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Review Article

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Enhancing students' problem-solving skills in algebra word problems: A systematic review of TAPPS and storyboarding strategies

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ABSTRACT

This systematic literature review investigates the effectiveness of the think aloud pair problem-solving (TAPPS) and storyboarding strategies in enhancing students' abilities to solve algebra word problems. Notably, algebra word problems pose a significant challenge to students due to their inherent complexity, requiring strong cognitive, linguistic, and problem-solving skills. Many students struggle with abstract reasoning, translating textual descriptions into algebraic expressions, and applying appropriate strategies for problem resolution. The study synthesizes 52 peer-reviewed articles from 2015 to 2025 using the preferred reporting items for systematic reviews and meta-analyses methodology to ensure a rigorous and structured analysis. The findings reveal four dominant challenges in algebra word problem-solving: cognitive limitations, reading comprehension difficulties, weak mathematization, and inadequate modeling skills. In particular, TAPPS emerges as a highly effective collaborative learning strategy that promotes metacognitive development, verbal reasoning, and peer-supported reflection. It fosters cognitive engagement and improves performance regardless of student background or learning style. Simultaneously, storyboarding is highlighted as an effective visual strategy, helping students conceptualize and sequence mathematical ideas, thus bridging gaps in comprehension and visualization. Comparative insights demonstrate that TAPPS and storyboarding outperform traditional instructional methods, offering unique yet complementary benefits. While TAPPS enhances verbal articulation and reasoning, storyboarding strengthens visual thinking and sequential planning. The review underscores the potential of integrating these strategies into hybrid instructional models to accommodate diverse students' needs and maximize educational outcomes. Thus, future research should further explore this integration, particularly in technology-enhanced environments, to deepen student understanding and engagement in solving complex algebra word problems.

Keywords: think aloud pair problem-solving, storyboarding, algebra word problems, challenges

INTRODUCTION

In mathematics, word problems are frequently complex since they require students to read and understand the problem in the text, determine the question that needs to be addressed, and then formulate and solve a numerical solution. Among the trickiest and most challenging topics in mathematics are algebra word problems (Jupri & Drijvers, 2016). Algebra word problems require students to combine contextual knowledge with abstract thinking. It takes more than just manipulating numbers to turn real-world scenarios into structured algebraic formulas. Extensive studies have examined the cognitive processes involved in solving algebra word problems (Lee et al., 2018). However, a significant number of students perceive algebra word problems as challenging to solve since they struggle to comprehend the problem, express the arithmetic, and execute the method in question (Ying et al., 2020). Moreover, Jupri and Drijvers' (2016) findings revealed that most students struggled with vertical mathematization and, more specifically, with mathematical problem-solving and reflection. Although the difficulties of algebra word problems among students have been the focus of many studies, they remain a substantial issue and have not yet been entirely addressed.

Numerous proven learning strategies have been widely employed to help students solve mathematical word problems, especially those involving algebra word problems. Polya's problem-solving model is one of the most widely used learning strategies to solve word problems. In Polya, students were taught to solve word problems using four steps: to understand the problem, devise a plan, conduct the plan, and reflect. Even though Polya's teaching methods are well known and have been proven successful, depending on them alone might be insufficient to manage the variety of difficulties that students encounter when attempting to solve word problems (Nandang et al., 2023). Considering the complexity of algebra word problems, an effective solution requires a multifaceted instructional approach that combines conceptual learning, problem-solving strategies, and metacognitive development (Reyes & Reyes, 2024). Therefore, educators must move beyond traditional teaching methods and adopt strategies that encourage active engagement, visualization, and collaborative reasoning.

Alternatively, Iilonga and Ogbonnaya (2023) examined the strategies used by grade 10 learners to solve algebraic word problems. They underscored the value of integrating multiple problem-solving strategies and not just relying on a single heuristic strategy. The authors also advocated for educators to actively model different methods to address the visual and linguistic challenges these problems often present. This highlights the value of using varied teaching strategies to make abstract algebraic ideas more understandable and to support better student achievement. Among the wide range of instructional methods employed in mathematics education, think aloud pair problem-solving (TAPPS) and storyboarding are highly regarded learning strategies. In particular, TAPPS encourages students to verbalize their thought processes through collaboration and discussion. This strategy enables them to gain insights from peer feedback, refine their reasoning, and strengthen their problem-solving skills (Sultan & Alasif, 2021). On the other hand, visualizing algebraic word problems is often a significant challenge for students. Furthermore, storyboarding assists by helping learners organize visual concepts, making abstract ideas more concrete and understandable (Yuliarni et al., 2019).

In their study, Simpol et al. (2017) highlighted a significant difference in students' problem-solving performance when Polya's learning strategies were mixed with TAPPS. These findings suggested that the collaborative nature of TAPPS promotes active participation, collective problem-solving, and reflective learning, making mathematical thinking clearer and more approachable. Meanwhile, Fadzil and Osman (2025) used a comparative example of TAPPS with other learning strategies and reported that students taught using the TAPPS strategy have better problem-solving skills than those taught with conventional methods. Other findings also reveal that there is no interaction between teaching style, gender, or learning style in affecting problem-solving abilities. This indicates that TAPPS improves skills regardless of these factors (Fauzan et al., 2019).

Furthermore, Cheng and Chuang (2018) highlighted that incorporating multimedia elements and storyboard-based designs to guide content flow and visual learning led to a moderate improvement in problem-solving performance. While the findings affirm the modules' potential as engaging educational tools, the study emphasized the significance of integrating collaborative, critical thinking, and assessment components to maximize their impact. Additionally, storyboarding is a great tool for collaborative learning (Ghafar et al., 2023). Students have extensive discussions about how they understand the situation when they work in small groups or pairs to construct storyboards. In addition, logical progression is an essential aspect of mathematics, and constructing a storyboard helps students remember the proper sequence of events. Thus, by planning out their ideas from start to finish, students develop their methodical thinking skills. This methodical approach reduces misunderstandings and encourages more precise, understandable problem-solving.

Consequently, the integration of these learning strategies is anticipated to foster a deeper understanding, enhance students' confidence, and improve the accuracy of their performance in solving algebraic word problems. In this regard, it is essential to provide a comprehensive articulation of the TAPPS and storyboard learning strategies, along with a critical discussion of how previous research has contributed to the ways in which these strategies can complement each other to enhance student's ability to solve algebraic word problems. This research aims to build on this basis by creating a conceptual framework that offers fresh perspectives on the essential ideas behind TAPPS and storyboards that improve students' problem-solving skills in algebra word problems. To address this issue, systematic literature review (SLR) has become a crucial tool that provides a methodical, uniform approach to evaluating previous research on related subjects. Unlike conventional literature reviews, SLR adheres to a protocol-driven procedure that includes establishing precise goals, methodical search tactics, inclusion or exclusion standards, and synthesizing findings either quantitatively or qualitatively. The following are a few research questions that have emerged to guide the completion of this study's findings:

1. What are the challenges students face in algebra word problems?
2. How effective is TAPPS in enhancing students' algebra problem-solving skills?
3. How does a storyboard improve students' conceptual understanding and problem-solving efficiency?
4. What are the comparative advantages and challenges of both strategies in algebra word problem instruction?

RESEARCH METHODOLOGY

Search Strategy

Writing an SLR on learning strategies in mathematics involves a structured, transparent, and replicable approach to identifying, selecting, analyzing, and synthesizing existing research. This SLR preferred reporting items for systematic reviews and meta-analyses (PRISMA). It helps ensure that the process of identifying, screening, and including studies is both clear and replicable. Referring to **Figure 1**, there are four steps used in SLR: identification, where we determine scientific repositories, perform screening to select and reject criteria, conduct data extraction and classification for eligibility, and analysis or synthesis for answers to include in the research questions. The first step involved a comprehensive and structured search across academic databases using Google Scholar.

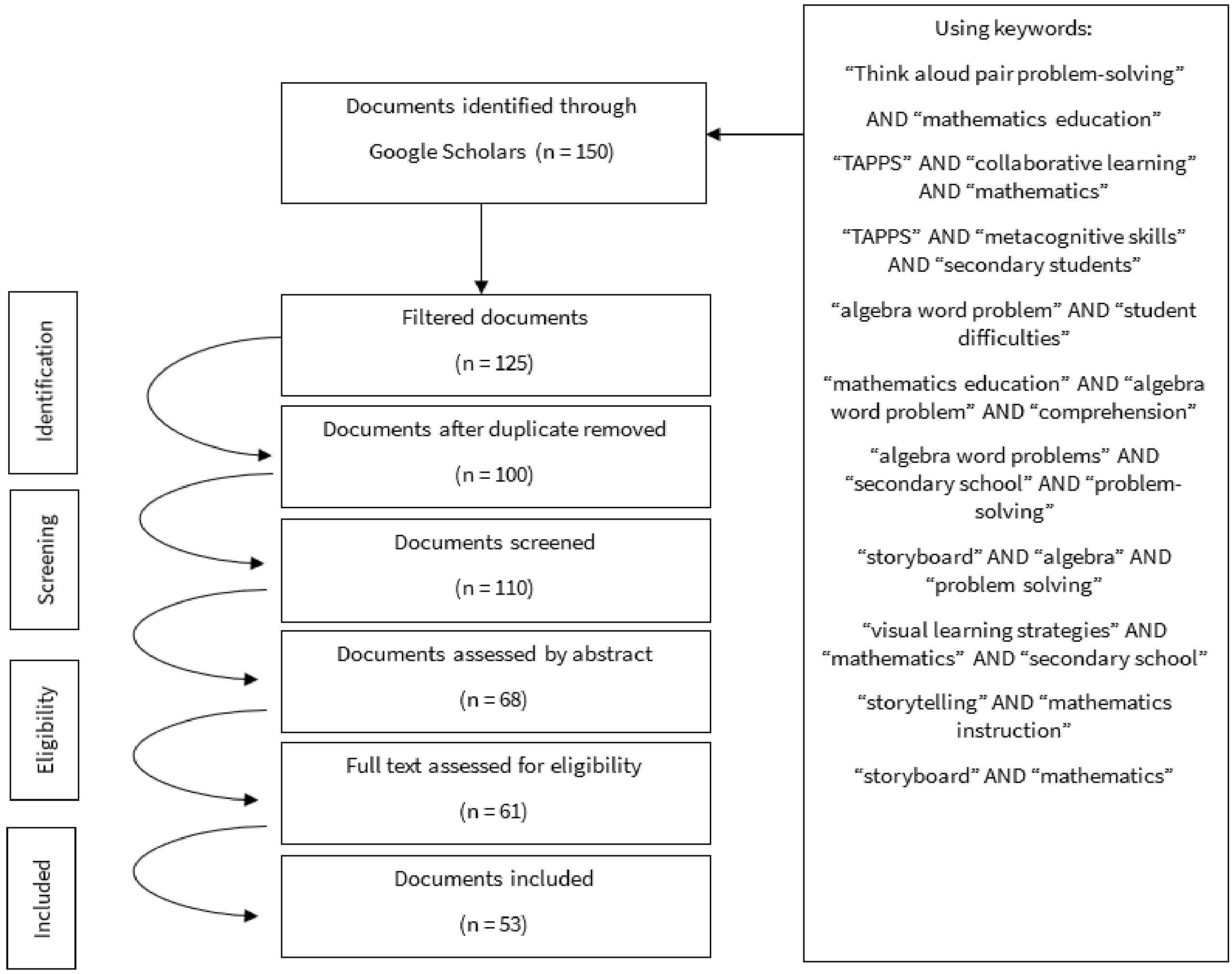

Figure 1. PRISMA flow diagram based on this SLR (Source: Authors' own elaboration)

Inclusion and Exclusion Criteria

The inclusion criteria were limited to studies published between 2015 and 2025, specifically peer-reviewed journal articles and conference proceedings that focused on applying these learning strategies in primary and secondary-level algebra education. Restricting the scope to the last decade allows for a focus on recent research that reflects updated pedagogical strategies and educational standards. This review includes only English-language publications to maintain consistency in interpretation and ensure accessibility of sources. Notably, English is widely used as the primary language in academic publishing, particularly in international journals, which allows for a broad and representative sample of high-quality, peer-reviewed studies. In addition, limiting the review to English-language papers also ensures clarity in understanding methodologies, findings, and theoretical frameworks, reducing the risk of misinterpretation due to translation.

Data Extraction and Analysis

During data extraction and analysis, a few keyword database searches were used in this study. The selected studies were examined for their reported effectiveness in enhancing students' algebra problem-solving skills, their influence on student engagement and cognitive development, and the challenges and limitations encountered during implementation. After a preliminary examination of the abstracts and titles, 150 possibly pertinent papers were yielded. Next, these papers underwent a thorough full-text review to observe if they met the established inclusion requirements. Accordingly, 98 articles were eliminated at this phase for various reasons, including poor methodological quality, a lack of focus on the relevant learning processes, or a lack of applicability to the educational setting of completing algebra word problems. Correspondingly, 52 excellent papers were selected for in-depth examinations. By ensuring that only the most relevant and methodologically sound research was included, this rigorous screening process offers researchers a strong basis to compare the efficacy and educational consequences of TAPPS and storyboard strategies. Then, the findings were synthesized thematically to identify common trends, variations, and gaps in the literature.

Significant knowledge gaps in the existing research on the application of TAPPS and storyboard learning strategies in algebra word problem-solving were identified by the analysis. This study highlights understudied topics by critically analyzing the approaches and conclusions of the selected research. This includes particular student demographics, classroom settings, and the long-term effects of these tactics. Moreover, these discoveries inform future research paths that aim to maximize the potential of TAPPS and storyboard learning strategy to improve student understanding and engagement.

Table 1. Challenges among students in algebra word problems

Item	Key findings	Study	Results
Challenges among students in algebra word problems	Cognitive skills, comprehension, mathematization, and modeling	Sugiarti and Retnawati (2019)	Students struggle due to abstract concepts in algebra
		Ying et al. (2020)	Students face difficulty translating verbal to algebraic expressions
		Chorrojprasert (2020)	Readiness impacts algebra learning success
		Pramesti and Retnawati (2019)	Students fail to understand variables and operations
		Hwang et al. (2019)	Multi-step algebra problems demand high cognitive effort
		Verschaffel et al. (2020)	Cognitive modeling is essential for algebra problem-solving
		Cortés Pascual et al. (2019)	Memory and cognitive flexibility are key to problem-solving
		Barbieri and Booth (2020)	Students cannot filter relevant information from text
		Jupri and Drijvers (2016)	Weakness in mathematization and modeling skills
		Soneira et al. (2023)	Trouble linking narrative to algebraic form
		Iilonga and Ogbonnaya (2023)	Most students fail to use formal modeling strategies
		Pongsakdi et al. (2020)	Reading comprehension and word complexity affect success
		Riccomini et al. (2015)	Misinterpretation of mathematical language like “product”
		Witzel and Myers (2023)	LD students especially struggle with comprehension
		Basir and Waluya (2022)	Students’ algebraic concepts are significantly influenced by cognitive processes

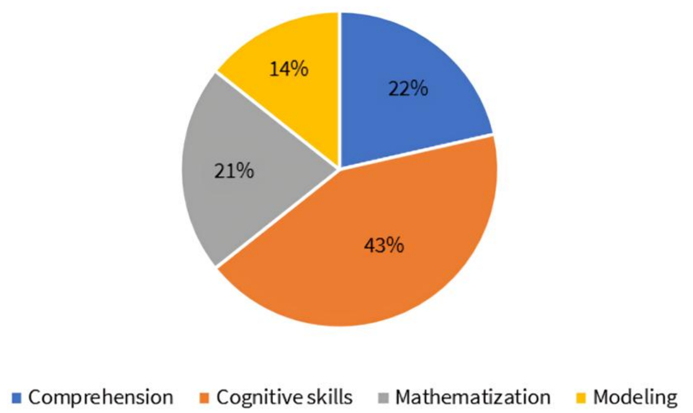

Figure 2. Distribution of challenges in the algebra word problem (Source: Authors’ own elaboration)

RESULTS AND DISCUSSION

This section presents the results of the literature extraction, focusing on three key areas: the challenges students face in solving algebra word problems and the implementation of TAPPS and storyboard learning strategies as potential interventions. The analysis aims to highlight specific cognitive, comprehension, and procedural difficulties that hinder students’ performance in algebra word problem-solving. Additionally, the review explores how TAPPS, a collaborative metacognitive strategy, and storyboard learning, a visual and sequential learning method, have been applied in educational settings to address these challenges. Building on that, the findings provide insights into the effectiveness of these approaches and their relevance in improving students’ mathematical thinking, problem-solving processes, and overall engagement in mathematics learning.

Challenges Among Students in the Algebra Word Problem

All the identified publications explored the challenges among students in algebra word problems. Consequently, each study addressed different issues in algebra word problems. The selected research spanned various educational levels and was conducted across various global regions. **Table 1** summarizes the challenges among students in algebra word problems.

The first research question is related to the challenges students face in algebra word problems. The key findings of this SLR for challenges in algebra word problems are cognitive skills, comprehension, mathematization, and modeling. As shown in **Figure 2**, the most common challenge students faced in solving algebra word problems was related to cognitive skills, accounting for 43% of the total findings. This was followed by difficulties in comprehension (22%), mathematization (21%), and modeling (14%).

Algebra word problem studies mathematical tasks and the principles that govern students to translate written scenarios into algebraic expressions or equations to identify a solution. In addition, algebra also expresses relationships, evaluates and interprets patterns, as well as investigates mathematical features in a range of problem scenarios (Sibgatullin et al., 2022). In order to understand how to introduce and develop algebraic-solving skills, numerous researchers and teachers have turned their attention to this topic. Moreover, it is vital to understand the developmental pattern of students’ thinking and reasoning in order to improve their mathematics learning. However, students have trouble understanding mathematics topics, particularly those in algebra, due to the nature of mathematics, which deals with abstract entities (Sugiarti & Retnawati, 2019; Ying et al., 2020). Hence, students’ readiness to learn algebra should be analyzed, as readiness is important to determine students’ ability to solve algebra questions. Students’ readiness is frequently used to describe students’ capacity to pick up new information and begin altering behavior, resulting in efficient and effective learning outcomes (Chorrojprasert, 2020).

The development of algebraic solving ability lies in the need for students to interpret and extract relevant information from the text. It is impossible to deny the crucial influence of the generalization approach in the development of algebraic problem-solving skills. According to Pramesti and Retnawati (2019), findings indicated that grasping the problem, comprehending the meaning of the variables, and operating algebra are the areas where students struggle when studying algebra. Furthermore, resolving algebraic word problems requires a methodical and planned approach to problem-solving. Accordingly, students need to set up the right algebraic expressions, identify the unknowns, and apply the proper operations in a logical order. For instance, higher-order cognitive abilities like analysis, modeling, and abstraction are used in this process, and many students still need to develop these abilities (Hwang et al., 2019). Due to this, when students are unable to solve complex multi-step problems, they frequently become frustrated or disengaged, underscoring the need for focused approaches to learning that can enhance comprehension and problem-solving abilities.

Success and the level of ability to understand mathematics concepts and problem-solving are intimately related to cognitive processes. According to Basir and Waluya (2022), the way in which students explore, comprehend, and apply algebraic concepts is significantly influenced by cognitive processes. The cognitive functions, including logical reasoning, critical thinking, pattern identification, and problem-solving, are necessary for algebra. Students proficient in algebra perform cognitive duties, including analyzing, synthesizing, and applying mathematical principles and techniques (Verschaffel et al., 2020). Therefore, students may efficiently answer complicated problems by connecting several algebraic. In line with that, students benefit from the help of cognitive processes, including abstraction, generalization, and schema development, as they construct a coherent conceptual framework for comprehending and working with algebraic expressions and equations. Moreover, good algebraic performance is influenced by productive memory and cognitive flexibility (Cortés Pascual et al., 2019). Hence, productive memory will enhance students' flexible thinking that can approach algebraic issues from several perspectives, leading to greater knowledge and better performance.

Students' difficulties in solving algebra word problems are often linked to broader issues in mathematization, where the ability to structure and model real-world problems using mathematical symbols and operations is tested. Findings by Barbieri and Booth (2020) indicated that many students find it challenging to distinguish between relevant and unnecessary information in problem statements, which can result in misunderstandings and mistakes while constructing equations. Similarly, Jupri and Drijvers (2016) also highlighted that the process of changing from word to equation demands not only familiarity with mathematical terminology but also the ability to interpret problem context accurately. In fact, mathematization requires students to be familiar with mathematical procedures and the conceptual understanding of how mathematics functions as a language to describe patterns, relationships, and changes. This additional layer of abstraction makes mathematization intimidating for many students, particularly those who still need to develop their reading and comprehension skills.

When addressing algebra word problem-solving, students frequently encounter two interrelated challenges. As stated by Soneira et al. (2023), these challenges involve deciphering the relationships between quantities described in the problem text and converting those relationships into algebraic language through equation formulation. The overlap of these difficulties often complicates the problem-solving process, making it challenging to determine the primary source of students' misunderstandings. Soneira et al.'s (2023) findings were aligned with those of Jupri and Drijvers (2016) and Iilonga and Ogbonnaya (2023). According to their studies, most students struggled to convert word problems into algebraic equations and could not employ suitable strategies. In particular, making a model or diagram was the most popular tactic, although many students struggled to employ these techniques, which supported the notion that formalization and strategy selection are significant challenges.

Since algebra word problems are embedded in the text, students' reading skills were challenged. Missing crucial details, misinterpreting the problem, or not understanding what is being asked are all consequences of poor comprehension (Pongsakdi et al., 2020). Riccomini et al.'s (2015) findings had earlier noted that words like "difference" and "product" have two meanings in both daily language and mathematics. It can be confusing if students are not taught to understand their mathematical significance in context. Additionally, without a strong foundation in reading comprehension and mathematical vocabulary, students may find deducing the right mathematical relationships from the word problem complicated. This could result in mistakes when converting the problem into equations, ultimately impairing their ability to solve problems accurately. Witzel and Myers (2023) also discussed in their findings that algebra word problems can be particularly challenging for students with specific learning disabilities due to their limited reading comprehension skills. This often leads to difficulty identifying relevant information and translating it into algebraic equations. As a result, these students may experience decreased confidence and motivation in learning mathematics.

Further analysis suggests that algebraic problem-solving involves more than just computation. It also calls for planning, reflection, and critical thinking. Students need to be able to apply problem-solving strategies like Polya's model to solve word problems, especially in algebra. Conversely, findings from Witzel and Myers (2023) indicated that a lack of exposure to diverse problem-solving techniques or ineffective instruction restricts students' strategic flexibility. Without this exposure, students become overly dependent on memorized formulas without truly understanding the underlying concept that lies in the algebra word problem. Meanwhile, Pramesti and Retnawati (2019) discussed in their findings that when teachers fail to accurately identify students' specific difficulties in learning algebra word problems, it becomes significantly more challenging to determine the most appropriate problem-solving strategies to employ. Consequently, students often grow even more confused and frustrated as a result of this gap, especially when they are unable to understand the fundamental ideas required for effective problem-solving.

In the final part of the analysis, findings indicate that Jupri and Drijvers (2016), Ying et al. (2020), and Verschaffel et al. (2020) mentioned that addressing students' challenges in solving algebra word problems is a critical priority in mathematics education. These challenges demand good cognitive, reasoning, and modeling abilities in addition to procedural fluency. In particular, students' confidence and performance are negatively impacted when they have trouble understanding word problems. Without targeted support, these issues can widen learning gaps, especially among students with specific learning difficulties. Therefore, it

Table 2. Effectiveness of TAPPS in the algebra word problem

Factor	Key findings	Study	Results
Cognitive	Thinking skills, metacognition, verbalization, and constructivism	Ling and Mahmud (2023)	TAPPS supports metacognition and strategic thinking
		Shah (2019)	
		Bada and Olusegun (2015)	
		Subia et al. (2020)	
		Kani and Shahrill (2015)	
		Fadzil et al. (2024)	
Collaborative learning	Teamwork, dialogue, peer support, and TAPPS roles	Widuri and Musdi (2018)	TAPPS improves communication, reasoning, and teamwork
		Sultan and Alasif (2021)	
		Syafitr et al. (2018)	
		Werdiningsih et al. (2019)	
		Fauzan et al. (2019)	
		Anggraeni and Andriani (2019)	
		Mashuri et al. (2018)	
		Nufus and Arnawa (2018)	
Student behavior	Motivation, confidence, attitude, and teamwork	Nasution et al. (2022)	TAPPS supports motivation, but confidence varies
		Yanuarti et al. (2022)	
		Sönmez and Sulak (2018)	
Algebra performance	Performance, achievement, academic outcome, and TAPPS vs. traditional	Mohammad (2023)	TAPPS improves performance, especially with tech/media integration
		Widuri and Musdi (2018)	
		Yanto and Wardono (2020)	
		Fadzil et al. (2024)	
		Rif'an (2023)	
		Saramika and Banjarnahor (2021)	
		Simpol et al. (2017)	
		Upu et al. (2024)	

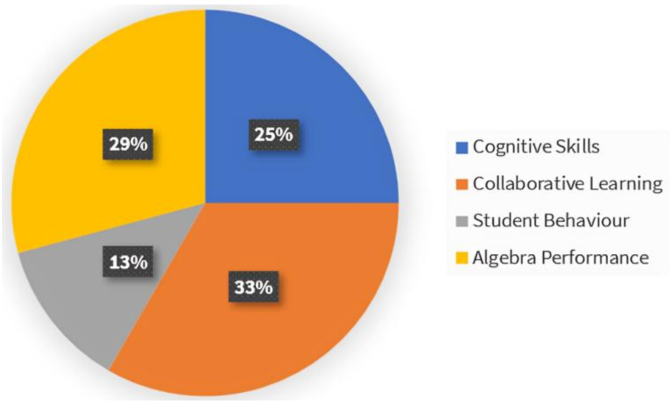

Figure 3. Factors contributing to the effectiveness of TAPPS (Source: Authors' own elaboration)

is essential to implement teaching approaches that actively diagnose students' problem areas and offer structured, strategic interventions to support deeper understanding and improved problem-solving capabilities.

Effectiveness of TAPPS

All the identified publications explored the effectiveness of TAPPS in algebra word problems. The selected research spanned various educational levels and was conducted across various global regions. **Table 2** summarizes the effectiveness of TAPPS in algebra word problems.

The second research question is related to the effectiveness of TAPPS in enhancing students' algebra problem-solving skills. The distinguishing factors that highlight the effectiveness of TAPPS in this SLR include cognitive skills, collaborative learning, student behavior, and student performance. According to **Figure 3**, the highest factor findings were contributed by collaborative learning, which indicates 33% of the total findings, followed by algebra performance (29%), cognitive skills (25%), and student behavior (13%).

TAPPS, originally known as "Whimbey-pairs," is a collaborative instructional method designed to enhance students' cognitive engagement during problem-solving tasks (Whimbey et al., 2013, as cited in Fadzil & Osman, 2025). Developed by Arthur Whimbey, this strategy emphasizes active verbal reasoning by pairing students and assigning them distinct roles: one as the problem solver and the other as the listener. Accordingly, the problem solver articulates their reasoning process out loud while the listener actively monitors the explanation, prompting clarity and ensuring the thought process continues. In the context of algebra word problems, TAPPS helps students verbalize the steps needed to translate textual information into algebraic expressions, thereby reinforcing conceptual understanding. Moreover, this method supports individual learning and fosters peer interaction, encouraging deeper reflection and critical thinking in tackling complex mathematical problems.

The TAPPS method is a useful cooperative learning activity that requires students to work in groups. The working group process encourages students to improve their communication skills by requiring them to verbalize their ideas and reasoning in addition to listening. This suggests that TAPPS is more focused on the process than the outcome. As a result, TAPPS indirectly enhanced problem-solving abilities in mathematics and produced higher-quality solutions. However, TAPPS also assists students in developing a greater awareness of their own cognitive processes and methods for solving problems. This is very beneficial since grades alone are insufficient to assess pupils' understanding.

Verbalization of thought processes

Students often face difficulties translating word problems into algebraic expressions, solving equations, and interpreting results. In Malaysia, this challenge is heightened by a reliance on rote learning and procedural knowledge rather than deep conceptual understanding (Ling & Mahmud, 2023). In TAPPS, one student verbalizes their problem-solving process, while the other acts as a supportive listener, offering constructive feedback and guided reflection. This interaction encourages metacognitive development, allowing learners to monitor their reasoning, recognize mistakes, and adjust their approaches effectively (Shah, 2019). Rooted in constructivist and social constructivist learning theories, TAPPS highlights the value of active participation and peer interaction in constructing knowledge (Bada & Olusegun, 2015). Thus, students reinforce existing knowledge and deepen their understanding by engaging in thoughtful dialogue and shared analysis, leading to improved mathematical performance and problem-solving abilities.

Solving mathematical problems involves complex cognitive processes in which the brain seeks effective strategies to achieve a specific goal. Therefore, a student's mathematical problem-solving ability can be examined through various levels of cognitive functioning. According to Subia et al. (2020), these levels include remembering, understanding, applying, analyzing, evaluating, and creating. At the basic stage, learners must recall and apply mathematical procedures, which are essential for foundational arithmetic. As they advanced, students were expected to engage in more abstract reasoning for solving algebraic problems and develop spatial thinking skills for tackling geometric and trigonometric tasks. Correspondingly, students who engage in solving mathematical word problems using the TAPPS approach are encouraged to minimize impulsive responses, as the strategy promotes deliberate thinking and structured problem-solving processes.

On the other hand, Kani and Shahrill (2015) investigated how year 9 students approached mathematical problem-solving and how they perceived the TAPPS method. Although the strategy did not significantly improve academic performance or conceptual understanding, it notably enhanced students' awareness of their own thinking processes. This is especially true in interpreting questions and fostering a positive attitude toward mathematics learning by promoting active engagement and reflective problem-solving. Another finding by Fadzil et al. (2024) emphasized that metacognitive skills can be enhanced by implementing the TAPPS strategy, where students are paired and encouraged to think collaboratively through problem-solving tasks. This structured interaction fosters self-awareness and the use of metacognitive strategies, enabling students to monitor their own progress and identify areas of weakness more effectively. Hence, through structured peer collaboration, TAPPS enhances students' cognitive engagement by encouraging them to articulate, reflect, and refine their problem-solving processes.

Peer collaboration

Collaborative learning through the TAPPS strategy has demonstrated significant effectiveness in enhancing students' mathematical abilities. The TAPPS strategy fosters collaborative learning by assigning distinct roles to each student: one takes on the role of the thinker, explaining their reasoning in detail, while the other serves as the listener, actively engaging by prompting, clarifying, and supporting the problem-solving process. According to Widuri and Musdi (2018), the TAPPS instructional approach reflects the cognitive development theories of Piaget and Vygotsky, emphasizing the importance of social interaction and collaboration in learning. Learners actively engage with their teachers and peers, specifically through structured roles as problem solvers and listeners. This interactive process fosters the development of higher-order thinking skills, allowing students to enhance their problem-solving abilities through dialogue, reflection, and shared cognitive engagement (Sultan & Alasif, 2021).

The collaborative environment fostered by TAPPS plays a significant role in shaping students' learning habits and attitudes toward mathematics. By engaging in structured pair work, students are less likely to feel overwhelmed when tackling problems independently, as the shared responsibility reduces anxiety and builds confidence. Furthermore, TAPPS encourages an appreciation for diverse perspectives and problem-solving approaches, deepening students' understanding of the complexity of mathematical reasoning (Simpol et al., 2017). As students experience the satisfaction of collaboratively overcoming mathematical challenges, they develop a more positive mindset and a greater willingness to engage with mathematical concepts. In addition, Sultan and Alasif (2021) noted that cooperation and teamwork are essential components of the TAPPS process, which students are required to actively engage in and adhere to throughout the learning activity.

A previous study by Syafitr et al. (2018) suggested that the TAPPS strategy impacted students' communication abilities in the context of mathematical problem-solving. The findings revealed that TAPPS significantly enhanced students' mathematical communication, as the strategy required learners to engage in meaningful dialogue, explain their reasoning clearly, and collaboratively explore solutions grounded in a solid understanding of mathematical concepts. Widuri and Musdi (2018) also presented the same results, as they mentioned that role division enhances focus and fosters mutual accountability. By clearly outlining what each student must do, TAPPS creates a more organized learning environment that encourages productive interaction, deepens comprehension, and cultivates mathematical thinking and communication skills.

Subsequent findings demonstrate that students in the higher-performing group typically demonstrate strong mathematical communication skills by clearly articulating their ideas in written form and effectively translating problem situations into appropriate mathematical models (Werdiningsih et al., 2019). These students were noted to be proficient in selecting and applying the correct mathematical formulas to solve a mathematical problem. Moreover, their ability to express reasoning both verbally and in writing, along with precise modeling and computation, reflects a deep understanding of mathematical concepts and problem-solving processes. This level of communication enhances their comprehension and supports collaborative learning, as they can clearly convey their thought processes to peers and contribute meaningfully to group discussions.

A few studies highlighted that students who engaged in TAPPS significantly improved their problem-solving abilities (Anggraeni & Andriani, 2019; Fadzil et al., 2024; Fauzan et al., 2019; Mashuri et al., 2018; Widuri & Musdi, 2018). The dynamic interaction between the pair partners allows students to structure their problem-solving abilities compared to traditional methods. Conversely, Nufus and Arnawa (2018) conducted a quasi-experimental study with a randomized group-only design to investigate the effects of TAPPS on students' problem-solving abilities. Their findings demonstrated that students who learn through the TAPPS cooperative model exhibit higher problem-solving abilities compared to those taught using conventional methods. This clearly highlights the positive contribution of the TAPPS approach to enhancing students' problem-solving skills.

Anggraeni and Andriani (2019) stated in their quantitative findings that the combination of TAPPS with audio-visual media had a positive impact on students' critical thinking. Critical thinking is essential for effectively solving word problems, as it enables students to analyze information, make logical connections, and evaluate potential solutions. In line with this, developing this skill allows students to approach complex mathematical tasks with greater confidence and precision. Additionally, further investigation revealed that students' learning styles influenced their effectiveness in using the TAPPS strategy across four stages of problem-solving (Mashuri et al., 2018). The study discovered that auditory learners were best suited to TAPPS due to their strong communication skills, while visual learners excelled in planning, and kinesthetic learners struggled with maintaining focus and reflecting on solutions.

Algebra performance

Emerging findings emphasize that, beyond cognitive development, fostering students' confidence and motivation is essential for effective mathematics studies. Notably, TAPPS has been increasingly recognized for its potential to enhance these affective factors by providing a structured, interactive learning environment that encourages active participation and reflection. Furthermore, Nasution et al. (2022) discovered that students with higher self-efficacy demonstrated stronger problem-solving skills, suggesting that TAPPS positively influences students' confidence in their mathematical abilities. Although Yanuarti et al. (2022) reported different results regarding the impact of TAPPS on mathematics learning achievement, their findings revealed that students' self-confidence was not directly correlated with the use of TAPPS. Instead, they concluded that students' self-confidence was significantly influenced by their own beliefs about learning mathematics.

TAPPS places a strong emphasis on collaboration and teamwork, which, according to Sultan and Alasif (2021), plays a crucial role in fostering meaningful interactions among students. When students develop mutual trust and stronger connections during the problem-solving process, the quality of their discussions and solutions significantly improves. On the other hand, Sönmez and Sulak (2018) noted that while TAPPS may have minimal influence on performance speed, it substantially enhances students' ability to recognize and regulate their cognitive processes. Thus, by encouraging deeper reflection and consideration of diverse viewpoints, TAPPS promotes more effective problem-solving and leads to a richer understanding of mathematical problems (Sultan & Alasif, 2021; Upu et al., 2024). Moreover, the collaborative nature of TAPPS helps to cultivate positive attitudes and behaviors in students, as they are motivated to actively participate, listen attentively, and express their ideas, thus creating a more supportive and engaged learning environment.

Recent investigations have provided further insights into the effectiveness of TAPPS in enhancing students' mathematical competencies. Mohammad (2023) investigated the impact of implementing the TAPPS strategy as an instructional tool to assess its effectiveness. The findings indicated that applying the TAPPS approach had a significant positive effect on students' academic performance in mathematics. Mohammad's (2023) findings align with Widuri and Musdi's (2018) findings that revealed a significant difference in problem-solving abilities between students in the experimental group and those in the control group. This indicates that the TAPPS-based learning approach effectively enhances students' problem-solving skills in trigonometry. According to Widuri and Musdi (2018), the structure of TAPPS provides assigned roles as problem solver and listener, hence students were able to strengthen their critical thinking and reasoning abilities during the problem-solving process.

In addition, Yanto and Wardono (2020) highlighted in their findings that the TAPPS model with Class Dojo support effectively improved students' mathematical literacy at varying levels. High-achieving students mastered nearly all components, while average students struggled with reasoning and formal language. Meanwhile, lower-performing students demonstrated strengths in basic skills, indicating TAPPS' overall effectiveness and highlighting areas needing further support. Next, a study by Fadzil et al. (2024) mentioned the impact of the TAPPS on students' problem-solving behaviors and academic achievement in linear algebra. The results demonstrated that TAPPS effectively enhances strategic thinking and academic outcomes, suggesting a moderate positive relationship between reflective problem-solving and performance.

Another finding by Rif'an (2023) discussed different perspectives on the effectiveness of TAPPS. Rif'an (2023) investigated the effect of integrating the Information Technology-based or IT-based TAPPS to enhance students' problem-solving skills. The IT-based TAPPS model effectively improved students' problem-solving soft skills compared to conventional methods. Motivation and process skills were also noted to influence students' performance significantly. Moreover, Saramika and Banjarnahor (2021) investigated the effects of applying the TAPPS strategy and Student Teams-Achievement Divisions (STAD) cooperative learning, both supported by GeoGebra software, on students' mathematical problem-solving abilities. Findings revealed that students using TAPPS with GeoGebra outperformed those using STAD with GeoGebra. This finding further underscores the significance of integrating TAPPS with supplementary teaching tools and instructional strategies to enhance its overall effectiveness.

Table 3. Effectiveness of the storyboard in the algebra word problem

Factor	Key findings	Study	Results
Visualization and conceptualization	Visuals, memory, bilingual students, and clarity of concept	Ghafar et al. (2023)	Storyboarding improves comprehension and creativity
		Naicker et al. (2020)	
		Ekeh (2023)	
		Powell et al. (2018)	
		Karlimah et al. (2021)	
		Altindağ Kumaş (2024)	
		Putra et al. (2024)	
		Azrillia et al. (2024)	
Sequential thinking	Sequencing ideas, StoryCircles, and narrative scaffolding	Jeon et al. (2024)	Sequencing via storyboarding helps structure lessons
		Taranto (2020)	
		Nissa et al. (2021)	
Creativity	Role-play, real-life link, memory, and storytelling for engagement	Altintas (2018)	Storytelling enhances creative problem-solving
		Ramdani et al. (2024)	

Additionally, Simpol et al. (2017) demonstrated that the integration of the TAPPS and Polya problem-solving strategies was positively received by students, fostering greater participation and engagement in mathematics lessons. Correspondingly, the findings suggest that using TAPPS and Polya strategies simultaneously can significantly strengthen problem-solving abilities, particularly in fractions, provided student pairings are balanced to optimize peer interaction and support. Notably, integrating the TAPPS strategy with audio-visual media has significantly enhanced students' critical thinking skills compared to traditional expository methods. Additionally, this approach promotes active participation, verbal reasoning, and a deeper conceptual grasp through visual support. Therefore, combining TAPPS with multimedia tools offers an effective instructional method for improving critical thinking in mathematics learning.

Effectiveness of Storyboarding and Storytelling

All the identified publications explored the effectiveness of storyboards in algebra word problems. The selected research spanned various educational levels and was conducted across various global regions. **Table 3** summarizes the effectiveness of storyboards in algebra word problems.

Storyboarding is a planning and visualization technique used to map the sequence of content, actions, or interactions in a structured and visual format (Yuliarni et al., 2019). It was established in the animation industry by Walt Disney Studios in the 1930s. Storyboarding has since been acknowledged in modern educational research as a valuable tool for structuring instructional content (Wahid & Aziz, 2022). Its transition into pedagogy reflects its versatility in enhancing lesson planning and instructional design. Moreover, storyboarding is recognized as an effective collaborative instructional approach that enhances the development of organizational competencies within educational settings. It serves as a structured planning tool for designing instructional programs across various scales and complexities. In essence, storyboarding supports systematic thinking and teamwork in the creation of meaningful and goal-oriented learning experiences.

The absence of detailed analysis regarding the essential principles or quality indicators in effective storyboard development highlights a significant research gap (Yuliarni et al., 2019). Specifically, there is limited scholarly attention on how storyboarding aligns with established instructional design frameworks, particularly in the context of mathematics education. Identifying and evaluating multimedia learning storyboards is, therefore, crucial. Furthermore, a well-structured storyboard serves as a visual planning tool and a pedagogical guide that maps out the sequence of content delivery, problem-solving steps, and student interaction. Thus, such an analysis would contribute valuable insights into the design of high-quality educational media.

In educational practice, storyboarding is intrinsically linked with storytelling, as it visually structures the narrative flow to enhance clarity and engagement. By organizing content into sequential frames, storyboarding supports the logical progression of storytelling, making it a valuable tool in instructional design. Together, they foster deeper comprehension and retention by aligning visual and verbal elements within a cohesive learning experience (Andres & Poler, 2017). While storytelling focuses on conveying content through structured and meaningful sequences, storyboarding visually maps out these sequences to ensure clarity, coherence, and engagement (Herbst et al., 2017). In educational contexts, especially mathematics, storyboarding supports storytelling by helping educators structure lesson flow, illustrate problem-solving processes, and create more interactive and learner-centered experiences.

Figure 4 illustrates the storytelling design model (SDM) with the competencies level of the storytelling phases. SDM, grounded in the concept of the visual portrait of story (VPS) by Ohler and Raymond (2008), cited in Albano and Pierri (2017), presents a time-based framework capturing the emotionally significant stages of a narrative. VPS is structured into three main segments: the Beginning, where the protagonist is introduced and confronted with a challenge; the Middle, characterized by increasing tension and the development of complexity; and the End, which reflects resolution and transformation. Moreover, the model emphasizes narrative progression through two primary points of tension, the emergence of a problem and its eventual resolution, supporting cognitive and emotional development throughout the storytelling process.

According to Albano and Pierri (2017), each learning objective has been aligned with a specific level of mathematical competence by referring to Bloom's taxonomy. These levels range from basic understanding in familiar contexts to advanced abstract reasoning and generalization. At level 1, learners follow straightforward instructions within familiar scenarios. Level 2 involves making simple inferences and executing basic procedures, while level 3 includes the ability to apply strategies, interpret data from multiple sources, and explain reasoning. Consequently, level 4 reflects competence in handling complex real-life

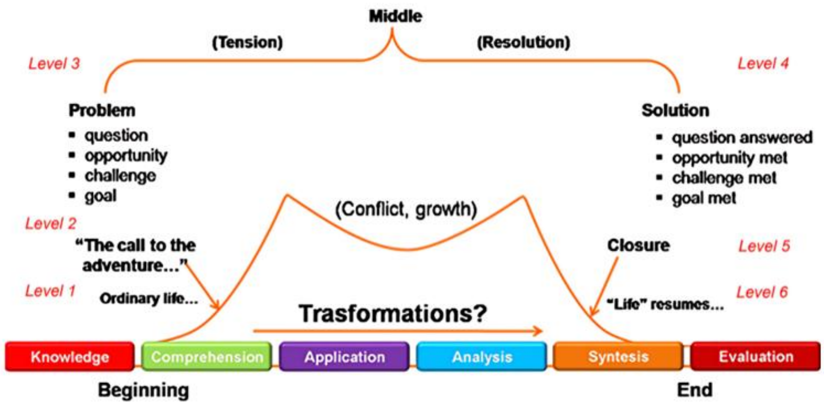

Figure 4. Competencies level with respect to the storytelling phases (Source: Albano & Pierri, 2017)

problems and integrating various representations. Next, level 5 indicates the ability to model sophisticated situations, recognize assumptions, and critically reflect on processes. Finally, level 6 involves high-level abstraction, generalization, and the integration of diverse information for advanced reasoning. This framework connects Bloom's cognitive taxonomy with narrative-based learning, allowing educational designers to map cognitive demand to storytelling phases and support progressive skill development in mathematics.

Visual representation

Bilingual students often struggle with linguistic limitations and unfamiliar writing structures, hindering effective composition. According to Ghafar et al. (2023), incorporating visual tools like storyboards could alleviate these challenges by transforming abstract ideas into organized visual formats. This visual scaffolding supports idea development and coherence, ultimately enhancing the quality of written expression. Notably, storyboarding serves as an effective visual methodology that aids in representing and interpreting complex narrative data. It enables researchers to externalize abstract ideas, facilitating clearer meaning-making while embracing diverse perspectives and emotional dimensions (Naicker et al., 2020). As a visual thinking tool, storyboarding enhances clarity, supports ethical representation, and strengthens the researcher's engagement with participants' lived experiences.

In addition, the study by Ekeh (2023) revealed that students exposed to a storytelling-based instructional approach demonstrated significantly higher performance in solving mathematical word problems than those taught using conventional methods. These findings supported the integration of narrative-based strategies as an effective pedagogical tool for enhancing mathematics achievement in early education settings. Correspondingly, Powell et al. (2018) developed The Telling Board, which enabled children aged 10 to 13 to construct and communicate visual narratives with enthusiasm and creativity. Participants demonstrated strong engagement and a willingness to share their stories, indicating the tool's potential for fostering expressive storytelling. These findings affirmed the effectiveness of the design in enhancing visualization and conceptual understanding while also indicating potential areas for further refinement and development of using storyboards to represent abstract algebraic concepts visually.

In contrast, the ADDIE framework used by Yuliarni et al. (2019), which includes Analysis, Design, Development, Implementation, and Evaluation, provides a structured and iterative approach to designing instructional materials that support analytical and critical thinking. In applying this model to storyboard development, particular attention was required to ensure visual representations aligned with established pedagogical concepts. This is due to the fact that inconsistencies may hinder the clarity and educational value of multimedia resources in mathematics learning. In particular, the storyboard acts as a crucial blueprint, integrating pedagogical goals with visual sequencing to ensure coherence and instructional value. Meanwhile, motion comics serve as engaging educational tools by incorporating animated elements into traditional comic formats, enhancing student interest and interaction (Karlimah et al., 2021).

The use of storyboards played a key role in organizing content visually and sequentially, which helped students better understand mathematical concepts and problem-solving steps (Azrillia et al., 2024). This structured, narrative-based approach contributed to increased clarity and engagement, especially for students who benefit from visual learning methods. In other words, the findings suggested that storyboard-based learning media support comprehension and make lessons more interactive and relatable.

Sequential thinking

Findings by Jeon et al. (2024) highlighted that teachers use strategic sequencing of student work to meet both subject-related goals and individual student needs. They focused on helping students understand math by organizing responses to compare strategies, build procedures, and learn from mistakes. The StoryCircles approach, which includes storyboard planning, helped teachers structure their lessons clearly and effectively (Jeon et al., 2024). Accordingly, storyboarding helps students understand how to follow logical steps in problem-solving and supports teachers in planning and reflecting on their teaching. On the other hand, storytelling is also presented as an effective pedagogical strategy for introducing mathematical concepts to pre-elementary learners by fostering emotional engagement and integrating playful, interdisciplinary activities (Taranto, 2020). By centering around a narrative and its characters, children participate more naturally in tasks designed as a didactical and often hands-on experience. Therefore, embedding mathematics within storytelling and visual planning, such as storyboarding, encourages young learners to engage sequentially and meaningfully with content through both cognitive and emotional pathways.

Altindağ Kumaş (2024) emphasized the positive impact of digital storytelling on the development of early mathematical skills among children with mild intellectual disabilities. Integrating interactive, visual narratives within digital platforms aligns with these students' cognitive preferences and enhances engagement and comprehension. In addition, the use of storyboards in digital storytelling emerges as a meaningful and adaptable method to promote active learning and conceptual clarity in mathematics for students with special needs. On the other hand, Putra et al. (2024) suggested that students taught with the search, solve, create, share model outperformed those under direct instruction in mathematical reasoning and problem-solving. The experimental group demonstrated stronger analysis, clearer explanations, and more accurate solutions. Visual aids like storyboards supported their understanding by helping structure and connect ideas, proving the effectiveness in enhancing thinking skills and student engagement.

Alternatively, Nissa et al. (2021) developed Articulate Storyline 3 with OBAR learning media for grade 8 algebra. This media followed a six-stage design process and was validated by experts as effective and feasible. Storyboarding was central to the media's design, helping present algebraic concepts in a clear, step-by-step sequence that supported students' understanding of abstract ideas. In essence, this visual and structured approach enhanced engagement and made the learning process more accessible and meaningful for students.

Creativity

Integrating storytelling into mathematics instruction allows students to explore content more meaningfully by bridging abstract concepts with relatable experiences. Students emphasized that stories promote memory retention, emotional engagement, physical participation through role-play, and relevance to real-life scenarios (Altintas, 2018). Visual elements such as images and videos further enhance comprehension. Students reported improved empathy, creativity, and understanding of content progression across grade levels. Furthermore, through structured visual storytelling and sequential design, whiteboard animation supports students in developing creative problem-solving skills. Its integration into learning frameworks enhances conceptual understanding and strengthens the ability to think independently and innovatively (Ramdani et al., 2024). In addition, creative thinking is vital in enabling students to generate innovative ideas and discover new solutions to real-world problems. Specifically, whiteboard animation offers several pedagogical advantages. It introduces dynamic and visually engaging content that encourages students to develop critical and creative thinking.

Comparative Insights

In recent years, there has been a growing interest in innovative instructional methods to improve students' mathematical problem-solving skills, particularly in tackling algebra word problems. Among these, the TAPPS strategy and storyboarding have gained significant attention for their distinct cognitive and pedagogical benefits. Studies comparing TAPPS with traditional teaching methods reveal that students exposed to TAPPS tend to outperform their peers in mathematical reasoning and solution accuracy. The structure of TAPPS, where students work in pairs, with one verbalizing their thinking and the other providing feedback, fosters deeper reflection and stronger retention of problem-solving steps (Fadzil et al., 2024; Mohammad, 2023). This contrasts with conventional instruction, which often emphasizes rote memorization and procedural drills, with limited engagement in metacognitive processes (Ling et al., 2019).

Similarly, storyboarding has emerged as an effective visual strategy to support student engagement and comprehension, especially among learners who struggle with abstract reasoning. Research indicates that when students use visual aids like storyboards to map out problem-solving steps, their understanding of algebraic concepts improves significantly (Ghafar et al., 2023; Yuliarni et al., 2019). Unlike traditional lecture-based instruction, which typically centers on teacher explanation and textbook practice, storyboarding allows learners to actively organize their thoughts and visualize the sequence of mathematical operations. This visual scaffolding is especially beneficial for students with lower verbal or reading proficiency, as it enables them to connect mathematical symbols with real-world contexts more intuitively.

The comparative effectiveness of TAPPS and storyboarding also relates to the learning modalities they primarily activate, including verbal and visual. TAPPS emphasizes verbal articulation and peer interaction, aligning well with auditory and social learners who benefit from spoken reflection and collaborative problem-solving. In contrast, storyboarding caters to visual learners by externalizing abstract mathematical ideas into visual frames or sequences. Studies comparing visual and verbal instructional strategies suggest that integrating both modalities enhances problem representation and solution quality in math word problems (Albano & Pierri, 2017; Altintas, 2018). While TAPPS supports the internalization of logic and reasoning through dialogue, storyboarding externalizes thinking processes, making them accessible and traceable.

Moreover, both strategies have been proven to improve affective outcomes, such as student motivation and confidence. TAPPS fosters a sense of shared responsibility and support, which reduces anxiety and encourages risk-taking in mathematical thinking (Sultan & Alasif, 2021). Conversely, storyboarding enhances engagement through creativity and narrative thinking, allowing students to personalize their problem-solving approaches and relate abstract content to familiar experiences. Compared to traditional methods, which often lack these affective benefits, TAPPS and storyboarding offer enriched learning experiences, combining cognitive development with emotional and social support.

In conclusion, comparative studies consistently highlight the superiority of TAPPS and storyboarding over conventional instruction in improving mathematical problem-solving performance. Each method offers unique strengths. TAPPS in verbal reasoning, metacognition, and storyboarding in visual representation and sequencing. Together, they provide complementary pathways for addressing the diverse needs of learners. Therefore, future research should explore hybrid instructional models that integrate these strategies, especially in technology-supported environments, to maximize their combined benefits across different learner profiles.

CONCLUSION

In summary, these results suggest an association between the key indicators of difficulty in mathematization, language comprehension, cognitive processes, and problem representation. The challenges students face in solving algebra word problems are multifaceted and deeply rooted in cognitive and instructional factors. In particular, difficulties such as limited reading comprehension, confusion over mathematical language, and weak mathematical skills hinder students' ability to translate real-world contexts into algebraic expressions. These issues are further exacerbated when educators are unable to accurately diagnose and address students' specific learning needs, leading to the use of ineffective strategies. Without targeted support and a clear understanding of these barriers, students are likely to continue facing obstacles in developing strong problem-solving skills. Hence, addressing these challenges requires a more informed, strategic, and student-centered approach to mathematics education.

The literature reveals that students face various challenges in solving algebra word problems stemming from cognitive, linguistic, and instructional shortcomings. Common difficulties include poor reading comprehension, misunderstanding of algebraic terminology, and limited ability to translate textual information into mathematical models. Additionally, the lack of strategic flexibility and insufficient exposure to effective problem-solving approaches further impede students' success. These challenges are often compounded by teaching practices that do not adequately identify or address students' underlying difficulties. Therefore, it is essential for future research and educational interventions to focus on addressing these multifaceted issues through more adaptive, inclusive, and strategy-rich instructional practices.

TAPPS has proven to be an impactful pedagogical method by encouraging students to think aloud, reflect on their reasoning, and receive immediate peer feedback. It enhances cognitive and social dimensions of learning, making it easier for students to engage with abstract mathematical problems. Meanwhile, storyboarding supports students in organizing their ideas visually and understanding complex concepts through narrative sequencing. This dual engagement, which is both verbal and visual, will help build a more holistic mathematical understanding, especially for students who benefit from diverse instructional modalities.

In integrating TAPPS and storyboarding, educators have a powerful opportunity to deliver differentiated instruction that caters to varied learning styles. These strategies offer complementary strengths that, when used in tandem, can substantially improve students' confidence, comprehension, and problem-solving performance. In real-world classrooms, hybrid models that combine verbal reasoning and visual planning should be implemented and further researched to optimize instructional effectiveness and close persistent learning gaps in mathematics education.

Limitations of the Study

While this SLR provides valuable insights into the effectiveness of TAPPS and storyboarding strategies in addressing students' difficulties with algebra word problems, several limitations must be acknowledged. First, the review is limited to studies published in English between 2015 and 2025, potentially excluding relevant findings published in other languages or outside this time frame. Second, the review relies predominantly on peer-reviewed journal articles and conference proceedings, which may introduce publication bias, as studies with non-significant or unfavorable results are less likely to be published. Third, while thematic synthesis was used to categorize findings, the diversity in research designs, sample sizes, and educational contexts across the included studies may limit the generalizability of the conclusions. Additionally, few included studies assessed long-term effects or follow-up outcomes, making it difficult to determine the sustainability of learning gains. Finally, due to the descriptive nature of the included studies, this review is unable to establish causal relationships between the implementation of TAPPS or storyboarding and improvements in student performance.

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