SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Communication in Mathematics Among School Children: A Systematic Review

Ahmad Shidki Mat Yusoff[1,*], Kamalambal Durairaj[2], Rosmawati Mohamed[3,♣], Fan Siong Peng[1], Norhasliza Abdullah[4], Hazram Ismail[1], Salmiah Md. Salleh[5] , Zuraidi Wahid[6]

[1] Department of Planning, Research and Innovation, Institut Pendidikan Guru Kampus Sultan Mizan, 22200 Besut, Terengganu, Malaysia
[2] Training and Research Division, Southest Asian Ministers of Education Organisation, Regional Centre for Education in Science and Mathematics, 11700 Gelugor, Penang, Malaysia
[3] Department of Science, Institut Pendidikan Guru Kampus Sultan Mizan, 22200 Besut, Terengganu, Malaysia
[4] Department of Mathematics, Institut Pendidikan Guru Kampus Sultan Mizan, 22200 Besut, Terengganu, Malaysia
[5] Institut Pendidikan Guru Malaysia, Block 2250, Jalan Usahawan 1, 63000 Cyberjaya, Selangor, Malaysia
[6] Pejabat Pendidikan Daerah Besut, Terengganu, Malaysia

ABSTRACT

Over the last two decades, a lack of mathematical communication (MC) skills has hampered elementary students' ability to comprehend mathematical content and solve mathematical problems. However, there are only a few articles that review the research patterns in MC among students in the early grades. Therefore, this paper offers a thorough and systematic overview of the research trend since 2020. This overview is useful for researchers because it provides a synthesis of available evidence and indicates in which directions further research should be directed. The first step is to search the Scopus database for documents in format. csv produces 34 articles. Five research themes emerged from the two-step analysis: publication trends, most cited papers, most published journals, top contributing countries, and methodological approaches. Because the subject is so important, it's essential to encourage collaborations between institutions that study MC and use the methods shown or more advanced ones across math content and student grade level.

Keywords:
Mathematics communication,
mathematics education, school,
systematic review

Received: 13 August 2022 **Revised: 11 October 2022** **Accepted: 17 October 2022** **Published: 31 October 2022**

1. Introduction

Communication is the process of exchanging information with others. These communication methods may be verbal or written. Both modes of communication are crucial for the transmission of ideas. Communication abilities are crucial in many disciplines, particularly in mathematics. Today's schools continue to lack an efficient communication method, notably in the mathematics subjects. In some aspects, true communication distribution is still imperialized in certain ways. This problem

**Corresponding Author*
E-mail address: shidki@ipgmksm.edu.my
♣ E-mail address: rosmawati2636@gmail.com

https://doi.org/10.37934/araset.28.2.275290

might be caused by a number of circumstances. Teachers are often held accountable for completing the allocated curriculum within the time frame indicated. Furthermore, teachers must evaluate programmes and other extracurricular activities that may have an impact on student attendance. These challenges and constraints lead to one-way communication in teaching mathematics.

In the conventional method of education, for example, the teacher presents the subject and then gives comments. Students can only learn what the teacher teaches them via this mode of communication, and they may have difficulties completing the example-heavy assignment. While communicating in a one-way method, students were unable to impart their newly gained information. Here, teachers impart information to their students and they do not get the opportunity to discuss the knowledge learned with their classmates and get acknowledgement from their teachers.

Students are required to share and transfer information obtained in class using mathematical languages in order for their understanding, knowledge, and capacity to transfer knowledge to be assessed. Unfortunately, how well have these been implemented in the classroom? One of the causes of students' inadequate level of mathematical communication abilities is that they are not accustomed to practising these skills, particularly in the field of resolving difficulties requiring high-order thinking skills (HOTS) [1]. The practise should begin in the classroom under the guidance of the teachers.

In order to effectively communicate in mathematics, students must be able to use mathematical language in a clear, accurate, and logical manner. For that, students must master two important skills: verbal and written mathematical communication skills, as well as applying mathematical connections to other subjects and in daily life. Teachers should prioritise the exposure of students to mathematical communication skills in this regard.

Different scholars defined mathematical communication in various perspective. Some scholars defined mathematical communication in term of skills which includes the ability of students to write, discuss, and listen about mathematics; the ability to connect mathematical relations or ideas in written or verbal communication with images, graphics, and real objects; the ability to find the connection of real images, objects, and diagrams into mathematical ideas; and the ability to arrange math questions that are relevant to the problem situation and understand the written math [2, 3]. Whereas [4], defined in term of intrapersonal perspective, which stated that communication can increase students' self-confidence and belief in their own abilities and also contribute to the students' ability to think mathematically, solve problems, and reason effectively since effective mathematical communication is fundamental to students' success in mathematics classes.

In the literature review, the National Council of Teachers of Mathematics (NCTM) [5] emphasised the importance of communication in mathematics and mathematics education. As such, in the classes that provide guidance, engagement, and opportunity for oral communication, children tend to learn to communicate mathematically [5]. In addition, NCTM [5] also stated that young children should use math language to express mathematical ideas. The communication standard emphasises the importance of the students' being able to communicate their mathematical reasoning to their teachers and classmates.

Another researcher, [6], defined mathematical communication as the ability to transfer images, graphs, and real-world objects into mathematical concepts; to use physical reality, visuals, drawings, and mathematics to explain ideas and mathematical relationships in writing or vocally; to use mathematical terminology and representations to convey everyday concerns; and to listen, negotiate, write, and give mathematical presentations.

This communication may be used to demonstrate the significance of students' mastery of mathematics and its relevance to everyday life. It is probable that students who can clearly express

themselves quantitatively also have a solid understanding of their subject area. Aside from mastery of communication skills, the ability to connect knowledge is also critical for students to be able to connect and share their ideas verbally and in writing. This will assist the students to master math concepts, like being able to explain connections and relate them to other subjects and everyday life.

According to [3], mathematical connections are the ability to convey mathematical ideas (orally and in writing), the ability to understand and accept others' mathematical ideas carefully, critically, analytically, and evaluatively to sharpen our understanding. As such, Rohendi [3] added, mathematical connection abilities are: applying mathematics in other fields of study or daily life; finding relationships between various representations of concepts and procedures; understanding equivalent representations of a concept; finding relationships of one procedure with other procedures in equivalent representation; understanding and applying the relationships between mathematical topics and between mathematical topics with other subject topics.

In elementary school mathematics, students learn the basics of mathematics skills and are expected to recognize, master, and reconstruct examples of them. Tasks that require students to build basic knowledge and generalise from examples emphasising the importance of generalisation As such, [7] elaborated on generalization as extending the use of an existing schema, reconstructing the generalisation and expanding its applicability, and disjunctive generalization, which separates an existing schema into several new ones in a new context.

In addition, [8] suggested a theory while dealing with younger students about how ideas might be built up from actual instances. The synthesis of knowledge is emphasised in the education of younger students, which starts with simple ideas and proceeds to more general concepts via experience and examples. The focus at this level is evolving to incorporate more problem-solving and open-ended study. Most of the time, teachers break down complicated ideas or larger parts into smaller pieces so that they can teach each piece separately. Even though the learner may understand the parts as they are given separately, they start to have trouble with the work because they don't see how the parts fit together to make the whole challenge.

Other researchers, [9], recommended using the Discovery Learning Model to enhance the students' communication abilities. From their study, they concluded that employing the Discovery Learning paradigm enhanced the communication abilities of seventh-grade pupils in mathematics. Teachers may choose to apply the Discovery Learning model to help students communicate more effectively about mathematics, and future studies are recommended to examine the approach's applicability to other math topics or at various educational levels.

In a nutshell, the importance of the construction of mathematics, mathematical ideas, and language includes input in the teaching, which comprises proper strategies, approaches, techniques, and activities from the teachers. However, teachers are found less emphasis on the understanding of mathematical language in class [10], of the existence of inaccurate and misleading language to explain mathematical constructs [11]. Therefore, teachers need to be smart in making the selection of teaching materials that match student learning [12] by developing understanding based on students' existing cognitive knowledge because lesson planned before class does not necessarily happen in the classroom [13].

Through mathematical communication, teachers have opportunity to identify students' mathematical communication skills and performance in students' results. Good or bad the results represent the feedback on teachers' approach for making students understand the mathematical concept. Therefore, other than that, the rationale for the need of this review paper also to increase researchers' or even educators' awareness and interest in study patterns in mathematical communication at the primary school level so that they realise the importance of understanding mathematical terms such as geometry in [14] and velocity which utilised across field or curriculum

and closely related to daily life as in [15]. Besides, the mathematical communication skills prepared the students with the ability to use and understand various internet of things (IoT) materials and solving problems regarding mathematics and technology. The rational is students who were found to be weak in mathematics and reasoning skills difficult for teachers to teach IoT to them [16].

This review paper provides suggested articles on mathematical communication which connected to reasoning, problem solving, mathematical concepts, or even various technology that help researchers to find and explore in dept on relevant issues during the limited time. Furthermore, the organised process of conducting research presented in a systematic literature review (SLR) offers researchers directions for conducting future research on communication in mathematics.

Therefore, the purpose of this research is to identify discussions about communication in mathematics in current educational studies. This SLR examines published works from the field of mathematics communication among primary school students to inform readers of the most recent trends, limitations of existing research, and future prospects. This SLR may be of tremendous use to educators and researchers and might serve as the foundation for future work, thus enhancing the quality of instruction and the significance of communication in mathematics. This review broke the studies down into topics so that we could better analyse, summarize, and make suggestions for more research. This paper's remaining sections are organised as follows: The next section discusses the research objectives and explanation, as well as the limitations and possible directions for future research. The following section discusses the key findings and contributions of the paper.

With this information, the objectives of this study are specifically interested to identify (i) the annual trends in publishing; (ii) the top ten most-cited papers; (iii) the top 20 published journals; (iv) countries contribute the most; and (v) the approaches to methodology.

2. Methodology

2.1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedure

This study used a systematic literature review, adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedure, to present a comprehensive and structural view of previous literature on mathematics communication in schools. There are two major steps involved: identifying and screening the abstracts of targeted journals, and later qualifying and including full-text articles.

This study used a systematic literature review, adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedure, to present a comprehensive and structural view of previous literature on mathematics communication in schools. There are two major steps involved: identifying and screening the abstracts of targeted journals, and later qualifying and including full-text articles.

2.1.1 Step 1 Identification and screening of the abstracts of targeted journals

On February 15, 2022, the first author leads the search through the Scopus database. By restricting the search platform, a Scopus database could provide a broad view of the credibility of articles in mathematics communication published across disciplines. Technology, cognitive behaviour, and the sciences, for example, are available and provide global researchers' perspectives. Previous studies have used a single database, such as [17] and [18]. This study follows the search key: "mathematical* communication" or "mathematic* representation" or "mathematic* reasoning" and "junior school" or "elementary school" because it covers all of the titles, abstracts, and key words in selected articles. A total of 79 articles were found. Then, for further use, a.csv file was downloaded and combined with Microsoft Excel.

Microsoft Excel was used to screen the profiles of the selected articles. Some articles were removed based on the following criteria: unrelated to mathematical communication; redundant; focusing solely on teachers; and no full text. Out of the 79 articles retrieved, 43 were excluded. The first step of analysis begins after removing two redundant articles and nine articles unrelated to mathematics as in Figure 1. This brings us to the existence of objective 1, 2, and 3.

2.1.2 Step 2 Article eligibility and inclusion in full-text

A second round of analysis was performed on the remaining 36 articles. After assessing full text articles for eligibility, there are two articles that need to be removed as the participants or sample involve university or college students whereby this study aims at mathematics communication among elementary children. Therefore, a total of 34 articles were included in the final analysis.

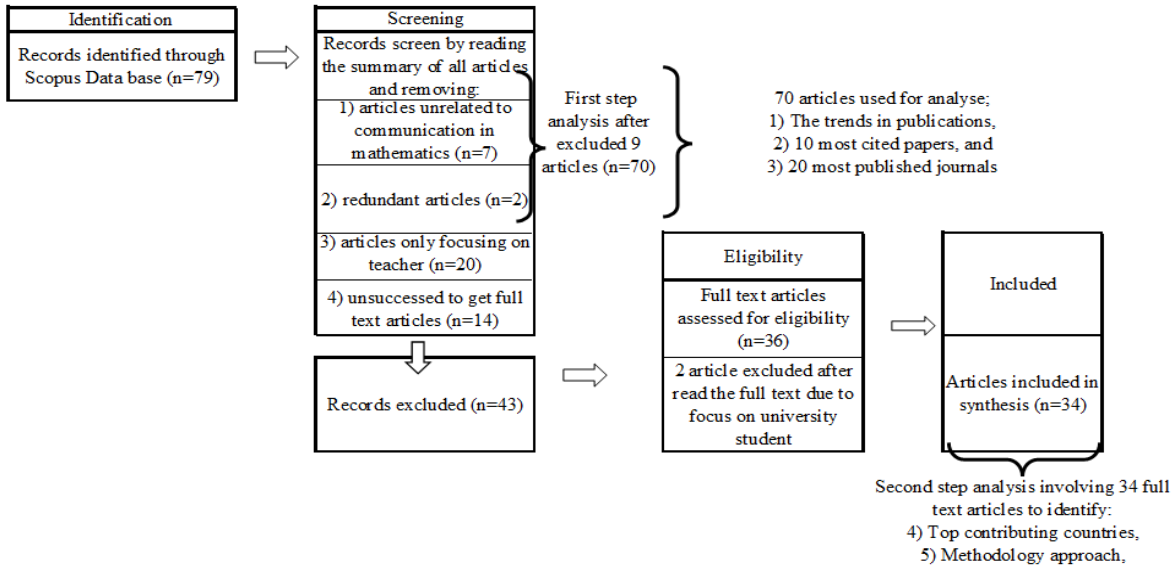

Fig. 1. The Down Stair of Systematic Review

2.2 The articles profile

As shown in Table 1, the profiles of 34 selected articles included from 79 articles identified in the Scopus database have been published for over two decades, from the year 2000 until 2021. More specifically, all articles selected involve students as participants or sample studies, and within the search keywords utilized, only four studies involve both students and teachers.

Table 1
The articles profile

Article	Title	Research sample/ participants	
		Student	Teacher
[19]	Learning scenario to promote comprehension of the meaning of subtraction	√	
[20]	Media Technology Takontikasi Games Based of Realistic Mathematics	√	√

[21]	The improvement of mathematical communication ability of elementary school students through project-based learning using mind map technique	√	
[22]	Developing mathematical communication skills for students in grade 8 in teaching congruent triangle topics	√	
[23]	Classification of mathematical reasoning competencies based on mathematical problem solving in elementary school	√	√
[24]	A pathway towards STEM integration: Embodiment, mathematization, and mechanistic reasoning	√	
[25]	Preliminary Research of Mathematics Learning Device Development Based on Realistic Mathematics Education (RME)	√	
[26]	Analysis of elementary student's mathematical connection and communication ability	√	
[27]	Characteristics of students' mathematical representation in solving algebraic thinking problems	√	
[28]	Analysis of elementary school students' ability on mathematical communication and mathematical representation	√	
[29]	The effect of metacognitive-based contextual learning model on fifth-grade students' problem-solving and mathematical communication skills	√	
[30]	Description of mathematical communication skills, logical thinking and its influence on the ability of mathematical literacy for students of grade v elementary school	√	
[31]	Gesture of slow learner student in mathematical Communication	√	
[32]	The effect of cooperative learning Type Teams-Games-Tournaments (TGT) on mathematical connection and communication ability in elementary schools	√	
[33]	Programming, mathematical reasoning and sense-making	√	
[34]	The effectiveness of learning models on written mathematical communication skills viewed from students' cognitive styles.	√	
[35]	Empowering students with specific learning disabilities: Jim's concept of unit fraction.	√	
[36]	Developing Students' Mathematical Literacy through Problem Based Learning	√	
[37]	Two-stay two-stray model on improving mathematical communication skill of elementary school students	√	
[38]	Students' Error Types and Reasoning Ability Achievement Using The Indonesian Realistic Mathematics Education Approach.	√	
[39]	Mathematical Representation of Deaf Students in Problem Solving Seen from Students' Creative Thinking Levels.	√	
[40]	Students' ability of mathematical representation on statistics topic in elementary school.	√	
[41]	The Effects of Using Representations in Elementary Mathematics: Meta-Analysis of Research.	√	
[42]	Mathematical reasoning fostered by (fostering) transformations of rational number representations	√	√
[43]	The Effect of Open-Ended Approach Towards Students' Mathematical Reasoning	√	

[44]	The quality of learning materials through mathematics reaslitic to improve students' mathematical communication ability in the elementary school	√	
[45]	Elementary students' representations in solving word problems	√	
[46]	Self-regulated math instructions for pupils with learning disabilities	√	
[47]	Examining how professional development influences elementary school teachers' enacted instructional practices and students' evidence of mathematical understanding	√	√
[48]	How young children view mathematical representations: a study using eye-tracking technology	√	
[49]	Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get	√	
[50]	The notion of proof in the context of elementary school mathematics	√	
[51]	Computer tools for interactive mathematical activity in the elementary school	√	
[52]	Elementary school students' logical reasoning on rolling	√	

3. Results

3.1 The annual trends in publishing

In order to evaluate the trends of publications, Table 2 and Figure 2 represent the general number of publications of all papers on communication in mathematics. As depicted in Table 2, papers have been structured by increasing year. The percentage of papers for each year is also indicated.

We discovered in our 20-year review of publications that the number of articles decreased from 2002 to 2012, but increased somewhat in 2013. The majority of papers published each year on mathematics communication include less than ten articles. Nonetheless, a 24.29 percent increase in publishing was recorded for 2020. There are several opportunities for this year to reach such heights. First, most colleges and universities around the world have made it a requirement for their postgraduate students to have at least one paper published in a high-impact journal.

Second, the journals in the Scopus database are rigorously evaluated by several reviewers, and papers published in these journals are of high quality. Third, this increasing value in the affective domain occurs when papers submitted to certain journal publishers are approved and published, as well as when the journal is indexed in the Scopus database. Fourth, the rapid increase in publications is presumably a result of the COVID-19 epidemic. Many scholars in this field work from home and devote more time to study and writing. Finally, the year 2020 will bring about a new normal in which the usage of online platforms increases and all internet users get knowledge and conduct information searches using online platforms. This gives users access to a million reputable publications where they can submit their work. Due to the time constraints of our article search, which started in the middle of the year 2021, it seems that the number of publications in 2021 will be less than in 2020.

Table 2
The trends of publications each year with percentages

Year	Number of publications	Percentage (%)
2000	2	2.86
2001	0	0.00
2002	1	1.43
2003	0	0.00
2004	0	0.00
2005	0	0.00
2006	1	1.43
2007	1	1.43
2008	2	2.86
2009	2	2.86
2010	0	0.00
2011	1	1.43
2012	1	1.43
2013	5	7.14
2014	0	0.00
2015	6	8.57
2016	5	7.14
2017	2	2.86
2018	8	11.43
2019	8	11.43
2020	17	24.29
2021	8	11.43

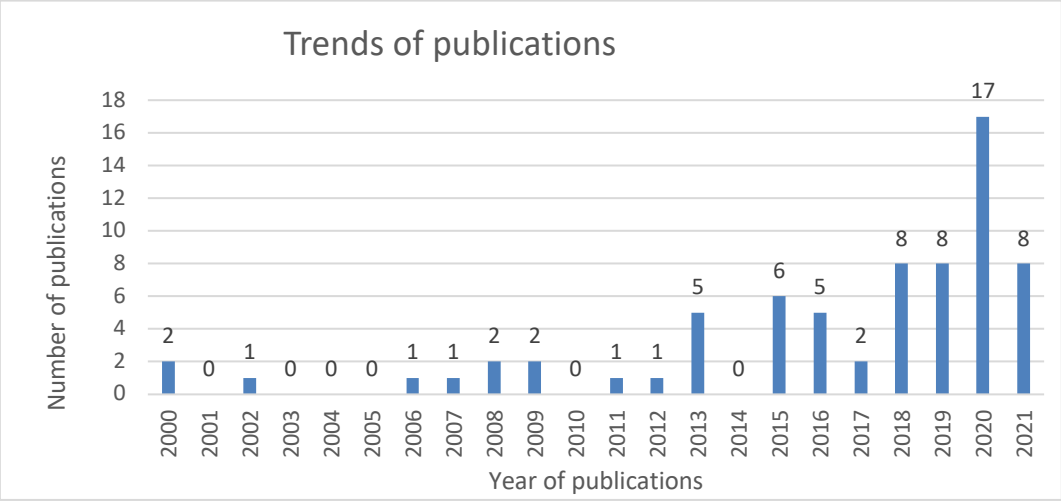

Fig. 2. Visual of Trends in Publications

3.2 The top ten most-cited papers

The top 10 most-cited papers were derived from 70 publications in reputable journals such as the Journal of Mathematics Teacher Education, Educational Studies in Mathematics, and Cognition and Instruction. Schack's work was the most-cited among the 10 most-referenced papers published

between 2000 and 2020 [53]. The Journal of Mathematics Teacher Education article titled "Prospective elementary school teachers' professional observation of children's early numeracy" has been cited 64 times. It is closely followed by [49] paper on assessment in primary school, which has been cited 61 times. Even though Schack's work was published later than Desoete's [49], academics cited Schack's article more frequently.

Table 3
The most cited papers

Authors	Title	Source title	Cited by
[53]	Prospective elementary school teachers' professional noticing of children's early numeracy	Journal of Mathematics Teacher Education	64
[49]	Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get	Metacognition and Learning	61
[50]	The notion of proof in the context of elementary school mathematics	Educational Studies in Mathematics	48
[54]	Improving the reasoning ability of elementary school student through the Indonesian realistic mathematics education	Journal on Mathematics Education	32
[55]	Designing case-based hypermedia for developing understanding of children's mathematical reasoning	Cognition and Instruction	23
[51]	Computer tools for interactive mathematical activity in the elementary school	International Journal of Computers for Mathematical Learning	22
[56]	Elementary mathematics teachers' perceptions and lived experiences on mathematical communication	Eurasia Journal of Mathematics, Science and Technology Education	20
[25]	Preliminary Research of Mathematics Learning Device Development Based on Realistic Mathematics Education (RME)	Journal of Physics: Conference Series	17
[57]	Prospective Teachers' Challenges in Teaching Reasoning-and-Proving	International Journal of Science and Mathematics Education	17
[48]	How young children view mathematical representations: a study using eye-tracking technology	Educational Research	15

3.3 The top 20 published journals

The most popular Journal of Physics: Conference Series (JPCS) for academics to submit papers to is a peer-reviewed, open-access journal from IOP Publishing that offers readers the most recent advances in physics presented at international conferences. The data reveals 20 submitted papers. It is part of the IOP Conference Series, a collection of open-access publications that specialise in proceedings publishing. This series also includes IOP Conference Series: Materials Science and Engineering and IOP Conference Series: Earth and Environmental Science. It is included in the databases Inspec, Scopus, INSPIRE-HEP, MathSciNet, ISI Proceedings, Chemical Abstracts, NASA Astrophysics Data System, INIS (International Nuclear Information System), and VINITI Abstracts Journal (Referativnyi Zhurnal). The journal's secure long-term archiving is protected by LOCKSS and Portico.

Similarly, a total of four articles Peer-reviewed journals includes the International Journal of Scientific and Technological Research. The journal publishes both original research articles and

review articles in all areas of scientific and technological research studies, including, but not limited to, a) the scientific method, engineering sciences, mathematics, and formal sciences, basic and applied research, research impact, the scientific community, and society, b) Emerging technologies, technology economics, technology impact assessments, technology and society.

Table 4
The most published journals

Source title	Number of articles
Journal of Physics: Conference Series	20
International Journal of Scientific and Technology Research	4
Educational Studies in Mathematics	3
European Journal of Educational Research	3
AIP Conference Proceedings	2
International Journal of Mathematical Education in Science and Technology	2
International Journal of Science and Mathematics Education	2
Investigations in Mathematics Learning	2
Journal of Mathematics Teacher Education	2
Acta Scientiae	1
ASEE Annual Conference and Exposition, Conference Proceedings	1
Assessment in Education: Principles, Policy and Practice	1
Cogent Education	1
Cognition and Instruction	1
Education Sciences	1
Educational Research	1
Eurasia Journal of Mathematics, Science and Technology Education	1
European Journal of Psychology of Education	1
Frontiers of Education in China	1
IAFOR Journal of Education	1

3.4 The top 20 published journals

The studies included were published between the years 2000 and 2022. Three studies each were conducted in the United States [47, 50, 24] and two studies conducted by scholars from Portugal [42, 19], followed by one study in Vietnam [22], England [48], Canada [52], Israel [46], Flanders [49], and finally nine studies by non. The most common study location was Indonesia, which accounted for 16 (45.71%) of the studies examined.

Table 5
The top contributing countries

Countries	Frequency	%
Indonesia	16	45.71
US	3	8.57
Portugal	2	5.71
Vietnam	1	2.86
England	1	2.86
Canada	1	2.86
Israel	1	2.86
Flanders	1	2.86
Non	9	25.71

3.5 The methodological approach

Methodologically, the majority of studies published on communication in mathematics (47.06 percent) used a qualitative approach, with interviews and observations of learning frequently used for data collection. The most common approach for incorporating students is task-based interviews, in which numerous students answer the specified assignment during the interview session in order to investigate the styles of communication, and then their responses are evaluated to determine the synchronised themes used. In addition, it is crucial for the validity of the research findings that the interviewees represent a range of academic levels. Furthermore, interviews often include instructors in order to investigate any issues faced throughout the teaching and learning process. This methodological approach enhances students' mathematical communication skills. However, the publications used a quantitative method with pre- and post-tests after the intervention session. In addition, questionnaire scale evaluations were undertaken by earlier researchers to obtain data on mathematics communication. However, only five of thirty-four papers (14.71%) included both methodological techniques.

Table 6
The methodological approach

Methodological approach	Frequency	%
qualitative	16	47.06
quantitative	13	38.24
quantitative and qualitative	5	14.71

3.6 Summary

The aim of this review article was to provide an overview of related research on mathematics communications, particularly annual trends, most-cited papers, most published journals, most contributing countries, and approaches to methodology on mathematics communications in schools. In this review, it is found that most authors are interested in mathematics communication among students rather than both teachers and students simultaneously. Furthermore, most scholars focusing on mathematics communications prefer to publish their articles in the Journal of Physics: Conference Series so that they can benefit from both being present at conferences and publishing

papers. Journal of Physics: Conference Series is quite popular among Indonesian researchers as the country has become a top contributor in the field.

However, when looking closely at the most referenced publications, those published in the Journal of Mathematics Teacher Education by [53] rather than the International Journal of Science and Mathematics Education by [57] were cited the most by other researchers. Schack et al. and Stylianides et al. published their articles in the same year, and Schack et al.'s on prospective teachers has drawn the attention of other researchers. This is likely due to many factors.

First, the journal itself is a first-quartile Scopus journal and a Web of Science (WOS) journal, with the Web of Science Core Collection status being Social Sciences Citation Index. This means that the journal picked the most credible papers for citation by other academics after a thorough peer review procedure. Second, other scholars [57] were interested in the real contributions of this article, which include a five-session module with three professional noticing strategies: attending, interpreting, and deciding. These strategies could have high practical implications and help develop professional noticing skills through the suggested module.

In mathematics communication research, the qualitative methodological approach was found to be the most dominant. According to [58], the most prevalent criticism of qualitative approaches is the restricted number of research participants. However, [59] and [22] performed mathematics education studies based on pedagogical observations preceding interviews. Although several papers did not specify the kind of interview conducted, it was clear that a semi-structured interview was used. For mathematics communication research, a qualitative approach involving data gathering techniques like observations and semi-structured interviews is necessary.

4. Conclusions

This research presents an overview of mathematical communication among schoolchildren, which is analysed in 2 steps. The first phase showed yearly trends, the ten most-cited articles, and the twenty most-published journals, while the second step centred on the leading contributing countries and approaches to mathematics communication methodology. Previous studies' publishing patterns indicate that the greatest number of publications were registered in 2020. The Journal of Mathematics Education had the most citations, while the Journal of Physics: Conference Series had the most publications. In addition to the three listed areas, Indonesia provided about half of the academic work in mathematics education, followed by the United States and Portugal. Vietnam, England, Canada, Israel, and Flanders each contributed a single article to the top five nations. Also, the results showed that there are three main types of methods, with qualitative methods being the most popular among scholars.

According to the findings of this study, scientists who want to be scholars in the subject of mathematics communication should focus on influential and current schools of thought. This is due to the fact that future article publication is contingent on ideas or methodologies that impact children's mathematical communication practices. Asian and Western academics must work together on mathematics communication research if they want to get the most out of their knowledge and citations.

Mathematics communications representations such as verbal-auditory, which required students to communicate, were the most effective means of evaluating the learning process as well as students' knowledge, attitude, and skills [22]. It would be crucial for instructors and researchers to recognise students' mathematical communications using a variety of modes of representation and to offer them as many opportunities as possible to use, exchange, and discuss mathematical

languages. Providing children with opportunities to use mathematical language will influence their mathematical development.

Future research might employ a qualitative approach when examining the mathematical communication skills of students, since this technique is more likely to reveal students' talents and challenges. With the study of yearly trends, the most-cited articles, the most-published journals, the most-contributing nations, and approaches to methodology, not only scholars, practitioners, and educators might recognise the significance of mathematical communication for young children. This includes the realisation of what ideas and real-life situations that are relevant to students should be implemented in classroom practises so that the potential of using mathematics communication is maximised and teachers have a more comprehensive view of students' various modes of mathematics communication in order to improve knowledge, attitude, and skills.

The study's limitations, which included 70 articles in first step analysis and 34 articles in second step analysis, will almost certainly result in different results if only first step analysis was used or other journals, conference proceedings, and e-books were considered. Future research should, however, overcome the limitations of this review by employing different systematic procedures and broader searching platforms, and provide logical conclusions about mathematics communication among students of different grade levels and across math content.

Acknowledgement
We'd like to thank everyone who made it possible for us to write this review article. The Ministry of Education and the Institute of Education Campus deserve special thanks for the grant. The Institute of Education and Ministry of Education gave a grant to pay for this article to be published.

References

[1] Pendidikan, Badan Standar Nasional. "Standar isi untuk satuan pendidikan dasar dan menengah: Standar kompetensi dan kompetensi dasar SMA/MA [“Content standards for basic and secondary education units: competency standards and basic competencies of sma/ma].” *Jakarta: Badan Standar Nasional Pendidikan* (2006).

[2] Latif, Sriwahyuni and Irwan Akib. "Mathematical connection ability in solving mathematics problem based on initial abilities of students at SMPN 10 Bulukumba." *Daya Matematis: Jurnal Inovasi Pendidikan Matematika* 4, no. 2 (2016): 207-217. https://doi.org/10.26858/jds.v4i2.2899

[3] Rohendi, Dedi. "Developing e-learning based on animation content for improving mathematical connection abilities in high school students." *International Journal of Computer Science Issues (IJCSI)* 9, no. 4 (2012): 1.

[4] Clark, Karen K., Jennifer Jacobs, Mary Ellen Pittman, and Hilda Borko. "Strategies for building mathematical communication in the middle school classroom: Modeled in professional development, implemented in the classroom." *Current Issues in Middle Level Education* 11, no. 2 (2005): 1-12.

[5] Joyner, Jeane, and Barbara Reys. "Principles and Standards for School Mathematics: What's in It for You?." *Teaching children mathematics* 7, no. 1 (2000): 26-29. https://doi.org/10.5951/TCM.7.1.0026

[6] Sumarmo, Utari. "Resiliensi Matematik (Mathematical Resilience)." *Available in Website: utari-sumarmo@ dosen. stkipsiliwangi. ac, id* (2015).

[7] Harel, Guershon, and David Tall. "The general, the abstract, and the generic in advanced mathematics." *For the learning of mathematics* 11, no. 1 (1991): 38-42.

[8] Dienes, Z. P. "Building Up Mathematics' Hutchinson Educational." *New York* (1960).

[9] Dani, Ulima, and Tuti Zubaidah. "Improving Year 7 Students' Mathematics Communication Skills by The Discovery Learning Model." *Journal of Mathematics and Mathematics Education* 10, no. 2 (2020): 87-96. https://doi.org/10.20961/jmme.v10i2.47084

[10] Abdullah, Abdul Halim, Nur Liyana Zainal Abidin, and Marlina Ali. "Analysis of students' errors in solving Higher Order Thinking Skills (HOTS) problems for the topic of fraction." *Asian Social Science* 11, no. 21 (2015): 133. https://doi.org/10.5539/ass.v11n21p133

[11] Getenet, Seyum, and Rosemary Callingham. "Teaching interrelated concepts of fraction for understanding and teacher’s pedagogical content knowledge." *Mathematics Education Research Journal* 33, no. 2 (2021): 201-221. https://doi.org/10.1007/s13394-019-00275-0

[12] Leu, Yuh-Chyn. "Elementary school teachers' understanding of knowledge of students'cognition in fractions." In *Proceedings of the Conference of the International Group for*, vol. 100, p. 1022. 1999.

[13] Stein, Mary Kay, and Margaret Schwan Smith. "Mathematical tasks as a framework for reflection: From research to practice." *Mathematics teaching in the middle school* 3, no. 4 (1998): 268-275. https://doi.org/10.5951/MTMS.3.4.0268

[14] Muhammad, Nura Muaz, Nor Azwadi Che Sidik, Aminuddin Saat, Yusuf Alhassan, and Yutaka Asako. "A Numerical Investigation on the Combined Effect of Aluminum-Nitride/Water Nanofluid with Different Mini-Scale Geometries for Passive Hydrothermal Augmentation." *Journal of Advanced Research in Numerical Heat Transfer* 1, no. 1 (2020): 1-12.

[15] Kamal, Muhammad Nabil Farhan, Izuan Amin Ishak, Nofrizalidris Darlis, Daniel Syafiq Baharol Maji, Safra Liyana Sukiman, Razlin Abd Rashid, and Muhamad Asri Azizul. "A Review of Aerodynamics Influence on Various Car Model Geometry through CFD Techniques." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 88, no. 1 (2021): 109-125. https://doi.org/10.37934/arfmts.88.1.109125

[16] Techanamurthy, Umawathy, Zanariah Ahmad, Noorfadhilah Kahar, Fadhlina Ahmad, and Ana Rohana Pataniah Salahuddin. "Potential of Problem-Solving Flipped Classroom Instruction in teaching Internet of Things (IoT) at Community Colleges: A Needs Analysis." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 18, no. 1 (2020): 14-23. https://doi.org/10.37934/araset.18.1.1423

[17] Rahman, Noor Anita, Roslinda Rosli, Azmin Sham Rambely, and Lilia Halim. "Mathematics Teachers' Practices of STEM Education: A Systematic Literature Review." *European Journal of Educational Research* 10, no. 3 (2021): 1541-1559. https://doi.org/10.12973/eu-jer.10.3.1541

[18] Spreitzer, Carina, Samuel Hafner, Konrad Krainer, and Andreas Vohns. "Effects of generic and subject-didactic teaching characteristics on student performance in mathematics in secondary school: A scoping review". *European Journal of Educational Research* 11, no. 2 (2022): 711-737. https://doi.org/10.12973/eu-jer.11.2.711

[19] Silva, Ricardo, Fernando Martins, Cecília Costa, José Cravino, and Joaquim Bernardino Lopes. "Learning Scenario to Promote Comprehension of the Meaning of Subtraction." *Education Sciences* 11, no. 12 (2021): 757. https://doi.org/10.3390/educsci11120757

[20] Zaenap, Siti, and Sri Utaminingsih. "Media Technology Takontikasi Games Based of Realistic Mathematics." In *Journal of Physics: Conference Series*, vol. 1823, no. 1, p. 012090. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1823/1/012090

[21] Farokhah, L., F. Nurmulia, T. Herman, A. Jupri, V. Pratiwi, N. Nurkaeti, and Z. Abidin. "The improvement of mathematical communication ability of elementary school students through project-based learning using mind map technique." In *Journal of Physics: Conference Series*, vol. 1806, no. 1, p. 012105. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1806/1/012105

[22] Uyen, Bui Phuong, Duong Huu Tong, and Nguyen Thi Bich Tram. "Developing Mathematical Communication Skills for Students in Grade 8 in Teaching Congruent Triangle Topics." *European Journal of Educational Research* 10, no. 3 (2021): 1287-1302. https://doi.org/10.12973/eu-jer.10.3.1287

[23] Rachmaningtyas, Nur Anisyah, Jailani Jailani, and Harina Fitriyani. "Classification of mathematical reasoning competencies based on mathematical problem solving in elementary school." In *AIP Conference Proceedings*, vol. 2268, no. 1, p. 030007. AIP Publishing LLC, 2020. https://doi.org/10.1063/5.0017000

[24] Weinberg, Paul Jason. "A Pathway Towards STEM Integration: Embodiment, Mathematization, and Mechanistic Reasoning." In *2020 ASEE Virtual Annual Conference Content Access*. 2020. https://doi.org/10.3102/1584376

[25] Ulfah, A. S., Y. Yerizon, and I. M. Arnawa. "Preliminary research of mathematics learning device development based on realistic mathematics education (RME)." In *Journal of Physics: Conference Series*, vol. 1554, no. 1, p. 012027. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1554/1/012027

[26] Pertiwi, I. "Analysis of elementary student's mathematical connection and communication ability." In *Journal of Physics: Conference Series*, vol. 1521, no. 3, p. 032001. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1521/3/032001

[27] Nada, Y. H., and S. Prabawanto. "Characteristics of students' mathematical representation in solving algebraic thinking problems." In *Journal of Physics: Conference Series*, vol. 1521, no. 3, p. 032009. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1521/3/032009

[28] Fauziyah, R. R., and A. Jupri. "Analysis of elementary school students' ability on mathematical communication and mathematical representation." In *Journal of Physics: Conference Series*, vol. 1521, no. 3, p. 032080. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1521/3/032080

[29] Ahdhianto, Erif, and Novi Nitya Santi. "The Effect of Metacognitive-Based Contextual Learning Model on Fifth-Grade Students' Problem-Solving and Mathematical Communication Skills." *European Journal of Educational Research* 9, no. 2 (2020): 753-764. https://doi.org/10.12973/eu-jer.9.2.753

[30] Bahtiar, Armanda, Agustan Syamsuddin, and Irwan Akib. "Description of mathematical communication skills, logical thinking and its influence on the ability of mathematical literacy for students of grade v elementary school." *International Journal of Scientific & Technology Research* 9, no. 4 (2020): 1075-1078.

[31] Sovia, A., and T. Herman. "Gesture of slow learner student in mathematical Communication." In *Journal of Physics: Conference Series*, vol. 1464, no. 1, p. 012046. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1464/1/012046

[32] Muslim, A. "The effect of cooperative learning Type Teams-Games-Tournaments (TGT) on mathematical connection and communication ability in elementary schools." In *Journal of Physics: Conference Series*, vol. 1469, no. 1, p. 012170. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1469/1/012170

[33] Olteanu, Constanta. "Programming, mathematical reasoning and sense-making." *International Journal of Mathematical Education in Science and Technology* (2020): 1-19.

[34] Chasanah, Chuswatun, and Budi Usodo. "The Effectiveness of Learning Models on Written Mathematical Communication Skills Viewed from Students' Cognitive Styles." *European Journal of Educational Research* 9, no. 3 (2020): 979-994. https://doi.org/10.12973/eu-jer.9.3.979

[35] Hunt, Jessica H., Juanita Silva, and Rachel Lambert. "Empowering students with specific learning disabilities: Jim's concept of unit fraction." *The Journal of Mathematical Behavior* 56 (2019): 100738. https://doi.org/10.1016/j.jmathb.2019.100738

[36] Junianto and Wijaya, A. "Developing Students' Mathematical Literacy through Problem Based Learning." In *Journal of Physics: Conference Series*, vol. 1320, no. 1, p. 012035. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1320/1/012035

[37] Suwangsih, E., M. R. Budiarti, K. Ruskandi, Y. Hendawati, and N. W. A. Majid. "Two-stay two-stray model on improving mathematical communication skill of elementary school students." In *Journal of Physics: Conference Series*, vol. 1318, no. 1, p. 012127. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1318/1/012127

[38] Ginting, Muhamad Saleh, Rully Charitas Indra Prahmana, Muhammad Isa, and Murni Murni. "Improving the reasoning ability of elementary school student through the Indonesian realistic mathematics education." *Journal on Mathematics Education* 9, no. 1 (2018): 41-54. https://doi.org/10.22342/jme.9.1.5049.41-54

[39] Arnidha, Y. "Mathematical Representation of Deaf Students in Problem Solving Seen from Students' Creative Thinking Levels." In *Journal of Physics: Conference Series*, vol. 1155, no. 1, p. 012030. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1155/1/012030

[40] Farokhah, L., T. Herman, and A. Jupri. "Students' ability of mathematical representation on statistics topic in elementary school." In *Journal of Physics: Conference Series*, vol. 1157, no. 3, p. 032110. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1157/3/032110

[41] Sokolowski, Andrzej. "The Effects of Using Representations in Elementary Mathematics: Meta-Analysis of Research." *IAFOR Journal of Education* 6, no. 3 (2018): 129-152. https://doi.org/10.22492/ije.6.3.08

[42] Morais, Cristina, Lurdes Serrazina, and João Pedro da Ponte. "Mathematical reasoning fostered by (fostering) transformations of rational number representations." *Acta Scientiae. Revista de Ensino de Ciências e Matemática* 20, no. 4 (2018): 552-570. https://doi.org/10.17648/acta.scientiae.v20iss4id3892

[43] Widiartana, I. Putu Hendra. "The Effect of Open-Ended Approach Towards Students' Mathematical Reasoning." In *Journal of Physics: Conference Series*, vol. 1028, no. 1, p. 012134. IOP Publishing, 2018. https://doi.org/10.1088/1742-6596/1028/1/012134

[44] Johar, R., and A. Ahmad. "The quality of learning materials through mathematics reaslitic to improve students' mathematical communication ability in the elementary school." In *Journal of Physics: Conference Series*, vol. 1088, no. 1, p. 012077. IOP Publishing, 2018. https://doi.org/10.1088/1742-6596/1088/1/012077

[45] Manoy, Janet Trineke. "Elementary students' representations in solving word problems." In *Journal of Physics: Conference Series*, vol. 1088, no. 1, p. 012017. IOP Publishing, 2018. https://doi.org/10.1088/1742-6596/1088/1/012017

[46] Bishara, Saied. "Self-regulated math instructions for pupils with learning disabilities." *Cogent Education* 3, no. 1 (2016): 1262306. https://doi.org/10.1080/2331186X.2016.1262306

[47] Polly, Drew. "Examining how professional development influences elementary school teachers' enacted instructional practices and students' evidence of mathematical understanding." *Journal of research in childhood education* 29, no. 4 (2015): 565-582. https://doi.org/10.1080/02568543.2015.1073198

[48] Bolden, David, Patrick Barmby, Stephanie Raine, and Matthew Gardner. "How young children view mathematical representations: a study using eye-tracking technology." *Educational research* 57, no. 1 (2015): 59-79. https://doi.org/10.1080/00131881.2014.983718

[49] Desoete, Annemie. "Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get." *Metacognition and Learning* 3, no. 3 (2008): 189-206https://doi.org/10.1007/s11409-008-9026-0

[50] Stylianides, Andreas J. "The notion of proof in the context of elementary school mathematics." *Educational Studies in Mathematics* 65 (2007): 1-20. https://doi.org/10.1007/s10649-006-9038-0

[51] Olive, John. "Computer tools for interactive mathematical activity in the elementary school." *International Journal of Computers for Mathematical Learning* 5, no. 3 (2000): 241-262. https://doi.org/10.1023/A:1009813723928

[52] Liu, Xiufeng. "Elementary school students' logical reasoning on rolling." *International Journal of Technology and Design Education* 10, no. 1 (2000): 3-20. https://doi.org/10.1023/A:1008915909164

[53] Schack, Edna O., Molly H. Fisher, Jonathan N. Thomas, Sara Eisenhardt, Janet Tassell, and Margaret Yoder. "Prospective elementary school teachers' professional noticing of children's early numeracy." *Journal of Mathematics Teacher Education* 16, no. 5 (2013): 379-397. https://doi.org/10.1007/s10857-013-9240-9

[54] Saleh, Muhamad, Muhammad Isa, Darhim Murni, and Bansu Irianto Ansari. "Students' error types and reasoning ability achievement using the Indonesian realistic mathematics education approach." *International Journal of Scientific & Technology Research* 8, no. 7 (2019): 364-369.

[55] Koehler, Matthew J. "Designing case-based hypermedia for developing understanding of children's mathematical reasoning." *Cognition and Instruction* 20, no. 2 (2002): 151-195. https://doi.org/10.1207/S1532690XCI2002_2

[56] Kaya, Defne, and Hasan Aydın. "Elementary mathematics teachers' perceptions and lived experiences on mathematical communication." *Eurasia Journal of Mathematics, Science and Technology Education* 12, no. 6 (2016): 1619-1629. https://doi.org/10.12973/eurasia.2014.1203a

[57] Stylianides, Gabriel J., Andreas J. Stylianides, and Leah N. Shilling-Traina. "Prospective teachers' challenges in teaching reasoning-and-proving." *International Journal of Science and Mathematics Education* 11, no. 6 (2013): 1463-1490. https://doi.org/10.1007/s10763-013-9409-9

[58] de Araujo, Zandra, Sarah A. Roberts, Craig Willey, and William Zahner. "English learners in K–12 mathematics education: A review of the literature." *Review of Educational Research* 88, no. 6 (2018): 879-919. https://doi.org/10.3102/0034654318798093

[59] Arani, Mohammad Reza Sarkar. "Cross cultural analysis of an Iranian mathematics lesson: A new perspective for raising the quality of teaching." *International Journal for Lesson and Learning Studies* (2015).