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A Systematic Review of Mathematical Communication Among Secondary and University Students

Una revisión sistemática de la Comunicación matemática en estudiantes de secundaria y universidad

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Abstract

Mathematical communication is an important tool in the process of teaching and learning mathematics, as it promotes conceptual understanding, critical thinking, and problem-solving; however, there are gaps that hinder its promotion in secondary and higher education. The objective of this study was to identify effective strategies for promoting mathematical communication through a systematic review. A search for articles was conducted in the Scopus scientific database, following the PRISMA 2020 protocol. Studies evaluated using the MMAT tool were analyzed, and studies published between 2019 and 2025 that met the established inclusion criteria were considered. Of the 75 articles identified, 41 were included. The findings highlight the effectiveness of collaborative strategies, educational technology, and reflective mathematical writing. However, limitations were identified regarding the duration of the studies, sample sizes, and the geographical concentration in Asia. It is concluded that mathematical communication is a fundamental tool in mathematics learning, the effectiveness of which depends on pedagogical, technological, and contextual factors; therefore, longitudinal, comparative, and cross-cultural studies are recommended. It is recommended to strengthen teacher training and implement multimodal approaches to optimize educational outcomes.

Keywords: Mathematics; Communication; Critical thinking; Problem solving; Learning

Resumen

La comunicación matemática constituye una herramienta importante para el proceso de enseñanza y aprendizaje de las matemáticas ya que favorece la comprensión conceptual, el pensamiento crítico y la resolución de problemas existen brechas que dificultan su fomento en educación secundaria y universitaria. El presente estudio tuvo como objetivo identificar estrategias efectivas para incentivar la comunicación matemática, mediante una revisión sistemática, así mismo se realizó una búsqueda de artículos en la base de datos científica scopus, siguiendo el protocolo PRISMA 2020, se analizaron estudios evaluados con la herramienta MMAT, se consideraron estudios publicados entre 2019 y 2025 que cumplieron con los criterios de inclusión establecidos. De 75 artículos identificados, 41 fueron incluidos. Los hallazgos destacan la efectividad de estrategias colaborativas, tecnología educativa y escritura matemática reflexiva, Sin embargo, se identificaron limitaciones con la duración de los estudios, tamaño de las muestras y la concentración geográfica asiática. Se concluye que la comunicación matemática constituye una herramienta fundamental en el aprendizaje de las matemáticas cuya efectividad depende de factores, pedagógicos, tecnológicos y contextuales, por lo que se recomienda estudios longitudinales, comparativos e interculturales. Se recomienda fortalecer la formación docente e implementar enfoques multimodales para optimizar los resultados educativos.

Palabras clave: Matemáticas; Comunicación; Pensamiento crítico; Resolución de problemas; Aprendizaje

Introduction

Mathematics is perceived as a complex science, which creates uncertainty and limits student participation in class. Mathematical communication facilitates the understanding and practical application of concepts, which is essential for enhancing learning and motivation. Therefore, this involves a process that offers a dual benefit for students: not only do they receive information, but they also transform and express their own knowledge (Ramírez Rincón, 2017).

In the field of mathematics, this includes various forms of expression, which are fundamental to logical reasoning (Ramadhan et al., 2023). However, in high school and college, there remains limited application of these methods for improvement. Teacher training, diverse approaches, and interaction are vital; their absence negatively impacts academic performance, whereas motivation, participation, active listening, and the use of digital tools strengthen students' skills (Planas & Pimm, 2024; Rachmawati et al., 2023).

Recent research has introduced various approaches that integrate figures, diagrams, and digital resources (Planas & Pimm, 2024). Furthermore, the application of methodologies such as problem-based learning is gaining prominence (A'la & Arnawa, 2023). Nevertheless, challenges remain, such as graphic and symbolic communication in specific areas (Nuraini et al., 2023) and the formulation of problems that can be developed into mathematical models (Yunita & Siswanto, 2023).

Mathematical communication structures, organizes, and fosters the discussion of concepts; however, traditional methods limit its development (Suratno et al., 2023). Therefore, it is essential to identify effective strategies that promote meaningful mathematical communication in secondary and higher education

Despite the abundant scientific literature on mathematical communication, there is a methodological gap: the absence of a comprehensive perspective. Research has become fragmented into subdisciplines such as classroom interaction or the use of information technologies, neglecting the necessary comparison across different levels. There is a clear disconnect in the transition from secondary school to college. In the absence of an integrated approach, it is difficult to validate practices that continuously expand and foster students' cognitive development.

The objective of this review is to go beyond existing research and explore mathematical communication comprehensively. Despite the large number of published studies, research has remained limited to isolated cases, creating a significant gap in the connection between mathematics in high school and college. This study does not merely aim to compile information; rather, it proposes a robust synthesis that establishes a less theoretical and more practical foundation for teaching practice, guiding future research that advances mathematical learning

Materials and Methods

The research was conducted using a qualitative, documentary approach, employing the systematic review method. The analysis focuses on the pragmatic paradigm, which facilitates a general understanding of educational phenomena in both their practical and theoretical aspects (Maarouf, 2019). The process was organized in accordance with the PRISMA 2020 statement, ensuring a rigorous process of identifying, selecting, and integrating scientific evidence.

Search Strategies and Information Sources

Information was collected from the Scopus database. Following guidelines on the importance, comprehensiveness, and accuracy of systematic reviews to ensure the reliability of the findings, search queries were developed using controlled descriptors and Boolean operators (Trifu, 2022). Therefore, the following search terms were used: ("mathematical communication" OR "mathematical discourse" OR "mathematical writing" OR "mathematical argumentation") AND ("mathematics education" OR "learning"). The search period was set between 2015 and 2025. The search was conducted in August 2025.

Eligibility Criteria

The following inclusion criteria were established for selecting the document sample:

1. Original empirical research articles
2. Studies specifically focused on mathematical communication in secondary or higher education
3. Publications subject to scientific rigor through peer review
4. Manuscripts in Spanish or English

Book chapters, conference proceedings, letters to the editor, and studies for which access to the full text was restricted—preventing an assessment of their technical quality—were excluded.

Selection and Data Extraction Process

To systematize the information, a data extraction matrix was designed that included variables such as author, year of publication, country, educational level, methodological approach, type of pedagogical strategy, main results, and limitations of each study. The process was carried out in four phases according to the PRISMA 2020 flowchart. Initially, 75 articles were identified; after eliminating duplicates by reviewing the titles and abstracts, the full texts of the documents were analyzed. Similarly, a final sample of 41 scientific articles that met the review's objectives was established. The selection was carried out in accordance with previously established criteria to minimize potential biases in the selection of studies.

Assessment of Methodological Quality

The quality of the included studies was assessed using the Mixed Methods Appraisal Tool (MMAT), version 2018. This instrument allowed us to verify the rigor of the selected studies by evaluating the relationship between methodology and results. Furthermore, the results of this assessment were considered when interpreting the methodological soundness of the studies, enabling a critical analysis of the evidence without automatically excluding any studies.

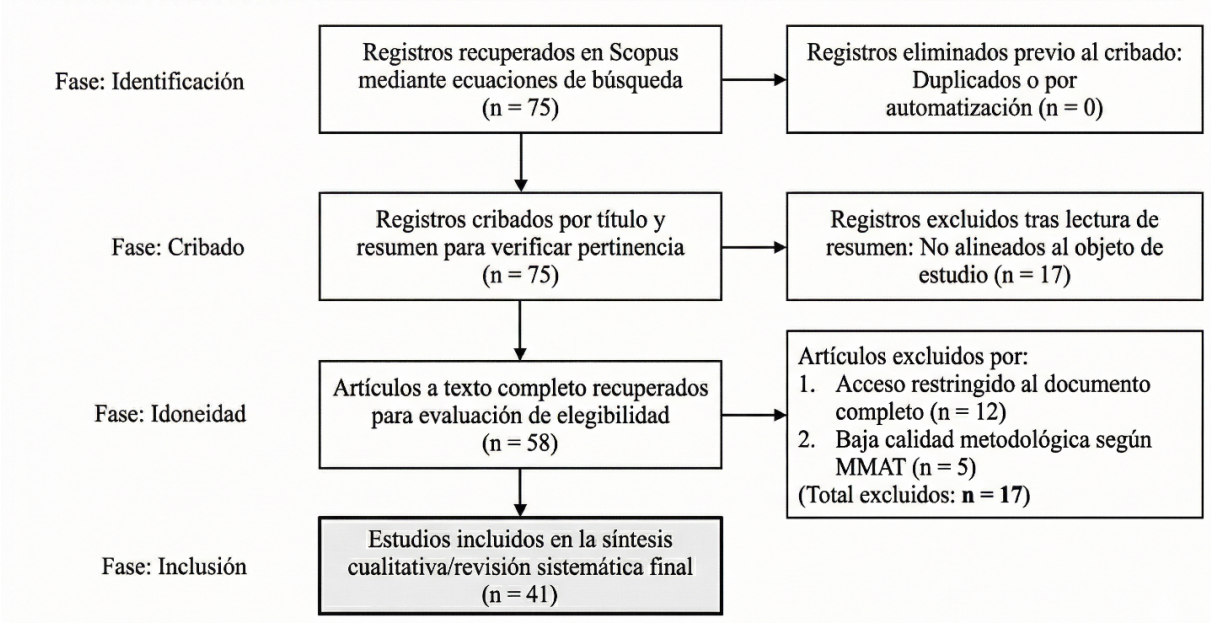

Figure 1. PRISMA flowchart for source selection

Results

A total of 75 records were identified in the Scopus database, of which 41 met the established inclusion criteria. The selected studies addressed various strategies aimed at strengthening mathematical communication among secondary and university students.

Table 1. *List of selected articles on mathematical communication and its impact on the academic performance of secondary and university students*

Author(s) and year	Language	Journal Name	Database
(Supriyanto et al., 2020)	English	Design of Worksheets for RME Models to Improve Mathematical Communication	Scopus
(Uyen et al., 2021)	English	Developing mathematical communication skills for 8th-grade students when teaching topics on congruent triangles	Scopus
(Saragih & Napitupulu, 2015)	English	Developing a Student-Centered Learning Model to Improve Higher-Order Mathematical Thinking Skills	Scopus

(Ummah & Sari, 2018)	Indonesian	The Effectiveness of the Missouri Mathematics Project Learning Model on Junior High School Students' Mathematical Communication Skills	Scopus
(Prabawanto, 2019)	English	Enhancement of Students' Mathematical Communication Through a Metacognitive Scaffolding Approach	Scopus
(Wardono et al., 2020)	English	Comparison between generative learning and discovery learning in improving written mathematical communication skills	Scopus
(Yaniawati et al., 2019)	Indonesian	Core model for improving mathematical communication and connection: Analysis of students' mathematical disposition	Scopus
(Le Thai Bao Thien Trung et al., 2020)	English	Enhancing mathematical communication in the classroom: A case study	Scopus
(Ismail et al., 2023)	English	Exploring self-regulated learning and its impact on students' mathematical communication skills regarding number patterns using a blended learning system	Scopus
(Tinungki et al., 2024)	English	Exploring team-assisted individualized cooperative learning to enhance mathematical problem-solving, communication, and self-efficacy in teaching nonparametric statistics	Scopus
(Paricahua-Peralta et al., 2023)	Spanish	Exploring visual, hearing, and learning disabilities among college students	Scopus
(Pantaleon et al., 2023)	English	Female Students' Mathematical Communication Ability in the Proof-Writing Process: A Review Based on Math Anxiety	Scopus
(Hidayat & Aripin, 2023)	English	How to Develop an E-LKPD with a Scientific Approach to Enhancing Students' Mathematical Communication Skills?	Scopus
(Nuraida & Amam, 2019)	English	Hypothetical learning trajectory in realistic mathematics education to improve the mathematical	Scopus

		communication of junior high school students	
(Ningsih et al., 2023)	English	Is communicating mathematics a factor in the ease of online learning?	Scopus
(Silva et al., 2021)	English	Learning scenario to promote understanding of the meaning of subtraction	Scopus
(Van Jaarsveld, 2016)	English	Making a case for precise language as an aspect of rigor in mathematics programs for pre-service teachers	Scopus
(Agustina et al., 2024)	English	Students' Creative Thinking Ability in Mathematics Literacy Problems	Scopus
(Bach et al., 2024)	English	Students' Dynamic Communication While Transforming Mathematical Representations in a Dynamic Geometry Environment	Scopus
(Suprapto et al., 2023)	English	Students' Mathematical Literacy Skills in Terms of Gender Differences: A Comparative Study	Scopus
(Kock et al., 2022)	Spanish	*Students' Writing in Mathematics Classes*	Scopus
(Sjöblom et al., 2023)	English	Teachers' Noticing to Promote Students' Mathematical Dialogue in Group Work	Scopus
(Rachmawati et al., 2023)	English	Students' Mathematical Communication Through the "Check-in-Pairs" Cooperative Learning Model	Scopus
(Muhtarom et al., 2021)	English	Profile of Prospective Teachers' Mathematical Communication Ability as Assessed by the Adversity Quotient	Scopus
(Argarini et al., 2020)	English	The Development of Learning Materials and Students' Level of Mathematical Communication Ability	Scopus
(Dewi & Kuswanto, 2023)	English	The effectiveness of using an augmented reality-assisted physics e-module based on a pedicab to improve mathematical communication and critical thinking skills	Scopus

(Siregar et al., 2020)	English	The effects of a discovery learning module on geometry for improving students' mathematical reasoning skills, communication, and self-confidence	Scopus
(Angraini, 2019)	English	The influence of the concept attainment model on mathematical communication ability among university students	Scopus
(Tinungki et al., 2022)	English	Team-Assisted Individualization: A Cooperative Learning Model for Improving Mathematical Problem-Solving, Communication, and Self-Proficiency: Evidence from Operations Research Instruction	Scopus
(Pratiwi et al., 2020)	English	Textual and Contextual Cognitive Conflict Among Students in Solving Improper Fractions	Scopus
(Kurniawan et al., 2021)	English	The PINTER learning model to enhance higher-order thinking and communication skills in algebra	Scopus
(Sánchez Paredes & Vargas D'Uniam, 2016)	Spanish	Using Blogs to Develop Mathematical Communication Skills in Secondary Education	Scopus
(Ingram et al., 2019)	English	When students offer explanations without the teacher explicitly asking them to	Scopus
(Alahmadi, 2019)	English	Mathematical Writing of Third-Year Female Students at Intermediate School Level in Riyadh and Its Relationship to Mathematical Thinking	Scopus
(Widodo et al., 2020)	English	Confirmatory Factor Analysis of Sociomathematics Norms Among Junior High School Students	Scopus
(Simelane-Mnisi & Mji, 2019)	English	Technology-Engagement Teaching Strategy Using Personal Response Systems to Influence Students' Approaches to Learning and Increase the Mathematics Pass Rate	Scopus
(Rosita et al., 2019)	English	Design of learning materials on circles based on mathematical communication	Scopus

(Palinussa et al., 2021)	English	Realistic mathematics education: Mathematical reasoning and communication skills in rural contexts	Scopus
(Maure et al., 2022)	English	Argument and demonstration exemplified in a mathematical dialogue	Scopus
(Kamid et al., 2020)	English	Mathematical communication skills based on cognitive styles and gender	Scopus
(Umbara et al., 2021)	English	Algebra Dominoes Game: Redesigning Mathematics Learning During the COVID-19 Pandemic	Scopus

Impact on Academic Performance

The reviewed studies agree on the positive association between effective mathematical communication and academic performance. Clarity in the expression of ideas not only contributes to problem-solving but also fosters conceptual understanding of the principles underlying mathematical operations (Alahmadi, 2019). In this vein, collaborative learning based on mathematical discourse is presented as a more structured and meaningful educational resource, as it promotes shared processes of knowledge construction (Prabawanto, 2019; Yaniawati et al., 2019; Ummah & Sari, 2018). However, classroom interaction takes on different nuances; it reinforces the exchange of ideas, the construction of arguments, and the rationale behind decisions (Widodo et al., 2020; Simelane-Mnisi & Mji, 2019), while others emphasize resilience and self-confidence, which have positive effects on student retention and achievement (Argarini et al., 2020).

Communication and Collaborative Work

The social dimension of mathematical communication is evident in various studies that recognize the value of teamwork as a strategy for strengthening problem-solving skills for highly challenging problems (Van Jaarsveld, 2016; Paricahua-Peralta et al., 2023) and stimulating creativity in the search for new solutions (Palinussa et al., 2021). Furthermore, constant interaction between teachers and students reinforces the understanding of complex concepts and improves performance on assessments, provided that constant and relevant feedback is maintained (Wardono et al., 2020; Sánchez-Paredes & Vargas D'Uniam, 2016). Meanwhile, self-assessment is seen as a resource that fosters autonomy and promotes confidence in problem-solving (Agustina et al., 2024),

reinforcing the idea that collaborative work integrates both social and cognitive processes.

Technological Tools and Innovative Strategies

The application of technology is a well-established and important tool in mathematical communication; various recent studies show that digital tools allow for the active manipulation of concepts, which is beneficial for students with various written and oral difficulties (Widodo et al., 2020; Tinungki et al., 2020). Likewise, these tools reinforce mathematical writing with precise and complex structure (Angraini, 2019; Siregar et al., 2020). Other complementary studies affirm the importance of playful activities and the use of online platforms, which increase participation, engagement, and the ability to learn independently (Ningsih et al., 2023; Ismail et al., 2023; Le Thai Bao Thien Trung et al., 2020). When collaborative strategies are integrated in a coordinated manner, technologies foster dynamic and meaningful learning (Bach et al., 2024).

Mathematical Writing as a Strategy

Mathematical writing is considered a key form of communication, as it bridges the abstract and the concrete, facilitating the organization of ideas and reinforcing logical reasoning (Supriyanto et al., 2020; Alahmadi, 2019). Consistent practice allows students to identify errors in problem-solving and correct them more consciously (Saragih & Napitupulu, 2015; Kurniawan et al., 2021). Furthermore, this strategy fosters critical thinking and promotes the generation of better-supported ideas (Kock et al., 2022), which contributes to both the development of analytical skills and individual confidence in the learning process. Empirical evidence also shows that consistent writing builds confidence in problem-solving and strengthens analytical competence at various educational levels (Pantaleon et al., 2023; Pratiwi et al., 2020; Tinungki et al., 2024).

Mathematical Communication and Critical Thinking

The reviewed research shows a clear relationship between mathematical communication and critical thinking. Student participation in discussions and writing activities promotes the development of analytical skills and fosters autonomy in decision-making (Alahmadi, 2019; Ingram et al., 2019; Pantaleon et al., 2023). Likewise, mathematical reasoning is recognized as a means of evaluating the logic and validity of solutions, identifying gaps in the process, and building solid knowledge (Simelane-Mnisi & Mji, 2019; Kamid et al., 2020; Maure et al., 2022). These findings indicate that mathematical communication is not

limited to the transmission of knowledge but serves as a catalyst for self-regulation and the development of significant cognitive skills.

Pedagogical Conditions for the Integration of Digital Technologies

The use of technological resources has been instrumental in improving mathematical communication by bringing students and teachers together in virtual environments, educational applications, and virtual reality simulators (Suprapto et al., 2023). These tools enhance mathematical communication by facilitating collaborative learning. At the same time, they facilitate the understanding of complex concepts and problem-solving, strengthening the link between technology and pedagogy. Furthermore, the integration of digital platforms fosters student engagement, which promotes autonomy, motivation, and a willingness to learn mathematics (Ningsih et al., 2023; Ismail et al., 2023). In summary, technology is not viewed as a mere supplement but as a mediator that expands the possibilities of mathematical communication and learning.

Based on this premise, the following table summarizes the key findings, comparing the strengths and critical aspects identified in the literature to provide a balanced view of their actual impact.

Table 2. *Summary of Findings on Mathematical Communication Strategies*

Category	Identified strengths	Reported Limitations
Use of digital technologies	Helps visualize abstract concepts and promotes student motivation	Risk to sustainability without adequate pedagogical guidance
Collaborative work	Fosters shared reasoning, peer learning, and critical thinking	Challenges in coordination; unequal participation in diverse groups
Mathematical Writing	Enhances precision in expressing ideas and fosters reflective and critical thinking	Requires ongoing teacher support; limited evidence of effectiveness in large-scale settings
Oral Communication and Argumentation	Enhances conceptual understanding and the development of metacognitive and discursive skills	Students with low mathematical literacy face greater obstacles in implementing these skills

ICT integration with teacher mediation	Enables inclusive and active learning experiences by connecting theory and practice	The observed benefits are limited and not very sustainable in the long term when there is no adequate pedagogical support.
Critical and reflective thinking	Promotes student autonomy, complex problem-solving, and the transfer of learning	Few longitudinal and comparative studies; lack of evidence across different educational levels

Impact on academic performance

The reviewed studies show that the impact of mathematical communication is not uniformly consistent. Furthermore, when teacher mediation is deliberate and organized, the results in justification and logical reasoning are more robust and can be applied in different contexts (Simelane-Mnisi and Mji, 2019; Pantaleon et al., 2023). On the other hand, in activities involving spontaneous participation, progress is more varied, demonstrating that mathematical communication depends on educational conditions and does not operate independently (Uyen et al., 2021), furthermore, complementary research on mathematical argumentation reinforces metacognition and reduces students' anxiety when faced with complex problems (Kurniawan et al., 2021; Kamid et al., 2020; Muhtarom et al., 2021). However, its effectiveness during reasoning varies depending on the complexity of the task and the educational level, which underscores the need for comparative and longitudinal studies that observe the process and its consolidation throughout students' educational careers.

Communication and Collaborative Work

While most research supports the effectiveness of teamwork in the mathematics learning process, the results must be interpreted with consideration of methodological and contextual limitations. Some of these studies were conducted with small samples or in different cultural settings, which limits the generalizability of the findings. Furthermore, while the effectiveness of group work is not consistent across all classrooms, in settings where a positive socioemotional environment is fostered and teachers are well-trained (Sjöblom et al., 2023), collaboration has a notable impact on performance and motivation. On the other hand, in settings with weaker bonds or less preparation, the benefits tend to diminish. These variations suggest that teamwork should not be viewed as an effective strategy in all cases, but rather as a practice that depends on different contexts requiring deeper analysis in comparative and larger-scale studies.

Technological Tools and Innovative Strategies

Technological tools have demonstrated multiple benefits in mathematical communication processes; however, the results vary. A significant portion of the studies lack follow-up at various stages, making it impossible to determine the sustainability of the benefits over time. Crucially, the initial motivation generated by playful activities diminishes in the absence of an accompanying pedagogical design, reflecting that technological resources depend on their integration into well-structured pedagogical processes. In conclusion, the evidence indicates that the greatest achievements occur when technology is integrated with collaborative practices and teacher mediation, whereas its isolated use leads to limited and short-term results.

Mathematical Writing as a Strategy

Available studies on mathematical writing show positive results in the development of students' reasoning and autonomy. On the other hand, it also has certain limitations that need to be examined. Most studies evaluate writing over short periods or in isolated experiences, which limits our understanding of its long-term impact. Furthermore, the reported achievements depend largely on the quality of teacher- y feedback: in contexts where this feedback is systematic and guiding, the benefits in logical reasoning and autonomy are more consistent; conversely, in settings with little mediation, progress tends to be superficial. This suggests that mathematical writing, while valuable, is not a self-sufficient practice but rather requires sustained pedagogical integration and rigorous teacher support to foster lasting learning

Mathematical Communication and Critical Thinking

The reviewed evidence supports the relationship between mathematical communication and the development of critical thinking; however, some studies have limitations that restrict the scope of their findings. Much of the evidence comes from Asian contexts, particularly Indonesia, Malaysia, and Vietnam, leaving a research gap in regions such as Latin America and Europe, where communicative and pedagogical practices may differ significantly. This geographic concentration raises questions about the transferability of the findings and underscores the need for cross-cultural comparative studies.

Although the empirical evidence comes primarily from Asian settings, its essential components are fully contextualized to the Peruvian reality. In contexts marked by pedagogical challenges, fostering argumentation and collaborative work emerges as a viable strategy for raising learning levels. However, this process must be approached critically; the effectiveness of digital tools and

mediation strategies depends on the specific characteristics of the educational system. The challenge, therefore, must focus on organic integration that addresses both teacher training and connectivity gaps, ensuring a meaningful transition toward communicative teaching models.

Furthermore, while some studies highlight the effectiveness of teaching through guided discussions to strengthen critical reasoning, others suggest that in settings with less teacher guidance, the benefits are less consistent. Consequently, the relationship between mathematical communication and critical thinking must be understood as an interplay of contextual, cultural, and pedagogical factors that still require further empirical study.

Pedagogical Conditions for the Integration of Digital Technologies

Despite various advances in the literature and the incorporation of technology into mathematical communication, the findings have limitations in terms of both methodology and context; the limited number of cases and the scarcity of information restrict the generalizability of the results to a broader scenario, and the existing evidence largely comes from highly connected environments, which does not allow for an assessment of technological limitations. In this regard, the impact of digital platforms depends not only on the tool itself but also on pedagogical support; interaction loses depth and does not guarantee meaningful mathematical dialogue.

Although the reviewed studies broadly validate the benefits of mathematical communication, difficulties persist when attempting to compare its relative effectiveness between secondary and higher education levels. Rather than a lack of results, we are faced with a diversity of approaches that hinders a meaningful comparative analysis. This limitation highlights the need to move toward more standardized assessment frameworks that allow us to identify which practices are consistent across levels and which ones correspond to characteristics specific to each educational stage. In this context, the evidence gathered positions mathematical communication not as a peripheral skill, but as a critical component in the architecture of learning. However, its effectiveness is not an intrinsic property of the technique itself, but rather emerges from the synergy between instructional design and the specific characteristics of the school environment.

Overall, the reviewed studies show that mathematical communication is an important tool for conceptual understanding, logical reasoning, argumentation, and problem-solving among secondary and university students. Furthermore, its effectiveness is conditioned by pedagogical, technological, and contextual factors that influence the quality of learning interactions; methodological limitations—such as short-term studies and small sample sizes, particularly in Asian contexts—restrict the generalizability of the

findings. Finally, future research should conduct longitudinal, comparative, and cross-cultural studies to understand the evolution of mathematical communication throughout the educational process and to establish assessment standards across different educational levels.

Conclusions

This systematic review, based on a comprehensive analysis of 41 documents, leads to the conclusion that mathematical communication transcends the simple transfer of information to become a fundamental two-way process in the development of critical thinking. The findings confirm that the ability to encode and decode mathematical messages is the foundation upon which conceptual understanding and the resolution of complex problems are built, acting as a bridge between symbolic abstraction and logical reasoning. In particular, it was identified that strategies such as collaborative work, mathematical writing, and the use of digital technologies yield consistent positive results across different educational levels, although these results are influenced by pedagogical and contextual factors.

It is established that the effectiveness of instructional strategies such as collaborative learning, reflective writing, and technological mediation is not only an inherent property of the pedagogical tool but also arises from a conscious pedagogical structure. By integrating emerging technological resources and digital tools, a shift is observed from traditional models toward dynamic learning environments that promote equity and reduce math anxiety. This emotional space emerges as an integral component of academic success, where communication acts as a source of support and autonomy for students.

Consequently, the study highlights the decisive role of the teacher as a facilitator of communication in various aspects. Professional training must go beyond disciplinary expertise to incorporate competencies in interpreting graphic, gestural, and digital expressions. This humanistic perspective on teaching allows the classroom to be transformed into a space for interaction through dialogue, where the reduction of communication barriers directly translates into improved academic performance and a more functional view of mathematics for civic and professional life.

As with any systematization process, there are limitations that must be acknowledged. The predominance of studies conducted in Asian settings poses a challenge regarding representativeness, suggesting that the results may not be fully applicable in contexts with different cultural or pedagogical dynamics. On the other hand, the short time frames analyzed in the available evidence limit our understanding of the long-term development of mathematical competence, leaving an important avenue open for future, more extensive research.

In short, the evidence gathered positions mathematical communication as an indispensable facilitator not only of academic performance but also of students' cognitive and socio-emotional development. Furthermore, its success is not accidental;

it stems from a critical interplay between instructional design, teacher intervention, and the specific characteristics of the learning environment. Looking ahead, the field requires a shift from observational studies to larger-scale research. It is important to prioritize longitudinal and comparative designs that test the stability of these findings and their adaptability across different educational settings.

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