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Reorienting School Mathematics Learning: Integrating Active, Differentiated, and Technology-Enhanced Instruction

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Abstract

Scientific and technological developments highlight the need for school mathematics instruction that responds to students' diverse characteristics and learning needs. This study synthesized concepts and research findings concerning the integration of active learning, differentiated instruction, and digital technology in mathematics education. A systematic literature review examined ten relevant scientific articles published between 2020 and 2026. Findings were analyzed thematically through identification, classification, comparison, and synthesis. The reviewed literature indicated that active learning supports students' engagement in constructing understanding and developing mathematical thinking. Differentiated instruction accommodates variations in readiness, interests, abilities, and learning needs, while digital technology facilitates access to interactive, flexible, and adaptive learning resources. Their integration has the potential to support meaningful, inclusive, participatory, and responsive mathematics instruction. The study contributes an integrative pedagogical perspective that positions active learning, differentiation, and technology as complementary dimensions of instructional design. Further research should develop and empirically test integrated instructional models across educational levels, examining their implications for conceptual understanding, mathematical reasoning, problem-solving skills, motivation, and learning autonomy.

Keywords: Active Learning; Differentiated Instruction; Technology-Enhanced Learning; Mathematics Education; Pedagogical Integration

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INTRODUCTION

School mathematics education is facing increasingly complex demands as a result of developments in science, changing student characteristics, and advances in digital technology. Mathematics can no longer be taught merely as a collection of concepts, formulas, procedures, and computational skills. Rather, learning should foster critical thinking, problem solving, mathematical reasoning, creativity, communication, and the ability to apply concepts in real-life situations. These changes call for a reorientation of mathematics learning: a shift from teacher-dominated instruction focused on content delivery toward student-centered learning that recognizes diverse learning needs and uses technology to support knowledge construction. Such reorientation is essential because successful mathematics learning depends not only on mastery of subject matter but also on students' active engagement, the relevance of their learning experiences, and opportunities to develop their mathematical potential.

The need to reorient mathematics learning is also underscored by the challenges faced by Indonesian students in mathematical literacy. The source manuscript reports that the Programme for International Student Assessment (PISA) 2025 results indicate an average mathematics score of 364 for Indonesian 15-year-olds, compared with the OECD average of 463. It further reports that approximately 17% of Indonesian students achieved at least Level 2 proficiency, compared with an OECD average of 65% (OECD, 2026). These figures, as cited in the original manuscript, point to continuing difficulties in interpreting relatively simple situations, representing problems mathematically, and applying mathematical knowledge to contextual problems. The bibliographic and publication status of the cited PISA 2025 report should be verified before submission.

Improving mathematics education therefore requires more than adding content or increasing the number of exercises. Teachers need to design learning experiences that stimulate intellectual engagement, provide support appropriate to students' levels of understanding, and enable conceptual exploration through diverse resources and media. Integrating active learning, differentiated instruction, and technology-enhanced learning offers a strategic response to these demands.

Active learning is a key component of this reorientation because it positions students as the main agents in knowledge construction. Through group discussion, investigation, problem exploration, project-based learning, guided discovery, and contextual problem

solving, students can construct concepts, test solution strategies, formulate arguments, and reflect on their thinking. Mathematical understanding cannot be developed solely by listening to explanations and memorizing procedures; it requires experiences through which learners identify relationships among concepts and develop reasoning. Nevertheless, active learning faces practical challenges, including teacher dominance, limited instructional time, uneven student participation, and group activities that do not always engage students in deep mathematical thinking. Active learning should therefore be understood not merely as a teaching-method variation but as a pedagogical orientation that develops students' cognitive, social, and reflective engagement.

The diversity of student characteristics also calls for more responsive mathematics instruction through differentiated instruction. Students in the same classroom differ in prior knowledge, mathematical ability, learning pace, interests, readiness, and preferences for processing information. A uniform instructional approach may consequently fail to provide optimal learning experiences for all students. Differentiated instruction responds to this diversity by adjusting content, process, product, and the learning environment according to students' needs and readiness. In mathematics, differentiation may involve problems of varying complexity, concrete and abstract representations, scaffolding, flexible grouping, and alternative task and assessment formats. Hu, (2024)'s systematic review of 61 empirical studies published between 2000 and 2022 indicates that differentiated instruction in K–12 settings encompasses student differences, instructional strategies, materials, learning tools, assessment, and instructional effectiveness. This complexity means that differentiation requires systematic planning rather than simply assigning different tasks.

Digital technology has also transformed how mathematical knowledge is presented, learned, explored, and assessed. Mathematical applications, visualization software, interactive simulations, digital learning platforms, instructional videos, and artificial-intelligence-based tools can create more dynamic and adaptive learning experiences. Technology enables students to visualize abstract concepts, explore mathematical relationships, receive feedback, conduct simulations, and solve problems through multiple representations. Yeung & Ng, (2023), in a systematic review of 34 studies on touchscreen technology in K–12 mathematics education, found that digital applications are frequently used to support number-concept understanding through interactive and gamified learning environments. Valero Larico et al. (2026), in a review of 49 studies published between 2020 and 2024, reported that interactive

applications integrated with active, collaborative, and problem-based learning can support the understanding of mathematical concepts, particularly abstract ones.

However, technology does not automatically improve learning quality when it is used merely to transfer conventional content delivery to a digital medium. Infrastructure constraints, unequal access to devices and the internet, teachers' digital competence, the quality of learning resources, and potential distractions must also be considered. UNESCO, (2023) emphasizes that robust empirical evidence of technology's added value in education remains limited and that technology use should be guided by relevance, equitable access, and learning quality. Technology should therefore function as a pedagogical instrument that strengthens learning activities and supports differentiation, rather than becoming the primary goal of instruction.

Although active learning, differentiated instruction, and technology-enhanced learning have each received substantial research attention, previous studies often examine them separately. Hu, (2024), for example, focuses on differentiated instruction across educational levels, while Yeung & Ng, (2023)emphasize touchscreen technology in mathematics learning. Valero Larico et al. (2026) examine digital applications in secondary mathematics education and their relationship with particular instructional approaches. These studies provide important empirical foundations but do not comprehensively explain how active learning, instructional differentiation, and digital technology can complement one another as an integrated pedagogical orientation in school mathematics. Previous research also varies in educational level, student characteristics, technology type, instructional strategy, and indicators of success. Consequently, findings remain dispersed, and the relationships among cognitive engagement, individual learning needs, social interaction, and mathematical reasoning are not always examined together.

Addressing this gap, this study, entitled "Reorienting School Mathematics Learning: Integrating Active, Differentiated, and Technology-Enhanced Instruction," develops a conceptual synthesis of the three approaches as mutually complementary pedagogical dimensions. Active learning encourages engagement and knowledge construction; differentiated instruction accommodates differences in readiness, ability, interests, and learning needs; and digital technology provides flexible environments, resources, representations, and learning support. The study identifies trends in previous research, compares empirical findings, examines relationships among the three components, and

analyzes conditions that facilitate or hinder their implementation in schools. Its expected contribution is an integrative conceptual framework that can inform instructional strategy development, pedagogical innovation, future empirical research, and the professional development of mathematics teachers.

METHODS

This study employed a Systematic Literature Review (SLR) with thematic synthesis to examine the reorientation of mathematics learning through the integration of active learning, differentiated instruction, and technology-enhanced learning. The data were drawn from scientific journal articles published between 2020 and 2026 and identified through searches in Google Scholar. The search terms included "active learning," "differentiated instruction," "technology-enhanced learning," and "mathematics education."

Studies were selected based on their relevance to the research focus, their connection to school mathematics learning, and the quality and traceability of their publication records. Based on these criteria, ten scientific articles published between 2020 and 2026 were used as the principal sources. The analysis involved identifying, classifying, comparing, and synthesizing findings across three themes: (1) active learning and its contribution to engagement and mathematical reasoning; (2) differentiated instruction and its role in accommodating diverse learning needs; and (3) technology use in supporting flexibility and innovation in mathematics learning. The synthesis was then used to identify connections among the three approaches, limitations in previous research, and a conceptual framework for adaptive, inclusive, and student-responsive mathematics learning.

To strengthen reproducibility, the final submitted version should additionally report the exact search date, complete search strings, screening and exclusion procedures, and the bibliographic details of all ten included studies. These procedural details were not specified in the source manuscript and have therefore not been invented in this translation.

RESULTS

The findings are presented through a synthesis of ten relevant scientific articles published between 2020 and 2026. The synthesis identifies research trends, principal findings, contributions, and relationships to the three areas of focus: active learning, differentiated instruction, and technology-enhanced learning.

Table 1. Synthesis of Previous Research on the Reorientation of Mathematics Learning

No	Authors and Year	Research Focus and Method	Main Findings
1	Ayari et al. (2025)	Systematic literature review of problem-based learning (PBL) in K–12 mathematics; 40 studies.	PBL promotes active participation, problem solving, and students' cognitive, social, and metacognitive skills.
2	Tañola & Lomibao (2024)	Systematic literature review of mathematics learning strategies among secondary students after the pandemic.	Cognitive strategies, visual representations, heuristic problem solving, differentiated activities, and metacognitive reflection support mathematical understanding and thinking.
3	Muryaningrum et al. (2026)	Systematic review of ten articles on discovery learning and conceptual understanding in primary mathematics.	All reviewed studies reported improved conceptual understanding following the implementation of discovery learning.
4	Mardati et al. (2025)	Quasi-experimental study of differentiated instruction among Grade 4 primary students.	Differentiation based on readiness, interests, and learning profiles produced significantly higher mathematics achievement than conventional instruction.
5	Adawiah et al. (2026)	Development of the Differentiated Mathematics Learning Style (DiMaLS) model for junior high school students.	DiMaLS improved achievement, engagement, and conceptual understanding; the reported implementation N-gain was 0.75.
6	Apsarini et al. (2026)	Systematic literature review of 40 articles on differentiated mathematics learning in the Merdeka Curriculum.	Differentiation of content, process, and product supports achievement, motivation, engagement, critical thinking, and problem solving.
7	Rahma & Nurlaelah (2024)	Meta-analysis of ten studies on digital technology and mathematics achievement in Indonesian secondary schools.	Digital technology had a moderate positive effect (mean effect size 0.417), although effectiveness varied by educational level and mathematical topic.
8	Erawati et al. (2025)	Systematic literature review of 27 articles on digital transformation in mathematics learning during 2020–2025.	GeoGebra, Desmos, Wordwall, augmented reality, e-modules, and collaborative platforms support conceptual understanding, problem solving, communication, and other mathematical competencies.
9	Darmanova et al. (2025)	Systematic review of technology use in secondary mathematics education.	Technology should be examined in relation to context, instructional methods, assessment characteristics, and learning outcomes rather than only its technical features.
10.	Valero Larico et al. (2026)	Systematic literature review of 49 studies on digital applications in secondary mathematics.	Interactive applications, simulations, gamification, and augmented/virtual reality are more meaningful when combined with active, collaborative, and problem-based learning.

The ten studies reveal three major trends in the development of school mathematics learning.

Active Learning as a Driver of Engagement and Mathematical Knowledge Construction

The synthesis indicates that active learning plays an important role in transforming mathematics lessons from information-reception activities into processes of knowledge construction. Ayari et al. (2025), Tañola & Lomibao (2024), and Muryaningrum et al. (2026) show that problem-based learning, discovery learning, discussion, exploration, and problem solving provide opportunities for students to develop conceptual understanding, reasoning, communication, and critical thinking. Active learning also allows students to connect prior knowledge with new problems. These findings suggest that mathematics learning outcomes depend not only on teachers' ability to explain content but also on the quality of the intellectual activities in which students engage. Active learning should therefore serve as a central foundation for reorienting mathematics pedagogy.

Differentiated Instruction as a Response to Student Diversity

The studies by Mardati et al. (2025), Adawiah et al. (2026), and Apsarini et al. (2026) indicate that differentiated instruction enables students to experience learning that corresponds to their readiness, interests, abilities, and individual needs. Differentiation can be implemented by adjusting content, processes, products, learning resources, and the complexity of mathematical problems. Adawiah et al. (2026), for example, report that the DiMaLS model can improve learning outcomes and engagement by organizing learning experiences in ways that are more responsive to student characteristics. Apsarini et al. (2026) further show that content and process differentiation are implemented more frequently than product differentiation. These findings challenge uniform approaches that assume all students have identical abilities and learning needs. Teachers need flexible instructional designs while maintaining common mathematics learning goals and competency standards.

Digital Technology as Support for Transforming Mathematics Learning Experiences

The studies by Rahma & Nurlaelah, (2024), Erawati et al. (2025), Darmanova et al. (2025), and Valero Larico et al. (2026) show that digital technology contributes to mathematics learning through visualization, simulation, exploration, interaction, and feedback. GeoGebra, Desmos, interactive media, digital applications, and augmented reality can help students understand abstract mathematical concepts through more concrete and dynamic representations. Nevertheless, Rahma & Nurlaelah, (2024) indicate that the effect of technology on achievement is not uniform across educational levels and mathematical

topics. The effectiveness of technology depends not only on the sophistication of the medium but also on its alignment with the content, instructional strategy, and students' needs. Technology should thus be integrated as a pedagogical instrument that strengthens learning activities, not merely as a channel for delivering content.

Table 2. Synthesis of the Integration of the Three Dimensions of Mathematics Learning Reorientation

Dimension	Primary Focus	Implementation in Mathematics Learning	Expected Contribution
Active learning	Student engagement	Exploration, discussion, investigation, PBL, and problem solving	Reasoning, critical thinking, communication, and conceptual understanding
Differentiated instruction	Diversity of learning needs	Differentiation of content, process, product, and assessment	Adaptive and inclusive learning responsive to students' abilities
Technology-enhanced learning	Flexibility and instructional innovation	GeoGebra, Desmos, simulations, interactive applications, and digital platforms	Concept visualization, interactivity, exploration, and feedback
Integration of all three	Pedagogical transformation	Mathematical activities adjusted to student needs and supported by technology	Participatory, personalized, adaptive, and meaningful mathematics learning

The integration of the three approaches can be understood through three relationships. First, active learning provides experiences through which students participate in constructing mathematical knowledge. Second, differentiated instruction ensures that these activities are accessible to students with diverse abilities and learning needs. Third, digital technology expands the possibilities for instruction by providing interactive media, visualization, simulations, and flexible learning resources.

The three approaches are therefore complementary. Active learning without differentiation may fail to accommodate differences in students' abilities. Differentiation without meaningful learning activities may become no more than the distribution of different tasks. Technology without a pedagogical orientation may function only as a medium for information delivery. Their integration can make mathematics learning more purposeful, responsive, and centered on the development of students' competencies.

DISCUSSION

Reorienting mathematics learning is essential in response to educational developments and changing student characteristics in the digital era. Mathematics instruction

should move beyond content delivery, formula memorization, and procedural exercises toward the development of critical thinking, reasoning, problem solving, creativity, and learner autonomy. Weigand et al. (2024) explain that digital developments have changed mathematics teaching, learning, and assessment. This perspective reinforces the need for flexible, student-centered approaches. Integrating active learning, differentiated instruction, and technology-enhanced learning offers one way to create meaningful mathematical experiences that respond to contemporary educational needs.

Active learning is a foundation for this reorientation because it gives students opportunities to participate directly in knowledge construction. Aprilia et al. (2026) argue that a constructivist approach through problem-based learning enables students to build understanding through experience, discussion, problem solving, and reflection. Mathematics lessons should therefore provide opportunities to explore concepts, identify patterns, ask questions, and develop solution strategies rather than being dominated by teacher explanations. Through group discussion, investigation, projects, and guided discovery, students can develop deeper reasoning and conceptual understanding. Active learning consequently strengthens students' intellectual engagement in mathematical activity.

Student diversity also requires differentiated instruction. Tomlinson (2014) emphasizes that instruction should respond to students' readiness, interests, and learning profiles so that each learner has an opportunity to learn effectively. Similarly, Wahyudi et al. (2026) identify differentiated instruction as an important approach for accommodating diverse student characteristics. In mathematics, differentiation may involve varying problem difficulty, using different media, providing learning support, and offering alternative activities and tasks. Students who have difficulty understanding a concept, for example, may receive support through images and concrete examples, while students who have mastered the material may be challenged with more complex problems. Differentiation enables students to learn in ways that respond to their needs without abandoning established learning objectives.

Digital technology offers substantial opportunities to improve mathematics learning. The Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra & Koehler (2006) explains that effective technology integration requires the interplay of content knowledge, pedagogical knowledge, and technological knowledge. Priyanda et al. (2025) emphasize the importance of integrating these dimensions in mathematics education.

Tools such as GeoGebra, Desmos, interactive videos, simulations, and digital learning platforms can help students understand abstract concepts through visualization and exploration. For example, GeoGebra can enable students studying geometric transformations to observe changes in the position and shape of objects directly. Technology therefore serves not only as a delivery tool but also as a means of promoting interaction, exploration, and mathematical understanding.

The relationship between differentiated instruction and technology is also important in creating adaptive learning environments. Universal Design for Learning (UDL) emphasizes providing multiple means for students to access information, engage in learning, and demonstrate their learning. Moleko (2026)'s review indicates that UDL principles in mathematics education are associated with instructional flexibility, varied representations, differentiated instruction, and technology use. Technology can help teachers provide learning experiences in multiple formats, including text, images, videos, animations, and digital simulations. Students can also demonstrate their understanding through problem solving, presentations, discussions, or projects. Integrating technology and differentiation can therefore create more flexible and inclusive mathematics learning opportunities.

The success of these three approaches depends substantially on teachers' capacity to design and manage instruction. Kadluba et al. (2025) identify TPACK competence as an important aspect of technology integration in mathematics education, although its assessment remains challenging. Teachers need not only mastery of mathematics content and technology but also the ability to select instructional strategies appropriate to student characteristics. They need to identify students' prior knowledge, select activities that encourage engagement, provide varied tasks, and use technology in alignment with learning objectives. Continuous assessment is also necessary to monitor students' developing understanding. Teachers consequently act as designers, facilitators, and guides in creating active, adaptive, and meaningful mathematics learning.

Taken together, active learning, differentiated instruction, and technology-enhanced learning are mutually supportive. Active learning encourages students to construct knowledge; differentiated instruction accommodates differences in ability and learning needs; and technology supports flexibility, visualization, and interactivity. These dimensions should be implemented coherently so that mathematics education focuses not only on learning outcomes but also on the process of developing student competencies. Integration

can take the form of collaborative problem solving, digital media use, tasks with varied levels of difficulty, and assessment that considers individual progress. Reorientation therefore requires a pedagogical redesign that positions students at the center of learning, teachers as facilitators, differentiation as a principle of instructional responsiveness, and technology as support for learning.

Overall, this review supports the development of a conceptual framework termed Integrated Adaptive Mathematics Learning. The framework brings together active, differentiated, and technology-enhanced learning as a unified pedagogical orientation. Its proposed novelty lies in treating the three approaches as interdependent dimensions rather than strategies implemented in isolation. The framework may guide teachers in designing mathematics learning that is participatory, adaptive, inclusive, and relevant to technological developments. It may also provide a basis for future empirical studies examining the effects of this integration on conceptual understanding, mathematical reasoning, problem-solving ability, and students' learning autonomy.

Several limitations should be acknowledged. The review draws on ten principal articles identified through Google Scholar, and the source manuscript does not provide a fully reproducible search protocol, detailed screening flow, or formal quality appraisal. The findings should therefore be interpreted as a thematic synthesis of the selected literature rather than an exhaustive estimate of intervention effects. Future reviews should expand database coverage, report transparent selection procedures, and assess study quality systematically.

CONCLUSION

This review concludes that school mathematics learning should be reoriented through the integration of active learning, differentiated instruction, and digital technology. Active learning encourages students to participate directly in constructing understanding and developing critical thinking. Differentiated instruction accommodates diversity in students' abilities, interests, readiness, and learning needs, while digital technology broadens access to learning resources and supports interactive and adaptive instruction. These approaches complement one another and can contribute to mathematics learning that is more meaningful, inclusive, and relevant to contemporary educational needs. The success of this

reorientation depends not simply on the presence of technology but on teachers' ability to design active learning experiences that respond to student characteristics.

Future research is recommended to develop and evaluate an integrative learning model that combines active learning, instructional differentiation, and digital technology in mathematics education. The model should be tested across various educational levels, taking into account differences in students' characteristics, teachers' readiness, and the availability of technological resources. Furthermore, long-term empirical studies are needed to investigate the effectiveness of integrating these three approaches in improving students' conceptual understanding, problem-solving skills, mathematical reasoning, motivation, and self-directed learning.

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