

Systematic Review

Exploring the Impact of Teachers' Pedagogical Competence on Students' Learning Outcomes in Activity-Based Mathematics Classrooms: A Systematic Review

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Abstract

Activity-based learning (ABL), as a student-centered approach, has gained significant attention for improving student achievement in mathematics worldwide. However, its practical use in different mathematics classrooms remains less explored. This review examines empirical evidence on how teachers' pedagogical skills affect students' learning outcomes in mathematics classrooms. A systematic literature review was conducted, focusing on peer-reviewed original studies published in academic journals. Two prominent databases, Scopus and Web of Science (WOS), were used to investigate various aspects of ABL, including teachers' ability to effectively implement ABL, challenges they face, its impact on students' math learning outcomes, and how ABL influences students' understanding, engagement, and academic achievement. The findings highlight that teachers' pedagogical skills are crucial for successful ABL implementation in middle and high school mathematics classes. Additionally, effective ABL use depends on several other factors, such as teachers' professional development and training, available resources, infrastructure, technological tools, school culture, curriculum, and leadership. The results suggest that ABL has the potential to improve students' learning, engagement, and academic performance in mathematics when implemented effectively. The study recommends that educators, school leaders, and policymakers consider local conditions and professional factors when adopting ABL strategies.

Keywords: activity-based learning; pedagogical competence; learning outcomes; mathematics education



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1. Introduction

Mathematics education is essential in preparing students for higher studies and active participation in a progressively knowledge-driven society. However, secondary mathematics classrooms often face difficulties in fostering deep understanding and maintaining student engagement, leading to ongoing gaps in academic performance. To overcome these issues, researchers and educators have adopted Activity-Based Learning (ABL), an instructional method that focuses on active participation, exploration, and problem-solving (Pokhrel, 2018). ABL is widely acknowledged for its ability to boost students' motivation and deepen their conceptual understanding across different subjects. It also encourages cooperative interaction, which stimulates creativity (Nwoke, 2021).

Despite its promise, the effective implementation of activity-based learning (ABL) in mathematics classrooms remains inconsistent (Bonwell & Eison, 1991; Patil et al., 2016; Tsai et al., 2020). It requires skilled teachers with a deep understanding of the approach, including the ability to integrate content knowledge (CK), pedagogical knowledge (PK), and classroom management to support student learning (Darling-Hammond, 2000). However, teachers may face challenges in the classroom, like limited resources, time constraints, or resistance from students accustomed to traditional methods (Altarawneh et al., 2023). While research on ABL is increasing, few studies have systematically examined its application in secondary mathematics and how teacher competence influences student outcomes. For example, the impact of teachers' pedagogical skills on student performance has been extensively studied across various fields (Darling-Hammond, 2000; Pandey & Kumar, 2020; Sirait, 2016; Stronge et al., 2007). Several studies also investigate the impact of activity-based learning (ABL) approaches, assess their pedagogical effectiveness, and analyze how teachers' competence affects student engagement (Çelik, 2018; Maphutha et al., 2022; Patil et al., 2016; Pokhrel, 2018). However, these findings are scattered across different contexts, methods, and educational levels. Therefore, this review aims to illuminate these challenges while identifying best practices that support the successful integration of activity-based learning in mathematics classrooms. Additionally, it can offer valuable insights into how activity-based learning can be effectively incorporated into mathematics instruction. A systematic review in this field can bridge the gap between theory and practice in successfully applying the activity-based approach. Consequently, this study has the following objectives:

1. To systematically review existing research on the level and characteristics of teachers' pedagogical competence in activity-based mathematics classrooms.
2. To identify and synthesize the challenges and barriers teachers encounter in implementing activity-based learning in mathematics classrooms.
3. To examine the relationship between teachers' pedagogical competence and students' learning outcomes in activity-based mathematics classrooms.
4. To evaluate the reported effects of activity-based learning on students' understanding, engagement, and academic performance in mathematics.

Therefore, this systematic review aims to consolidate the knowledge and identify trends, gaps, and inconsistencies by synthesizing existing literature on teachers' pedagogical competence and its role in activity-based mathematics instruction. Specifically, the review is guided by the following four research questions:

1. What does the existing literature reveal about teachers' pedagogical competence in implementing activity-based learning in mathematics classrooms?
2. What challenges do teachers face in effectively implementing activity-based learning in mathematics classrooms?
3. How does teachers' pedagogical competence influence students' learning outcomes in activity-based mathematics classrooms?
4. What evidence exists on the effect of activity-based learning on students' understanding, engagement, and performance in mathematics?

By thoroughly examining these questions, the review aims to clarify the relationship between teacher competence, instructional practices, and student outcomes, thereby providing evidence-based insights for research and classroom practice.

1.1. Activity-Based Learning

Activity-based learning is widely encouraged as an engaging, interactive instructional approach that develops 21st-century skills such as teamwork, leadership, communication, presentation, and creativity, in addition to learning mathematics (Pokhrel, 2018). Accord-

ing to Niesz and Ryan (2018), ABL is a student-centered pedagogical approach that has evolved over the years through classroom teachers and educational leaders' efforts to re-engage disengaged students from school. It is mainly based on educational theories like constructivism (Usman et al., 2020). In mathematics education, ABL refers to an instructional approach in which students develop mathematical understanding through structured activities that involve calculating, generating, manipulating, testing, or applying ideas, guided by the teacher (Pokhrel, 2018). This perspective, following Dewey, assumes that experience becomes educational only when it reorganizes prior understanding, rather than simply providing activity or exposure (Dewey, 1938, pp. 25–28). It also aligns with Bruner's view of concept formation as emerging from acting on and representing mathematical structures (Bruner, 1966, pp. 40–45). ABL positions activity as the main driver of epistemic learning rather than as a secondary motivation. This aligns with Mayer's argument that learning requires guided cognitive processing rather than unstructured experience (Mayer, 2004, pp. 16–18) and with the view that lasting learning results from engagement with disciplinary ideas rather than mere reception (Bonwell & Eison, 1991, pp. 2–5; Prince, 2004, pp. 224–227). ABL, as one form of active learning, can encourage students to ask questions, explore new ideas, experiment with concepts, collaborate with peers, reflect on their activities, and engage in higher-order thinking (Vale & Barbosa, 2023). Additionally, strategies that encourage active learning can be described as “instructional activities involving students in doing things and thinking about what they are doing” (Bonwell & Eison, 1991).

Generally, active learning is a broader pedagogical philosophy that requires students to engage cognitively with content rather than passively receive information. Bonwell and Eison (1991) described active learning as instructional approaches that involve students in doing things and thinking about what they are doing. It encompasses any activity that encourages students to participate in classroom learning and engage with the material to enhance critical thinking as they apply it beyond the classroom (Adkins, 2018). Activities may include discussion, questioning, problem-solving, reflection, peer interaction, debates, or collaborative learning. However, ABL is a more specific instructional approach rooted in the principle of learning by doing. Students acquire knowledge through structured activities such as hands-on tasks, experiments, projects, simulations, games, role-plays, fieldwork, or practical exercises. These activities are the primary means of learning. The emphasis is on experiential involvement and the application of knowledge in real-world situations (Skulmowski, 2024). Therefore, in the ABL approach, activities are designed to promote critical thinking, creativity, and problem-solving skills, leading to a deeper understanding of the subject matter (Edwards, 2015). Pokhrel (2018) developed a conceptual framework (see Figure 1) that explains how activity-based mathematics instruction (ABMI) transforms mathematics learning into 21st-century skills when implemented effectively in the classroom through various strategies.

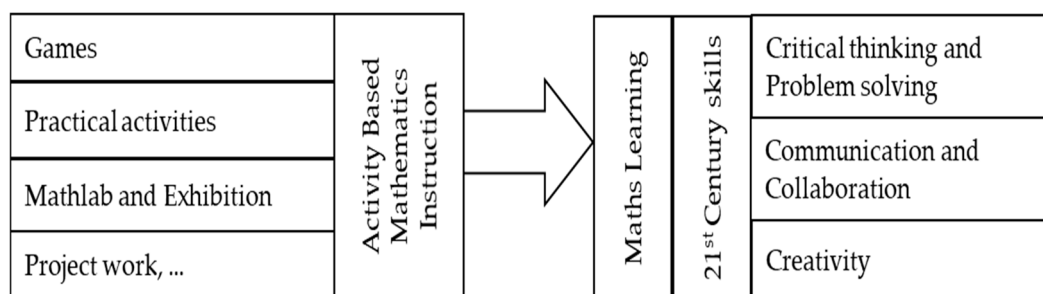


Figure 1. Processes of learning in activity-based mathematics instruction. A conceptual framework adopted from (Pokhrel, 2018).

The most compelling aspect of ABL as a learning method is that it incorporates activities aimed at developing knowledge, attitude, and skills (Çelik, 2018). By fostering active learning experiences, ABL teaching helps students become independent and self-directed learners who are better prepared to face real-world challenges (Amiruddin et al., 2023). In essence, ABL encourages students to become metacognitive learners as they build understanding through a deep learning approach. Learners often engage in self-evaluation of their task performance, self-monitoring, and planning (Wafubwa & Csíkos, 2021). This occurs because they are typically required to plan, monitor, and assess their thinking processes while working through mathematics (Csíkos & Szitányi, 2020). With this in mind, reviewing empirical studies in this context can help link theoretical perspectives with real-world teaching experiences. Furthermore, the impact of ABL may vary depending on contextual factors such as school environment and student demographics. Therefore, its implementation in the classroom must be validated through practical studies to ensure it effectively supports educational goals (Patil et al., 2016).

1.2. Teacher Competence

Several studies have shown that teachers' pedagogical competence is a crucial factor in creating and implementing an effective ABL environment for learning mathematics. According to various scholars, teachers' pedagogical competence refers to their ability to integrate content, pedagogy, and technological knowledge to foster productive learning environments in mathematics classrooms. Pantić and Wubbels (2010) adopt a broader definition of teachers' competence that includes knowledge and understanding, skills and abilities, and beliefs and values. Medley (1977) also defined teachers' competence as encompassing a knowledge component, such as understanding the relationship between students' behavior and learning outcomes, and a performance component, the ability to act in ways that encourage students to display these behaviors and achieve these outcomes. This idea aligns with the framework of pedagogical content knowledge (PCK) developed by Shulman (1986), which emphasizes the teacher's ability to organize, adapt, and represent subject matter in a comprehensible form for students. Shulman considers PCK to be the deeply interconnected knowledge that teachers draw on, involving both content and pedagogical knowledge. The technological, pedagogical content knowledge (TPACK) framework developed by Mishra and Koehler (2006) further emphasizes that effective teaching requires an understanding of how technology integrates with pedagogy and content knowledge. These frameworks indicate that teachers must possess a range of skills and abilities to ensure high-quality instruction in ABL mathematics classrooms.

2. Methodology

2.1. First Stage: Data Search and Article Collection

We used a systematic literature review (SLR) methodology to examine the influence of teachers' pedagogical competence on students' learning outcomes in the ABL environment. SLR is a thorough scientific approach that synthesizes findings and implications from extensive research, helping to manage and interpret otherwise overwhelming amounts of information (Hearn et al., 1999). Therefore, a comprehensive search was conducted to explore the level of teachers' pedagogical competence, the challenges they face, the effect of teachers' pedagogical competence on students' achievement, and the impact of activity-based learning on students' mathematics performance. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, developed by Moher et al. (2009), was used to ensure transparent reporting of the study's purpose, method, and findings. The relevant articles were reviewed and summarized following PRISMA guidelines for the SLR. SCOPUS and Web of Science (WoS) databases were used to collect

literature for this review. These databases were chosen due to their widespread use by the scientific community for endorsing high-quality research reports and studies (Leydesdorff et al., 2016; Zhu & Liu, 2020), and because they encompass a broader range of highly cited journals compared to other sources like ProQuest and Google Scholar (Aguillo, 2012). Since this review focuses on two distinct background variables, separate searches were performed to generate more comprehensive results and ensure access to rich resources, as outlined in Table 1. In Scopus, search terms were applied to titles, abstracts, and keywords, limiting results to articles, whereas in WoS they were applied to topics, refining results to articles.

Table 1. Literature search technique and strategy.

No	Application of Search Terms
1	("teacher competence" OR "pedagogical competence" OR "pedagogical knowledge" OR "pedagogical content knowledge" OR "teacher knowledge" OR "teaching skills" OR "teacher skills" OR "instructional competence" OR "teacher practices" OR "teaching practices" OR "teacher effectiveness")
2	("learning outcomes" OR "student achievement" OR "academic performance" OR "student performance" OR "student engagement" OR "student learning" OR "mathematics outcomes" OR "mathematics learning outcomes" OR "mathematics achievement" OR "mathematics performance" OR "mathematical success" OR "math proficiency" OR "math skills" OR "math competence")
3	("activity-based learning" OR "activity-based approach" OR "activity method" OR "activity-oriented learning" OR "active learning" OR "student-centered learning")
4	(mathematics OR math OR "mathematics education" OR "math instruction" OR "math teaching")
5	(challenges OR barriers OR difficulties OR obstacles OR limitations OR constraints)
S1	1 AND 3 AND 4
S2	3 AND 4 AND 5
S3	1 AND 2 AND 3 AND 4
S4	2 AND 3 AND 4
S5	1 AND 2 AND 3

These keywords were combined using Boolean operators ("AND" and "OR") to construct a search string that produces more precise and fruitful outcomes. Specifically, the first search (S1) used the research terms "1 AND 3 AND 4", specifically designed to identify articles that explained teachers' competence in ABL mathematics classrooms, addressing research question 1. the second (S2) used "3 AND 4 AND 5", to address research question 2; the third (S3) used '1 AND 2 AND 3 AND 4', the influence of teachers' pedagogical competence on students' learning outcomes in ABL mathematics classrooms; and the fourth used '2 AND 3 AND 4' to find out the evidence exists on the effect of activity-based learning on students' understanding, engagement, and performance in mathematics. Finally, the fifth search, S5, used '1 AND 2 AND 3 to examine the relationship between teachers' competence in ABL and students' outcomes in the literature (see Table 1). Nevertheless, the search was not restricted by publication year to ensure comprehensiveness, historical perspectives, and unbiased inclusion of all relevant evidence in this review. The search process was completed in the first week of January 2026.

2.2. Second Stage: Identification and Screening

All journal articles were combined and organized in an Excel sheet for initial screening and quality assessment. At this stage, where available, duplicate records were removed using the article's unique Digital Object Identifier (DOI). For records without a DOI, duplicates were identified based on "title", "author + year", and "journal/source title + volume + issue + page numbers." The remaining articles were then screened stepwise for adherence to the inclusion criteria by reviewing titles, then abstracts and keywords.

2.3. Third Stage: Eligibility and Inclusion

To ensure transparency in the article selection process, the PRISMA flow chart guidelines were followed (see Figure 2). For eligibility in this review at this stage, studies had to meet the following criteria: (a) have a relevant article title, abstract, or keywords, (b) be published in peer-reviewed journals, (c) be situated within a junior/secondary education setting, and (d) focus on mathematics education content. To maintain the validity and reliability of this review and minimize the risk of bias (selection, publication, contextual, confirmation, etc.), a robust inclusion criterion was applied, aligned with the PRISMA protocol outlined in Table 2. Adherence to the inclusion criteria and the PRISMA protocol improved the review's reliability and validity. However, PRISMA does not, by itself, evaluate the methodological quality of individual studies. Therefore, we assessed each paper's internal validity (the soundness of its design, data collection, and analysis) and reliability (the consistency and replicability of its findings). In this review, strong methodological rigor was consistently demonstrated across the reviewed studies through the systematic use of validated instruments, statistical testing, and triangulation procedures. Most quantitative studies reported Cronbach's alpha value above 0.80, indicating high internal consistency, while several employed confirmatory or exploratory factor analysis (CFA/EFA) to confirm construct validity. Expert review of instruments before data collection was a common practice, enhancing content validity and ensuring contextual relevance in mathematics education. In qualitative and mixed-method studies, credibility and dependability were strengthened through member checking, inter-rater reliability, and data triangulation. Despite these strengths, a few papers offered limited details on external validity or long-term generalizability, suggesting that future research could benefit from a more standardized validation framework across different contexts. Overall, the combined evidence reflects a high level of methodological reliability and a shared commitment among researchers to ensure trustworthy and reproducible results. For further reference, see Appendix A, Table A2.

Table 2. Inclusion and Exclusion criteria.

Criterion	Inclusion	Exclusion
Language	English	Others
Type of Literature	Published articles	Gray literature
Type of source	Original empirical studies: Journal articles	Conference proceedings, book chapters, theoretical papers and review papers
Accessibility	Full-text articles	Not accessible in specific databases
Relevance	Relevant titles that meet the study's research questions	Irrelevant titles that do not meet the research questions
Sample	In-service teachers and junior-secondary school students	Others
Education context	Junior-secondary schools	Other
Field of study	Mathematics, Mathematics education	Others

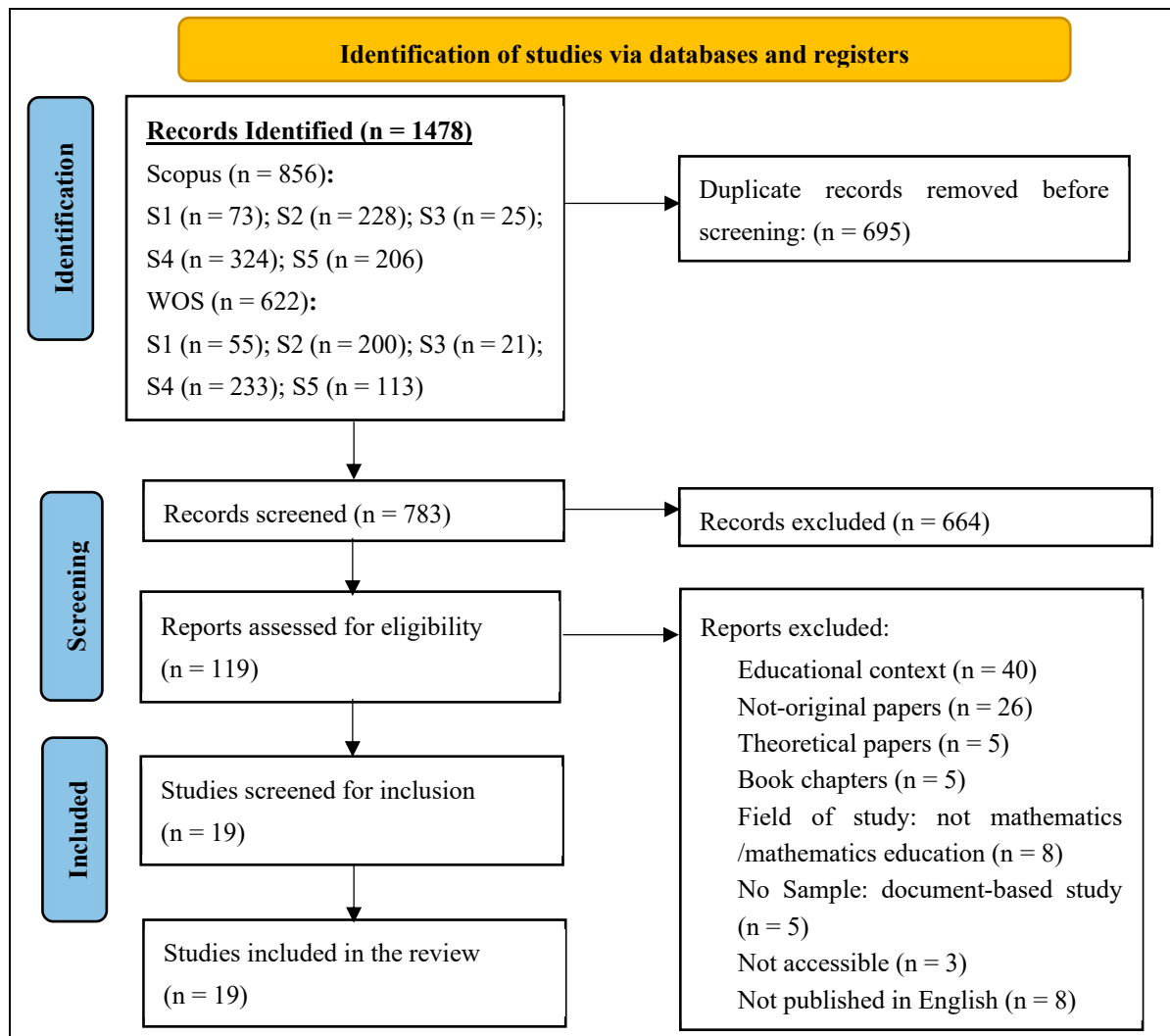


Figure 2. PRISMA protocol flow chart.

For the final selection of studies, this review includes the following criteria: (a) reporting original empirical research; (b) explicitly addressing teachers' pedagogical competence, activity-based or active learning strategies, or student academic achievement or outcomes; (c) published in English; and (d) aligned with the target sample. Only studies that meet these criteria were considered for inclusion. Theoretical papers, conference papers, books, and review papers were excluded. Additionally, full-text access had to be freely available. After screening 783 documents for eligibility, 119 articles remained for further review and final selection. Ultimately, 19 articles were identified as meeting the criteria after an in-depth reading to assess their relevance to the research questions of this systematic literature review.

The systematic review aimed to understand how teachers' pedagogical competence influences students' performance in activity-based mathematics classrooms, as evaluated in previous studies within active learning environments across STEM subjects. To address the research questions and report the findings, initial inductive coding was performed to guide the content analysis of the 19 papers (see Table 3).

Table 3. Pre-determined Codes and sub-codes for thematic analysis.

Teachers Pedagogical Competence	Challenges Encountered	Influence of Pedagogical Competence	Influence of ABL
Content knowledge (CK)	Resource constraints	Cognitive outcomes	Conceptual understanding
Pedagogical knowledge (PK)	Teacher beliefs and attitudes	Affective outcomes	Engagement and motivation
Pedagogical content knowledge (PCK)	Professional development gaps	Behavioral outcome	Academic performance
Classroom management (CM)	student-related challenges	Teaching Learning Alignment	Collaborative skills
Assessment literacy	Curriculum and Assessment Barriers		Long-term retention
-	Leadership-related Challenges	-	-

The codes explain what the existing literature reveals about teachers' pedagogical competence, including content knowledge, pedagogical knowledge, and pedagogical content knowledge, which are fundamental to effectively implementing instructional time; the challenges teachers encounter in implementing ABL in mathematics classrooms, including resource constraints, attitudinal barriers, inconsistent professional development programs, curriculum and assessment barriers, and leadership-related challenges; and how teachers' pedagogical competence and ABL influence students' mathematics learning through related but distinct mechanisms. Pedagogical competence refers to the teacher's professional ability to plan instruction, manage the classroom, select appropriate strategies, and assess learning effectively. This competence shapes students' cognitive, affective, and behavioral outcomes, as well as the alignment between teaching objectives, learning activities, and assessment. In contrast, ABL represents a specific instructional approach that promotes learning through hands-on activities, collaboration, and active participation. While pedagogical competence reflects the quality of the teacher, ABL reflects the method of instruction. Therefore, a competent teacher is believed to enhance learning directly and to improve the effectiveness of ABL implementation, which, in turn, strengthens students' understanding, engagement, and academic performance in mathematics.

Based on these predefined codes, the articles were mapped to interpret differences in research designs regarding the study of teachers' pedagogical competences, the challenges faced, and the overall impact of activity-based learning. This review specifically includes studies designed to highlight various research methods related to the pedagogical skills of in-service mathematics teachers. It also examines the geographical distribution of the studies, the years they were conducted, and the evaluation tools used. These elements were analyzed to provide a comprehensive overview based on the selected papers.

2.4. Quality Assessment

Selected articles were screened in terms of methodological quality using MMAT (Mixed Method Appraisal Tool) to assist the evaluation process (Hong et al., 2018). Each article was evaluated based on two general screening questions and five specific criteria related to the nature of the article's design: qualitative, quantitative (non-randomized or descriptive), and mixed-methods studies.

2.4.1. Qualitative Studies

All four qualitative studies met the MMAT screening and qualitative appraisal criteria (see Table 4). The research objectives were clearly articulated, and the qualitative case study

design was appropriate for addressing the study aims. Data were collected from multiple qualitative sources, including focus groups, observations, research journals, and video recordings, thereby adequately addressing the research objectives. The findings were supported by participant quotations, and coherence was evident across the study design, data collection, analysis, findings, and interpretation, indicating high methodological quality.

Table 4. Quality assessment of qualitative studies.

	9	13	14	16	19
Are there clear research questions?	Y	Y	Y	Y	Y
Do the collected data allow to address the research questions?	Y	Y	Y	Y	Y
Is the qualitative approach appropriate to answer the research question?	Y	Y	Y	Y	Y
Are the qualitative data collection methods adequate to address the research question?	Y	Y	Y	Y	Y
Are the findings adequately derived from the data?	Y	Y	Y	Y	Y
Is the interpretation of results sufficiently substantiated by data?	Y	Y	Y	Y	Y
Is there coherence between qualitative data sources, collection, analysis and interpretation?	Y	Y	Y	Y	Y

Y—Yes.

2.4.2. Quantitative Studies

Eight quantitative studies were appraised using the Mixed Method Appraisal Tool (MMAT) qualitative assessment for non-randomized studies. Overall, the studies demonstrate moderate to high methodological quality (see Table 5). All studies had clear research questions, collected appropriate data to address their objectives, used suitable outcome measures, reported complete outcome data, and implemented the interventions as intended. However, limitations were identified regarding participant representativeness, as samples were drawn from specific educational settings, potentially limiting generalizability. Additionally, confounding variables were not adequately controlled in three studies, whereas one study accounted for key confounders in its design and analysis. Overall, the evidence from these studies was considered methodologically acceptable, with some caution warranted regarding external validity and potential confounding effects.

Table 5. Quality assessment of quantitative non-randomized studies.

Studies	2	3	4	5	6	12	15	18
Are there clear research questions?	Y	Y	Y	Y	Y	Y	Y	Y
Do the collected data allow to address the research questions?	Y	Y	Y	Y	Y	Y	Y	Y
Are the participants representative of the target population?	C	Y	Y	C	C	N	Y	Y
Are measurements appropriate regarding both the outcome and intervention (or exposure	Y	Y	Y	Y	Y	Y	Y	Y
Are there complete outcome data?	Y	Y	Y	Y	Y	Y	Y	Y
Are the confounders accounted for in the design and analysis?	N	Y	Y	N	Y	N	Y	Y
During the study period, is the intervention administered (or exposure occurred) as intended?	Y	C	Y	C	Y	Y	Y	N

Y—Yes; N—No; C—Can't tell.

2.4.3. Quantitative Descriptive

The MMAT quality assessment indicated that the articles were high-quality quantitative descriptive studies (see Table 6). Both studies had clear research objectives, appropriate sampling strategies, relevant measurement instruments, and suitable statistical analyses

to address their research questions. The samples were appropriate for their target populations, with a low risk of non-response bias. However, Michael et al. (2023) strengthened their methodological rigor by combining questionnaire data with classroom observations, providing deeper evidence of actual implementation practices. Overall, the studies were assessed as high quality and with a low risk of bias.

Table 6. Quality assessment of quantitative descriptive studies.

Studies	7	10
Are there clear research questions?	Y	Y
Do the collected data allow to address the research questions?	Y	Y
Is the sampling strategy relevant to address the research question?	Y	Y
Is the sample representative of the target population?	Y	Y
Are the measurements appropriate?	Y	Y
Is the risk of nonresponse bias low?	Y	Y
Is the statistical analysis appropriate to answer the research question?	Y	Y

Y—Yes.

2.4.4. Mixed Method Studies

The MMAT assessment of the mixed-methods studies showed mostly moderate to high quality (see Table 7). Two studies met all criteria, indicating solid methodological procedures in both their quantitative and qualitative parts. Two other studies offered limited details on how differences between qualitative and quantitative results were handled and on the methodological rigor of each component, leading to some criteria being marked as “Can’t tell.” Overall, the mixed-methods evidence was deemed strong enough to provide valuable insights for the review.

Table 7. Quality assessment of mixed-method studies.

Studies	1	8	11	17
Are there clear research questions?	Y	Y	Y	Y
Do the collected data allow to address the research questions?	Y	Y	Y	Y
Is there an adequate rationale for using a mixed methods design to address the research question?	Y	Y	Y	Y
Are the different components of the study effectively integrated to answer the research question?	Y	Y	Y	Y
Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	Y	Y	Y	Y
Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?	Y	Y	C	C
Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	Y	Y	Y	C

Y—Yes; C—Can’t tell.

2.5. Data Analysis

Data Extraction and Thematic Analysis

The data extraction followed a structured and transparent method to ensure consistency and thoroughness throughout the review. After selecting the final studies, relevant information was extracted using a standardized form that captured author details, publication year, study context, research design, participants, data collection methods, and key findings related to teachers’ pedagogical competence and students’ learning outcomes in activity-based mathematics classrooms. Each study was carefully read to gain a comprehensive understanding of its content, with attention to both explicit and implicit references to the research questions.

A thematic qualitative analysis was conducted using a deductive-inductive coding approach for further reference. Initially, predefined codes and sub-codes were developed based on the four research questions and key theoretical concepts (e.g., pedagogical content knowledge, activity-based learning principles, and student learning outcomes). These codes created the analytical framework guiding the review (see Table 3). Additional sub-codes were inductively generated during the analysis whenever new or unexpected patterns appeared across studies, ensuring the framework remained flexible and comprehensive.

The coding process involved systematically tagging relevant excerpts from each study, such as findings, interpretations, and discussion sections, according to the predefined categories. Data were organized and analyzed using thematic matrices to compare findings across different contexts. For example, reports of teachers' difficulties with time constraints or large class sizes were coded under "Challenges-Resource constraints," while discussions of improved student collaboration were coded under "Effects-Collaborative skills."

The coding definitions were refined through repeated reading and discussions among the authors to improve credibility and reliability. Each code included a clear definition from literature (see Table 8) outlining inclusion and exclusion criteria, ensuring consistency in data interpretation. After coding, themes were combined (see Appendix A, Table A3) by grouping related sub-codes to identify broader patterns that address each question. The resulting thematic synthesis offered a coherent narrative connecting teachers' pedagogical skills, implementation challenges, and the observed effects of activity-based learning on students' understanding, engagement, and academic performance.

Table 8. Deductive-inductive codes and subcodes used in the review.

Main Code	Sub-Code	Definition/Description
Teachers' Pedagogical Competence	Content knowledge (CK)	Teachers' mastery of mathematics concepts and ability to connect ideas effectively.
	Pedagogical knowledge (PK)	Knowledge of teaching methods, classroom techniques, and student-focused strategies in an ABL environment.
	Pedagogical content knowledge (PCK)	Integrating pedagogy and subject matter knowledge to effectively implement ABL in mathematics classrooms.
	TPACK	Teachers' ability to understand how technology integrates with pedagogy and content knowledge in the ABL mathematics classroom.
	Classroom management	Teachers' capacity to organize, motivate, and manage ABL environments.
	Assessment literacy	Proficiency in designing and interpreting assessments aligned with active learning objectives.
	Affective disposition	Teachers' ability to encourage, motivate, and enhance meaningful engagement in the ABL mathematics environment.
	Metacognitive skills	Teachers' awareness of their own thinking processes in selecting and applying appropriate ABL strategies in mathematics classrooms.
	Reflective practices	Teachers' ability to critically examine and evaluate their own teaching practices
	Collaborative practices	Teachers' ability to work effectively with colleagues, students, and administrative staff.

Table 8. *Cont.*

Main Code	Sub-Code	Definition/Description
Challenges in Implementing Activity-Based Learning	Resource constraints	Limitations in materials, space, time, or administrative support for activity-based teaching.
	Teacher beliefs and attitudes	Teachers' resistance or misconceptions about activity-based pedagogy.
	Inconsistent professional development	Lack of sufficient training or exposure to innovative teaching strategies.
	Curriculum and assessment barriers	Exam-oriented systems or overloaded curricula that restrict active learning.
	Student-related challenges	Learner Factors Influencing Engagement or Participation.
	Administrative-related challenges	Limitations in addressing issues related to the ABL implementation strategy.
	Technology-related challenges	Challenges in effectively integrating technology into mathematics concepts in ABL classrooms.
Influence of Pedagogical Competence on Student Outcomes	Knowledge and thinking	Effects on students' cognitive understanding, problem-solving, and higher-order thinking.
	Feelings and attitudes	Impact on students' motivation, confidence, and attitude toward mathematics.
	Observable actions	Impact on student engagement, collaboration, and participation.
	Teaching-learning alignment	Alignment between instructional methods and learners' needs.
Influence of Activity-Based Learning on Student Performance	Conceptual understanding	Enhancing students' understanding of mathematical principles through active learning.
	Engagement and motivation	Student enthusiasm and persistence during learning activities.
	Academic performance	Quantitative improvement in test scores or grades.
	Collaborative skills	Increase in teamwork, communication, and peer support.
	Long-term retention	Long-term understanding or transfer of knowledge beyond immediate lessons.

2.6. Features of the Review Process

The study's information, including research methods, research context, and demographic location, is shown in the tables below. Regarding research methods, the studies indicated that the reviewed papers were proportionally represented by five qualitative, 10 quantitative, and four mixed-methods studies (see Table 9). This shows that the area covers all types of research with abundant resources. An overview of the studies included in this review is provided in Appendix A, Table A1.

Considering the research context and samples of the study, our initial focus was on published articles related to secondary schools; however, due to the limited number of studies available from the databases on this specific topic, we decided to include research conducted at the junior school level and across different education levels to draw meaningful conclusions from the related activity-based learning contexts (see Table 9).

Table 9. Research Methods, research context, and demographic location.

		N	Studies
Research Design	Qualitative	5	9, 13, 14, 16, 19
	Quantitative	10	2, 3, 4, 5, 6, 7, 10, 12, 15, 18
	Mixed	4	1, 8, 11, 17
Research Context	Middle	4	1, 2, 5, 10
	Secondary	11	3, 6, 8, 9, 11, 12, 14, 15, 16, 18, 20
	Multi-level	4	4, 7, 17, 19
Location	Africa	3	8, 10, 14
	Asia	8	1, 2, 6, 7, 9, 11, 12, 18
	Europe	3	3, 4, 19
	USA	3	5, 13, 16
	Central America	1	15
	Cross Continental	1	17

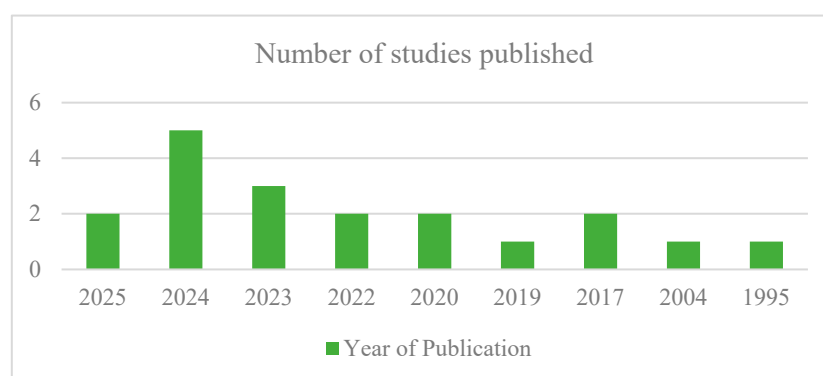
The demographic information in the reviewed studies included research conducted across various continents and countries, indicating a diverse geographical representation (see Tables 9 and 10). This offers a lens for understanding educational, cultural, and policy influences that shape how ABL is implemented. Reporting the country of each study enhances the transferability and comparability of findings, whether results originate from similar or diverse educational systems. In this review from Asia, studies were carried out in China (study 1), Indonesia (study 9), Malaysia (study 18), India (study 12), Thailand (study 2), Vietnam (study 6), the Kingdom of Saudi Arabia (study 7), and Jordan (study 11). Africa was represented by three studies: Nigeria (study 14), Rwanda (study 8), and Ethiopia (study 10). One study was conducted in Central America, specifically in Costa Rica (study 15). In Europe, studies were spread across Estonia (study 4), Spain (study 3), and the United Kingdom (study 19). Additionally, one study was conducted in multiple locations, such as Greece, Scotland, and the USA (study 17). North America, represented by the United States, contributed four studies (studies 5, 13, and 16). This review encompasses research from multiple continents, emphasizing that the issue holds global importance and providing a comprehensive, diverse perspective by including findings and data from various regions worldwide. However, according to the findings derived from the SLR results, Asian countries hold a prominent stage in this topic.

The following chart (Figure 3) shows the year of publication of the studies included in this paper. The year of publication provides important contextual and analytical insights and helps us to trace the temporal development of research trends. In this review, most of the included studies (73.7%) were published in the last 5 years, revealing how research interest in activity-based mathematics learning and teachers' pedagogical competence has evolved over time. This allows us to identify emerging themes, shifts in methodological preferences, or growing emphasis on a specific pedagogical model in activity-based instruction.

The evaluation tools were also systematically identified and reported to assess the quality of evidence, ensure comparability across studies, and provide insights into common measurement practices (see Table 10). Documenting the instruments used, such as questionnaires, tests, interviews, and performance tasks, enhanced the transparency and reproducibility of the review while guiding methodological recommendations for future research on the need for teachers' pedagogical competence in implementing effective activity-based mathematics instruction to improve students' mathematics outcomes.

Table 10. Country, year, and evaluation tools of the studies.

Study	County	Year	Evaluation Tools Used
1	China	2025	Theory of planned behavior (TPB) questionnaire (Likert scale); Interview
2	Thailand	2023	Survey/Questionnaire
3	Spain	2022	Attitude, belief, and knowledge questionnaire (Likert Scales)
4	Estonia	2024	Questionnaire (Likert scale)
5	USA	2004	Questionnaire (Likert scale)
6	Vietnam	2025	Survey/Questionnaires; Achievement test scores (Pre/post-test)
7	Saudi Arabia	2024	Achievement test (Pre/post-test)
8	Rwanda	2024	Limits & Continuity achievement test (LCFAT); RTOP classroom observation protocol; focus group interviews
9	Indonesia	2024	Semi-structured interviews; Classroom observation notes (Researcher); Thematic coding (Qualitative analysis tool)
10	Ethiopia	2023	Teachers' self-report questionnaire (Likert scale); classroom observation checklist
11	Amman, Jordan	2023	Questionnaire (Likert scale); interview
12	India	2022	Achievement test (Pre/post-test); Structured interview guide
13	USA	2020	Semi-structured interview
14	Nigeria	2019	observation (Video recorded); reflective interviews; researcher fieldnotes/journals
15	Costa Rica	2017	Classroom observation checklists
16	USA	2017	Focused student interaction observation
17	Greece, Scotland, and the USA	1995	Observation checklist; Task performance assessment; Questionnaires
18	Malaysia	2024	Questionnaire (Likert scale)
19	UK	2020	Unstructured observation; Interviews; Task performance assessment

**Figure 3.** The trend of published articles included in this study.

3. Results

These results were synthesized from studies, most of which focus on active learning strategies that promote hands-on learning, engagement, and personalized education. In this context, we regard activity-based learning as one approach within active learning methods that highlight academic growth through a carefully designed series of sequential activities aimed at helping students advance in their learning.

3.1. Teachers' Pedagogical Competence

Findings from the review proved that teachers' deep understanding of mathematics (CK) (Altarawneh et al., 2023; Du et al., 2025) and pedagogical knowledge (PK) (Altarawneh et al., 2023; Manakul et al., 2023; Michael et al., 2023; Moliner & Alegre, 2022; Zakaria et al., 2024) are key components for implementing activity-based learning in mathematics classrooms. Furthermore, beyond subject knowledge and pedagogy, the review strongly emphasizes the need to understand how to teach specific content effectively (Berlinski & Busso, 2017; Moliner & Alegre, 2022; Rao et al., 2017; Zakaria et al., 2024). This combination of mathematical knowledge and PK, along with an understanding of how students learn specific mathematics, constitutes pedagogical content knowledge (PCK). Additionally, the findings revealed that teachers' technological competence greatly influences student retention rates in an ABL environment. For example, competence in using multimedia tools and digital platforms is essential for implementing ABL in modern classrooms (Ali et al., 2022; Bature & Atweh, 2019; Manakul et al., 2023; Munyaruhengeri et al., 2024; Putranto et al., 2024; Xuan et al., 2025). This competence assists teachers in integrating various digital resources, such as video, simulations, and interactive software, to enhance students' engagement and support active learning in mathematics. Classroom management competence is also identified as a key factor in effectively implementing ABL (Altarawneh et al., 2023; Bature & Atweh, 2019; Putranto et al., 2024; Rao et al., 2017). This skill enables teachers to accurately monitor students' progress in their understanding of mathematical concepts.

Teachers' ability to assess and provide effective, timely feedback is reported as a key aspect of their competence (Michael et al., 2023; Putranto et al., 2024; Surrette, 2020). This includes a teacher's skill to assess students' understanding effectively in an ABL environment, embracing skills related to evaluating students' progress, providing timely feedback, and using assessments to guide learning. Expert feedback from mentors or peers also supports the teacher's growth in using assessment as a tool for continuous improvement (Surrette, 2020). Moreover, teachers' ability to encourage peer and self-assessment can enhance understanding of assessment principles, reflection, and critical thinking, support professional development, and shift the focus from grading to learning in ABL environment classrooms.

Metacognitive skills are identified as essential for teachers' ability to learn from their teaching experiences. Teachers must have reflective skills to evaluate their teaching methods, modify their strategies, and improve their lesson planning (Ali et al., 2022; Putranto et al., 2024; Rao et al., 2017; Xuan et al., 2025; Zakaria et al., 2024). Developing metacognitive abilities, such as self-monitoring and assessing learning processes, helps individuals become more collaborative, advocates of active learning, and better equipped to address classroom challenges. This can lead teachers to implement differentiated instruction to tailor learning to students' needs (Putranto et al., 2024; Rao et al., 2017; Surrette, 2020).

Although pedagogical competence was identified as essential across all contexts, its influence differed between developed and developing educational systems. Studies from developed contexts (Jesionkowska et al., 2020; Tammets et al., 2024; Triadafilidis, 1995) emphasised teachers' pedagogical competence in facilitating inquiry, collaboration and student autonomy, suggesting that teachers often had access to resources and professional

development that supported ABL implementation. In contrast, studies from developing contexts (Altarawneh et al., 2023; Bature & Atweh, 2019; Michael et al., 2023; Munyaruhengeri et al., 2024) highlighted challenges related to limited teaching resources, insufficient training, and curriculum constraints, indicating that teachers' competence alone may not guarantee successful ABL implementation. Furthermore, these differences might result from variations in teacher training systems, access to resources, and institutional support, suggesting that the development of pedagogical competence is shaped not only by individual teacher characteristics but also by broader educational settings.

3.2. Challenges in Implementing Activity-Based Learning

Several factors reported in the literature influence the successful implementation of ABL in mathematics classrooms. Some challenges are directly related to teachers' beliefs and attitudes toward active learning and the effective use of ABL strategies (Ali et al., 2022; Alkhatatneh, 2024; Bature & Atweh, 2019, p. 8; Michael et al., 2023; Munyaruhengeri et al., 2024; Putranto et al., 2024; Tammets et al., 2024; Zakaria et al., 2024). Teachers with a positive attitude toward implementing ABL strategies enhance the approach's pedagogical value by encouraging students to collaborate and actively participate in tasks. Conversely, teachers with a negative attitude toward ABL are seen as barriers to creating an effective ABL environment, according to the literature. Additional issues include concerns about the effectiveness of peer and self-assessment by teachers and the challenges of managing critique and revision, which are central to active learning strategies. Challenges related to students are also noted, such as resistance to shifting to active learning, lack of confidence in evaluating peers' work, and difficulty accepting peer feedback, all of which complicate assessment and evaluation in the ABL mathematics classroom environment (Altarawneh et al., 2023; Bature & Atweh, 2019; Berlinski & Busso, 2017; Munyaruhengeri et al., 2024; Putranto et al., 2024; Triadafilidis, 1995).

Limitations in materials, space, time, or administrative problems for activity-based teaching, as reported in the literature, generally refer to logistical and technological challenges that hinder the implementation of ABL. Insufficient manipulatives or ICT tools in mathematics classrooms, such as digital tools, physical materials, and information technology infrastructure, are often lacking or inadequate to support the more hands-on, project-driven approach to learning (Alkhatatneh, 2024; Altarawneh et al., 2023; Jesionkowska et al., 2020; Michael et al., 2023; Munyaruhengeri et al., 2024; Putranto et al., 2024).

The professional development gap is often identified in the literature as the main obstacle in the ABL environment. Many teachers in the reviewed studies report insufficient training or exposure to innovative instructional strategies, with only a small proportion having attended workshops on active learning methods (Alkhatatneh, 2024; Bature & Atweh, 2019; Jesionkowska et al., 2020; Michael et al., 2023; Munyaruhengeri et al., 2024; Putranto et al., 2024; Rao et al., 2017; Schmitt, 2004; Tammets et al., 2024; Zakaria et al., 2024). These barriers hinder the effective implementation of ABL.

Institutional challenges are viewed as one of the main hindrances to implementing ABL strategies in the classroom by teachers, students, and parents. These include a lack of institutionalized professional development, misalignment between policy and practice (Altarawneh et al., 2023; Bature & Atweh, 2019; Michael et al., 2023; Surette, 2020), and leadership-related challenges (such as administrative pressure to complete the syllabus, teachers' heavy workloads, large class sizes, and ineffective resource and human management), which made it difficult to sustain active learning in inclusive classrooms (Michael et al., 2023; Putranto et al., 2024).

Curriculum and related challenges, such as exam-oriented systems or overloaded curricula that limit active learning, along with curricular pressure, restrict the implementation

of hands-on learning (Altarawneh et al., 2023; Berlinski & Busso, 2017; Jesionkowska et al., 2020; Munyaruhengeri et al., 2024; Putranto et al., 2024).

The challenges of implementing ABL in middle and secondary mathematics classrooms vary across educational contexts, developmental levels, and research approaches. Studies from developed contexts mainly highlight challenges related to integrating ABL with curriculum demands, assessment systems, and teachers' ability to facilitate student-centred learning (Jesionkowska et al., 2020; Schmitt, 2004; Surette, 2020; Tammets et al., 2024; Triadafillidis, 1995). In developing contexts, implementation barriers are more frequently associated with limited resources, large class sizes, insufficient teacher training, and difficulties in shifting away from traditional practices (Altarawneh et al., 2023; Michael et al., 2023; Munyaruhengeri et al., 2024). These differences may indicate variations in how structural organizations and educational institutions are structured, suggesting that structural development is necessary to implement ABL strategies in the classroom to meet practical contextual demands. Differences in research design also influence reported challenges: quantitative studies often emphasize teachers' perceived barriers, such as confidence and training needs (Bature & Atweh, 2019; Jesionkowska et al., 2020; Putranto et al., 2024), while qualitative and classroom-based studies reveal practical challenges, including classroom management, activity adaptation, and maintaining student engagement (Berlinski & Busso, 2017; Michael et al., 2023). Overall, successful ABL implementation requires strengthening teachers' pedagogical competence while addressing contextual and institutional conditions. Furthermore, this discrepancy may indicate that self-report measures overemphasize perceived barriers, highlighting the importance of triangulating teachers' perceptions with observational evidence when evaluating teachers' practices.

3.3. Influence of Pedagogical Competence on Students' Outcomes

Teachers play a crucial role in enhancing students' outcomes through various methods, especially as pedagogically competent teachers influence student achievement across all aspects. According to the literature, teachers' pedagogical skills impact the students' cognitive, affective, and behavioral outcomes. Several studies have reported that teachers can influence students' understanding, problem-solving abilities, and higher-order thinking skills (Ali et al., 2022; Berlinski & Busso, 2017; Munyaruhengeri et al., 2024; Putranto et al., 2024; Schmitt, 2004), which motivates students to dedicate energy and focus to their math learning, transforming them into self-directed learners for better achievement in their learning. Additionally, teachers play a vital role in shaping students' engagement, collaboration, and participation during classroom activities, creating a more practical and engaging learning environment. Students' motivation, confidence, and attitude toward mathematics significantly reduce math anxiety, helping them concentrate on their learning (Ali et al., 2022; Berlinski & Busso, 2017; Putranto et al., 2024; Rao et al., 2017; Zakaria et al., 2024). Furthermore, several reviewed studies highlight that aligning teaching and learning practices is essential for implementing ABL strategies, ensuring instructional methods meet learners' needs for improved outcomes and academic success (Michael et al., 2023; Putranto et al., 2024; Zakaria et al., 2024). The literature emphasizes the importance of reflective practices and self-regulation in student engagement. Educators who encourage students to reflect on their learning, evaluate their progress, and receive regular feedback foster greater engagement through increased self-awareness and ownership of learning (Ali et al., 2022; Putranto et al., 2024; Rao et al., 2017; Xuan et al., 2025; Zakaria et al., 2024).

The influence of teacher pedagogical competence on students' mathematics outcomes varied across educational contexts. In developed contexts, where teachers generally had greater access to professional learning and instructional resources, their influence on students' outcomes was associated with high levels of student engagement and mathematical

reasoning (Rao et al., 2017; Schmitt, 2004). In developing contexts, teacher competence remained a critical factor; however, its effect on student outcomes was mediated by contextual constraints, including limited resources, class size, and curriculum demands (Berlinski & Busso, 2017; Munyaruhengeri et al., 2024). This suggests that pedagogical competence may not operate independently but is influenced by various contextual factors. Consequently, improvement in student mathematics outcomes may depend not only on teachers' competence but also on the conditions that enable effective pedagogical practice. Differences in reported student outcomes may also be related to study design. Quantitative survey studies often reported positive relationships between teacher competence and student outcomes, based on self-reported measures (Berlinski & Busso, 2017; Zakaria et al., 2024), whereas intervention studies provided strong evidence of how competence influenced actual learning processes (Ali et al., 2022; Munyaruhengeri et al., 2024; Putranto et al., 2024). This finding suggests that teachers' perceptions of their pedagogical practices may not always align with their enacted classroom practices, highlighting the importance of using multiple measures to evaluate pedagogical competence and its influence on student learning. The review suggests that not all dimensions of pedagogical competence contribute equally to mathematics outcomes. Differentiated instruction competence (Putranto et al., 2024; Rao et al., 2017; Surrette, 2020) and the ability to facilitate active mathematical engagement appeared more consistently associated with student achievement than classroom management alone. This finding implies that while maintaining an orderly learning environment is necessary, pedagogical practices that actively support conceptual understanding and mathematical reasoning may have a more direct influence on students' learning outcomes.

3.4. The Effect of ABL on Students' Performance

Students' engagement and motivation are crucial in an ABL environment for fostering student enthusiasm and persistence during mathematics learning activities (Ali et al., 2022; Bature & Atweh, 2019; Du et al., 2025; Jesionkowska et al., 2020; Michael et al., 2023; Putranto et al., 2024; Schmitt, 2004; Zakaria et al., 2024). It is a key feature characterized by hands-on activities and a strong focus on understanding mathematical concepts, which is clearly suggested by the reviewed literature. Engagement can boost the confidence of both students and teachers. When students are engaged and confident, they are more likely to put effort into their learning, which can improve their academic performance. ABL fosters collaboration, where students work together to solve problems, share ideas, and learn from one another. Collaborative skills develop teamwork, communication, and peer support. Collaborative learning in mathematics can improve understanding and foster a positive learning community, leading to better student performance (Altarawneh et al., 2023; Bature & Atweh, 2019; Jesionkowska et al., 2020; Michael et al., 2023; Munyaruhengeri et al., 2024; Putranto et al., 2024; Tammets et al., 2024; Triadafilidis, 1995). ABL also allows teachers to collaborate on lesson planning, share engagement strategies, and discuss their progress in professional development. For example, group projects enhance cooperation and dialogue. Additionally, it encourages students to take responsibility for their learning. By promoting self-directed learning, students become more responsible and proactive in seeking solutions, which is essential for mastering mathematics concepts (Zakaria et al., 2024).

Conceptual understanding is a crucial element of the ABL approach. It deepens students' comprehension of mathematical principles through active learning. Most of the reviewed papers suggested that ABL can influence students' conceptual understanding of the subject. For example, activity-based geometry learning can enhance students' spatial reasoning (Ali et al., 2022; Munyaruhengeri et al., 2024; Rao et al., 2017; Triadafilidis, 1995). ABL helps students remember mathematical concepts over the long term by offering real-world applications and hands-on experiences. Studies emphasize ABL's impact on

deep understanding and its capacity to produce meaningful and lasting learning outcomes. It also promotes the development of higher-order thinking skills, such as problem-solving, critical thinking, and reflection. Long-term retention supports the understanding or transfer of knowledge beyond immediate lessons; for instance, students retain key algebraic concepts after several weeks. These skills are essential for mastering mathematics, as they enable students to approach problems systematically and thoughtfully (Munyaruhengeri et al., 2024). As mentioned above, the ability to produce meaningful and lasting learning outcomes contributes to academic success. Academic performance fosters the development of higher-order thinking skills. These skills are vital for mastering mathematics, as they help students approach problems systematically and thoughtfully (Munyaruhengeri et al., 2024; Putranto et al., 2024).

The reviewed studies reported that ABL positively influences students' mathematical performance across educational contexts; however, the nature and strength of its effects vary with contextual conditions. In developed contexts, ABL was commonly associated with improvements in mathematical reasoning, conceptual understanding, problem-solving skills, and student autonomy, and was supported by stronger instructional resources, access to technology, and teacher professional development (Jesionkowska et al., 2020; Rao et al., 2017; Triadafillidis, 1995). In developing and emerging contexts, ABL also enhanced students' achievement, engagement, and motivation; however, its effectiveness was influenced by contextual challenges such as limited resources, examination-oriented systems, and teachers' preparedness (Bature & Atweh, 2019; Michael et al., 2023; Munyaruhengeri et al., 2024). Across contexts, ABL appears to improve not only academic achievement but also students' participation, collaboration, and positive attitudes towards mathematics. Nevertheless, differences in reported outcomes may be related to variations in implementation quality and research design. Studies using experimental or quasi-experimental approaches provided stronger evidence of achievement gains (Ali et al., 2022; Triadafillidis, 1995), while descriptive and qualitative studies highlighted improvements in engagement and classroom participation (Bature & Atweh, 2019; Jesionkowska et al., 2020; Putranto et al., 2024). Overall, the findings suggest that ABL's effectiveness depends not only on the approach itself but also on teachers' pedagogical competence and the educational environment in which it is implemented. Future research should continue to examine the contextual factors that influence the effectiveness of ABL and identify the specific pedagogical mechanisms through which it contributes to improved mathematics outcomes.

4. Discussion

This review systematically examines the impact of teachers' pedagogical competence on students' academic performance in an activity-based learning mathematics classroom setting. The reviewed articles report that teachers' pedagogical competence is essential for the effective implementation of ABL in mathematics classrooms. This finding aligns with the "macro tool" proposal that identifies and characterizes critical competencies for mathematics teachers' practice (Pino-Fan et al., 2023). Teachers' knowledge and skills significantly contribute to creating an active learning environment in mathematics classrooms. Pedagogically competent teachers are expected to cultivate successful students through carefully designed teaching and learning strategies in an ABL setting. According to Shulman (1986), PCK focuses on the teacher's ability to design and implement effective, student-centred learning that promotes engagement and critical thinking. Several research studies agree that teachers' competencies for effectively implementing ABL in mathematics classrooms include deep knowledge of mathematics, pedagogical knowledge, pedagogical content knowledge (Shulman, 1986), technological literacy, classroom management, and assessment literacy (Cojorn & Sonsupap, 2023; Galimova et al., 2023; Murphy & Ingram,

2023; Pino-Fan et al., 2023). Additionally, teachers' metacognitive skills (Flavell, 1979) and ability to differentiate instruction based on students' needs are crucial for teaching and learning mathematics. Similar findings are reported in several studies (e.g., Barrientos et al., 2025; Chen et al., 2025; Rahnev, 2025). The following conceptual framework (see Figure 4) is developed to illustrate the relationship between teachers' pedagogical competence and students' mathematics outcomes in activity-based learning mathematics classrooms.

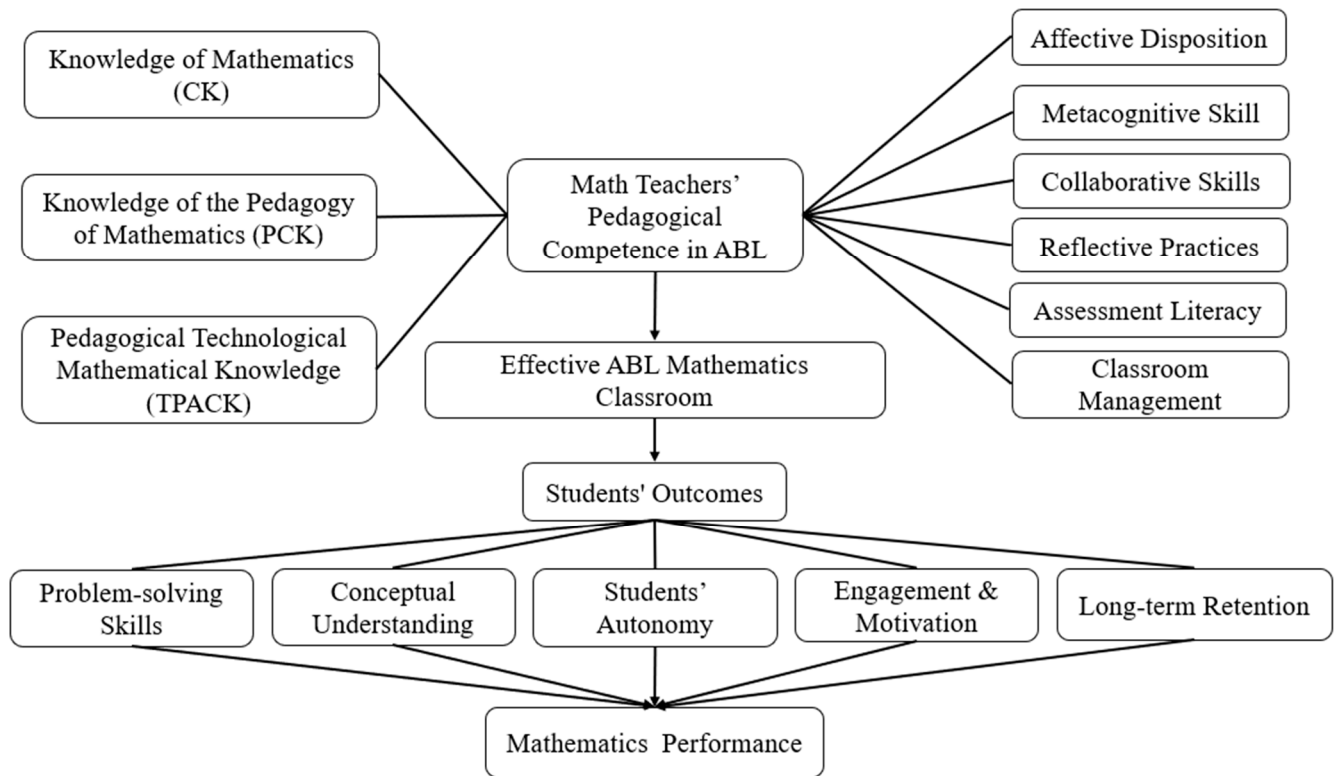


Figure 4. The relationship between teachers' competence in ABL and students' outcomes.

Pedagogical competence is essential but not sufficient for effective ABL implementation. Structural, institutional, and cultural factors can either enable or hinder the practical use of that competence. During implementation, teachers face several challenges in the classroom. These challenges can hinder learning as teachers and school leaders become hesitant to address them. The reviewed literature reports various types of challenges: resource limitations, teachers' beliefs and attitudes, gaps in professional development, students' resistance, curriculum and assessment barriers, leadership-related issues, and institutional constraints—these are the most critical factors affecting successful ABL implementation. These findings align with other research studies (Bonwell & Eison, 1991; Johnson et al., 2017; Jutta & Van Wyk, 2020; Pino-Fan et al., 2023; Pokhrel, 2018). According to the literature, higher expectations for students lead teachers to invest more energy and focus on their mathematics learning, which aligns with studies (e.g., Bonwell & Eison, 1991; Stronge et al., 2007). Teachers' ability to adopt ABL's self-directed nature is also crucial, as many prefer traditional methods due to limited awareness and professional development. ABL typically requires materials, manipulatives, flexible spaces, and training. If these resources are missing, teachers cannot effectively implement what they know. Competence needs conducive conditions for expression. A competent mathematics teacher without resources still struggles to deliver active learning. These findings are directly related to results from multiple studies (e.g., Kajander & Colgan, 2023; Kurianski et al., 2022). Curriculum and policy factors can also hinder ABL, since a rigid, overloaded, or exam-centric curriculum can

restrict teachers' ability to creatively apply ABL methods. Even if teachers are competent, they might be forced to 'teach to the test' instead of engaging students through hands-on activities. Additionally, the focus on exam scores and high-stakes testing often pushes teachers toward rote memorization or procedural teaching, reducing the time and flexibility needed for ABL, which emphasizes understanding and exploration. This creates tension between teachers' knowledge (competence) and the pressure to conform. The findings are consistent with Pokhrel (2018). School environment factors also block ABL, even as teachers try to improve their instructional strategies. If the school climate does not support innovation, collaboration, or experimentation, teachers may lack the encouragement or support to use ABL methods—even if they are willing and competent. These findings match studies like Mandelid et al. (2024) and Tadesse et al. (2023). A culture resistant to change can stifle pedagogical creativity. These challenges reflect leadership decisions and external pressures that influence successful ABL adoption. Hamad et al. (2022) also pointed out that a school culture discouraging innovation hinders effective active learning. Teachers' difficulty in assessing students' progress within an ABL setting is another barrier, along with resource and technology shortages, and the need for student autonomy, since ABL is rooted in student-centered learning. As Lotter et al. (2020) explained, teachers often struggle to balance maintaining control with allowing students to make decisions and take ownership of their learning. Several reports note that teachers are rarely involved enough in professional development programs, which can limit ABL's effective implementation. Time and scheduling constraints are major obstacles because ABL strategies require substantial time for design and execution, affecting the overall effectiveness of ABL in mathematics classrooms.

Teachers' influence on students' outcomes is vital and is seen as the primary factor in students' academic achievement. They play an important role in students' cognitive, emotional, and behavioral growth. Highly skilled and effective teachers can affect students' learning and engagement through active and experiential activities, reflective practices to manage their learning pace, and the use of technology and multimedia tools. These findings align with studies that examine teachers' quality and students' learning results, e.g., Darling-Hammond (2000).

Activity-based learning is closely connected to students' engagement, deeper understanding, academic success, better retention of mathematical concepts, and promotes collaboration among students and with teachers. The impact of ABL on students' learning depends on their ability to create environments that support cooperation and socialization among peers, as well as self-direction and independent learning. Several studies have reported similar findings. For example, Çelik (2018) noted that, in addition to students' outcomes, ABL also provides teachers with opportunities for professional growth within student-centered education, assists in designing effective lesson plans, and encourages the use of innovative methods to meet students' needs.

This review emphasizes teachers' skills for successfully implementing ABL in mathematics classrooms. Most of the reviewed research focuses on active learning strategies and the challenges of adopting them worldwide, showing a positive link between students' performance and teachers' effective use of active learning strategies. However, the limited number of studies examining how teachers' pedagogical skills affect ABL implementation highlights a significant gap in this area. This study tried to fill that gap by exploring how teachers' competence in ABL directly affects students' mathematics performance. Future research could also examine student engagement in ABL mathematics classes and develop specific assessment tools or models to measure students' understanding of particular mathematical concepts.

5. Conclusions

This review suggests that teachers’ pedagogical skills can positively affect students’ academic performance in ABL classrooms, a finding that is crucial for improving students’ mathematics learning outcomes. These findings can offer insights into managing and enhancing teachers’ strategic approaches to delivering effective mathematics instruction in secondary schools, thereby increasing students’ understanding of key mathematical concepts. Additionally, the review suggests a vital contribution to promoting teachers’ use of activity-based instruction in mathematics classrooms. Furthermore, the review can play an important role in guiding teacher training programs by clarifying the factors that influence student performance in mathematics, examining teachers’ confidence in teaching and learning mathematics, and addressing the challenges teachers face when implementing ABL (such as resource shortages, time management, lack of training, and large class sizes). Recognizing these barriers is essential for developing policies and interventions to address them and support teachers in adopting effective teaching methods.

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Abbreviations

The following abbreviations are used in this manuscript:

ABL Activity-based learning
WoS Web of Science

Appendix A

Table A1. Overview of the studies included in the review.

Study	Author(s) Name, Year	Sample	Method	Key Findings
1	Du et al. (2025)	435 Secondary students	Mixed	Enjoyment boosts motivation and engagement. Teachers’ positive beliefs about students’ abilities build confidence and encourage active participation. Other cognitive and emotional factors may also indirectly influence engagement.

Table A1. Cont.

Study	Author(s) Name, Year	Sample	Method	Key Findings
2	Manakul et al. (2023)	1226 junior high school teachers	Quantitative	All teachers demonstrated high smart teaching ability. Grade 7 teachers showed the strongest abilities, followed by Grades 8 and 9. Teachers with 1–10 years of experience had higher abilities than those with over 20 years, indicating better adaptability to digital environments.
3	Moliner and Alegre (2022)	402 Secondary school teachers	Quantitative inferential	Teachers showed more positive attitudes and beliefs than practical or theoretical knowledge about peer tutoring. Less experienced teachers had greater knowledge, likely due to recent training in active methods.
4	Tammets et al. (2024)	1788 elementary, primary, secondary	Quantitative	Student-centered learning (SCL) was least used, but when implemented, teachers found ERT more effective. Math teachers relied more on independent tasks. Collaboration with colleagues and parents increased SCL and synchronous practices. SCL practices were linked to perceived learning success, though they also increased teacher workload. Leadership support boosted collaboration but sometimes limited SCL adoption depending on leadership style.
5	Schmitt (2004)	292 Middle-level educators	Quantitative, quasi-experimental study	High professional middle-level schools consistently scored well on the mathematics assessment, and a model showing a statistically significant relationship was found for mathematics scores. Teachers in high PD schools reported more PD activities, better alignment with school goals, and stronger support for innovation. High PD schools generally had slightly higher percentages of students at proficient or advanced levels in math. Some variation in math achievement was explained by grade configuration ($R^2 = 12.3\%$).
6	Xuan et al. (2025)	120 students	Quantitative, comparative quasi-experimental	Private schools: Students in AI-assisted groups outperformed teacher-supported peers (average ≈ 5.09 vs. 4.39) because of stronger digital literacy and self-regulated learning skills. AI offered personalized feedback, boosting engagement and independence. Public schools: Teacher-led instruction was more effective (average ≈ 6.73 vs. 4.14 for AI group) due to limited infrastructure and lower digital literacy. Traditional scaffolding and interaction remained crucial. Overall, AI's impact depends on context; its effectiveness varies with socioeconomic and technological readiness. Constructivist and self-regulated learning frameworks explain performance differences.

Table A1. Cont.

Study	Author(s) Name, Year	Sample	Method	Key Findings
7	Alkhatatneh (2024)	350 mathematics teachers, primary, middle and secondary	Quantitative, descriptive survey	Mathematics teachers generally held positive perceptions and beliefs about the value and importance of the STEAM approach. However, many teachers mentioned challenges such as a lack of training, limited resources, and curriculum rigidity. Teachers with 5–10 years of experience were more willing to adopt STEAM practices than those with more than 10 years.
8	Munyaruhengeri et al. (2024)	252 students and 21 mathematics teachers	Mixed	Performance variance revealed significant gaps in conceptual and procedural understanding. There is a lack of visualization skills when sketching graphs. Contributing factors include an overreliance on rote memorization and algebraic calculation. Use of multiple representations—such as graphical, numerical, and symbolic—is limited. Instruction is teacher-centered with little active learning. The syllabus is overloaded, creating pressure to cover content quickly. Additionally, there is insufficient pedagogical content knowledge among teachers and large class sizes.
9	Putranto et al. (2024)	9 visually impaired students and 7 mathematics teachers	Qualitative, case study	Low Self-Efficacy (Human-Side Barrier). Self-efficacy issues significantly hindered engagement in active learning. Teachers lacked strategies to promote equitable participation. Technology and learning media limitations. Insufficient training on adaptive technologies worsened this issue. Lack of classroom management skills and fast teaching pace, along with the absence of differentiated instruction, caused learning gaps among VI students.
10	Michael et al. (2023)	186 teachers	Quantitative, Descriptive survey	Teachers associate AL with student-centered teaching, participation, collaboration, and independent thinking. However, some misunderstand AL as simply group work or pair discussions, without a deeper understanding of learner autonomy and problem-solving. Teachers often revert to traditional lecture methods because of this. Only a small percentage of teachers regularly use active learning techniques, highlighting a gap between theory and practice. Factors Hindering Implementation include institutional barriers, teacher-related barriers, student-related barriers, and resource barriers.
11	Altarawneh et al. (2023)	268 teachers	Mixed	Teachers' use of ALs was moderate, with means ranging from 3.27 to 3.65 on a 5-point scale. Brainstorming was used most often ($M = 3.65$), while Project-based learning was used the least ($M = 3.27$). Teachers still heavily depend on traditional instructional methods due to time limitations and classroom challenges. Obstacles: Teacher-related, student-related, curriculum-related, and school environment-related.

Table A1. Cont.

Study	Author(s) Name, Year	Sample	Method	Key Findings
12	Ali et al. (2022)	60 students	Quantitative, Experimental	The experimental group (flipped classroom) achieved significantly higher mean scores on the post-test. The difference was statistically significant at the 0.01 level, confirming that the flipped classroom model is superior to the traditional method. Enhancing Engagement and Understanding. They found that pre-class video materials and in-class discussions were more interactive and effective than lecture-based instruction. The flipped model promoted peer learning, student autonomy, and critical thinking during classroom sessions.
13	Surette (2020)	28 secondary or science teachers	Qualitative	Professional communities and interactions with mentors influenced the Early Career Teachers (ECTs) to adopt key aspects of a learner-centered approach to teaching. This included engaging students in active learning, utilizing formative assessment strategies, and responding to students' individual needs. They developed the ability to incorporate active learning into their teaching, implement formative assessment techniques, and address students' unique circumstances.
14	Bature and Atweh (2019)	12 secondary school students	Qualitative, case study	Over time, students embraced group work, finding it valuable for understanding complex mathematics concepts. Teachers shifted from authoritarian figures to facilitators of learning. Collaborative groups with mixed abilities and genders enhanced peer learning. Challenging, higher-order problems encouraged deeper engagement and discussion. Flexible classroom roles like leader and secretary boosted participation. Improved teacher-student and peer interactions led to a reduced fear of mathematics and increased confidence in sharing ideas. Students also started to take responsibility for their learning.
15	Berlinski and Busso (2017)	1800 students and 190 teachers	Quantitative	Contrary to expectations, students in the control group outperformed those in all active learning treatments. Less experienced teachers and high-ability students showed the most negative outcomes. This suggests that teachers struggled to adapt to the new pedagogy and that advanced students disengaged under the AL framework. Teacher effect increased, with more discussion and a greater willingness to innovate. However, teacher-student interaction quality decreased significantly (-0.52 to -0.72 SD). Student effort was slightly negative but not statistically significant. This indicates that, although teachers adopted AL behaviors, they lacked the mastery to sustain instructional quality and effective classroom management.

Table A1. Cont.

Study	Author(s) Name, Year	Sample	Method	Key Findings
16	Rao et al. (2017)	2 teachers and 38 students	Qualitative Design-based research	Students needed structured support to become self-directed learners in activity-based mathematics. Teachers encouraged independence through guided questioning, pair work, and clear expectations. Mathematical understanding was mainly built through oral reasoning and dialogue, supported by teacher language scaffolds. Individual differences in motivation, confidence, and social skills significantly influenced engagement. Students with higher self-regulation and communication skills excelled, while less confident learners often withdrew. Overall, effective student-centered learning required teachers to balance scaffolding, communication support, and attention to individual needs.
17	Triadafilidis (1995)	203 Greek students, 313 Scottish students, and 64 U.S. students	Mixed, Activity-based experimental	Low success rates were observed in identifying and naming shapes, especially less familiar ones like kites, trapezia, parallelograms, prisms, and tetrahedrons. Students often depended on everyday metaphors or analogies, such as “roof” or “rocket,” to describe shapes they could not name, highlighting a gap between informal and formal geometric knowledge. Haptic exploration uncovered deep-rooted misunderstandings about shape properties and logical reasoning. Students showed positive attitudes toward the “Feely Box” activities, enjoying the novelty, group work, and hands-on engagement. Tasks involving both touch and vision were the most successful, indicating that combining sensory modalities improves understanding.
18	Zakaria et al. (2024)	15 secondary mathematics teachers	Quantitative	Teaching activities were validated as appropriate for heutagogical mathematics instruction. The highest-rated activity is teachers assigning projects that require students to explore real-world applications of mathematical concepts. The lowest-rated activity is teachers organizing virtual sessions with guest speakers from the mathematics field. The findings emphasize that student-driven, exploratory, and creative tasks best align with heutagogical principles, while passive activities (like lectures) are less effective.
19	Jesionkowska et al. (2020)	15 students and 4 teachers	Qualitative	All student groups successfully created working AR game prototypes. The workshop boosted engagement, motivation, and confidence in coding and STEAM subjects. Students enjoyed the hands-on, creative, and collaborative aspects. Teachers recognized the potential for integrating AR into areas like mathematics (e.g., vectors, geometry, trigonometry). Challenges included lack of AR hardware (such as HoloLens cost and limited access), need for technical support and teacher training, and infrastructure limitations (like no Wi-Fi and long app build times).

Table A2. Validity and reliability assessment of each study.

Studies	Validity Measures	Reliability Measures	
		Cronbach's Alpha	Others
1	Expert-reviewed and refined questionnaire items; conducted CFA with composite reliability, AVE, and factor loadings (>0.7); assessed discriminant validity using HTMT and Fornell-Lacker criteria to confirm distinct constructs.	0.8	Skewness and kurtosis within ± 3.2
2	Content validity based on the Khon Kaen University Smart Teaching and Learning (KKUSL) framework and experts' reviews Construct validity supported by four defined dimensions (learning outcome, content management, pedagogy, and digital learning environment)	0.973–0.979	
3	Content validity using Lawshe's Content Validity Ratio (CVR). Inter-expert agreement was confirmed with an Intraclass Correlation Coefficient (ICC) of 0.82. Construct validity was verified through EFA (Kaiser–Meyer–Olkin test, 0.81; Bartlett's test significant)	0.85	Spearman–Brown coefficient = 0.63
4	Validity ensured through EFA using Maximum Likelihood estimation and oblique rotation. SEM confirmed good model fit (CFI = 0.910, RMSEA = 0.047, SRMR = 0.052)	0.47–0.94 Most scales met the acceptable threshold ($\alpha \geq 0.7$)	
5	Validity ensured through standardized state achievement data and validated teacher survey instruments on professional development participation. Construct validity was examined through EFA using Maximum Likelihood extraction and Direct Oblimin rotation	0.93 Second set of questions $\alpha = 0.96$	
6	The study does not report formal validity testing. Instead, it ensures validity conceptually by grounding its framework and instruments in prior research and expert-informed design in mathematics education and AI	No explicit reliability measures	
7	The study ensured content and construct validity by presenting the survey instruments to a panel of experts in teaching methodology, assessment, and measurement.	$\alpha = 0.934$ –0.973	Correlation coefficients = 0.39 to 0.95, significant at $p < 0.05$ and $p < 0.01$.
8	Expert validation of test items and observation tools (content validity). Data triangulated through achievement tests, classroom observations, and interviews.	$\alpha = 0.72$,	
9	Expert validation of interview protocols. Member checking to confirm interpretation accuracy. Triangulation (students + teachers + researcher notes).		Triangulation, member checking, an audit trail, thick description, and internal peer review
10	Experts reviewed the questionnaire for face and content validity. Triangulated through observation.	0.84 >0.7 for each scale	

Table A2. Cont.

Studies	Validity Measures	Reliability Measures	
		Cronbach's Alpha	Others
11	Content validity (Expert-reviewed 38 items).	0.7	Correlation coefficients (item–total) from 0.41 to 0.87, $p < 0.01$.
12	Content validity was confirmed by creating specific lesson objectives for each test area. Expert-reviewed interview questions		Tests normally distributed (p -values > 0.05). Thematic analysis followed, citing Braun and Clarke's (2012)
13	Typological and inductive analysis, citing Hatch (2002), ensured systematic coding of transcripts. Using predetermined codes grounded in the literature (teacher socialization, knowledge, mentoring, communities of practice) strengthened construct validity.	-	Researchers' reflexivity and alignment with established qualitative standards, citing Erickson, (1986) and Denzin & Lincoln, (2025), enhanced credibility and dependability.
14	Triangulating multiple data sources (observations, interviews, journals) and member checking through reflection meetings and iterative data analysis enhanced trustworthiness.	-	Member checking Triangulation
15	Random assignment and pre-treatment balance checks ensured internal validity. The schools were nationally representative of Costa Rica's public system, ensuring external validity. Triangulation is confirmed by combined quantitative (test data) and qualitative (logs, observations) data used to validate findings.	-	Psychometrically designed standardized tests. Multiple measures (surveys, logs, observations) for consistency
16	Researcher collaboration across disciplines enhanced interpretive validity. Member checking was ensured by teachers reviewing observation summaries for accuracy. Triangulation involved using multiple data sources (observations, interviews, field notes).	-	Triangulation Collaborative coding
17	The study's validity is supported by its cross-cultural replication (Greece, Scotland, U.S.). Construct validity was improved by using multiple data sources (observations, worksheets, interviews). Activities were aligned with national curricula (the Greek syllabus and the 5–14 Scottish Guidelines), ensuring content validity.	-	Consistent activity design and teacher collaboration support reliability Conducting replication across three different countries enhanced external reliability
18	Conducted face and content validity with four assessment, curriculum, and mathematics education experts. Items with a content validity index (CVI) above 0.75 were retained.	0.93	
19	Design validity was supported by iterative classroom testing Content validity by expert review and framework alignment Construct validity by triangulating observations, surveys, and performance data.	-	Qualitative coding, which multiple researchers review, enhances internal reliability

Table A3. Primary and secondary identified themes from the reviewed studies.

Studies	Primary Themes	Secondary Themes
1	Teacher beliefs and enjoyment enhanced behavioral engagement, and students' intentions to engage were a strong predictor of actual participation.	1. Mathematics anxiety, self-efficacy, mathematical knowledge, parental belief, and attitude showed limited participation effects. 2. Positive learning environments and teacher support enhanced engagement and motivation
2	Smart planning, instruction, assessment, and management abilities reflect teachers' competence in integrating technology, pedagogy, and innovation into classroom practice.	1. Age, teaching experience, and access to technology influenced teachers' competence levels. 2. Continuous professional development strengthens smart pedagogy.
3	Peer tutoring reinforces learning and encourages collaboration. Teachers view peer tutoring as a means to promote responsibility, confidence, and leadership among students.	1. Teachers emphasized the need for clear structure, training, and monitoring for peer tutoring to be effective. 2. Unequal participation among peers creates opportunities for misconceptions. 3. Effective peer tutoring was linked to teachers' pedagogical content knowledge (PCK) and classroom management skills.
4	A supportive school culture, characterized by collaboration, trust, and open communication among staff, was essential for student-centered learning. It also included adaptive teaching practices, like teachers employing flexible, interactive strategies (e.g., online discussions and formative feedback) to keep students engaged and autonomous.	1. Limited digital access and varying teacher readiness hindered the consistent implementation of student-centered approaches. 2. Professional development needs: 3. Leadership roles.
5	Grade configuration and achievement: Schools with grades 6-8 demonstrated stronger academic outcomes than K-8 or 7-9 configurations, particularly in mathematics. Professional Development Impact: Ongoing, content-focused professional development positively correlated with higher student achievement.	1. Teacher collaboration. 2. Contextual factors like socioeconomic status and school size moderated the relationship between configuration and achievement. 3. Structural alignment of grade levels and targeted professional development can enhance student outcomes.
6	AI improves conceptual understanding and engagement	1. Access, dependence, and teacher readiness
7	Mathematics teachers positively conceptualize and understand the STEAM approach to integrate it into their instructional practices. This study explores teachers' attitudes toward adopting interdisciplinary and innovation-driven pedagogy.	1. Pedagogical needs and challenges in implementing STEAM practically. 2. Instructional and practical requirements for effectively applying STEAM in classrooms include teacher preparation, interdisciplinary collaboration, and adapting teaching materials to STEAM principles.
8	Students' conceptual and procedural misconceptions in learning limits and continuity.	1. Influence of teacher pedagogical competence and instructional approach on student understanding.

Table A3. Cont.

Studies	Primary Themes	Secondary Themes
9	Barriers to implementing active learning for visually impaired students in mathematics classrooms.	1. Teachers' and students' self-efficacy, technology use, and classroom environmental challenges.
10	Teachers' understanding and classroom implementation of active learning strategies.	1. Institutional and contextual factors constraining effective active learning practices.
11	Teachers use questioning, group work, and problem-solving as active learning strategies.	1. Barriers included large class sizes, limited time 2. Inadequate training in student-centered methods.
12	The flipped classroom improves performance and motivation.	1. Time management 2. Initial student resistance
13	Professional development and mentoring enhance teachers' pedagogical competence and promote learner-centered instruction.	1. Active learning integration, mentoring, and peer collaboration encouraged teachers to move from lecture-based to activity-based, inquiry-driven instruction. 2. Teachers use of ongoing assessment (Formative Assessment) strategies (e.g., pre-assessments, feedback cycles, "traffic light" methods) to monitor learning. 3. Teachers' sensitivity to students' unique personal and academic needs enhances classroom relationships. 4. Mentoring and communities fostered professional identity, confidence, and pedagogical competence among early-career teachers. 5. Career-changer teachers require tailored mentoring approaches to help them adopt contemporary, student-centered methods.
14	Collaboration enhances mathematics classroom practice by fostering student-centered learning, shared responsibility, and active engagement through cooperative teacher-student and peer interaction.	1. Initial resistance and adaptation 2. Use of group work, peer dialogue, and challenging tasks to encourage interdependence and critical thinking. 3. Teachers' roles shift from knowledge transmitters to facilitators and negotiators of learning. 4. Enhanced student confidence, peer support, and positive teacher-student relationships. 5. Systemic change in mathematics classrooms from rote learning to constructivist, collaborative approaches, aligning with national policy goals. 6. Continuous teacher professional development.

Table A3. Cont.

Studies	Primary Themes	Secondary Themes
15	Teachers' technological competence impacts active learning reform and technology integration on mathematics performance.	1. Implementation challenges and 2. Teacher adaptation affecting reform outcomes in developing contexts.
16	The need for structured support to become self-directed learners in activity-based mathematics. Supports and difficulties for struggling learners in student-centered mathematics instruction.	1. Balancing constructivist teaching with explicit scaffolding for diverse learners.
17	Active and multisensory learning in geometry, haptic exploration as a pedagogical tool. The study uses haptic (tactile) exploration to overcome visual limitations in learning geometric shapes. It argues that "hands-on" exploration engages students in deeper conceptual understanding of geometric properties and spatial reasoning, linking sensory experience with abstract thought.	1. Overcoming conceptual misconceptions and visual biases in mathematical learning. 2. The limitations of visual prototypes in teaching geometry. 3. Cross-modal perception (touch, action, and visualization) plays a role in developing geometric reasoning. 4. The potential of activity-based learning to correct misconceptions and support including learners with diverse sensory strengths.
18	Heutagogy empowers teachers to become self-determined, reflective, and innovative in pedagogy.	1. Professional development and 2. Experiential learning is essential for fostering teacher autonomy.
19	Integration of augmented reality (AR) to enhance active learning in STEAM education. Focuses on how AR tools facilitate student engagement, creativity, and problem-solving in STEAM contexts through experiential, active learning.	1. Pedagogical innovation and teacher readiness for AR-based STEAM instruction. 2. Highlights the challenges of teacher preparation, technological competence, and curriculum adaptation necessary to implement AR successfully.

References

- Adkins, J. K. (2018). Active learning and formative assessment in a user-centered design course. *Information Systems Education Journal*, 16(4), 34–40.
- Aguillo, I. F. (2012). Is Google Scholar useful for bibliometrics? A webometric analysis. *Scientometrics*, 91(2), 343–351. [\[CrossRef\]](#)
- Ali, H. M. H. H. M., Asamoah, D., & Shahrill, M. (2022). Effectiveness of flipped classroom model through multimedia technology in improving students' performance in directed numbers. *Infinity Journal*, 11(2), 193–210. [\[CrossRef\]](#)
- Alkhatatneh, S. (2024). Mathematics teachers' perceptions the STEAM approach: Science, technology, engineering, arts, and mathematics and its relationship with some variables. *Journal of Curriculum and Teaching*, 13(4), 71–92. [\[CrossRef\]](#)
- Altarawneh, A. F., Abu-Ghalyoun, O., & Marei, S. T. (2023). The employment of active learning strategies by mathematics teachers and the obstacles to their use. *Journal of Educational and Social Research*, 13(3), 253–364. [\[CrossRef\]](#)
- Amiruddin, A., Baharuddin, F. R., Takbir, & Setialaksana, W. (2023). May student-centered principles affect active learning and its counterpart? An empirical study of Indonesian curriculum implementation. *Sage Open*, 13(4), 1–16. [\[CrossRef\]](#)
- Barrientos, M. S., Reyes, G., & Sackur, J. (2025). Facets of metacognition and their impact on associative learning. *Metacognition and Learning*, 20(1), 37. [\[CrossRef\]](#)
- Bature, I. J., & Atweh, B. (2019). Collaboration: A collective bargain for achieving quality mathematics classroom practice. *International Journal of Educational Methodology*, 5(3), 347–360. [\[CrossRef\]](#)
- Berlinski, S., & Busso, M. (2017). Challenges in educational reform: An experiment on active learning in mathematics. *Economics Letters*, 156, 172–175. [\[CrossRef\]](#)
- Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom*. ASHE-ERIC Higher Education Reports No. 1. School of Education and Human Development, George Washington University. Available online: <https://eric.ed.gov/?id=ED336049> (accessed on 20 June 2026).

- Bruner, J. S. (1966). *Toward a theory of instruction*. Harvard University Press.
- Chen, S., Guo, M., & Dousay, T. A. (2025). Grow to learn: A metacognitive approach to early childhood teachers' science professional development. *Research in Science & Technological Education*, 43(2), 390–410. [\[CrossRef\]](#)
- Cojorn, K., & Sonsupap, K. (2023). An activity for building teaching potential designed on community of practice cooperated with lesson study. *Journal of Curriculum and Teaching*, 12(4), 62. [\[CrossRef\]](#)
- Csikós, C., & Sztányi, J. (2020). Teachers' pedagogical content knowledge in teaching word problem solving strategies. *ZDM*, 52(1), 165–178. [\[CrossRef\]](#)
- Çelik, H. C. (2018). The effects of activity based learning on sixth grade students' achievement and attitudes towards mathematics activities. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(5), 1963–1977. [\[CrossRef\]](#) [\[PubMed\]](#)
- Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives*, 8(1), 1–44.
- Dewey, J. (1938). *Experience and education*. Kappa Delta Pi.
- Du, W., Wijaya, T. T., Cao, Y., & Li, X. (2025). What factors influence secondary students' active participation in mathematics classrooms: A theory of planned behavior perspective. *Acta Psychologica*, 253, 104694. [\[CrossRef\]](#) [\[PubMed\]](#)
- Edwards, S. (2015). Active learning in the middle grades. *Middle School Journal*, 46(5), 26–32. [\[CrossRef\]](#)
- Flavell, J. H. (1979). *Metacognition and cognitive monitoring*. Stanford University.
- Galimova, E. G., Zakharishcheva, M. A., Kolomoets, E. N., Chistyakov, A. A., Prokopyev, A. I., Beloborodova, A. V., & Ilaeva, R. A. (2023). A review of research on pedagogical content knowledge in science and mathematics education in the last five years. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(2), em2223. [\[CrossRef\]](#) [\[PubMed\]](#)
- Hamad, S., Tairab, H., Wardat, Y., Rabbani, L., AlArabi, K., Yousif, M., Abu-Al-Aish, A., & Stoica, G. (2022). Understanding science teachers' implementations of integrated STEM: Teacher perceptions and practice. *Sustainability*, 14(6), 3594. [\[CrossRef\]](#)
- Hearn, J., Feuer, D., Higginson, I. J., & Sheldon, T. (1999). Systematic reviews. *Palliative Medicine*, 13, 75–80. [\[CrossRef\]](#) [\[PubMed\]](#)
- Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M. P., Griffiths, F., Nicolau, B., O'Cathain, A., & Rousseau, M. C. (2018). The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for Information*, 34, 285–291. [\[CrossRef\]](#)
- Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education: A case study. *Education Sciences*, 10(8), 198. [\[CrossRef\]](#)
- Johnson, C. C., Sondergeld, T., & Walton, J. B. (2017). A statewide implementation of the critical features of professional development: Impact on teacher outcomes. *School Science and Mathematics*, 117(7–8), 341–349. [\[CrossRef\]](#)
- Juta, A., & Van Wyk, C. (2020). Classroom management as a response to challenges in mathematics education: Experiences from a province in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, 24(1), 21–30. [\[CrossRef\]](#)
- Kajander, A., & Colgan, L. (2023). What does it mean to know mathematics for teaching? *Canadian Journal of Science, Mathematics and Technology Education*, 23(4), 832–838. [\[CrossRef\]](#)
- Kurianski, K. M., Marzocchi, A. S., & Soto, R. C. (2022). Tools for humanizing mathematics classes in a virtual world (and beyond). *International Journal of Mathematical Education in Science and Technology*, 53(3), 698–707. [\[CrossRef\]](#)
- Leydesdorff, L., Wouters, P., & Bornmann, L. (2016). Professional and citizen bibliometrics: Complementarities and ambivalences in the development and use of indicators-a state-of-the-art report. *Scientometrics*, 109(3), 2129–2150. [\[CrossRef\]](#) [\[PubMed\]](#)
- Lotter, C., Carnes, N., Marshall, J. C., Hoppmann, R., Kiernan, D. A., Barth, S. G., & Smith, C. (2020). Teachers' content knowledge, beliefs, and practice after a project-based professional development program with ultrasound scanning. *Journal of Science Teacher Education*, 31(3), 311–334. [\[CrossRef\]](#)
- Manakul, T., Somabut, A., & Tuamsuk, K. (2023). Smart teaching abilities of junior high school teachers in Thailand. *Cogent Education*, 10(1), 2186009. [\[CrossRef\]](#)
- Mandelid, M. B., Dyngeland, E. S., Teslo, S., Lerum, Ø., Tjomsland, H. E., Jenssen, E. S., Eriksen, P. B., Wergeland, T. C., Sandal, M. Ø., Stein, H., Schjerven, H., Stokke, R., Engelsen, K. S., Andersen, S. A., Trautner, N., & Resaland, G. K. (2024). Workplace-based continuing professional development program for physically active learning: Designing a framework and prospective directions. *Frontiers in Education*, 9, 1407542. [\[CrossRef\]](#)
- Maphutha, K., Maoto, S., & Kibirige, I. (2022). The effect of the activity-based approach on grade 11 learners' performance in solving two-dimensional trigonometric problems. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(10), 1–14. [\[CrossRef\]](#) [\[PubMed\]](#)
- Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, 59(1), 14–19. [\[CrossRef\]](#) [\[PubMed\]](#)
- Medley, D. M. (1977). *Teacher competence and teacher effectiveness: A review of process-product research*. American Association of Colleges for Teacher Education.
- Michael, K., Alemu, M., Desie, Y., Atnafu, M., Assefa, S., Regassa, C., Wodaj, H., & Abate, A. (2023). Understanding and practice of active learning among upper primary school science and mathematics teachers. *Heliyon*, 9(6). [\[CrossRef\]](#) [\[PubMed\]](#)

- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. [\[CrossRef\]](#)
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting item for systematic reviews and meta-analysis: The PRISMA statements. *PLoS Medicine*, 6(7), e1000097. [\[CrossRef\]](#) [\[PubMed\]](#)
- Moliner, L., & Alegre, F. (2022). Attitudes, beliefs and knowledge of mathematics teachers regarding peer tutoring. *European Journal of Teacher Education*, 45(1), 93–112. [\[CrossRef\]](#)
- Munyaruhengeri, J. P. A., Umugiraneza, O., Ndagijimana, J. B., & Hakizimana, T. (2024). Students' misconceptions and difficulties with learning limits and the continuity of functions at selected Rwandan secondary schools. *International Journal of Education and Practice*, 12(2), 467–482. [\[CrossRef\]](#)
- Murphy, S., & Ingram, N. (2023). A scoping review of research into mathematics classroom practices and affect. *Teaching and Teacher Education*, 132, 104235. [\[CrossRef\]](#)
- Niesz, T., & Ryan, K. (2018). Teacher ownership versus scaling up system-wide educational change: The case of activity based learning in south India. *Educational Research for Policy and Practice*, 17(3), 209–222. [\[CrossRef\]](#)
- Nwoke, B. L. (2021). Enhancing primary school pupils' mathematics creative ability through activity based learning approach. *Malikussaleh Journal of Mathematics Learning (MJML)*, 4(2), 70. [\[CrossRef\]](#)
- Pandey, A., & Kumar, D. A. (2020). Relationship between teachers' teaching competency and academic achievement of students. *International Journal of Applied Research*, 6(7), 31–33.
- Pantić, N., & Wubbels, T. (2010). Teacher competencies as a basis for teacher education: Views of Serbian teachers and teacher educators. *Teaching and Teacher Education*, 26(3), 694–703. [\[CrossRef\]](#)
- Patil, U., Budihal, S. V., Siddamal, S. V., & Mudanagudi, U. K. (2016). Activity based teaching learning: An experience. *Journal of Engineering Education Transformations*, 29, 1–5. [\[CrossRef\]](#)
- Pino-Fan, L. R., Castro, W. F., & Moll, V. F. (2023). A macro tool to characterize and develop key competencies for the mathematics teacher's practice. *International Journal of Science and Mathematics Education*, 21(5), 1407–1432. [\[CrossRef\]](#)
- Pokhrel, T. (2018). Activity-based mathematics instruction: Experiences in addressing the 21st-Century Skills. *Journal of Mathematics Education*, 11(1), 46–61. [\[CrossRef\]](#)
- Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223–231. [\[CrossRef\]](#)
- Putranto, S., Marsigit, M., & Arliani, E. (2024). Active learning barriers in developing mathematical proficiency: Comparing visual impairment students' and teachers' perspective. *Journal of Curriculum and Teaching*, 13(1), 48–60. [\[CrossRef\]](#)
- Rahnev, D. (2025). A comprehensive assessment of current methods for measuring metacognition. *Nature Communications*, 16(1), 701. [\[CrossRef\]](#) [\[PubMed\]](#)
- Rao, K., Slovin, H., Zenigami, F., & Black, R. (2017). Challenges and supports for struggling learners in a student-centered mathematics classroom. *Investigations in Mathematics Learning*, 9(2), 69–85. [\[CrossRef\]](#)
- Schmitt, V. L. (2004). The Relationship between middle level grade span configuration, professional development, and student achievement. *RMLE Online*, 27(2), 1–13. [\[CrossRef\]](#)
- Shulman, L. S. (1986). Those who understand knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14. [\[CrossRef\]](#)
- Sirait, S. (2016). Does teacher quality affect student achievement? An empirical study in Indonesia. *Journal of Education and Practice*, 7(27), 34–41.
- Skulmowski, A. (2024). Learning by doing or doing without learning? The potentials and challenges of activity-based learning. *Educational Psychology Review*, 36(1), 28. [\[CrossRef\]](#)
- Stronge, J. H., Ward, T. J., Tucker, P. D., & Hindman, J. L. (2007). What is the relationship between teacher quality and student achievement? An exploratory study. *Journal of Personnel Evaluation in Education*, 20(3), 165–184. [\[CrossRef\]](#)
- Surette, T. N. (2020). Influence of mentoring and professional communities on the professional development of a cohort of early career secondary mathematics and science teachers. *School Science and Mathematics*, 120(3), 175–188. [\[CrossRef\]](#)
- Tadesse, A., Lehesvuori, S., Posti-Ahokas, H., & Moate, J. (2023). The learner-centred interactive pedagogy classroom: Its implications for dialogic interaction in Eritrean secondary schools. *Thinking Skills and Creativity*, 50, 101379. [\[CrossRef\]](#)
- Tammets, K., Ley, T., Seitlinger, P., & Eisenschmidt, E. (2024). School culture and teaching practices for the effective student-centred learning during emergency remote teaching. *European Journal of Teacher Education*, 49(3), 534–556. [\[CrossRef\]](#)
- Triadafilidis, T. A. (1995). Circumventing visual limitations in teaching the geometry of shapes. *Educational Studies in Mathematics*, 29(3), 225–235. [\[CrossRef\]](#)
- Tsai, M. C., Shen, P. D., Chen, W. Y., Hsu, L. C., & Tsai, C. W. (2020). Exploring the effects of web-mediated activity-based learning and meaningful learning on improving students' learning effects, learning engagement, and academic motivation. *Universal Access in the Information Society*, 19(4), 783–798. [\[CrossRef\]](#)
- Usman, A. N., Musta'ámal, A. H., Muhammad, H. A., & Mohammed, I. A. (2020). Effects of place-based and activity-based approaches in technical education, Interest and retention. *Universal Journal of Educational Research*, 8(5A), 73–80. [\[CrossRef\]](#)

- Vale, I., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. *European Journal of Science and Mathematics Education*, 11(3), 573–588. [[CrossRef](#)] [[PubMed](#)]
- Wafubwa, R. N., & Csikos, C. (2021). Formative assessment as a predictor of mathematics teachers' levels of metacognitive regulation. *International Journal of Instruction*, 14(1), 983–998. [[CrossRef](#)]
- Xuan, S. H., Nguyen, A. T., Nguyen, T., Nguyen, L., Nguyen, H., Pham, N., Phung, T., Ngo, B., Nguyen, V., Nguyen, M., Tran, T., Le, T., Nguyen, K., & Fnu, P. (2025). Evaluating the impact of generative AI in mathematics education: A comparative study in Vietnamese high schools. *Human Behavior and Emerging Technologies*, 2025(1), 8886206. [[CrossRef](#)]
- Zakaria, M. I., Nasran, N. A. H. N., Abdullah, A. H., Alhassora, N. S. A., & Hanid, M. F. A. (2024). Heutagogy in action: Empowering mathematics teachers through innovative pedagogical approaches. *International Journal of Instruction*, 17(4), 135–148. [[CrossRef](#)]
- Zhu, J., & Liu, W. (2020). A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics*, 123(1), 321–335. [[CrossRef](#)]

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