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How Intervention of Self-Assessment on Self-Regulated Learning and Problem-solving Skills in Mathematics?

A Systematic Literature Review

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Abstract:
This study aims to explore the impact of self-assessment on problem-solving skills in mathematics and self-regulated learning and identify self-assessment interventions in mathematics learning. This study used a systematic literature review conducted on studies from 2015 to 2024 using databases such as ERIC, ScienceDirect, and Google Scholar. Articles were categorized based on the quartile ranking of the journal according to the Scopus index. The categories include Q1, Q2, Q3, and Q4**,** which indicate decreasing quality. Ten empirical studies that met the criteria were reviewed and analyzed. The studies reviewed involved samples at various levels of education, with a focus on interventions that link self-assessment to self-regulated learning and problem-solving in mathematics. This research shows that self-assessment can improve students' mathematics problem-solving and self-regulated learning. Self-assessment helps students identify strengths and weaknesses, set goals, and adjust learning strategies. Interventions such as presenting assessment rubrics and constructive feedback proved effective in supporting self-regulated learning and problem-solving skills. The success of the interventions was influenced by teacher support, the use of appropriate instruments, and a structured approach to learning. However, the specific mechanism that links self-assessment with self-regulated learning and problem-solving needs further research. The findings also indicate that effective interventions need a structured design, such as constructive feedback, appropriate level of complexity, and presenting the assessment rubric according to the purpose of the assessment. Further research is needed to examine the cause-and-effect of interventions with specific and constructive mechanisms to obtain empirical data related to self-assessment at various levels of education.

Keywords: Self-Assessment, Self-Regulated learning, Mathematics Education

1. Introduction

Self-assessment is the process by which students evaluate their achievements and assess their performance based on predetermined criteria (Panadero et al., 2017). Klenowski (1995) Self-assessment is the evaluation or assessment of the 'value' of one's performance and the identification of one's strengths and weaknesses to improve learning outcomes (Panadero et al., 2017). Self-assessment supports learning because students are involved in reviewing their performance and competencies. The assessment students make is based on information and evidence about their performance gathered from various sources of learning outcomes. Self-assessment allows students to monitor and adjust their work, helping them close the gap between their current performance and the desired standard. Self-assessment is proven to influence students' self-regulated learning (Panadero et al., 2017) and math problem-solving ability (Barana et al., 2022; Kangaslampi et al., 2022).

Self-assessment helps students see how much they have achieved, and they can set higher goals to improve their abilities (Nicol et al., 2006). It is an efficient way for effective learning (Andrade et al., 2009). Several studies have highlighted how self-assessment can be effective in improving problem-solving competence in Mathematics (Liljedahl, 2016; Tachie, 2019). Mathematics learning requires self-assessment because it can

support the development and improvement of problem-solving skills in mathematics. Students can identify their strengths and weaknesses to improve their learning outcomes. In addition, self-assessment encourages metacognitive skills (Schoenfeld, 1985; Yoong, 2002), and reflection, which are important in the problem-solving process (Liljedahl, 2016). Metacognition and reflection are central to the self-assessment process (Black & Wiliam, 1998).

Self-assessment has a relationship with motivation in the context of learning. Self-assessment helps students to learn and motivates them. Kangaslampi et al., (2022). This suggests that the self-assessment process can increase students' motivation by making them more aware of their progress and achievements, which in turn can encourage them to continue learning and improve their performance. The research conducted by Panadero et al., (2017) Stated that problem-solving and self-regulated learning are important in the self-assessment process in mathematics learning because both play a role in improving students' ability to regulate their learning process, level of effort, engagement, and commitment to practicing mathematics.

Self-assessment allows students to independently reflect on their learning progress, recognize weaknesses, and strengths, and improve strategies for solving mathematical problems (Beumann et al., 2018). This can increase students' intrinsic motivation and responsibility towards their learning, which in turn can improve overall learning outcomes (Hadi et al., 2023; Matzavela & Alepis, 2023; Waldeyer et al., 2024). Self-assessment is also used to enhance students' reflective and evaluative skills, which can contribute to the development of learning independence and problem-solving ability. Chen (2006) Showed that self-assessment skills are positively affected by performance in mathematical problem-solving. Thus, self-assessment and problem-solving appear to be closely interrelated (Barana et al., 2022). However, the results of previous studies show that the specific impact of self-assessment on mathematical problem-solving often varies, depending on the learning design and the context in which it is applied (Andrade & Valtcheva, 2009; Panadero et al., 2017). Research conducted by (Barana et al., 2022) Shows students tend to doubt their performance. Therefore, an in-depth study is needed to understand how the application of self-assessment can be maximized in evaluating students' potential. Especially to develop problem-solving and self-regulated learning skills.

2. Method

Systematic Literature Review (SLR) is a research method that focuses on the stages of identification, collecting articles, selecting articles that correlate with the research objectives, analyzing articles, and then making conclusions to answer research questions (Kalogiannakis et al., 2021). The review was conducted to present trends regarding measurement recommendations, especially self-assessment in mathematics learning, which may be used as recommendations for future research. In this study, SLR used three stages: identify, screen, and include, and then the articles selected in the last stage will be reviewed in more depth (Haddaway et al., 2022).

The initial search was conducted at the end of November 2024. The search for related articles was for the period 2015-2024. The author conducted an independent search using his university access to ERIC, Scopus, ScienceDirect, and Google Scholar. The keywords used were: self-regulated learning + self-assessment in mathematics learning; self-regulated learning + self-evaluation in mathematics learning; self-regulated learning + monitoring in mathematics learning; Self-regulation + self-assessment in mathematics learning; Self-regulation + self-evaluation in mathematics learning; Self-regulation + monitoring; Self-assessment + self-regulated learning + Problem Solving". The inclusion criteria used were: (a) the study included empirical results of *self-assessment* interventions with mathematical problem-solving and/or self-regulated learning; (b) the study had at least one control group; (c) the study was published in English; d) the study only included Q1-Q4 indexed articles. An explanation of the SLR stages is shown in Figure 1.

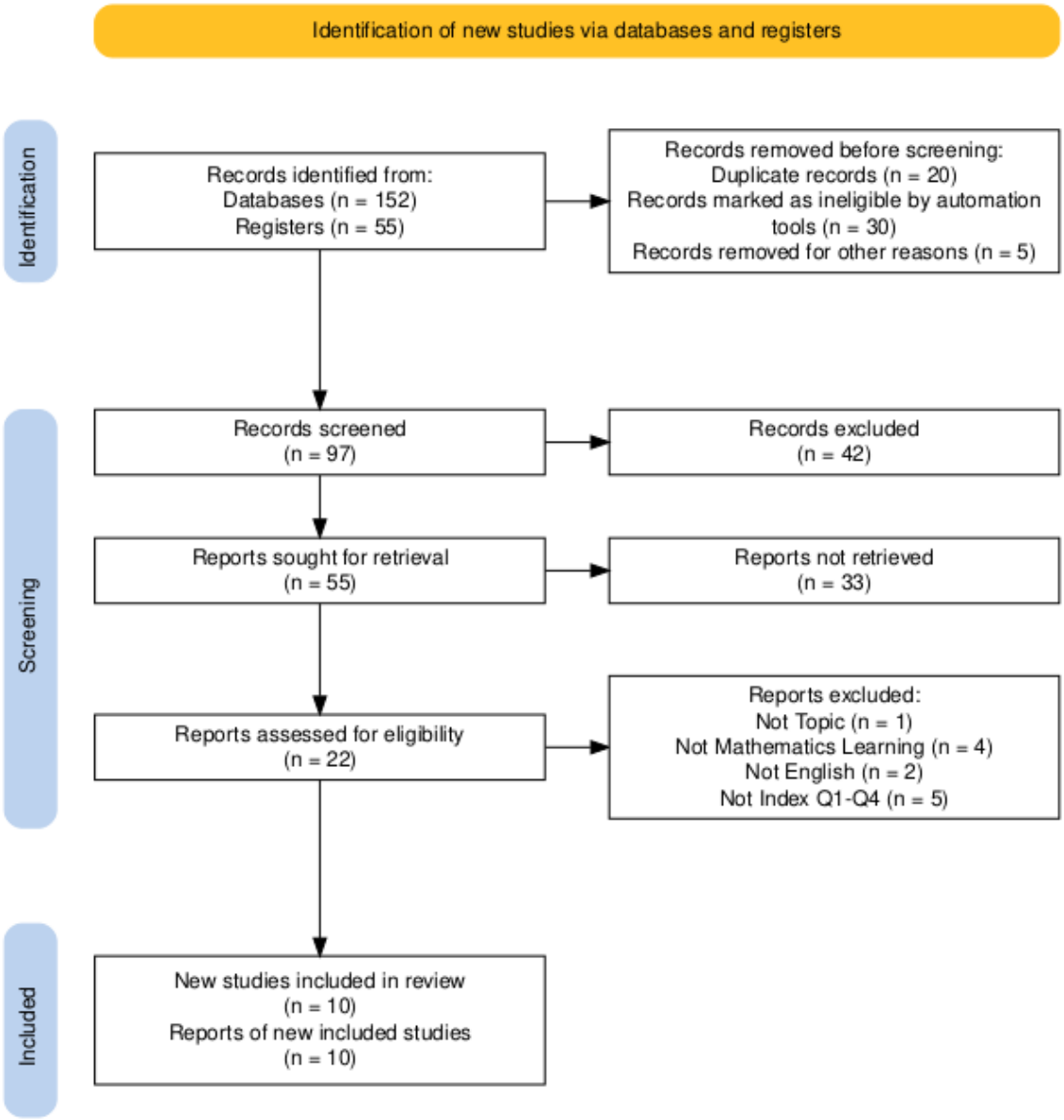

Figure 1: Flowchart Article Self-Assessment Review

3. Result and Discussion

3.1 Result

1. Inclusion and Exclusion Criteria

The total number of articles included in this review was 152 records identified through manual and database searches. After removing duplicates, 55 publications remained at the screening stage by selecting only empirical studies. The full texts of 22 empirical studies were read and assessed. After excluding the studies, 10 articles with inclusion criteria were analyzed and reviewed in more depth. The following information was collected from the selected articles: general information (author name, year of publication), sample characteristics (sample size, subject, and education level), study design (instrument, study design), procedure (aspects of the *self-assessment* intervention), results, and conclusions. The size of the studies in the sample ranged from 64 to more than 300 participants in the reviewed articles with education levels ranging from elementary school to higher education. Figure 1 shows the number of research publications related to self-assessment in mathematics education categorized by Scopus Quartile Ranking.

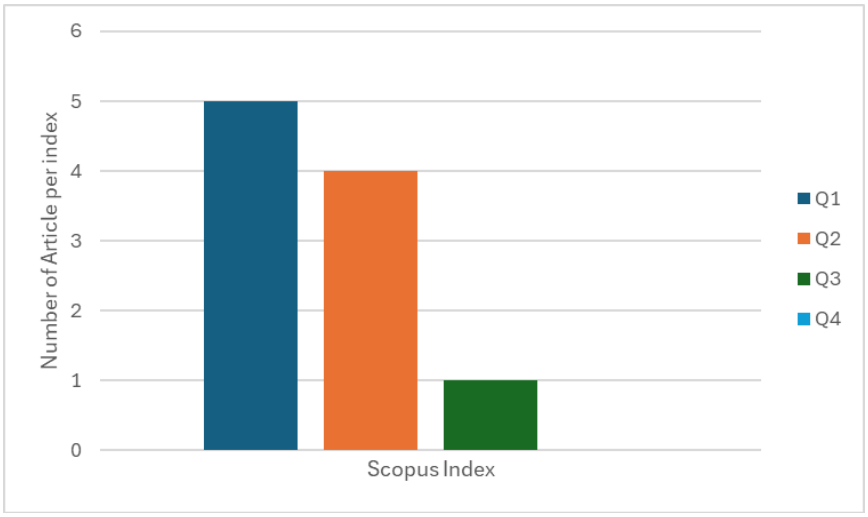

Figure 2. Number of Studies by Scopus Quartile Ranking

Based on the graph, publications in the highest quartile (Q1) dominate with a total of 5 articles. The Q4 and Q3 quartiles had only 1 article, while Q4 had no selected articles that may have been eliminated at the screening stage. This data shows that most of the research on this topic was successfully published in high-quality journals (Q1), which discussed self-assessment interventions, especially on problem-solving and/or self-regulated learning. Publications in Q1 journals tend to have a greater impact, so this choice reflects the ambition of researchers to reach a wider audience and make a significant contribution to the literature. The small number of publications in the Q4 quartile indicates that researchers tend to avoid journals with a lower reputation, although these journals can be one place to explore more innovative ideas.

2. Type of Research

The article reviews were categorized based on empirical studies. Figure 3 shows the distribution of the number of studies on self-assessment on problem-solving and/or self-regulated learning.

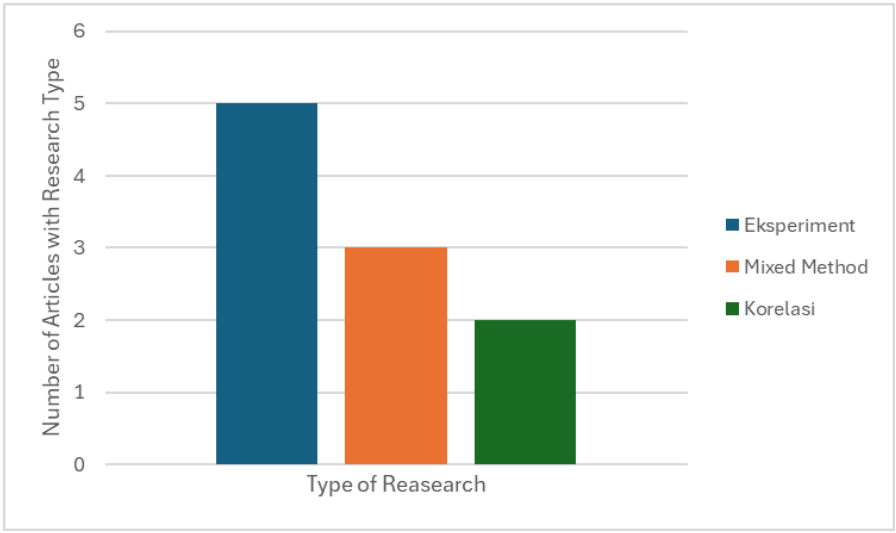

Figure 3. Number of Articles with Research Type

Based on the graph, the most dominant type of research is quantitative research with 5 articles. The mixed Method consists of 3 articles and 2 articles for correlation research. This data shows that the qualitative approach is more often used by researchers to explore the application of self-assessment in mathematics learning.

3. Research Subject

The subjects in this study consisted of all levels of education, ranging from elementary school, junior high school, senior high school, and university. The sample size can be seen in Figure 4.

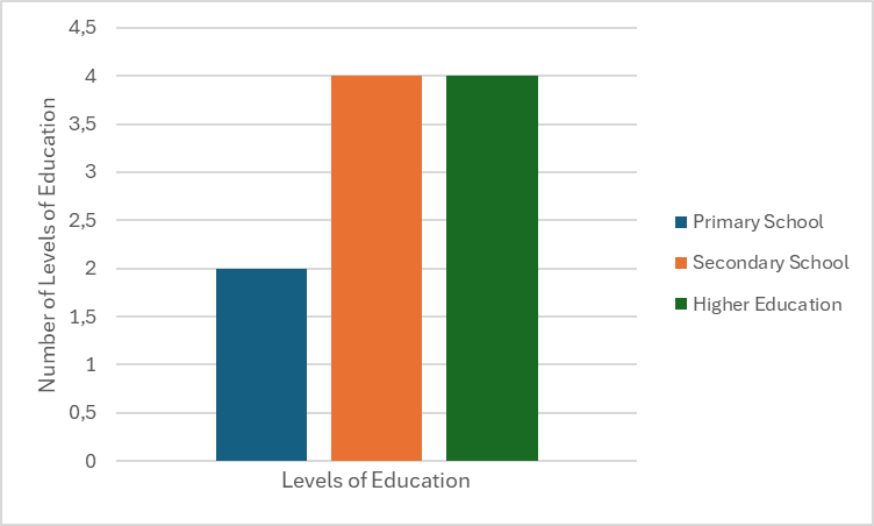

Figure 4. Research Subject

The research subjects consisted of 4 universities, 4 secondary schools, and 2 elementary schools. Thus, universities and elementary schools dominate as subjects in the articles reviewed. Information regarding sample size, self-assessment interventions, and others, can be seen in Table 1.

Table 1: List of reviewed articles

Authors	*Index*	*Subject and Education Level*	*Sample Size*	*Instrument*	*Research Method*	*Intervention Aspects*
(Waldeyer et al., 2024)	Q1	University Students from different universities in Germany	135 and 252 students	Test and Questionnaire	Experiment	Aspects considered are *prior knowledge*, *problem-solving* Performance, understanding of Stochastics problems, *mental effort*, *cognitive load*, and *self-assessment*.
(Granberg et al., 2021)	Q1	Students 13-14 years old from various social and cultural backgrounds.	32 Student	Test and Questionnaire	Mixed Method (Quantitative and Qualitative)	Aspects of self-assessment include goal setting, task completion, and self-reflection.
(Matzavela & Alepis, 2023)	Q1	Mathematics students from 6 schools	177 Students	Test and Questionnaire	Mixed Method (Development and experiment)	Aspects of the intervention include student performance, self-assessment, identification of low-performing students, and personalized learning.
(Cabedo & Maset-Llaudes, 2020a)	Q1	Higher Education	422 Student University	Self or Formative Assessment (problem-solving, self-correction, and reflection)	Mixed Method (Development and Experiment)	Aspects considered include formative assessment program participation, number of exams, and grade point average.

(Beumann & Wegner, 2018)	Q1	Mathematics education students	104 Student University	Homework assignments (*feedback*)	Experiment	This study uses self-assessment. This study compares the results of teacher and student assessments and presents student feedback.
(Huang et al., 2024a)	Q2	Primary School	69 Students	Test, Questionnaire, and interactive e-book for feedback	Experiment	Aspects of self-assessment include academic goal setting, cognitive strategies, metacognition, intrinsic motivation, and self-efficacy.
(Ruelmann et al., 2022a)	Q2	Primary School	634 Students	Questionnaire	Experiment	Aspects of the intervention addressing the quality of self-assessment (SA) and peer assessment (PA) in everyday mathematics teaching
(Barana et al., 2022)	Q2	Senior High School	182 Students	Questionnaire	Correlation	Self-assessment is the ability to assess oneself based on various indicators, by comparing student and tutor assessments and verifying data through student questionnaires.
(Özcan, 2016)	Q2	Secondary Schools	323 Students	Homework Behaviour Scale (MHBS)	Correlation	Study the relationship between mathematical problem-solving and dimensions of self-directed learning, such as motivation, metacognition, and on-task behavior.
(Kangaslampi et al., 2022)	Q3	Higher Education	52 Student	Questionnaire	Experiment	Students take two self-assessment exercises during the course and a weekly self-assessment for one homework problem.

The results of the study show that self-assessment has a positive impact on problem-solving skills in mathematics and self-regulated learning. Through self-assessment, students can identify weaknesses, set goals, and adjust their learning strategies. This process increases students' self-awareness, intrinsic motivation, and responsibility, thus supporting more effective learning and improving learning outcomes. It also encourages students to be more reflective and critical of their learning, which is an important skill in problem-solving. Self-assessment assists students in setting goals, monitoring progress, and adjusting their learning strategies as needed. However, the use of self-assessment must be adjusted to the purpose of use,

because the implementation of the intervention depends on the purpose of its use.

3.2 Discussion

Self-assessment shows that although students' attitudes towards self-assessment are negative at first, the experience of self-assessment can make those attitudes more positive. Waldeyer et al., (2024) Stated that the use of performance-based cues and providing prior instruction can help improve the accuracy of students' self-assessments. That is, if students are told in advance which cues they should pay attention to when performing a task, they will be better at accurately assessing their understanding and ability. In other words, mental preparation before the task helps students in making a more precise self-assessment. Research conducted by Matzavela & Alepis, (2023) Using technology-assisted questionnaires to predict students' academic performance before/after final exams through an intelligent decision system. So, with self-assessment students can focus more on difficult material, while institutions can adjust learning strategies according to individual needs. This approach not only improves learning effectiveness but also supports smarter decision-making in a digital education environment. However, its success depends on many different factors, the promising ones for self-assessment seem to be small study groups and tasks where weaker students can a priori catch up with stronger students by increasing their practice time. Thus, self-assessment is more effective when accompanied by mental preparation, technological support, and a conducive learning environment.

The recommended self-assessment interventions are the use of assessment rubrics, coaching and mentoring, structured self-reflection, peer assessment feedback, and learning journals (Beumann & Wegner, 2018; Cabedo & Maset-Llaudes, 2020; J. Huang et al., 2024; Ruelmann et al., 2022). By implementing these interventions, self-assessment can become a more effective tool for improving students' learning and self-regulation skills (Beumann & Wegner, 2018; Cabedo & Maset-Llaudes, 2020). Factors that contribute to the effectiveness of self-assessment interventions include: 1) Implementation by Teachers as intervention success is often higher when conducted by researchers than by teachers, although teacher involvement is also important for integration into daily classroom practice; 2) Use of appropriate Instruments related to metacognitive and self-regulated learning can help in measuring and improving SRL; 3) Structured approaches such as the use of diaries to monitor daily learning, can improve self-regulation skills and math achievement. In addition, self-assessment should be integrated into daily learning activities to train students' consistency in using these skills. This approach is more effective when applied within an independent learning framework, where students actively control their learning process (Chen, 2006).

The impact of self-assessment on problem-solving in mathematics learning is significant (Chen, 2006). Self-assessment serves as a methodology that motivates students to actively engage in reviewing their performance, which is crucial for developing and improving problem-solving skills in mathematics(Andrade & Valtcheva, 2009; Barana et al., 2022; Hadi et al., 2023). Research shows that self-assessment can improve learning effectiveness and quality. According to Zimmerman, (2000) Self-regulated learning is “self-generated thoughts, feelings, and actions that are planned and cyclically adjusted to the achievement of personal goals”. Self-assessment involves monitoring and reflecting on one's work, which is a typical metacognitive process in self-regulated learning (Yan, 2020). The combination of self-assessment and self-regulated learning significantly improves math learning achievement, including critical thinking and problem-solving skills. By applying these strategies, self-assessment can become a more comprehensive tool for supporting meaningful and independent mathematics learning. It can be concluded that self-assessment plays a significant role in improving mathematics problem-solving skills and supporting the development of self-regulated learning.

Self-assessment influences self-regulated learning, including planning, monitoring, and reflection (Digiacomo, 2014; Özcan, 2016; Panadero et al., 2017a). However, the exact mechanism by which self-assessment impacts self-regulated learning is not fully understood, indicating the need for further research. In mathematics, self-assessment helps students become more precise in evaluating certain aspects of their problem-solving process (Özcan, 2016). However, students may face challenges in accurately assessing their understanding of the problem and argumentation of their chosen strategies (Huang et al., 2024; Özcan, 2016). Overall, self-assessment plays an important role in improving problem-solving ability and independent learning in mathematics, but further research is needed to fully understand its mechanism and

optimize its implementation. Research conducted by Huang et al., (2024) also showed that the intervention of self-regulated learning depends on the aspects used in the learning process.

The indicators with lower correlation coefficients between external assessment and self-assessment were “Understanding of the problem situation” and “Argumentation”, which refer to the “understanding” and “reflection” phases in Polya's framework. So, it turns out that if students find it difficult to understand the task, then they find it more difficult to comment and illustrate clearly and completely the steps they perform, so they have difficulty assessing themselves appropriately. This is in line with the literature which shows that performance has a positive effect on self-assessment (Fan & Zhu, 2007). If for the comprehension indicator the results show that in general students find it easy to achieve and self-assess on this step, except on certain questions, argumentation seems to be a weak point on all questions, both for performance and self-assessment. On the other hand, classroom teaching often does not pay enough attention to the argumentation process, which is more than just a series of calculations, or does not give students an active role in explaining the process and results (Sriraman, 2014). So, when students are faced with different solution strategies and interpretations of the problems, they may raise doubts about their solutions.

Various types of self-assessment interventions in research (Ackerman & Levontin, 2023; J. Huang et al., 2024; Olivares et al., 2021; Panadero et al., 2017; Semana & Santos, 2018; Yan, 2020) Show the positive impact of self-assessment on students' self-directed learning (SRL) and problem-solving ability in mathematics, although its effectiveness is highly dependent on design and implementation. In the context of SRL, self-assessment helps students develop metacognitive skills such as planning, monitoring and evaluating performance, which increases motivation to learn and reflection on learning outcomes. Data-driven approaches, such as technology-based feedback systems, enable the personalization of guidance based on students' needs, which significantly strengthens their independent learning. On the problem-solving aspect, self-assessment encourages students to analyze the strategies used, evaluate their effectiveness, and identify areas for improvement. The use of rubrics as an evaluation tool improved students' ability to understand complex tasks and devise more purposeful solution steps (Granberg et al., 2021). Research shows that rubric-based interventions are more effective in helping students understand success criteria, especially on math tasks that demand in-depth analysis. Important factors influencing the success of these interventions include a structured design, an appropriate level of complexity for students' abilities and the quality of feedback provided. Data-driven feedback, for example, provides specific and actionable insights to students, helping them to refine their learning strategies and improve learning outcomes. In conclusion, the effectiveness of self-assessment interventions is determined by the extent to which the approach is designed to promote students' active engagement in the process of mathematical reflection and learning (Cabedo & Maset-Llaudes, 2020; Granberg et al., 2021; Matzavela & Alepis, 2023).

However, the specific mechanisms by which self-assessment directly affects self-directed learning are not fully understood, so further research is needed. The articles reviewed show the importance of maximizing the impact of self-assessment in mathematics learning, especially in the development of problem-solving ability and SRL, various strategies can be applied. First, self-assessment can be used to develop students' self-regulation skills, such as the ability to set goals, monitor progress and evaluate their learning outcomes independently. Second, providing clear rubrics and assessment criteria allows students to understand the expected standards and identify areas that need improvement, so that they can be more structured in solving problems. Third, specific and constructive feedback based on self-assessment results can help students realize their mistakes, understand how to correct them, and improve the quality of their learning process.

3. Conclusion

Self-assessment has a significant impact on improving problem-solving skills in mathematics and self-regulated learning. Self-assessment encourages students to engage in a metacognitive process, which allows them to identify their strengths and weaknesses, set goals, and adjust their learning strategies. This reflective practice not only helps to improve math problem-solving skills but also fosters a sense of responsibility and motivation in students, which are important components of self-regulated learning. Interventions involving self-assessment have shown positive results when well-structured and integrated into the learning process. Effective interventions often include clear guidelines and instruments, such as rubrics or reflective journals,

that help students systematically evaluate their learning progress. Teachers' involvement in facilitating these interventions is also very important, as it ensures that students receive the support and feedback needed to improve their self-assessment skills.

Several factors contribute to the effectiveness of self-assessment in mathematics learning. These factors include the clarity of students' self-assessment criteria and the level of teacher support. When students understand what is expected of them and believe in their ability to succeed, they are more likely to engage deeply with the self-assessment process and benefit from it. Further research is needed to explore the specific mechanisms of how self-assessment affects self-regulated learning and problem-solving ability in mathematics learning. Experimental studies are needed to identify cause-and-effect relationships and test the most effective implementation strategies, such as the use of rubrics, feedback, and technology to see in detail how much impact self-assessment has on students' mathematics problem-solving ability and self-regulated learning.

4. Limitation

This study has several limitations that should be considered. First, the systematic review relied on existing literature, which may introduce publication bias as studies with significant results are more likely to be published. Second, the search was limited to articles published in English and only Q1-Q4 Scopus-indexed articles on mathematics learning contexts. Third, this review focused on a specific timeframe (2015-2024), which may have overlooked earlier foundational research. In addition, heterogeneity in methodology, intervention design, and measures of self-assessment effectiveness across the included studies makes direct comparisons difficult.

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