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Student's Mathematical Communication Skills and *Self-Regulated Learning*: A Systematic Literature Review

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ABSTRACT

This study aims to synthesize research findings from published articles addressing students' mathematical communication skills and self-regulated learning. A systematic literature review (SLR) was conducted following a structured, standardized procedure, including the formulation of review questions, database selection, keyword identification, the definition of inclusion and exclusion criteria, article screening, and data extraction. Relevant studies were identified from reputable academic databases and systematically reviewed to ensure methodological rigor and transparency. The results of the analysis indicate that mathematics learning implemented through specific instructional models or learning strategies contributes to improvements in students' mathematical communication skills and self-regulated learning. Furthermore, several studies report a positive relationship between mathematical communication skills and self-regulated learning in mathematics education. However, other studies reveal no significant relationship between these two variables. Various factors, including differences in sample characteristics, learning contexts, and research designs, influence these inconsistencies. Therefore, further studies using more controlled and consistent methodologies are needed to obtain more specific findings and to identify the key factors influencing the relationship between mathematical communication skills and self-regulated learning, thereby improving the quality of future research.

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1. INTRODUCTION

Mathematics is an exact science that is closely related to real-life contexts and supports other scientific disciplines [1]. Mathematics is a subject encountered continuously from elementary school through higher education. The development of mathematical knowledge does not cease, as it is required in various aspects of life to support more effective activities [2]. To learn mathematics, students need the ability to analyze the problems they encounter. These abilities include basic skills, cognitive abilities, and mathematical reasoning. Students gain a deeper understanding of mathematics through communication, as communication plays an important role in gathering information, data, and facts in the processes and applications of mathematics [3]. Students' communication skills align with the objectives expected by the NCTM [4], which include problem-solving skills, communication skills, connection skills, reasoning skills, and representation skills. Among these five mathematical competencies, one important component is communication.

In the *Merdeka Curriculum*, one of the learning objectives is to communicate a concept through symbols, tables, diagrams, or other media by explaining a given situation or problem, and to express that situation in symbolic or mathematical models [5]. Mathematical communication involves students' skills in articulating mathematical concepts through both spoken and written expressions [6], emphasizing the exchange of ideas in reflecting mathematical concepts, information, and understanding. According to NCTM [4], mathematical communication skills consist of: : (1) t the capacity to explain concepts and express one's thoughts about mathematical ideas verbally or in written form, (2) the ability to represent images, diagrams, or graphs into mathematical thinking, and (3) the ability to use mathematical language or notation accurately across various mathematical ideas.

Ansari [28] identifies several indicators for measuring students' mathematical communication skills, which are grouped into three categories: (1) drawing, which refers to reflecting real objects, images, and diagrams into mathematical thinking and, conversely, translating mathematical thinking into visual forms such as pictures or diagrams; (2) mathematical expression, which involves expressing mathematical concepts by representing everyday events using mathematical language or symbols; and (3) written text, which includes expressing answers in one's own words, modelling situations or problems using verbal, written, graphical, or algebraic representations, explaining ideas, formulating questions about learned mathematical concepts, listening, engaging in discussions, writing about mathematics, making conjectures, and constructing arguments or generalizations. Effective mathematical communication is expected to help students develop a broader perspective on mathematics and foster logical, accurate attitudes when applying mathematics to solve everyday problems. Therefore, communication skills in mathematics learning are essential, as they support learning activities and facilitate the delivery of ideas and concepts presented by teachers to students, as well as interactions among students.

The goals of mathematics learning cannot be achieved without students possessing strong soft skills. Quality education encompasses both hard and soft skills, enabling students to become independent, professional, competent, and hardworking individuals. One essential soft skill for improving the quality of mathematics learning is *self-regulated* *learning*. *Self-regulated learning* refers to students' ability to regulate themselves in the learning process to enhance their personal quality and performance. It highlights the importance of an individual's capacity to manage and control themselves, especially when facing academic tasks. Students with strong *self-regulated learning* tend to develop greater self-confidence. Wolters and Pintrich [7] argue that *Self-regulated learning* refers to an active and constructive learning process in which students determine their own learning goals and actively monitor, manage, and adjust their cognitive processes, motivation, and behaviors in accordance with those goals and the surrounding contextual conditions. Khairrunnisa [8] states that *self-regulated learning* refers to an individual's ability to manage, control, and regulate their own learning process. This involves self-awareness of learning objectives, the ability to monitor progress, and the ability to apply effective learning strategies. Students with strong *self-regulated learning* are capable of managing their thoughts, motivation, and behaviors. They also demonstrate responsibility and awareness in managing their study time and can independently evaluate their own performance. These abilities allow students to achieve the academic outcomes they aim for. *Self-regulated learning*, as a form of independent learning, should not be interpreted narrowly. Instead, it represents a broader ability that helps individuals develop themselves and achieve success.

Despite the recognized importance of mathematical communication skills and *self-regulated learning* in mathematics education, existing empirical studies have reported inconsistent findings regarding the relationship between these two constructs. Several studies indicate that *self-regulated learning* significantly predicts students' mathematical communication skills, suggesting that students with higher levels of self-regulation tend to express mathematical ideas more clearly and effectively. However, other studies report weak or non-significant relationships, indicating that high *self-regulated learning* does not always correspond to strong mathematical communication skills. This mixed evidence highlights an unresolved issue in the literature and suggests that the relationship between *self-regulated learning* and mathematical communication skills may be influenced by contextual factors such as instructional approaches, learning environments, or student characteristics.

In addition, although numerous instructional models and learning strategies-such as Problem-Based Learning, Guided Discovery, blended learning, and technology-assisted instruction, have been reported to improve either mathematical communication skills or *self-regulated learning*, there is a lack of comprehensive synthesis that systematically examines which types of instructional interventions effectively enhance both constructs simultaneously. Most prior studies focus on isolated contexts or specific educational levels, resulting in fragmented evidence that limits broader theoretical and practical conclusions. Therefore, a systematic literature review is needed to synthesize previous findings, clarify the pattern of relationships between mathematical communication skills and *self-regulated learning*, and identify dominant instructional approaches that support the development of both constructs in mathematics learning. Accordingly, this study is guided by the following research question: (1) what patterns of relationship between mathematical communication skills and *self-regulated learning* are reported in mathematics education research during the period 2018-2025? (2) what instructional approaches or learning models are most frequently associated with improvements in both mathematical communication skills and *self-regulated learning*?

2. METHOD

This study employs a systematic literature review (SLR) as its research methodology, conducted in accordance with a structured and transparent procedure to ensure methodological rigor. The SLR was used to synthesize previous research examining the relationship between mathematical communication skills and *self-regulated learning* education. The SLR process involves several stages, including formulating research questions, searching for literature using software such as Publish or Perish and platforms such as Google Scholar, Semantic Scholar, and ResearchGate; selecting and screening studies; evaluating the quality of studies; analyzing and synthesizing information; and interpreting the results. According to Triandini et al. [9], the stages in the SLR method include: formulating research questions; conducting a literature search; applying inclusion and exclusion criteria; screening and eligibility assessment; quality assessment of selected studies; and data extraction, synthesis, and interpretation.

Formulating the research questions is the first step, which includes: (1) *Were patterns of relationship between students' mathematical communication skills and self-regulated learning reported in mathematics education research during the period 2018–2025?* (2) *What instructional approaches dominate studies linking mathematical communication skills and self-regulated learning in mathematics learning during the period 2018–2025?* The second stage involves a systematic literature search conducted using the Publish or Perish application, accessing academic databases such as Google Scholar and Scopus, focusing on articles published in Sinta-indexed journals and reputable international journals. The keywords used in the search process were "*mathematical communication skills*" and *"self-regulated learning"*.

At the identification stage, 55 articles were retrieved. During the screening stage, duplicate records were removed, and the remaining articles were screened based on their titles and abstracts. As a result, 43 articles were excluded because they were not related to mathematics education or did not explicitly address mathematical communication skills and self-regulated learning. The eligibility stage involved a full-text assessment of the remaining 12 articles against predefined inclusion and exclusion criteria, including relevance to the research questions, clarity of the research methods, and availability of empirical findings. All 12 articles met the eligibility criteria and were therefore included in the final analysis. To ensure transparency and replicability, the article selection process is visually presented using a PRISMA flow diagram, which illustrates the stages of identification, screening, eligibility, and final inclusion of studies in this systematic literature review.

Table 1. Prisma Article Selection Process

Stage	Description	Number of Articles (n)
Identification	Records identified through database searching (Google Scholar, Semantic Scholar, ResearchGate, Scopus) using Publish or Perish	55
	Records identified through other sources	0
Screening	Records after duplicates removed	55
	Records screened by title and abstract	55
	Records excluded based on title and abstract	43
Eligibility	Full-text articles assessed for eligibility	12
	Full-text articles excluded, with reasons	0
Included	Studies included in the systematic literature review	12

Table 2. Inclusion and Exclusion Criteria of the Study

Criteria	Inclusion Criteria	Exclusion Criteria
Research topic	Articles discuss both mathematical communication skills and *self-regulated learning* in mathematics education.	Articles focusing on only one construct, non-mathematics subjects, or unrelated educational topics
Publication period	Articles published between 2018 and 2025	Articles published before 2018 or after 2025 are to maintain relevance and currency.
Type of publication	Peer-reviewed national journals (Sinta-indexed) and reputable international journals (Scopus)	Conference papers, theses, dissertations, book chapters, or non-peer-reviewed publications
Language	Articles written in English or Indonesian	Articles written in other languages are limited due to translation limitations and potential interpretation bias.
Research design	Empirical studies with clear methodology and reported findings	Conceptual papers, opinion articles, or studies with insufficient methodological clarity
Availability	Full-text articles accessible	Articles with inaccessible full texts or incomplete data

During the screening stage, articles were excluded if their titles and abstracts did not address mathematics education or explicitly examine mathematical communication skills and *self-regulated learning.* At the eligibility stage, full-text articles were excluded if they lacked empirical data, did not meet the predefined inclusion criteria, or did not provide sufficient methodological detail to support reliable analysis.

Initially, the literature search used the keywords "mathematical communication skills" and "*self-regulated learning".* However, during the search, several relevant studies were found to use alternative terms. Therefore, additional keywords such as "*mathematical communication ability*" and "*self-regulation in learning mathematics"* were incorporated to ensure a more comprehensive retrieval or relevant articles. This modification represents a justified deviation from the initial protocol, aimed at minimizing the risk of omitting relevant studies and enhancing the completeness of the systematic review.

3. RESULTS AND DISCUSSION

3.1. Results

Following the systematic literature review (SRL) procedure, the keywords' mathematical communication skills' and 'self-regulated learning' yielded 12 relevant articles that met the predefined inclusion criteria. These studies were analyzed to address the formulated reserach questions. Table 3 summarizes the key findings of the selected studies related to mathematical communication skills and *self-regulated learning*.

Table 3. Research Findings on Mathematical Communication Skills and *Self-Regulated Learning*

No.	Journal	Authors & Year	Research Findings
1.	*Journal of Innovative Mathematics Learning*, Vol. 1, No. 3	Barnas et al., 2018 [10]	The SQ3R strategy (Survey, Question, Read, Recite, Review) plays a significant role in improving seventh-grade students' mathematical communication skills and *self-regulated learning*. However, despite improvements, students' mathematical communication skills remained in the low category, while their *self-regulated learning* was at a moderate level.
2.	*Journal of Innovative Mathematics Learning*, Vol. 2, No. 1	Fadhillah & Hernawati, 2019 [11]	Students' mathematical communication skills were found to be at a moderate level, with challenges in solving non-routine problems and understanding visual concepts. Their *self-regulated learning* was categorized as good, indicating that they were able to learn with minimal dependence on the teacher.
3.	*International Journal of Innovative Research and Scientific Studies*, Vol. 7 No. 2	Najoan et al., 2024 [12]	The TAI (Team-Assisted Individualization) model was proven effective in improving mathematical problem-solving, mathematical communication, and students' self-regulated learning.
4.	*International Journal of Innovation, Creativity and Change*, Vol. 12 No. 7	Sudia & Muhammad, 2020 [13]	Problem-Based Learning (PBL) improved mathematical communication skills, particularly for students with *high self-regulated learning*. Students with high SRL demonstrated a better understanding and explanation of mathematical concepts than those with moderate or low SRL.
5.	*International Conference on Mathematics and Sciences Education*	Lidinillah et al., 2024 [14]	Edmodo-based blended learning effectively improved high school students' mathematical communication skills, although the improvement remained within the moderate category. It also enhanced students' *self-regulated learning*, especially for those with high and low prior mathematical abilities (KAM).
6.	*Kreano: Jurnal Matematika Kreatif-Inovatif*, Vol. 12 No. 2	Efriyadi & Nurhanurawati, 2021 [15]	Learning motivation and *self-regulated learning* have a significant role in enhancing students' mathematical communication abilities. Students with high motivation and SRL demonstrated better communication skills than those with lower levels of motivation and SRL.
7.	*Kreano: Jurnal Matematika Kreatif-Inovatif*, Vol. 14 No. 2	Aida Sari et al., 2023 [16]	*Self-regulated learning* influenced students' mathematical communication skills, although the effect size was relatively low (21%). Students with high SRL were more independent, better organized, and more capable of expressing mathematical ideas in written form.
8.	*Journal of Education and*	Surya et al., 2018 [17]	Problem-Based Learning (PBL) effectively improved students' mathematical communication skills and *self-regulated learning*. Female students scored higher in

No.	Journal	Authors & Year	Research Findings
	Practice, Vol. 9, No. 6		both aspects compared to male students, although both groups showed significant improvement through PBL.
9.	*Journal of Medives*, Vol. 7 No. 1	Nurjanah et al., 2019 [18]	The higher the students' *self-regulated learning*, the better their mathematical communication skills.
10.	*Journal of Primary Education*, Vol. 9, No. 2	Rofiah et al., 2019 [19]	The LAPS-Heuristic learning model, combined with the Guilford approach, effectively improved students' mathematical communication skills and *self-regulated learning*. SRL played a crucial role in determining communication quality—students with higher SRL demonstrated better communication skills.
11.	*Journal of Physics: Conference Series*	Junaila & Yerizon, 2021 [20]	The Guided Discovery method improved students' mathematical communication skills and *self-regulated learning*.
12.	*Jurnal Analisa*, Vol. 9 No. 2	Sitanggang et al., 2023 [21]	Interactive learning media based on Problem-Based Learning was found to be valid, practical, and effective in enhancing students' mathematical communication skills and *self-regulated learning*.

Rather than presenting the findings descriptively, the results were synthesized thematically to identify a dominant pattern across studies. Three main themes emerged from the analysis: (1) *self-regulated learning* as a predictor of mathematical communication skills; (2) the role of instructional models as moderating factors, and (3) differences in findings based on educational level and learning context.

3.2. Discussion

Self-Regulated Learning as a Predictor of Mathematical Communication Skills

The thematic synthesis of the reviewed studies indicates that *self-regulated learning* (SRL) plays a central predictive role in the development of students' mathematical communication skills. This relationship is theoretically grounded and empirically supported across the field of mathematics education research. From a theoretical perspective, SRL is defined as an active and constructive process in which learners set goals for their learning, monitor their progress, regulate cognitive and motivational processes, and reflect on learning outcomes [22], [23]. These regulatory processes are closely aligned with the demands of mathematical communication, which require organizing ideas, justifying reasoning, and expressing mathematical concepts clearly using appropriate representations [24]. Students with high levels of SRL tend to demonstrate stronger cognitive organization and metacognitive awareness, enabling them to articulate mathematical ideas more coherently. Planning skills help students structure explanations logically before expressing them, while monitoring skills help them identify errors or gaps in reasoning during communication. Evaluation processes further refine explanations, leading to clearer, more accurate mathematical discourse. As a result, SRL facilities both written and oral mathematical communication, including explaining solution strategies, interpreting symbols, and constructing mathematical arguments [25]

Empirical evidence from the reviewed studies consistently shows that students with high SRL outperform those with lower SRL in mathematical communication tasks. Several studies report that SRL significantly predicts students' ability to explain problem-solving procedures, use mathematical language appropriately, and present solutions systematically.

These findings align with previous research indicating that self-regulated learners are more independent, persistent, and confident in expressing their mathematical thinking [26]. However, the synthesis also reveals variation in the strength of this predictive relationship. Some studies report a relatively weak or non-significant influence of SRL on mathematical communication skills. Methodological and contextual factors can explain these discrepancies. First, differences in SRL measurement instruments contribute to inconsistent findings. Studies that rely heavily on self-report questionnaires may capture students' perceived regulatory abilities rather than their actual regulatory behaviors during mathematical problem-solving [27]. Second, mathematical communication is operationalized differently across studies-some emphasize written communication, while others include oral explanations and classroom discourse, resulting in varied outcomes.

In addition, the predictive role of SRL is highly dependent on instructional opportunities for communication. SRL does not function in isolation; instead, its influence becomes more apparent in learning environments that encourage discussion, reflection, and explanation. In a teacher-centered classroom where mathematical communication is limited, students may possess moderate SRL but still demonstrate low communication skills. This supports the arguments that SRL is a necessary but not sufficient condition for effective mathematical communication. Furthermore, motivational components of SRL, such as self-efficacy and task value, also contribute to mathematical communication outcomes. Students who believe in their ability to succeed and perceive mathematics as meaningful are more willing to engage in communication activities, ask questions, and defend their reasoning. This motivation dimension further strengthens the predictive relationship between SRL and mathematical communication skills.

In summary, this thematic synthesis confirms that *self-regulated learning* is a key predictor of mathematical communication skills, supported by both theoretical framework and empirical evidence. Nevertheless, the magnitude of this relationship varies depending on how SRL and communication are measured, as well as how instructional context supports student engagement and discourse. These findings highlight the importance of integrating SRL-oriented strategies within mathematics instruction to foster students' ability to communicate mathematical ideas effectively.

The Role of Instructional Models as Moderators

The thematics synthesis indicates that instructional models function as critical moderating variables that shape the extent to which *self-regulated learning* (SRL) contributes to students' mathematical communication skills. Across the reviewed studies, the effectiveness of SRL in enhancing communication outcomes is strongly influenced by the pedagogical characteristics of the learning models employed. From a pedagogical perspective, student-centered instructional models, such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), Guided Discovery, Team Assisted Individualization (TAI), blended learning, and heuristic-based approaches, consistently demonstrate stronger impact on both SRL and mathematical communication skills. These models require students to actively engage in problem analysis, collaborative discussion, reflection, and explanation of reasoning processes. As a result, students are not only encouraged to regulate their own learning but are also provided with opportunities to externalize their thinking through mathematical communication.

In PBL-oriented environments, for example, students are confronted with contextualized problems that demand independent planning, monitoring of solution strategies, and evaluation of outcomes. These regulatory activities are inherently aligned with SRL processes. At the same time, PBL emphasizes group discussion, solution presentations, and justification of mathematical reasoning, which directly foster communication skills. Consequently, SRL becomes more visible and impactful when supported by instructional models that prioritize discourse and inquiry. Empirical findings from the reviewed studies further confirm the moderating role. Studies implementing interactive and inquiry studies further confirm this moderating role. Studies implementing interactive, inquiry-based learning models report significant improvements in students' ability to articulate mathematical ideas, both orally and in writing, particularly among students with high or moderate SRL. Conversely, studies conducted in more teacher-centered or procedural learning contexts tend to report weaker relationships between SRL and mathematical communication skills. In such a context, students may possess self-regulatory capacities but lack sufficient opportunities to express, discuss, and refine mathematical ideas.

Moreover, the synthesis reveals that instructional models also influence equity in learning outcomes. Collaborative and adaptive learning models, such as TAI and blended learning, appear to support students with varying levels of SRL by providing scaffolding, peer interaction, and flexible learning pathways. This reduces the gap between students with high and low SRL and enables broader development of mathematical communication skills. In contrast, rigid instructional structures may amplify differences in SRL, resulting in uneven communication outcomes. Another identified moderating factor is the integration of technology into instructional models. Studies incorporating digital platforms (e.g., Edmodo-based blended learning or interactive learning media) show that technology- enhanced environments can support SRL by facilitating access to learning resources, self-paced exploration, and reflective activities. When combined with interactive instructional strategies, technology strengthens the link between SRL and mathematical communication skills by encouraging students to document, revise, and present mathematical ideas more effectively.

In summary, this thematic synthesis demonstrates that instructional models play a decisive moderating role in determining whether *self-regulated learning* translates into improved mathematical communication skills. Student-centered, inquiry-based, and technology-supported learning models create conditions that activate SRL processes and provide meaningful opportunities for mathematical discourse. Without such instructional support, the potential of SRL to enhance communication skills may remain underutilized. This finding underscores the importance of aligning instruction with SRL principles to maximize students' development of mathematical communication.

Differences in Findings Based on Educational Level and Learning Context

The thematic synthesis reveals that educational level and learning context play a significant role in shaping the relationship between *self-regulated learning* (SRL) and mathematical communication skills. Variations in research findings across the reviewed studies can be largely explained by differences in students' cognitive development, metacognitive maturity, and instructional environments at different educational levels. At the secondary and upper-secondary education levels, the relationship between SRL and mathematical communication skills tends to be more pronounced. Students at these levels generally demonstrate more advanced metacognitive ability, enabling them to plan, monitor, and evaluate their learning more effectively. These regulatory processes support students in organizing mathematical reasoning and articulating explanations in both oral and written forms. As a result, studies conducted at the junior and senior high school levels frequently report moderate to strong relationships between SRL and mathematical communication skills.

In contrast, studies conducted at the primary education level often report weaker or inconsistent relationships. This can be attributed to the developmental stage of younger learners, who are still acquiring foundational self-regulatory skills and rely more heavily on external guidance from teachers. At this level, students may demonstrate emerging SRL behaviors; however, these behaviors are not yet sufficiently internalized to consistently support complex mathematical communication. Consequently, mathematical communication skills at the primary level are more strongly influenced by instructional scaffolding than by students' independent regulatory capacities. Learning context also contributes to differences in findings. Studies implemented in classroom settings that emphasize student-centered learning environments, such as collaborative problem-solving and discussion-based instruction, tend to report stronger associations between SRL and mathematical communication skills, regardless of education level. In such a context, students are encouraged to explain reasoning, negotiate meaning with peers, and reflect on their learning processes. These practices amplify the role of SRL by creating opportunities for students to externalize and refine their mathematical thinking.

Conversely, studies conducted in more teacher-dominated or examination-oriented contexts often report a limited, non-significant relationship between SRL and mathematical communication skills. In these settings, instructional practices focus primarily om procedural mastery and correct answers, leaving minimal space for mathematical discourse and self-reflection. As a result, even students with moderate or high SRL may exhibit low levels of mathematical communication due to limited opportunities for expression. Additionally, differences in findings are influenced by context variables, such as prior mathematical ability, learning motivation, class size, and assessment practice. For example, students with high prior knowledge may demonstrate strong communication skills regardless of SRL level, while students with lower prior ability may require structured instructional support to activate SRL and the communication process simultaneously. Assessment methods that prioritize written tests over oral explanations may also underrepresent students' actual communication competence.

In summary, this thematic synthesis indicates that differences in research findings are not contradictory but rather reflect variations in educational level, developmental readiness, and instructional context. The relationship between SRL and mathematical communication skills becomes stronger as students progress to higher educational levels and when learning environments actively support self-regulation and mathematical discourse. This finding highlights the importance of adapting instructional strategies to students' developmental stages to optimize both *self-regulated learning* and mathematical communication skills.

4. CONCLUSION

This systematic literature review synthesizes research findings on the relationship between mathematical communication skills and *self-regulated learning* (SRL) in mathematics education. The results indicate that SRL plays a crucial role in shaping students' ability to communicate mathematical ideas effectively, although the strength and nature of this relationship vary across instructional contexts and educational levels. The thematic synthesis reveals that SRL functions as an important predictor of mathematical communication skills, particularly in learning environments that encourage students' autonomy, reflection, and explanation. Students with higher levels of SRL tend to demonstrate better organization of ideas, clearer reasoning, and greater confidence in expressing mathematical concepts, both orally and in writing. However, SRL alone is insufficient to guarantee strong mathematical communication; its impact is more pronounced when supported by instructional practices that actively promote discourse and reasoning.

Furthermore, the review highlights that learning models serve as significant moderators of the relationship between SRL and mathematical communication skills. Student-centered instructional approaches-such as Problem-Based Learning, Guided Discovery, cooperative learning models, and technology-assisted learning-provide structured opportunities for interaction and reflection, thereby amplifying the influence of SRL on communication outcomes. In contrast, teacher-centered instruction tends to limit students' opportunities to express and refine their mathematical thinking, resulting in weaker observable connections between SRL and communication skills. Differences in findings across studies are also explained by educational level and methodological variations. At a higher educational level, students' more mature cognitive and metacognitive abilities allow SRL to exert a stronger influence on mathematical communication. Meanwhile, inconsistencies in measurement instruments and research design contribute to varied results across studies. These differences suggest that the relationship between SRL and mathematical communication is dynamic and context-dependent rather than uniform.

Overall, this review contributes to mathematics education research by providing a comprehensive thematic understanding of how SRL interacts with instructional models and educational levels to influence mathematical communication skills. The findings imply that improving students' mathematical communication requires not only fostering *self-regulated learning* but also designing learning environments that support meaningful mathematical discourse. Future research is encouraged to employ longitudinal designs, diverse assessment methods, and cross-level analyses to further the mechanisms through which SRL supports mathematical communication across different learning contexts.

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