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A systematic literature review on developing students' mathematical communication skills

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Abstract

This study aims to reveal the analysis of previously published articles based on the PRISMA procedure that guides researchers' self-directed learning on online platforms through a search conducted on the ERIC database with general keywords such as 'mathematical communication skills' and related terms. This review exhibits exclusion criteria in the publication distribution. Whilst, all included documents are articles in English language. The distribution of articles published specifically by years and full text available. The varied of findings show ERIC database provides essential information pertaining to mathematical communication and approach carried out involving students from various level. Meanwhile, developing student's mathematical communication using student-centered teaching methods is one of the effective strategies.

Keywords*: systematic literature review, mathematical communication skills, students*

Abstrak

Penelitian ini bertujuan untuk mengungkapkan analisis artikel yang diterbitkan sebelumnya berdasarkan prosedur PRISMA yang memandu pembelajaran mandiri para peneliti di platform online melalui pencarian yang dilakukan pada database ERIC dengan kata kunci umum seperti 'keterampilan komunikasi matematis' dan istilah terkait. Ulasan ini menunjukkan kriteria eksklusi dalam distribusi publikasi. Sedangkan semua dokumen yang disertakan adalah artikel dalam bahasa Inggris. Distribusi artikel yang diterbitkan secara spesifik berdasarkan tahun dan teks lengkap tersedia. Beragamnya temuan menunjukkan database ERIC memberikan informasi penting berkaitan dengan komunikasi matematika dan pendekatan yang dilakukan dengan melibatkan siswa dari berbagai tingkatan. Sementara itu, mengembangkan komunikasi matematis siswa dengan menggunakan metode pengajaran yang berpusat pada siswa merupakan salah satu strategi yang efektif.

Kata kunci: tinjauan literatur sistematis, kemampuan komunikasi matematis, siswa

INTRODUCTION

Communication skills in the context of learning mathematics are often known as mathematical communication skills. In simple terms, mathematical communication skills is the skills of students to convey their mathematical ideas. Mathematical communication ability is defined as the ability to share ideas and clarify understanding in learning mathematics (Suryadi, 2019). Students who have good mathematical communication skills tend to find it easy to express their mathematical ideas/thoughts so that friends, teachers and others understand them. In mathematical communication, the object of discussion comes from ideas based on the results of the problem solving process (NCTM, 2000). In addition, in mathematical communication there is interaction. Interaction occurs where students share mathematical ideas from various perspectives. This can help students to hone understanding, and improve their mathematical communication skills. In line with the opinion of Takahashi et al. (2006) that interaction between students during class activities as a whole provides opportunities for students to improve their mathematical abilities including procedural and conceptual understanding. When students are challenged to solve a problem that is relatively difficult for them, they will instinctively think about it and try to solve it. The problem given is a potential source to train students to explain, share, or discuss problems.

Mathematical communication skills is one of the important abilities that students must have. In particular, the importance of mathematical communication was first put forward from the NCTM standard document in 1989 (Kosko & Gao, 2015). The importance of mathematical communication skills is included in one of the competencies that must be honed (NCTM, 2000). Not only that, the Ministry of National Education states that communication is an important goal in the process of learning mathematics (Depdiknas, 2006). Several previous researchers agreed that one of all important and essential aspects of mathematics education is communication (Cooke & Buchholz, 2005; Karl W & Jesse, 2010) . Communication skills are one of the most important skills of the 21st century and play an important role in learning. Communication is fundamental in social interaction, in building and maintaining all relationships (Selman, 2020). As stated by NCTM that communication is an essential part of mathematics and mathematics education, both literature and practice show that communication in mathematics has an important place to develop students' understanding of mathematics (Kaya & Aydın, 2016). Thus, mathematical communication skills are no less important to support students in taking part in the 21st century.

Mathematical communication skills are not of particular concern if students as a whole are able to meet the existing indicators. However, if the indicators of students' mathematical communication abilities have not been fully met, then there is an indication of a problem with students' mathematical communication skills. Several studies explain that the mathematical communication skills of Indonesian students still need special attention and development (Rohid et al., 2019; Saidah & Mardian, 2021).

The facts show that students' mathematical communication skills at the school level are still relatively low (Hibatullah & Sofyan, 2014; Saidah & Mardian, 2021). For example, research conducted by (Pane et al., 2018) states that students' mathematical communication skills are still in the poor category because most students have not been able to achieve indicators of mathematical communication skills. Not only that, research by Rakhman et al. (2018) states that there are other causes related to the low mathematical communication skills of junior high school students besides the learning model problem. The other findings examined by Saidah & Mardian (2021) found difficulties faced by students when working on questions related to mathematical communication skills, including that students still had difficulty writing down mathematical ideas and had difficulty constructing words to explain their mathematical ideas. Not only that, in several regions in Indonesia it was found that students' mathematical communication abilities still needed improvement (Aditya & Sukestiyarno, 2019; Tiara et al., 2020). These evidences attract the attention of researchers that students' mathematical communication skills need special attention.

Students' mathematical communication skills can be developed by applying appropriate teaching methods. Based on the results of the research (Ahdianto et al., 2019; Chasanah et al., 2020; Dina et al., 2019; Rohid et al., 2019; Yaniawati et al., 2019) mathematical communication skills can increase after implementing a learning model/ strategy. Therefore, the researcher is interested in conducting research in the form of a Systematic Literature Review to see what teaching methods influence the development of mathematical communication skills among students, to the knowledge of the researcher, this Systematic Literature Review has never been conducted.

Based on the introduction presented, the research questions are as follows: First, who are the research subjects of the collected articles? Second, how are the articles distributed over the years? Third, what are the recommendations for teaching methods that can influence the development of mathematical communication skills among students?

METHOD

The study adopted the widely preferred PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses. PRISMA was developed in 2005 and was regularly reported by David Moher and the team in their published medical article ((Mother et al., 2009). PRISMA statement consist of four steps, namely: identification, screening, eligibility and inclusion criteria. Identification is the process to enrich main keywords using several steps so that articles from the database could be retrieved as wider as possible. The second phase is screening, a process to include or exclude articles base on criteria decided by authors and generated using database. Exclude articles means to remove unnecessary articles according to the types of articles. The third phase is eligibility, all articles were examined by reading through the title, abstract, method, result and discussion to ensure they meet the inclusion criteria and parallel with the current research objectives. The final phase, inclusion criteria where the articles left and fulfil the requirement to be analyzed. The following is figure 1. PRISMA flowchart.

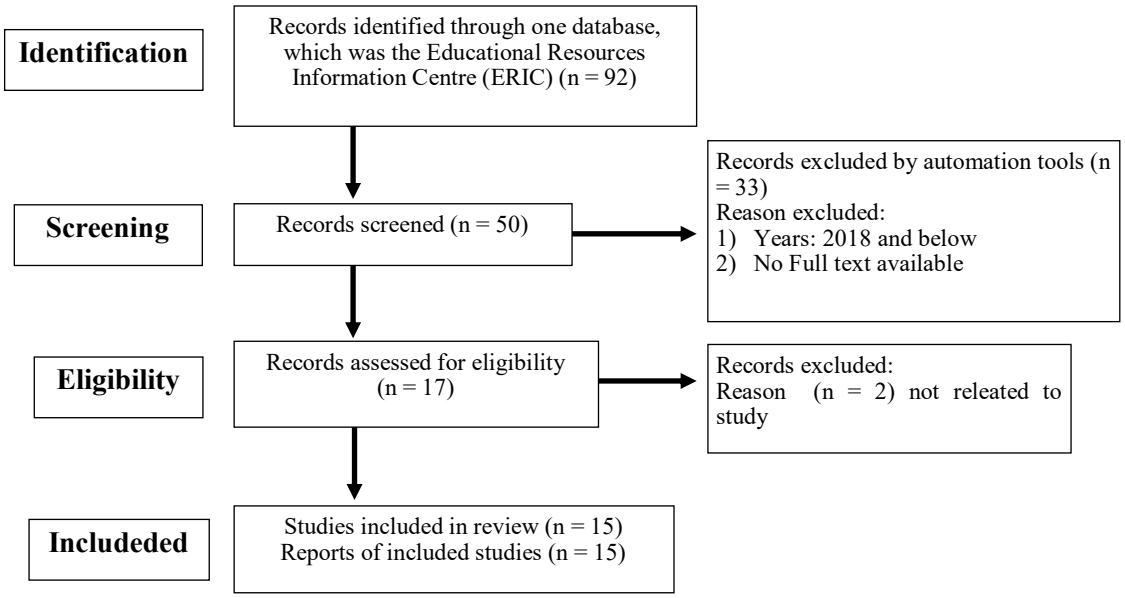

Figure 1. PRISMA flowchart

The first step is to determine certain keywords to ensure that the articles found are relevant to the research questions set by the researcher. The keywords in this research are (("mathematical communication" OR "mathematical communication skills") AND ("learning mathematics") AND ("students")). The conjunction "AND" is used to find articles about mathematical communication skills that focus on learning math and students.

During the article search, four selected records were excluded to guide the article selection process and ensure that the selected articles met the research requirements. Records excluded by automated tools, namely: 1) Year: 2018 and below, and 2) No full

text available. The first step in the process of collecting articles with predetermined keywords is entered into the database and there are 92 articles registered with ERIC. The research articles were then screened and 50 articles were obtained. Subsequently, 33 articles were issued. Thus, only 17 articles met the criteria. Each article was reviewed to ensure that firstly, it focused on mathematics communication skills in education only, and secondly, discussed teaching methods that influence the development of mathematical communication skills. Based on these criteria, 2 articles were excluded from the review process, and only 15 research papers were retained for further review.

Identification

The first process involves the identification process whereby main keywords are enriched by identifying, searching and listing its synonyms so that articles from the database could be retrieved as many as possible. The researchers began to gererate search strings using ERIC in 2018 - 2022 (Table 1). Next, the search string was pasted on Enter query string in Advanced menu (Figure 2).

Table 1. The search string

Database	Search String
ERIC	(("mathematical communication" OR "mathematical communication skills") AND ("learning mathematics") AND ("students"))

Figure 2. Advances menu to enter search string

Screening

The second phase is called the screening process whereby articles areexcluded based on the criteria decided by the researchers and generated using database. Whilst, the term ‘excluded articles’ refers to the unnecessary articles that are removed according to its’ types. The included and excluded criteria are summarised in Table 2.

The researchers continued the process by selecting the types of document in the database for ‘article’ and those that are in ‘full text available’. The procedure to include the types was carried out by clicking on right side box of the website interface (Figure 3). Consequently, the screening process produced 50 articles. Later, the researchers

examined the distribution of articles published specifically by years, subject areas, authors, countries and authors' affiliated universities.

Table 2. The search string

Criteria	Inclusion
Type of articels	Full text available on ERIC

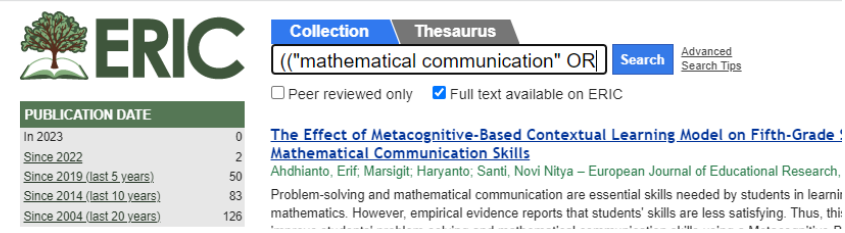

Figure 3. Website interface ERIC

Eligibility

Therefore, 17 articles were included in the third phase known as the eligibility process. All articles were examined by reading through the titles, abstract, method, result and discussion to ensure they met the inclusion criteria and parallel with current research objectives. It was discovered that two articles needed to be rejected based on criteria not releated to study. Finally, only 15 articles left and fulfilled the requirements to be analyzed (Figure 1).

Included

Finally, only 15 articles left and fulfilled the requirements to be analyzed (Figure 1)

RESULTS AND DISCUSSION

Mathematical communication skills are simply the ability to convey mathematical ideas through speech or writing. Mathematical communication skills mean the process of transferring mathematical ideas or ideas to students to be interpreted and understood by them (Pramuditya et al., 2021). Another understanding says that mathematical communication is the ability to express mathematical ideas that are interrelated to friends, teachers, and others through spoken and written language (NCTM, 2000). Mathematical communication skills are a national standard in learning in America (Kosko & Gao, 2015). This indicates that mathematical communication skills are very important.

Indicators of mathematical communication skills in learning mathematics adapted based on (NCTM, 2000)), namely:

1) The ability to express mathematical ideas through writing, orally, and describe or demonstrate them visually.
2) The ability to understand, evaluate, and interpret mathematical ideas either orally or in other visual forms.
3) Ability to use mathematical notations, terms, and mathematical structures to present ideas, explain relationships and model situations.

Other sources state that indicators of students' mathematical communication skills (Depdiknas, 2006), namely:

1) Presenting mathematical statements orally, in writing, pictures and diagrams.
2) Propose conjectures and perform mathematical manipulations so that students can draw conclusions, compile evidence, and give reasons for free solutions.
3) Be able to check the validity of an argument.

To determine learning that is able to develop students' mathematical communication skills, the authors refer to the indicators used by NCTM (2000).

The steps taken to examine the articles and obtain data for research were the researchers investigating the PRISMA Screening phase (Figure 1); where 15 articles were obtained because the filtering process took place automatically using the ERIC database. It is important to note that a total of 3 categories: subject, author's country of origin, year, and teaching method were examined to address the first to third sub-objectives.

Table 3. Research subjects

Subject	F
Elementary School	5
Junior High School	6
Senior High School	4

Table 3 to answer research question number 1. RQ1: Who are the research subjects of the articles that have been collected?. Next, research question number 2 (RQ2: How are the articles distributed over the country and the years? can be answered through Table 4 below.

Table 4. Research years and country

Years	F	Country	F
2018	-	Indonesia	13
2019	6	Singapura	1
2020	5	Vietnam	1
2021	4		
2022	-		

RQ3: What is recommendations for teaching methods that can influence the development of mathematical communication skills among students? can be answered through table 5 below.

Table 5. Methods Used in Teaching

Teaching method	F
Teacher-centered teaching methods	2
Student-centered teaching methods	13

The analysis found only two articles, which discussed the influence of teacher-centered teaching methods on the development of mathematical communication skills. The study found that conventional learning methods showed a significant improvement in their mathematical communication skills associated with congruent triangles. In addition, the results of other studies show that students' mathematical communication skills increase with the application of technology in conventional learning (Kusumah et al., 2022; Uyen et al., 2021).

The analysis indicated that 13 out of 15 articles focused on the use of student-centered teaching methods. There are three forms of student-centered teaching implemented, which are a problem-based learning, group-based learning, and model-based learning. The reviewed articles show that group-based learning can help improve mathematical communication skills among students. For example, implementing discussion activities in group-based learning can train students to express mathematical ideas and interpret mathematical ideas both orally and in other visual forms, both of which are indicators of mathematical communication skills. In addition, problem based learning can also improve students' communication skills on indicators of using mathematical notation, understanding, and evaluating mathematical ideas. The use of model-based learning, such as using discovery learning model, teh PINTER learning model, and metacogtive-based contextual learning model have also been found to have a positive impact on the development of mathematical communication skills among students (Ahdianto et al., 2019; Rohid et al., 2019; Yaniawati et al., 2019).

DISCUSSIONS

Through communication teachers and students benefits in several aspects. From teachers' perspectives, it involves verbal communication which helps teachers to explore different aspects of students' perception pertaining to specific words as well as to detect words that are still unclear for students. Besides, the shifts in roles of teacher and learners in learning production also occurred (O'Brien, 2010). In performing the role, teachers need to be concerned with factors that inhibit students' comprehension involving the

unspoken and shared understandings while providing opportunity for students to communicate in group; although at the beginning of the discussion, students fail to generate any idea about the expected learning (Pirie, 1997).

From students' perspective, it is important to provide students with the opportunity to utilize words so that they can learn to speak mathematically and build their own meanings. Building meaning requires combination of several words since knowledge of words alone does not assure that students will be able to communicate. Therefore, providing students with building meaning experience through communication should be guided with questions and subsequent feedback that will enhance their knowledge.

With respect to utilize of PRISMA procedures, identification phase is the process of building keywords whereby understanding of the words are required. For example, in finding articles related to mathematical communication skills in the study, the researchers listed different words but within the same category for students. Those three categories are: a) students; b) Years publication 2018 - 2022, and c) Full text available. This first phase refers to the researcher's attempt to explain the meaning of words in context of learning mathematic.

Meanwhile, the second phase is screening, and third phase is eligibility. Both require researchers to search ERIC database to obtain relevant articles before examining and analyzing the words category used in the acquired articles. Then, the relevance of articles are evaluated before the inclusion phase. This process involves the researchers' efforts in exploring the words related.

Besides, with the guidance of PRISMA procedure becomes easier and faster for researchers. Table 8 indicates a big number of articles focus on mathematical communication skills among primary school and senior high schools.

CONCLUSIONS

This systematic review examined studies related to mathematical communication skills published in ERIC. The results are as follows: First, most studies focused on elementary and junior high school students (RQ1). Second, the articles collected from 2018 to 2022 show a relatively stable publication trend, except for 2018 and 2022, where no publications were found (RQ2). Third, student-centered teaching methods can development students' mathematical communication skills (RQ3).

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