, Culture and Social Interaction, 29, 100457. https://doi.org/10.1016/j.lcsi.2020.100457
Topping, K., Douglas, W., Robertson, D., & Ferguson, N. (2022). Effectiveness of

online and blended learning. Review of Education, 10(1), e3353. https://doi.org/10.1002/rev3.3353
Wijaya, T., Cao, Y., Weinhandl, R., & Tamur, M. (2022). Effects of e-books on students' mathematics achievement. Heliyon, 8, e09432. https://doi.org/10.1016/j.heliyon.2022.e09432
Xu, W., Dong, X., & Ouyang, F. (2025). The effects of three scaffoldings on computer-supported learning. International Journal of Human-Computer Interaction, 41(8), 4987–5002.