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The Effectiveness of Mathematics Learning with an Open-Ended Approach Reviewed from Students' Self-Regulated Learning

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Abstract

This study investigates the effectiveness of mathematics learning with an open-ended approach in improving students' Self-Regulated Learning (SRL) compared to the conventional scientific approach in Indonesian junior high schools. A quasi-experimental design with pretest-posttest control group was employed at a Muhammadiyah Junior High School in Yogyakarta, involving 48 grade VIII students divided into experimental (open-ended approach) and control (scientific approach) groups. Data were collected using a validated SRL questionnaire measuring three dimensions: cognitive, motivational, and behavioral. The intervention was conducted over four learning sessions on linear function topics, with data analysis including paired t-tests, one-sample t-tests, and Hotelling's T^2 test at a significance level of 0.05. The results showed that the open-ended approach significantly improved students' SRL with an average increase of 10.16 points (from 65.38 to 75.54, p = 4.613e-06), surpassing the control group's increase of 8.77 points. The motivation dimension demonstrated the largest improvement (5.70 points), followed by behavioral (3.04 points) and cognitive (1.50 points) dimensions. Following the intervention, 92% of experimental class students achieved high or very high SRL categories, compared to 87.5% in the control class. Hotelling's T^2 test confirmed significant differences between approaches, with the open-ended method proving more effective in developing students' autonomy, responsibility, and self-reflection. These findings suggest that open-ended learning effectively fosters intrinsic motivation and learning independence, making it a recommended strategy for developing SRL in 21st-century mathematics education.

Keywords: *Self-Regulated Learning; Open-Ended Approach; Mathematics Learning*

Introduction

Mathematics education in the 21st century era faces increasingly complex challenges. Along with the development of technology and changing job market needs, students are not only required to master mathematical concepts, but also develop continuous independent learning skills (Howard et al, 2019) One of the crucial aspects of modern learning is Self-Regulated Learning (SRL), which is the ability of students to manage their learning process independently through planning, monitoring, and self-evaluation. The urgency of developing SRL becomes even more important considering that this ability not only supports academic achievement but also prepares students to become lifelong learners who can adapt to rapid changes in the digital era (Feraco et al, 2023).

Problems faced in mathematics learning in Indonesia include the low ability of students to manage independent learning and the lack of innovation in teaching methods (Tesi et al, 2018; Wanelly & Fauzan, 2020). PISA survey data 2022 shows that the mathematical ability of Indonesian students is still relatively low, with a score of 366 points, far below the OECD country average of 472 points. This condition indicates the need for fundamental changes in the approach to mathematics learning that can facilitate the development of student learning independence. Furthermore, several studies have shown that students' SRL levels in mathematics learning are still in the low to moderate category, which is caused by learning approaches that are less supportive of the development of student autonomy (Rahmatika & Waluya, 2023).

Self-Regulated Learning is defined as the ability of students to manage their learning process independently, including planning, monitoring, and self-evaluation (Zimmerman, 1989). SRL encompasses three main interrelated dimensions: (1) the cognitive aspect, which involves understanding learning needs and setting learning goals; (2) motivational aspects, which include self-confidence and learning initiatives; and (3) behavioral aspects, which include the application of effective learning strategies and evaluation of learning outcomes. The importance of SRL lies in its ability to create learners who are independent and responsible for their own learning (Lawson et al., 2023). Research by Pekrun et al (2002), emphasizes that SRL enables students to flexibly adjust their learning strategies according to tasks and progress, thereby supporting better academic achievement.

The open-ended approach offers a potential solution to improve students' Self-Regulated Learning. This approach is a learning method that presents a mathematical problem with more than one correct solution or solution method (Becker & Shimada, 1997; Kwon et al, 2006). By providing open-ended problems that allow for a variety of solution strategies, this approach encourages students to take initiative, think independently, and develop personalized learning strategies (Grace et al, 2022). The main characteristics of the open-ended approach include: (1) open problems with multiple possible correct answers; (2) students' freedom in choosing solution strategies; (3) emphasis on the thought process rather than the final result; (4) encourage active participation and collaboration of students; and (5) the creation of a learning environment that supports creativity and independence (Kholil, 2020; Kurniawati et al, 2020).

The relationship between the open-ended approach and Self-Regulated Learning is very close and theoretically grounded. By providing freedom in choosing completion strategies, this approach encourages students to identify their own learning needs, increase intrinsic motivation, practice the application of various learning strategies, and facilitate self-reflection (Kwon et al, 2006). According to Ali, et al (2021), the stages in open-ended learning—starting from understanding the problem, constructing solutions individually and in groups, to presenting results—systematically involve various aspects of SRL. At the stage of understanding and constructing problems, cognitive aspects of SRL are very active, where students need to plan strategies to understand problems and monitor their understanding. During the exploration and problem-solving stage, behavioral aspects of SRL become important as students must manage time and available resources effectively. Furthermore, at the presentation and discussion stage, motivational aspects of SRL are strengthened through increased self-confidence and the formation of clearer learning goals for the future.

Previous research has shown that learning with an open-ended approach can significantly improve students' SRL. The study by (Nufus et al., 2024) showed that the implementation of the open-ended approach to SRL showed a significant increase in students' pretest and posttest results, where students' average SRL scores increased from 27.6% (pretest) to 64.07% (posttest) after the implementation of the open-ended approach. Similarly, (Rahmatika & Waluya, 2023) concluded that the open-ended approach successfully increased students' self-regulated learning because this method encouraged students to be actively involved in the learning process, take initiative in determining problem-solving strategies, and collaborate with classmates. In addition, (Githua & Changeiywo, 2021) found that the open-ended approach significantly increased students' learning motivation by encouraging active involvement and interaction in learning, providing space for students to explore solutions and share ideas.

Although research has identified potential benefits of the open-ended approach, there is still a gap in the literature regarding the specific mechanisms by which this approach develops the dimensions of SRL in the context of mathematical learning, particularly in Indonesian junior high school settings. Most previous studies focused more on general academic achievement or cognitive aspects, with less in-depth attention to transformations across all dimensions of SRL (cognitive, motivational, and behavioral) holistically. This study aims to describe in detail the effectiveness of mathematics learning with an open-ended approach reviewed from students' Self-Regulated Learning, with a special focus on the analysis of improvements in the three dimensions of SRL (cognitive, motivational, and behavioral) as well as transformations in the distribution of students' SRL levels. Furthermore, this research also compares the effectiveness of the open-ended approach with the scientific approach that is currently dominantly used in the Indonesian curriculum, thereby providing empirical evidence for educators in choosing the most optimal learning approach to develop students' SRL in mathematics learning.

Method

Research Design and Participants

This study uses a quasi-experimental design with a pretest-posttest control group design, carried out at one of the Muhammadiyah Junior High Schools, Yogyakarta during October-November 2024. The research sample consisted of 48 students of class VIII who were selected through purposive sampling, with 24 students in class VIII B as the experimental class (open-ended approach) and 24 students in class VIII C as the control class (scientific approach). The learning material used is a straight-line equation (linear function) which is delivered during four learning meetings, with two additional meetings for pretest and posttest.

Instruments

The data collection instrument used was a Self-Regulated Learning (SRL) questionnaire with 25 statement items measured using a four-category Likert scale (Strongly Agree, Agree, Disagree, Strongly Disagree). The questionnaire was given twice, namely before learning (pretest) and after learning (posttest), to measure the three dimensions of SRL: cognitive (understanding learning needs, setting goals, mind management), motivation (confidence, learning initiative, overcoming distractions), and behavior (application of strategies, evaluation of results, use of time). Additional instruments in the form of observation sheets on learning implementation are used to ensure that both learning approaches can be implemented consistently.

Validity and Reliability

The validity of the instrument has been tested through the validity of the content using the Aiken formula with two expert validators, resulting in a validity index of 0.81 (high criterion), as well as the validity of the construct through factor analysis which results in a KMO value of 0.66 (continuable). The reliability of the SRL questionnaire instrument was tested using Cronbach's Alpha with a result of 0.85, indicating high reliability, and a Standard Error of Measurement (SEM) of 3.362 indicating a low measurement error rate.

Effectiveness Criteria

The criteria for the effectiveness of the learning approach were set including: (1) a significant increase from pretest to posttest ($p < 0.05$), (2) the average posttest reached a minimum of 68.75 points (75% of the ideal maximum score), and (3) a minimum of 75% of students reached the "high" or "very high" category.

Data Analysis

Data analysis was carried out in two stages: descriptive analysis included the calculation of the mean, standard deviation, and distribution of the SRL category, as well as inferential analysis using a statistical test with the program R at a significance level of $\alpha = 0.05$. Prerequisite tests include multivariate (Henze-Zirkler) and univariate (Shapiro-Wilk) normality tests, as well as multivariate (Box's M) and univariate (F-test) homogeneity tests. Hypothesis testing was conducted using paired t-test to compare the pretest-posttest in each class, one sample t-test to find out if the average posttest reached the set standard, and Multivariate Hotelling's T^2 to compare the effectiveness of the two approaches.

Variables

The independent variable in this study is the learning approach consisting of an open-ended approach (experimental class) and a scientific approach (control class), while the dependent variable is the student's Self-Regulated Learning measured through a questionnaire. Control variables include learning implementation time, teachers, learning materials (straight line equations), and the same assessment instruments for both classes. The learning implementation of the two approaches reached 95.75% (experimental class) and 95% (control class), respectively, showing that both approaches can be implemented consistently in the field with good teacher and student adaptation.

Results and Discussion

Result

Description of Research Implementation

The research was carried out with high learning implementation in both classes. In the experimental class (open-ended approach), the average percentage of learning implementation was 95.75%, with details: meeting 1 = 94%, meeting 2 = 100%, meeting 3 = 96%, and meeting 4 = 93%. In the control class (scientific approach), the average percentage of implementation was 95%, with details: meeting 1 = 100%, meeting 2 = 92%, meeting 3 = 95%, and meeting 4 = 93%. The high percentage of implementation shows that both learning approaches can be implemented consistently in the classroom, with teachers and students able to adapt well to the learning methods applied

Descriptive Analysis of SRL Data

The data reveals that both the experimental and control classes experienced improvements in their average Self-Regulated Learning (SRL) scores. Specifically, the experimental class saw an increase from 65.38 in the pretest to 75.54 in the posttest, marking a significant rise of 10.16 points. In contrast, the control class improved from 63.94 to 72.71, resulting in an increase of 8.77 points. While both classes demonstrated progress, the experimental class exhibited a greater enhancement in SRL scores, highlighting the effectiveness of the interventions employed in that group. Table 1 presents the descriptive statistics of SRL pretest and posttest scores.

Table 1. *Descriptive Statistics of SRL Pretest and Posttest Scores*

Statistics	**Experimental Classes (Open-ended)**		**Control Class (Scientific)**	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Average	65,38	75,54	63,94	72,71
Median	65,00	76,50	63,50	72,50
Std. Dev	6,94	6,88	6,87	7,04
Min	52	69	52	60
Max	78	90	75	84
N	24	24	24	24

Dimensional analysis highlights distinct trends in the cognitive dimension of learning between the experimental and control classes. The control class demonstrated a slightly greater improvement of 1.79 compared to the experimental class's 1.50. This difference may be attributed to the scientific approach employed in the control class, which emphasizes systematic reasoning and structured thought processes. Such a framework can facilitate deeper cognitive engagement and understanding, leading to more pronounced improvements in this dimension.

In contrast, the motivation dimension revealed a significant disparity favoring the experimental class, which experienced an improvement of 5.70, compared to the control class's 2.50. This suggests that the open-ended approach utilized in the experimental class effectively fosters intrinsic motivation among students. By allowing for greater exploration and personal engagement with the material, students are likely more driven to learn and participate actively, resulting in a substantial boost in their motivational levels.

Finally, in the behavioral dimension, the control class again outperformed the experimental class, showing an improvement of 4.46 compared to 3.04. This trend may reflect the structured environment provided by the scientific approach, which likely offers clearer guidelines and expectations for student behavior. Such clarity can enhance students' ability to engage in desired learning behaviors, thereby contributing to a more effective learning experience in the control class. Overall, these findings underscore the varying impacts of different instructional approaches on cognitive, motivational, and behavioral dimensions of learning. Table 2 presents the improvements on every dimension of SRL.

Table 2. *Improvements on Every Dimension of SRL*

Dimension	**Experimental Classes**		Increased	**Control Class**		Increased
	Pretest	Posttest		Pretest	Posttest	
Cognitive	20,00	21,50	1,50	19,21	21,00	1,79
Motivation	21,38	27,08	5,70	22,54	25,04	2,50
Behaviour	23,92	26,96	3,04	22,21	26,67	4,46
Total	65,30	75,54	10,24	63,96	72,71	8,75

The distribution transformation indicates a notable success in both classes after the learning intervention. In the experimental class, an impressive 92% of students attained the "high" or "very high" category, reflecting the effectiveness of the instructional methods used. Similarly, the control class also performed well, with 87.5% of students achieving the same categories. Importantly, the data reveals that no students were classified in the "low" or "very low" categories in either class after the learning process, highlighting a significant overall improvement in student performance and understanding across both groups. Table 3 presents the distribution of SRL categories before and after learning.

Table 3. *Distribution of SRL Categories Before and After Learning*

Category	Experimental Classes (Open-ended)		Control Class (Scientific)	
	Pretest	Posttest	Pretest	Posttest
Very High	0	25	0	12,5
Tall	33	67	37,5	75
Keep	54	8	41,7	12,5
Low	13	0	20,8	0
Very Low	0	0	0	0

Prerequisite Test Results

Normality Test

The normality test for students' Self-Regulated Learning (SRL) data was conducted using the Shapiro-Wilk test. Based on the results of the normality test, it can be seen that the p-value for both classes (experiment and control) is greater than 0.05. This shows that the SRL data of students in both classes is normally distributed. This normality test is important to ensure that subsequent statistical analyses, such as the t-test and MANOVA, can be validly applied. With the data being normally distributed, we can proceed with hypothesis testing to evaluate the effectiveness of the open-ended approach in mathematics learning, particularly in improving students' Self-Regulated Learning. Table 4 presents the normality test results.

Table 4 *Normality Test Results*

Class	Dependent Variable	P-value	Information
Eksperimen	Self-Regulated Learning (SRL)	0.846	Normal
Control	Self-Regulated Learning (SRL)	0.246	Normal

Homogeneity Test

The homogeneity test for students' Self-Regulated Learning (SRL) data was conducted using the F test. From the results of the homogeneity test, it can be seen that the p-value for both classes (experiment and control) is greater than 0.05. This showed that the variance of students' SRL data in both classes was homogeneous, meaning there was no significant difference in data variability between the experimental and control classes before treatment. This homogeneity test is important because it ensures that both groups have equal conditions in terms of SRL variability prior to the implementation of the learning approach. Table 5 presents the homogeneity test results.

Table 5 Homogeneity Test Result

Class	Dependent Variable	P-value	Information
Eksperimen	Self-Regulated Learning	0.754	Homogeneous
Control	Self-Regulated Learning	0.782	Homogeneous

Hypothesis Test Results

Paired T-Test

The results of the paired t-test for Self-Regulated Learning (SRL) show that the learning approach applied has a significant impact on students' ability to self-regulate. In the experimental class, the p-value obtained was 4.613e-06, which is much smaller than 0.05. This indicates that there is a significant difference between the SRL pretest and posttest scores, with a mean difference of 8.25 points. This shows that students who follow learning with an open-ended approach experience a marked improvement in their SRL abilities.

Similarly, in the control class that applied the scientific approach, the test results showed a p-value of 4.781e-07, also well below the significance limit of 0.05. These results show that the scientific approach has succeeded in significantly improving students' SRL, with the average difference between pretest and posttest being 8.75 points. Both approaches show effectiveness in developing students' self-regulated learning abilities, indicating that the learning methods used contribute to the improvement of these skills.

Overall, the results of the paired t-test for SRL confirm the importance of choosing the right learning method in supporting student skill development. The significant improvement in SRL after the implementation of both approaches suggests that the interventions performed are not only successful, but also have a substantial positive impact. This indicates that innovative learning approaches can play a key role in facilitating students' academic progress and independent learning skills.

One Sample T-Test

The results of the One Sample t-test for Self-Regulated Learning (SRL) in the experimental class showed that the average posttest score of students was 75.54. This value is significantly higher than the hypothetical value of 68.75, with a t-value of 5.2724 and a p-value of 1.19e-05. Since this p-value is much smaller than 0.05, H_0 is rejected. This shows that the average SRL score of students after the implementation of the open-ended learning method significantly meets the established effectiveness criteria.

In the control class, the results of the One Sample t-test also showed a significant improvement. The average SRL posttest score of students in the control class was 72.71, which is also higher than the hypothetical score of 68.75. With a t-value of 3.2577 and a p-value of 0.001733, H_0 was rejected, indicating that a scientific approach has succeeded in improving students' SRL abilities. Both approaches have a real positive impact on the development of self-regulated learning.

Overall, the results of the One Sample t-test show that both open-ended and scientific approaches are effective in improving students' self-regulated learning. The significant increase in SRL posttest scores in both classes indicates that the learning methods applied were not only successful, but also met the expected standards of effectiveness. This emphasizes the importance of choosing and implementing learning strategies that support the development of independent learning skills among students.

Comparison of the Effectiveness of the Two Approaches

Hotelling's Multivariate Test T^2

The results of Hotelling's Multivariate Test T^2 for Self-Regulated Learning (SRL) in the posttest data showed that the statistical value of T^2 was 2388.3 with a p-value of 2.2e-16. This value is greater than the critical value of 7.199746, and the very small p-value indicates that the result is statistically significant. Thus, H_0 was rejected, which means that there was a significant difference between the average SRL of students in the experimental class and the control class after the application of the learning method.

This test proves that the learning approach applied, both open-ended in the experimental class and the scientific in the control class, has a significant positive impact on students' self-regulated learning ability. This significant difference suggests that both methods have their own effectiveness in improving students' self-regulation skills, which is an important aspect of the learning process.

Independent Sample T-Test

The results of the Independent Sample t-test for Self-Regulated Learning (SRL) show that the statistical test value of t is 1.6 with a p-value of 0.1164. Since this p-value is greater than 0.05, H_0 is accepted, which means that there is no significant mean difference between the SRL of students who follow the open-ended approach in the experimental class and the SRL of students who follow the scientific approach in the control class. In other words, both groups showed relatively similar levels of self-regulated learning ability.

These findings indicate that although both learning approaches—open-ended and scientific—have a positive impact on improving students' SRL individually, there is insufficient evidence to state that either approach is more effective than the other in this context. This can be due to a variety of factors, including student characteristics, learning context, or the implementation of the same method in both classes.

Discussion

Significant Effectiveness of Open-ended Approaches

The results showed that mathematics learning with an open-ended approach significantly improved students' Self-Regulated Learning with an increase of 10.16 points (from 65.38 to 75.54) and a p-value of 4.613e-06, proving the statistical effectiveness of this approach. The dramatic transformation in the distribution of categories, where 92% of students reached the "high" or "very high" category after learning, suggests that the open-ended approach not only improves students' overall SRL, but also universally lifts those students who initially had low SRL. Before learning, 13% of students were in the "low" category and 54% in the "medium" category, but after learning, all students managed to get out of the low category and most of them reached the high category. These results are in line with previous research that found that open-ended learning encourages students to take responsibility for their own learning and develop sustainable learning independence (Ali, et al, 2021; Nufus et al., 2024).

Analysis of the increase in all three dimensions of SRL reveals a very interesting and informative pattern. The motivation dimension showed the largest increase of 5.70 points, far exceeding the cognitive (1.50 points) and behavioral (3.04 points) dimensions. This significant increase in motivation suggests that the open-ended approach is particularly effective in enhancing students' intrinsic motivation through the granting of autonomy, appropriate challenges, and success experiences. Whenever students successfully solve a problem in their own way, they experience a sense of accomplishment that increases their confidence and self-efficacy. This phenomenon is important because high intrinsic motivation is the main driver for continuous independent learning, which is a fundamental goal of SRL (Pekrun et al, 2002).

Cognitive Dimension Analysis and Its Implications

The improvement in the cognitive dimension was relatively smaller (1.50 points) in the experimental class, although it remained statistically significant. This can be explained by the fact that the development of cognitive aspects of SRL—such as the ability to diagnose learning needs, set appropriate goals, and manage one's own mind—is a more fundamental process and takes longer than motivational changes. Cognitive development involves changing the structure of the way of thinking that requires deep reflection and repeated experiences. However, it is important to note that although the improvement is small on an absolute scale, the cognitive aspect of SRL remains very important as it is the foundation for the development of other aspects in the long term (Kristiyani, 2016) . Students who develop cognitive awareness of their learning process will be better able to adapt their strategies in the future.

Behavioral Dimensions and Learning Habit Development

An increase in the behavioral dimension of 3.04 points in the experimental class showed that students had developed more positive and regular learning habits. This change is reflected in students' ability to implement more effective learning strategies, evaluate learning outcomes more critically, and use time more wisely. In the context of open-ended learning, students consistently learn to manage their own time in exploring problems, making choices about the resources to use, and evaluating whether their approach is working. This experience repeatedly trains students to develop more independent and effective learning behaviors, creating a foundation for lifelong learning (Cetin, 2015).

The effectiveness of the open-ended approach in developing SRL can be explained through several key learning mechanisms. First, giving students autonomy in choosing solution strategies generates a sense of ownership over their learning, increasing intrinsic motivation according to Self-Determination Theory. When students feel that learning decisions are their own choices, rather than decisions imposed by teachers, they show higher levels of engagement (Grace et al, 2022). This autonomy differs significantly from a more structured scientific approach, where learning steps are clearly defined. Previous research has shown that individuals who have control over their decisions show higher motivation and greater satisfaction with the learning process (Amiruddin et al, 2022).

The second and third mechanisms that make an open-ended approach effective are the provision of optimal challenges and continuous feedback from a variety of sources. Open-ended problems are designed to provide a level of difficulty that corresponds to the student's proximal developmental zone, creating conditions where students are at the limits of their abilities but can still achieve goals with effort and creativity. These appropriate challenges increase student engagement and encourage them to go beyond the limits of their current abilities (Kwon et al., 2006). In open-ended learning, students receive feedback from a variety of sources: from teachers observing the thought process, from peers who provide alternative perspectives, and from the problem-solving process itself (when the strategy does not produce a sensible solution). This diversity of feedback sources helps students develop independent judgments about the quality of their work, an important component of SRL (Lawson et al., 2023).

The fourth and fifth mechanisms involve metacognitive reflection and social learning facilitated by open-ended learning structures. The presentation and class discussion phases in open-ended learning encourage students to reflect on the way they think. When students see how their friends solve the same problem in different ways, they do metacognition—thinking about how to think. This process increases their awareness of their own learning strategies and their cognitive flexibility, a key component of SRL (Michalsky, 2024). Collaboration and social learning in classroom discussions also create a rich learning environment where students learn from each other. Research shows that learning from peers is often more effective than simply receiving instruction from teachers, as students are often more receptive to constructive criticism from peers (Barr & Askell-Williams, 2020).

Comparison with the Scientific Approach

Although the scientific approach also showed a significant increase in SRL (8.77 points), the increase was smaller compared to the open-ended approach (10.16 points), with a difference of 1.39 points. This difference can be explained by several factors. First, the scientific approach follows structured and pre-established steps (observing, questioning, gathering information, associating, communicating). Although this structure is beneficial for developing systematic and procedural thinking, it limits sis=wa autonomy in choosing their approach and reduces freedom of exploration (Mubarika et al., 2022). Second, in a scientific approach, teachers often provide more specific guidance and direction, which can reduce students' opportunities to develop learning independence and make decisions on their own. Third, scientific approaches tend to emphasize correct procedures and valid answers, which can make students focus on following the steps rather than developing their own learning strategies (Lutfi, 2019).

Conclusion

This study shows that mathematics learning with an open-ended approach is significantly effective in improving the Self-Regulated Learning of grade VIII junior high school students. An increase of 10.16 points (from 65.38 to 75.54) with a significance level of p = 4.613e-06 proves the effectiveness of this approach. The transformation of student distribution, with 92% reaching the "high" or "very high" category after learning, shows that the open-ended approach improves SRL not only on average but also universally at all levels of students. The largest increase occurred in the motivation dimension (5.70 points), indicating that the open-ended approach is particularly effective in developing students' intrinsic motivation to learn independently. The mechanisms that make an effective open-ended approach involve a complex combination of granting autonomy, optimal challenge, diverse feedback, metacognitive reflection, and social learning. A comparison with the scientific approach shows that although structures and procedures are important, freedom and autonomy are more important for developing motivation and independence to learn. These findings reinforce the need for a paradigm shift in mathematics learning from an approach that focuses solely on procedures and outcomes to an approach that pays attention to the development of students' independence and self-regulation comprehensively.

The implications of this research are clear for various education stakeholders. Math teachers should integrate more open-ended learning tasks in their practice while retaining important procedural exercises; the curriculum needs to be designed by balancing procedural exercises with open-ended tasks; and teacher professional development programs should equip them with the skills to effectively facilitate open-ended learning and create a learning environment that supports SRL. By adopting an open-ended approach, schools can prepare students not only to master math material but also to become independent, reflective learners, and able to organize their own lifelong learning, which is a fundamental need in this 21st century.

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