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Student's Mathematical Problem-Solving Skills and Self-Efficacy on Word Problems through Technology-Based Learning

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ABSTRACT

Students' ability to solve mathematical word problems is closely linked to their mathematical problem-solving skills and self-efficacy. This study examines the influence of two technology-based learning approaches, namely synchronous learning through Zoom and Google Meet and asynchronous learning through WhatsApp, on students' problem-solving performance and self-efficacy levels. The research involved 27 seventh-grade students in Bandung and employed a mixed-method design with an explanatory sequential approach. The findings revealed a strong relationship between the type of technology-mediated learning and students' self-efficacy in mathematical problem solving. Students who engaged in synchronous learning demonstrated better performance in interpreting problems, developing strategies, and justifying solutions compared to those who used asynchronous methods. Learners with moderate to high self- efficacy consistently outperformed those with low self-efficacy, particularly in identifying relevant information, making conjectures, and generalizing patterns. In contrast, students with low self-efficacy showed difficulties in solving word problems and exhibited limited use of key processes in mathematical problem solving. These results emphasize the importance of aligning instructional approaches with students' self-efficacy levels and providing structured support for students involved in asynchronous learning to strengthen their mathematical problem-solving abilities.

Keywords: Mathematical Problem Solving, Self-Efficacy, Word Problems, Synchronous Learning, Asynchronous Learning.

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Introduction

The development of digital technologies in education has created different types of learning paradigms, such as synchronous and asynchronous learning. In synchronous learning, students attend classes using Zoom or Google Meet, and these platforms allow for interaction and instant feedback, fostering engagement (Mairing et al., 2021). Asynchronous learning, on the other hand, free students from time constraints, using communication tools such as WhatsApp, thus, enabling self-paced learning (Arianto et al., 2022). Both approaches improve accessibility and flexibility; however, their suitability for mathematics instruction remains a concern (Orhani, 2024).

As with other disciplines, mathematics demands advanced thinking skills, especially within the context of mathematical problem solving. Mathematical problem solving is an essential mathematical skill, useful not only in academics, but also in making informed decisions in daily life (Polya, 1945; OECD, 2019). Some of the most challenging skills to master are the ones involved in solving word problems, as the students need to interpret a statement and convert it into mathematical form (Depaepe et al., 2015; Pongsakdi et al., 2020; Verschaffel et al., 2020). Anderson & Krathwohl (2001) explain that most students experience difficulties because of the word problems' intricate language, whereas Audi (2004) and Depaepe et al. (2015) focus on the challenges posed by unframing pertinent details and appropriate strategy choice. These students frequently experience cognitive overload, which prevents the problem from being solved in an effective manner. This pattern has also been noted by Pongsakdi et al. (2020) and Verschaffel et al. (2020).

A preliminary study conducted in a junior high school in Bandung revealed that a significant number of students failed to reach the minimum passing grade when solving word problems. Interviews with students showed that they perceived word problems as more confusing and difficult than standard numerical exercises. As these difficulties accumulated, students' problem-solving performance declined and was accompanied by a loss of confidence. Several participants expressed uncertainty about their ability to complete mathematical tasks on their own, indicating a reduced level of self-efficacy (Bandura, 1997; Yildiz & Özdemir, 2019; Zhou et al., 2020).

Self-efficacy plays a crucial role in influencing students' mathematical performance. Students with high self-efficacy are more likely to persevere, stay motivated, and engage in effective problem-solving strategies (Bandura & Schunk, 1981). In contrast, Students who reported low self-efficacy in this study tended to avoid challenging problems and doubted their own ability to solve them, a pattern that aligns with findings that negative experiences and emotional factors weaken learners' confidence (Usher & Pajares, 2009).

In the context of digital instruction, synchronous and asynchronous learning approaches may influence students' learning experiences in different ways. Research indicates that synchronous learning fosters a more interactive environment that mimics traditional classrooms, thereby supporting deeper conceptual understanding (Kusuma & Hamidah, 2020). However, technical challenges such as unstable internet connections and limited access to devices remain obstacles, particularly for students in underserved areas. On the other hand, asynchronous learning offers greater flexibility, but it often limits immediate feedback and active engagement. These aspects are critical for mastering complex mathematical tasks such as word problems.

Although previous studies have examined the effectiveness of individual platforms or the role of self-efficacy in mathematics learning, few have explored the combined influence of technology-based learning approaches, self-efficacy, and mathematical problem-solving skills, particularly in the context of word problems. This research seeks to address that gap by investigating how synchronous and asynchronous learning approaches affect students' problem-solving performance and how self-efficacy moderates that relationship.

The purpose of this study is to analyze the effectiveness of synchronous and asynchronous learning in enhancing students' mathematical problem-solving skills when working with word problems. In addition, it aims to examine the influence of self-efficacy on students' performance. By exploring the interplay between instructional approach, self-efficacy, and mathematical problem solving, this study contributes to the development of more adaptive and context-sensitive instructional strategies for mathematics education in the digital era.

Methods

This study employed a mixed-methods approach using an explanatory sequential design, which began with the collection and analysis of quantitative data, followed by qualitative exploration for deeper understanding (Setiawan et al., 2025; Salajegheh et al., 2024; Mansoor et al., 2025). The research was conducted in three junior high schools in Bandung, namely SMP Salman, SMP Baitul Izzah, and SMPN 51, involving 27 seventh-grade students selected through purposive sampling. The sampling criteria included students' access to digital learning tools, prior experience with word problems, and representation across three self-efficacy levels: low, moderate, and high.

Quantitative data were collected in three main phases. First, students' mathematical problem-solving skills were assessed through pretests and posttests focusing on their ability to interpret, strategize, and justify solutions to word problems. The test instrument was developed based on key cognitive processes in mathematical problem solving, focusing on the topic of *arithmetic sequences and series*. The items were designed to measure students' abilities in identifying patterns, determining general terms, and solving contextual problems involving both arithmetic sequences and the sums of their terms. The instrument was validated by three mathematics education experts and demonstrated strong internal consistency (Cronbach's alpha = 0.82). In addition to comparing mean scores, normalized gain (N-Gain) was calculated to measure the improvement in students' problem-solving performance as a result of the instructional intervention. The N-Gain was computed using the formula:

N-Gain = (Posttest score – Pretest score) / (Maximum score – Pretest score),

and interpreted based on established criteria (Hake, 1998) to determine the effectiveness of the learning intervention.

Second, students participated in a three-week learning intervention utilizing two types of technology-based instructional approaches: (1) Synchronous learning, facilitated through Zoom and Google Meet, involved real-time lessons, teacher-student interaction, and collaborative discussions using breakout rooms. In this study, synchronous learning is differentiated based on the platform used, namely Zoom Meeting and Google Meet. Although both are video-conferencing tools, they have different characteristics that may influence students' learning experiences. Zoom offers more diverse features, such as *breakout rooms*, more flexible host controls, and more stable displays when accommodating a large number of participants. In contrast, Google Meet is simpler, directly integrated with Google accounts, and generally lighter in terms of device and network requirements.

These differences in characteristics are assumed to affect interaction, comfort, and student participation during the learning process. Therefore, in this study, synchronous learning is not treated as a single category but is divided into two groups, Zoom-based synchronous learning and Google Meet-based synchronous learning, so that the effects of each platform on the learning process and outcomes can be analyzed more specifically and accurately. (2) Asynchronous learning, delivered through WhatsApp, involved independent study with instructional lesson, tasks, and teacher feedback provided in a non-real-time format. All instructional content focused on mathematical word problems and was standardized across all groups to ensure consistency in learning objectives and content scope.

Third, students' self-efficacy levels were measured using a 10-item questionnaire administered at the beginning of the learning process, prior to the implementation of the instructional treatments, which assessed dimensions such as confidence, persistence, and coping strategies in mathematics. Responses were rated on a 5-point Likert scale and categorized into high, moderate, and low self-efficacy groups.

To complement the quantitative findings, qualitative data were collected through classroom observations and semi-structured interviews with selected students and teachers. The students were purposively selected based on their performance levels (high, medium, and low) and their level of participation during learning activities, while the teachers were chosen based on their direct involvement in implementing the instructional treatments. Observations focused on student engagement, interaction styles, and problem-solving behaviors, recorded in detailed field notes. Semi-structured interviews were chosen to allow flexibility in exploring participants' perspectives while maintaining a consistent set of guiding questions. This format enabled the researcher to probe further based on participants' responses and clarify emerging themes. The interview protocol covered topics such as students' perceptions of synchronous and asynchronous learning, their engagement with mathematical tasks, and challenges they faced during the intervention. Interviews explored students' experiences, challenges, and learning preferences related to synchronous and asynchronous instruction. All interviews were audio-recorded and transcribed verbatim for analysis.

Data analysis involved both quantitative and qualitative procedures. Quantitative data were analyzed using descriptive statistics to summarize performance trends. Two-way ANOVA was used to examine the effects of instructional approach and self-efficacy level on students' problem-solving outcomes. Post hoc tests were conducted to explore significant group differences. In addition, N-Gain scores were analyzed to assess learning improvement across the different instructional settings and self-efficacy levels.

Qualitative data were analyzed thematically through coding of recurring patterns and themes from interview transcripts and observation notes. The analysis process began with data familiarization, where transcripts and field notes were read multiple times to gain a deep understanding. This was followed by initial coding using open coding techniques to identify key segments related to student engagement, learning experiences, and instructional preferences. These codes were then grouped into categories and refined into overarching themes through axial and selective coding. To enhance consistency, two researchers independently coded a subset of data and discussed discrepancies to reach consensus.

To ensure the validity and trustworthiness of the findings, data triangulation was applied by comparing results across interviews, observations, and questionnaire responses (Morgan, 2024; Ahmed, 2024). The convergence of themes across multiple data sources supported the credibility of the findings. For example, themes identified in interview data were consistently reflected in classroom observations and questionnaire responses, indicating strong internal validity. In addition, member-checking was conducted by inviting participants to review and verify the interpretations and summaries of the findings. Participants generally confirmed the accuracy of the interpretations, and minor clarifications provided were incorporated into the final analysis. This process further reinforced the trustworthiness and authenticity of the qualitative results.

Results and Discussion

A. Learning Observation

Differences in student engagement were evident between synchronous and asynchronous learning. In Google Meet, students tended to be passive due to the structured format. In contrast, Zoom fostered more dynamic interaction, especially through breakout rooms, enabling students with moderate to high self-efficacy to participate more confidently (Serhan, 2020). In WhatsApp (asynchronous), communication was mostly one-way, which caused difficulties for students, especially those with low self-efficacy, in solving word problems without real-time feedback (Bandura, 1997).

B. Pretest Results Based on Self-Efficacy Levels

Students with high self-efficacy achieved higher scores compared to those with moderate and low levels. The lowest scores were recorded in asynchronous learning, reinforcing that the lack of interactive scaffolding hinders comprehension of word problems (Kusuma & Hamidah, 2020). The differences in average scores are shown in Table 1.

Table 1. *Average Pretest Problem-Solving Scores by Self-Efficacy*

	Google Meet	WAG	Zoom Meet
High	31.67	20.25	38.00
Medium	26.00	12.33	26.00
Low	30.33	15.33	25.67

C. Posttest Results Based on Self-Efficacy Levels

All groups showed improvement, but students with high self-efficacy in synchronous learning (especially Zoom) achieved the most substantial gains (Serhan, 2020). Conversely, students with low self-efficacy in asynchronous settings continued to struggle with problem interpretation and solution formulation (Verschaffel et al., 2020).

Table 2. *Average Posttest Problem-Solving Scores by Self-Efficacy*

	Google Meet	WAG	Zoom Meet
High	45.00	31.67	45.00
Medium	33.67	19.00	42.67
Low	30.33	14.67	29.67

The results of the two-way ANOVA test revealed that both the learning approach and self-efficacy level had a significant main effect on students' mathematical problem-solving skills in the posttest. Specifically, the type of technology-based learning (synchronous vs asynchronous) significantly influenced students' performance $F(2, 18) = 11.528,\ p = 0.001$, as did their level of self-efficacy $F(2,18) = 8.201, p = 0.003$.

However, there was no significant interaction between the learning approach and self-efficacy level $F(4, 18) = 0.453,\ p = 0.769$. This indicates that the effect of instructional approach on students' problem-solving outcomes did not vary depending on students' self-efficacy level, and vice versa.

The overall model was statistically significant, explaining approximately 69.6% of the variance in posttest scores $R^2 = 0.696, Adjusted\ R^2 = 0.561$.

Table 3. *Two-Way ANOVA of Post-test Problem-Solving Skills*

Source	F	Sig.	Interpretation
Learning Approach	11.528	.001	Significant effect
Self-Efficacy	8.201	.003	Significant effect
Learning Approach × Self-Efficacy	0.453	.769	Not significant (no interaction)

Post hoc analysis using pairwise comparisons further confirmed that there were significant differences in students' posttest scores across the three learning platforms. The synchronous learning approaches (Zoom and Google Meet) resulted in significantly higher problem-solving scores compared to the asynchronous approach (WhatsApp).

Among the synchronous platforms, Zoom showed the highest mean score, likely due to its interactive features such as breakout rooms that support student collaboration and engagement. This supports previous findings (Serhan, 2020) on the efficacy of interactive digital environments for promoting mathematical understanding. In contrast, students in the WhatsApp group, particularly those with low self-efficacy, showed the lowest improvement, underscoring the challenges of self-directed learning in less interactive environments.

D. Improvement in Mathematical Problem-Solving Skills (N-Gain)

The N-Gain analysis showed the greatest improvement among high self-efficacy students in Zoom learning ($\boldsymbol{N-Gain=1.00}$), while the lowest was found among low self-efficacy students in WhatsApp learning ($\boldsymbol{N-Gain=-0.18}$). This confirms that synchronous learning, particularly via Zoom, was the most effective in enhancing mathematical problem-solving skills, especially for students with moderate to high self-efficacy. In contrast, the limited feedback and interaction in WhatsApp posed significant challenges (Kusuma & Hamidah, 2020). Table 4 illustrates the average N-Gain scores across groups.

Table 4. *N-Gain in Problem-Solving by Self-Efficacy and Approach*

	Google Meet	WAG	Zoom Meet
High	1.00	0.53	1.00
Medium	0.43	0.01	0.90
Low	0.07	-0.18	0.23

E. Hypothesis Testing on the Improvement of Students' Mathematical Problem-Solving Skills.

The two-way ANOVA results showed that both the type of technology-based learning approach and students' self-efficacy levels had a significant effect on improving problem-solving skills ($p < 0.05$). Unlike the previous analysis of posttest scores, this test detected a significant interaction between the two variables, $F = 4.768, p = 0.008$. This indicates that the effectiveness of instructional approaches depended on students' self-efficacy levels, and vice versa. Overall, synchronous learning (Zoom, Google Meet) yielded greater improvement than asynchronous learning (WhatsApp), while students with high self-efficacy consistently demonstrated stronger progress than those with low self-efficacy. These results highlight that instructional effectiveness is shaped by both cognitive and affective factors.

Table 5. *Two-Way ANOVA of Problem-Solving Improvement*

Source	F	Sig.	Interpretation

Learning Approach	56.303	.000	Significant effect
Self-Efficacy	102.156	.000	Significant effect
Learning Approach × Self-Efficacy	4.768	.008	Significant interaction

F. Enhancing Students' Mathematical Problem-Solving Skills through Synchronous and Asynchronous Learning Based on Self-Efficacy Levels

Further analysis confirmed significant differences in the average N-Gain scores across platforms (Zoom, Google Meet, WhatsApp). Post hoc tests revealed that synchronous approaches (Zoom and Google Meet) consistently outperformed WhatsApp in fostering students' understanding of mathematical word problems (Adedoyin & Soykan, 2023; Kusuma & Hamidah, 2020). Classroom observations reinforced these findings: Zoom and Google Meet enabled real-time interaction, direct teacher explanations, and engagement monitoring via webcam (Romero-Ivanova et al., 2020), whereas WhatsApp lacked feedback and interactivity. Prior studies similarly confirmed the advantages of synchronous platforms in supporting cognitive engagement (Kusuma & Hamidah, 2020; Martin et al., 2024; Romero-Ivanova et al., 2020), though they may also cause technological fatigue (Serhan, 2020).

Nevertheless, the most notable challenges were found among students with low and moderate self-efficacy, who tended to be passive, hesitant to ask questions, and required constant prompting. This is consistent with Bandura's (1997) theory on the role of self-efficacy in academic behavior. The ANOVA further indicated that students with high self-efficacy achieved significantly greater improvement compared to moderate and low groups, while the difference between moderate and low groups was not statistically significant (Yildiz, 2023).

Qualitative findings supported these patterns: students with low to moderate self-efficacy frequently struggled with understanding problem contexts, recalling formulas, and identifying strategies, relying instead on mechanical rather than conceptual thinking (Hillock & Shulman, 1999; Verschaffel et al., 2020). Remote learning environments worsened these difficulties, as students reported anxiety, cognitive overload, and physical tension that undermined performance. Bandura (1997) emphasized that such physiological states can reduce confidence and resilience in learning. Thus, adaptive instructional strategies—such as scaffolded feedback, structured practice, and motivational support—are essential, particularly for low self-efficacy students when tackling complex mathematical word problems.

G. Student Interviews Based on Self-Efficacy Level

To gain deeper insight into students' perspectives on mathematics learning and the challenges encountered across different learning approaches, semi-structured interviews were conducted with selected students representing various self-efficacy levels. The findings are summarized as follows:

The qualitative data were analyzed using thematic analysis, resulting in several overarching themes that describe students' experiences and behaviors in learning mathematics across different levels of self-efficacy. These themes include: (1) perceptions of mathematics, (2) difficulties with word problems, (3) preferences for learning platforms, (4) problem-solving strategies, and (5) teachers' observations of student behavior. Each theme represents a pattern that consistently emerged across interviews and classroom observations. The excerpts presented below illustrate representative responses within each theme.

1. Perceptions of Mathematics

a. High Self-Efficacy Students: These students generally perceived mathematics as a meaningful and stimulating subject. One participant noted, *"I like math because it trains my logic, especially when solving difficult word problems, even though it sometimes takes time to understand."*

b. Low and Moderate Self-Efficacy Students: Students in these categories expressed feelings of confusion and difficulty, particularly when dealing with word problems. A student with low self-efficacy commented, *"I often get confused when reading word problems, especially if they are long and have many numbers."*

2. Difficulties with Word Problems

a. Low Self-Efficacy: These students reported challenges in recalling appropriate formulas and problem-solving steps. One participant stated, "Sometimes I forget the formulas, so I just guess the answer."

b. High Self-Efficacy: In contrast, high self-efficacy students showed more confidence and strategy in problem-solving. One explained, "I usually write *down all the information first, then figure out how to solve the problem."*

3. Preferences for Learning Platforms

a. Zoom (Synchronous): High self-efficacy students favored Zoom due to its breakout room feature, which supported collaborative learning and peer discussion. As one student expressed, "The breakout room discussions helped me understand the concepts, especially when my peers had different ways of solving problems."

b. WhatsApp Group (Asynchronous): Some students with low self-efficacy preferred the WhatsApp platform, appreciating the flexibility and reduced pressure to interact. One student shared, "Learning in the WhatsApp group is more comfortable because I can review the lesson anytime without needing to ask directly."

4. Problem-Solving Strategies

a. Low and Moderate Self-Efficacy: These students often relied on trial-and-error or mimicking examples from textbooks or peers. A moderate self-efficacy student stated, “I look at examples in the book or my friends’ answers; sometimes it works, sometimes it doesn’t”.

b. High Self-Efficacy: Students in this group tended to use more systematic and logical approaches, aligning with instructional strategies taught in class. One remarked, *"I try to understand the word problem by breaking down the information and applying the formulas the teacher taught us."*

5. Teachers’ Observations

Teachers also recognized distinct behavioral patterns among students with varying self-efficacy levels:

a. A participating teacher stated, "High self-efficacy students usually try to solve the problem on their own before asking for help, while others often wait for assistance."

b. Another teacher noted the greater dependency of some learners, stating, *"They [students with low self-efficacy] often give up halfway unless they are helped immediately."*

These findings underscore the importance of self-efficacy as a mediating factor in how students engage with mathematics learning and utilize available learning tools. Interactive and supportive environments – such as Zoom’s collaborative features – can foster deeper understanding and motivation, particularly for students with lower confidence in their abilities. Tailoring instructional strategies to students’ self-beliefs can therefore play a critical role in improving mathematical problem-solving outcomes.

H. Tendencies in Students’ Mathematical Problem-Solving According to Self-Efficacy Levels

This study examines students’ mathematical problem-solving tendencies in relation to their self-efficacy levels, employing Stacey (2006) framework, which comprises four key components: specialization, generalization, conjecture, and convincing. Data were derived from students’ written responses, triangulated with interviews involving both students and teachers.

Findings indicate two main groups of problem-solving approaches. The first group demonstrated mastery of specialization, conjecture, and generalization, yet failed to reach the stage of convincing. In contrast, the second group successfully exhibited all four components and, in addition, employed extended cognitive strategies such as substantive thinking (Fyhn, 2008; Hillock & Shulman, 1999; Millar, 2000) and information filtering (Polya, 1957).

Students with high self-efficacy displayed advanced problem-solving competence, including the ability to interpret problems, conduct accurate calculations, identify patterns, and justify their reasoning (Dwirahayu et al., 2018; Lane & Harkness, 2012; Leron, 2003; Stacey, 2006; Tall, 2009). They were also able to select relevant information while disregarding irrelevant details (Anderson & Krathwohl, 2001; Polya, 1957), and consistently demonstrated confidence, active engagement, and self-reflection (Bandura, 1997; Sunaryo, 2017; Suryani et al., 2020; Usher & Pajares, 2009).

Students with moderate self-efficacy showed adequate understanding by translating problems into numerical relations but frequently committed errors in applying formal concepts. Their reasoning often relied on contextual knowledge derived from daily experiences (Fyhn, 2008; Hillock & Shulman, 1999; Millar, 2000). They were proactive in seeking assistance and engaging in group discussions (Bandura & Schunk, 1981; Sunaryo, 2017; Suryani et al., 2020), which in turn reduced mathematics anxiety and supported comprehension (Yildiz & Özdemir, 2019; Zhou et al., 2020).

Meanwhile, students with low self-efficacy demonstrated limited competence. Their responses often reflected mere memorization of formulas without adequate comprehension, leading to misinterpretations and incorrect calculations (Spindler, 2020). They tended to rely on peers' answers, showed passivity in classroom interactions, and experienced high levels of anxiety, which negatively impacted academic performance (Bandura, 1997; Parker et al., 2014).

Overall, the study highlights that the effectiveness of digital learning environments is strongly mediated by students' self-efficacy levels and instructional modes. Synchronous learning platforms (e.g., Zoom) were found to be most effective for high self-efficacy students, whereas those with lower self-efficacy struggled particularly with conjecture and justification. These findings suggest that teachers should integrate interactive and scaffolded instructional strategies, provide constructive feedback, and design contextual learning experiences to foster both mathematical problem-solving skills and students' self-efficacy.

Conclusion

This study demonstrates that the effectiveness of digital learning platforms in enhancing students' mathematical problem-solving skills is shaped by both instructional mode and self-efficacy. Synchronous learning tools, particularly Zoom, yielded the highest improvements, especially for students with high self-efficacy who performed strongly across all components of mathematical thinking. In contrast, students with lower self-efficacy experienced greater difficulties in conjecture and justification, often showing less confidence in validating their reasoning. These findings emphasize that learning outcomes are influenced by the integration of instructional strategies and psychological factors.

Based on these findings, teachers are encouraged to prioritize synchronous and interactive environments that provide scaffolding and collaborative opportunities. Instruction should be adapted to different self-efficacy levels by offering guided practice, constructive feedback, and structured support where needed. Embedding metacognitive strategies such as justification, self-checking, and reflection, alongside contextual learning linked to real-life experiences, can strengthen students' reasoning and engagement. Future research is recommended to design interventions that integrate contextual learning, adaptive scaffolding, and collaborative approaches across diverse digital platforms to further enhance problem-solving skills and self-efficacy.

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