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"EXPLORING STUDENTS' PROBLEM-SOLVING ABILITY IN MATHEMATICS EDUCATION: A SYSTEMATIC LITERATURE REVIEW"

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Abstract: This systematic literature review explores problem-solving abilities in mathematics education and their impact on the learning process. The study analyzes 40 review articles from the ERIC and Scopus databases published between January 2020 and January 2024 to address three research questions. The results indicate that research on problem-solving is distributed across six continents: Europe, Oceania, North America, South America, Asia, and Africa. The United States has the highest number of publications, g-index, and h-index, making it the most productive country. The majority of research focuses on its relevance to teachers and prospective teachers, with 15 published articles. The remaining articles address mathematical problem-solving abilities related to students at different educational levels. There are 5 publications related to the elementary school level, 5 publications for the junior high school level (n = 5 articles), 5 publications for the senior high school level (n = 5 articles), and 9 publications for the higher education level. Additionally, the researcher identifies factors influencing students' mathematical problem-solving abilities. It is found that these abilities are influenced by factors originating from individuals (internal factors) and factors originating from outside individuals (external factors). This research is crucial for recommending effective learning methods to enhance students' mathematical problem-solving abilities by considering the influencing factors.

Keywords: Mathematics Education; Systematic Literature Review; Problem-Solving Abilities

1. INTRODUCTION

Education has a noble goal of shaping individuals into competent and character-driven personalities. This noble objective is aimed at preparing individuals to adapt to ever-evolving circumstances, demanded by the changing times. As articulated by Ramadhanti, Juandi, and Jupri (2022) Education plays a crucial role in equipping human resources to face the increasingly complex challenges of the 21st century. One of the sciences that plays a role in shaping various skills in an individual to tackle global challenges is mathematics.

According to Azzahra and Herman (2022), "Mathematics is one of this knowledge that is useful for humans because it teaches humans to recognize and explain phenomena that occur in everyday life". This implies that mathematics is a knowledge discipline beneficial for daily living. This aligns with the perspective of Suhendri (2011), stating that mathematics encompasses numbers, two-dimensional and three-dimensional shapes, set concepts, logical thinking using symbolic language, and is utilized to solve everyday life problems. One way to convey that mathematics is closely related to life concepts is through education in schools.

Considering the substantial benefits of mathematics in daily life, such as conducting business transactions, calculating distances and travel times, understanding patterns of daily activities, and making comparisons between two objects, all are performed using mathematical concepts. Understanding this is essential for every individual, especially students starting from elementary school, as they will continually face new and

increasingly complex problems as they age. Without equipping them to be accustomed to problem-solving, they may find it challenging to seek solutions. Therefore, the delivery of material and the provision of contextual mathematical problems that adapt to everyday phenomena are necessary. According to Wahyuni (2022) assigning problem-solving tasks in mathematics can enhance students' cognitive abilities because regularly exploring ideas about mathematics can train a child's reasoning and creativity in problem-solving.

Numerous studies have been conducted to assess an individual's problem-solving abilities from various perspectives. Some research, carried out by numerous academicians, focuses on investigating the influence of a particular instructional model that can enhance students' problem-solving skills. Additionally, the mathematical problem-solving abilities or processes of students can also be examined from various affective aspects. Several studies aim to maximize the mathematical problem-solving capabilities possessed by students. Nevertheless, there is still a gap in the literature concerning mathematical problem-solving abilities in the educational context. This gap is evidenced by the prevalence of students easily giving up when presented with math problems based on real-world situations, which they perceive as different from provided examples, making it more complex and ultimately fostering a stigma that mathematics is a difficult subject (Utami & Wutsqa, 2017).

2. LITERATURE REVIEW

2.1 Conceptualization of the Problem-Solving Ability Framework

Problem-solving ability is an individual's capacity to explore alternative solutions to various encountered problems. Polya (1973) states that problem-solving is one of the efforts to find a way out of obstacles experienced by an individual. The endeavor to find a solution is a strategy to transform a challenging situation into an easier one with an appropriate solution. This condition can train a student to develop planning skills, make decisions, and observe the outcomes of their actions. The goal of problem-based learning is to cultivate a child's ability to solve problems related to everyday life.

Mourtos (2004) argues that “problem solving is defined as a process, used to obtain a best answer to an unknown, or a decision subject to some constraints”. This implies that problem-solving is defined as a process used to find the best answer to something unknown or interpreted as a decision subject to certain constraints. Problem-solving ability plays a crucial role in the mathematics learning process since the majority of mathematical problems faced by children are scenario-based. Every constraint they encounter in solving problems demands them to think more critically than when receiving example problems from their teacher.

An individual needs to consider several factors when facing mathematical problems. According to Polya (1973) “the materials necessary for solving a mathematical problem are certain relevant items of our formerly acquired mathematical knowledge as formerly solved problems, or formerly proved theorems”. This means that someone aiming to solve a mathematical problem must delve into the knowledge and theorems they have acquired previously as prerequisites for finding the best solution method. Without doing so, one will struggle to identify a solution method, leading to a lack of motivation to solve a mathematical problem.

Based on the nature of their resolution, mathematical problems are divided into two categories: routine and non-routine (Wahyudi & Anugraheni, 2017). Routine problems in mathematics learning are those that a student encounters or works on repeatedly. Non-routine problems, on the other hand, are mathematical problems seldom encountered by a student. For an educator, determining whether a problem is routine or non-routine can be quite dilemmatic and challenging. It is possible that a non-routine problem becomes routine for some students due to regular practice at home or in other learning environments. This situation compels teachers to broaden their teaching experiences to enrich them, particularly in creating examples of mathematical problems.

The explanation regarding routine and non-routine problems is also outlined by Lechner, who classifies mathematical tasks as follows (Nisa, 2015):

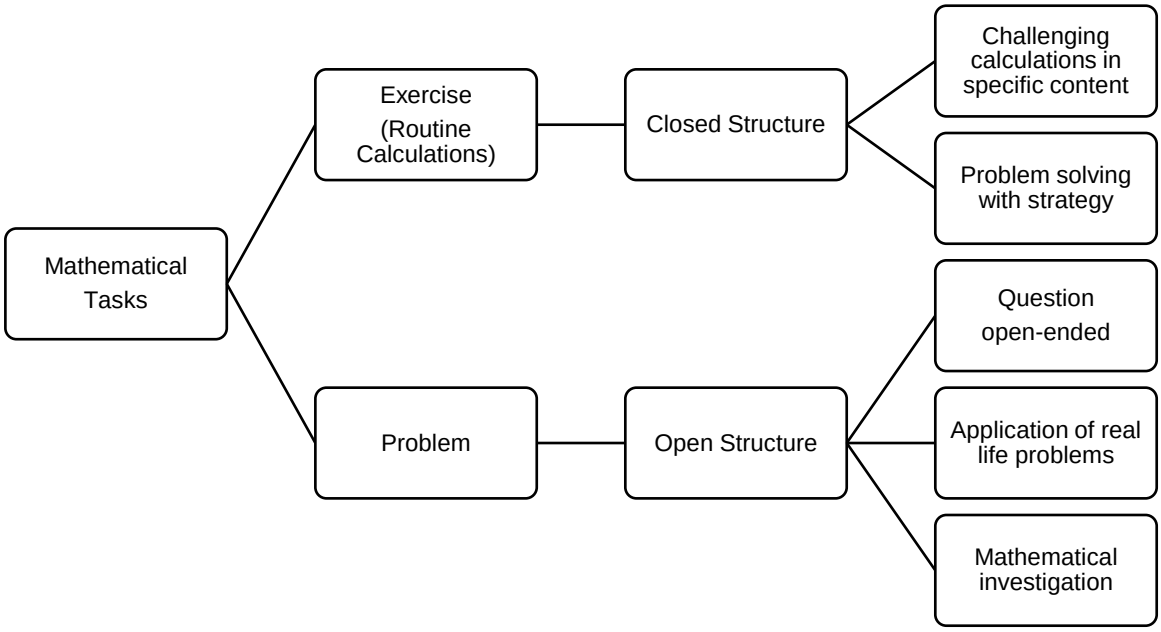

Figure 1. Classification of Mathematical Tasks

Based on Figure 1, mathematical tasks can be categorized into two types: mathematical exercises and mathematical problems. Mathematical exercises, characterized as routine calculations, exhibit a closed structure or implicitly possess the meaning of a closed mathematical problem. This implies that these closed mathematical problems have a well-defined structure and a single correct answer. Tasks in this category involve challenging calculations within specific content and problem-solving strategies. On the other hand, mathematical tasks in the form of problems have an open structure or implicitly carry the meaning of an open mathematical problem. This means that these mathematical problems have a more flexible structure and can have multiple answer options. Tasks in this category encompass open-ended questions, the application of problems in real-life scenarios, and mathematical investigations.

2.2 Challenges

Evidence indicates that mathematics is often taught through a formal process with normative and dogmatic principles, detached from the socio-cultural realities of society. This has an impact on the loss of meaningful mathematics learning processes, as students only comprehend mathematics in a textual manner (Hendriyanto, et al., 2023). This condition renders students unable to understand the implementation of mathematics in real-life situations. Additionally, students may develop a tendency to feel disinterested, perceiving mathematics as a difficult and boring subject. Based on these facts, it is not surprising that the results of the PISA tests in mathematics in Indonesia have shown a concerning trend over the years. Although there has been an improvement in Indonesia's PISA 2022 rankings recently released, an analysis of the scores in each aspect reveals a decline compared to the previous year. Specifically, in the area of mathematical proficiency, Indonesia's average score decreased by 13 points to 366, compared to the previous edition's score of 379. This figure is also 106 points lower than the global average score (Lubis, 2023). It is imperative to address these issues promptly to prevent mathematics from becoming a subject avoided by students in schools. One approach to tackle this challenge is by training students to be accustomed to contextual and problem-based mathematical questions.

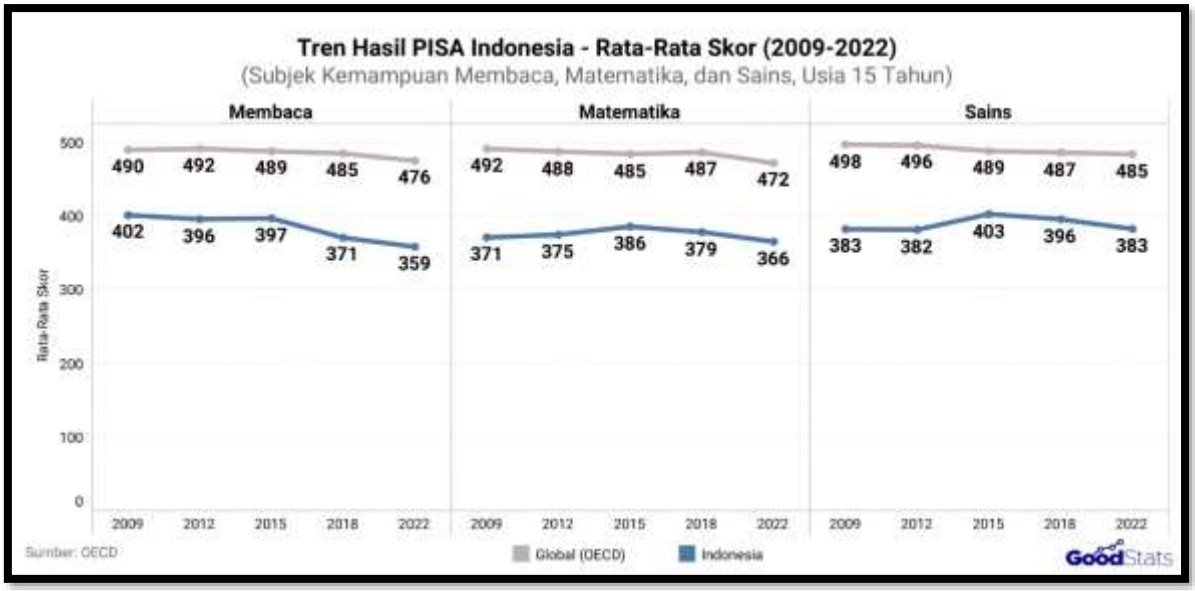

Figure 2. Trends in PISA Results (Lubis, 2023)

Presentation above indicates that students' mathematical problem-solving abilities tend to be low. However, according to the report published by the OECD on the Future of Education and Skills 2030, it is highlighted that robotics techniques are becoming a necessity on a broad scale (Lertyosbordin, Maneewan, & Srikaew, 2021). Consequently, driving student learning in schools must align with these needs. Problem-solving emerges as one of the essential skills that a student must possess to adapt to these advancements. Thus, this research aims to explore the extent of the role and benefits of problem-solving skills in mathematics education.

2.3 Objectives of the Review

This research aims to gather, review, and analyze empirical data on the role of problem-solving abilities in mathematics education. It is a systematic, retrospective, and comprehensive scholarly review designed to address the established research questions using the Systematic Literature Review (SLR) procedure, as follows:

1. What are the characteristics of research on the role of problem-solving skills in mathematics education, considering the years and subjects involved?
2. What are the characteristics of students' mathematical problem-solving skills?
3. What factors influence students' problem-solving abilities?

3. RESEARCH METHODOLOGY

In this segment, the researcher elucidates the method employed to examine recent research (between January 2020 and January 2024) on the role of problem-solving abilities in mathematics education. This study utilizes the systematic literature review (SLR) approach. As articulated by Kitchenham (2004), Systematic Literature Review (SLR) identifies, assesses, and interprets all research relevant to a specific research question, topic area, or related to an intriguing phenomenon. The process of review adheres to the primary protocol outlined in The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA), which comprises four stages: (1) identification, (2) screening, (3) eligibility, and (4) inclusion (Liberati, et al., 2009). These stages are conducted to achieve a thorough and high-quality literature review that aligns with the objectives of this SLR research.

3.1 Inclusion Criteria

The inclusion criteria in this study are utilized as the eligibility standards to meet all the criteria of primary review articles obtained from the initial search. These articles are

examined and assessed using the inclusion criteria to obtain research data that aligns with the research objectives, making the literature review in this study more systematic and detailed. The inclusion and exclusion criteria for this study are as follows:

Table 1. Inclusion Criteria

Criteria	Inclusion	Excklusion
Title and content of the article	Title that is appropriate and meets research requirements	Does not meet research requirements and the title is not relevant
Year of publication	Publication from 2020 to 2024	Publications outside the specified range
Publication type	Journal article	Reviews, conference and non-empirical studies
Language use	English	Other than English
Field of study of the article	Mathematics education	Apart from mathematics education
Accessibility	Full text or open access	Preview articles or paid articles
Article Index	Scopus	Other

3.2 Systematic Review Process

The primary study review process through the examination of the Scopus and Education Resources Information Center (ERIC) databases using the keywords "Problem Solving" and "Mathematics Education" or "Mathematics Learning" or "Mathematics Teaching." This research utilized several synonyms based on thesauri and common terms used in previous studies. Some synonymous terms for mathematics education include mathematical learning and mathematical teaching. Subsequently, the use of database sources and keywords was systematically reviewed in four stages.

In the identification stage, using the specified keywords, a total of 4,300 articles were obtained through literature searches in the two databases (n = 1,860 – Scopus; n = 2,440 – ERIC). In the screening stage, based on the predefined inclusion and exclusion criteria, a total of 372 articles remained from the two databases (n = 67 – Scopus; n = 305 – ERIC). Articles were eliminated if they fell outside the predetermined inclusion criteria, such as maximum publication year, publication type being an article, and not accepting forms like proceedings, recordings, book reviews, etc. In the subsequent screening, the researcher eliminated articles unrelated to this research, resulting in 162 articles remaining from the two databases (n = 35 – Scopus; n = 127 – ERIC). The next stage was eligibility, where articles were carefully examined to be used as data for analysis, leaving only 40 articles from the two databases (n = 14 – Scopus; n = 26 – ERIC). Thus, 40 articles were included in this study and served as the basis for data analysis.

The process of collecting primary data used for analysis in this research is explained in Figure 1 below:

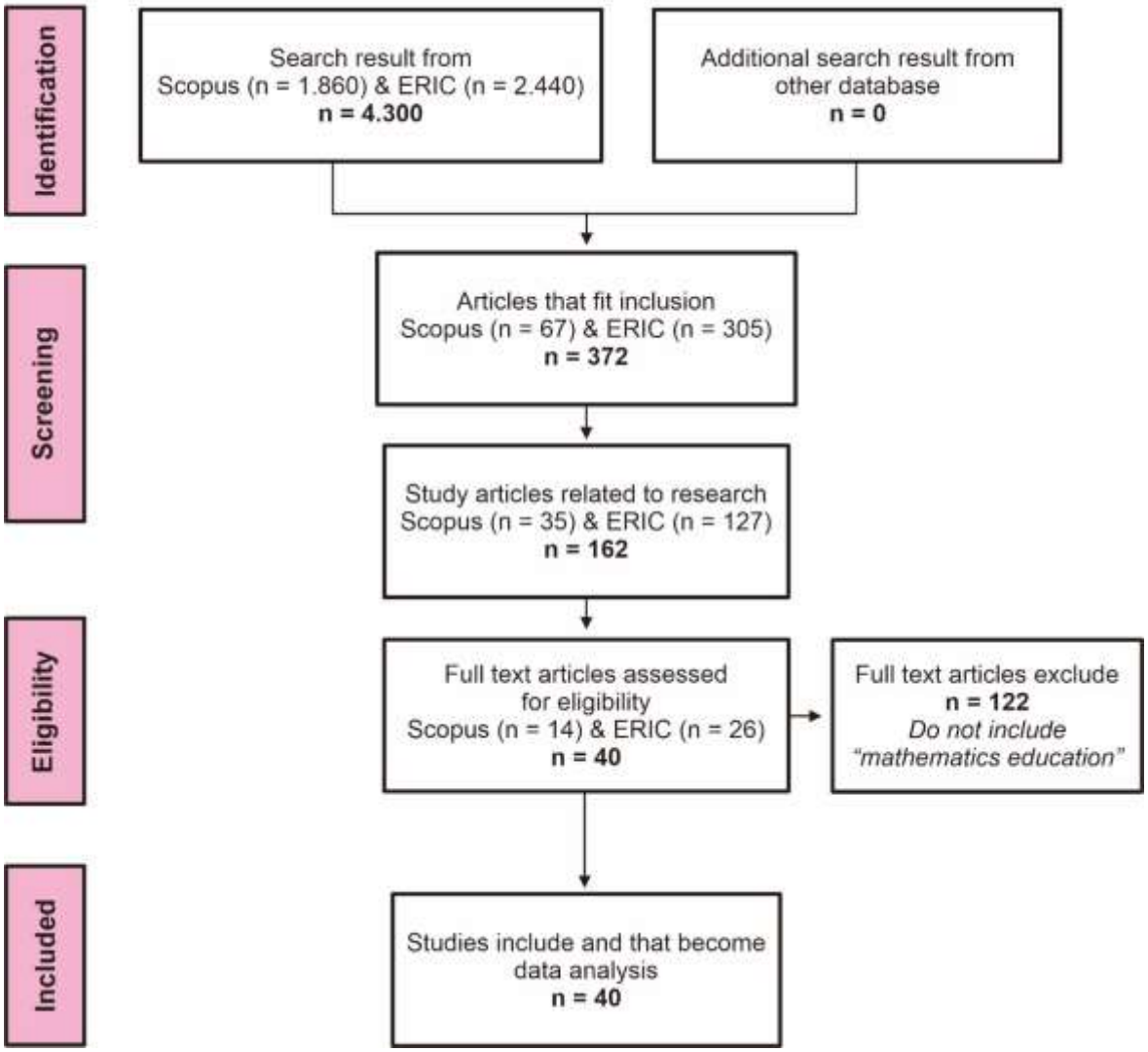

Figure 3. Primary Data Collection Flow

4. RESULTS AND DISCUSSION

4.1 Characteristics of Problem-Solving Abilities in Mathematics Education

Based on the researcher's findings from two popular databases, Scopus and ERIC, the publications between January 2020 and January 2024 amounted to 40 articles relevant to the research study. There were 13 articles (32%) in 2020, 11 articles (28%) in 2021, and 8 articles in both 2022 (20%) and 2023 (20%). When considering the total number of articles in each database, 26 articles were obtained from ERIC (65%), and 14 articles from Scopus (35%).

An explanation regarding the distribution of article publications based on the year and their respective percentages is as follows:

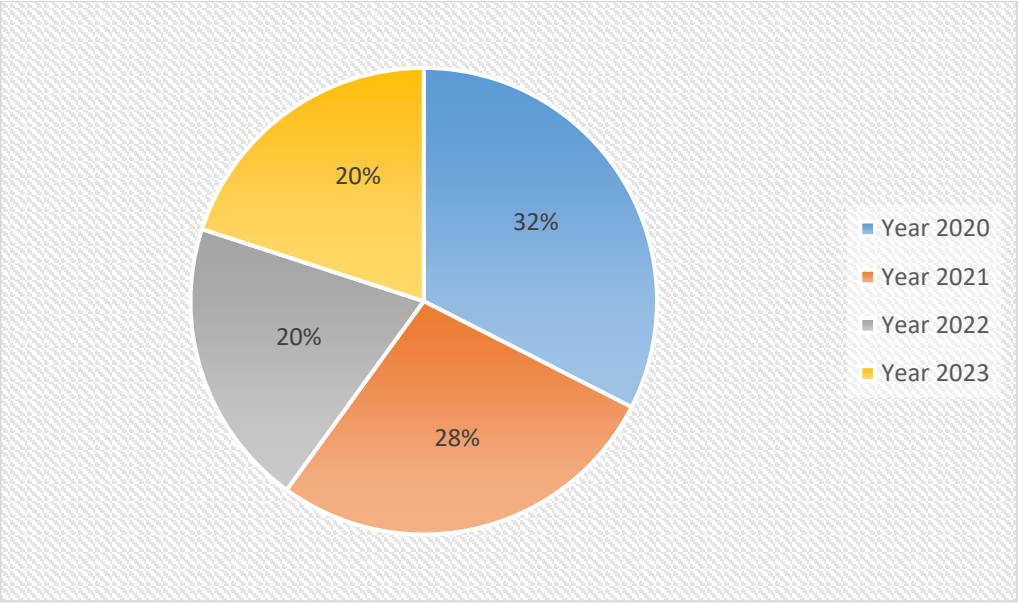

Figure 4. Distribution of Article Publications

Seseelan, Chew, and Chin (2022) conducted research on mathematical problem-solving from 1969 to 2021 through bibliometric analysis. A total of 159 bibliographic data were extracted from the Scopus database, revealing an increasing trend in publications and citations over the years. The identified research focuses on (i) problem-solving involving arithmetic and mathematical representations; (ii) problem-based learning in mathematics; (iii) students' cognition and affective domain in mathematical problem-solving; and (iv) algebraic problem-solving and the role of teachers in problem-solving instruction.

According to Seseelan, Chew, and Chin (2022) there are six continents that constitute the distribution of the majority of research on problem-solving, namely Europe, Oceania, North America, South America, Asia, and Africa. The United States has the highest number of publications, g-index, and h-index, making it the most productive country. The geographical distribution of publications is illustrated in Figure 5. The map depicts the distribution based on the number of publications in each country with different color codes. The darkest color indicates regions or countries with the highest number of publications, and as the number of publications decreases, the color of that region becomes lighter.

Referring to the map illustrated in Figure 5, the United States (n = 41) is the country with the highest contribution to problem-solving publications, followed by Australia (n = 16) with the second darkest color on the map. This indicates that among the countries included in the dataset, the United States has the highest impact. Almost 90% of the published research works have drawn the attention of other researchers and have been cited a total of 537 times.

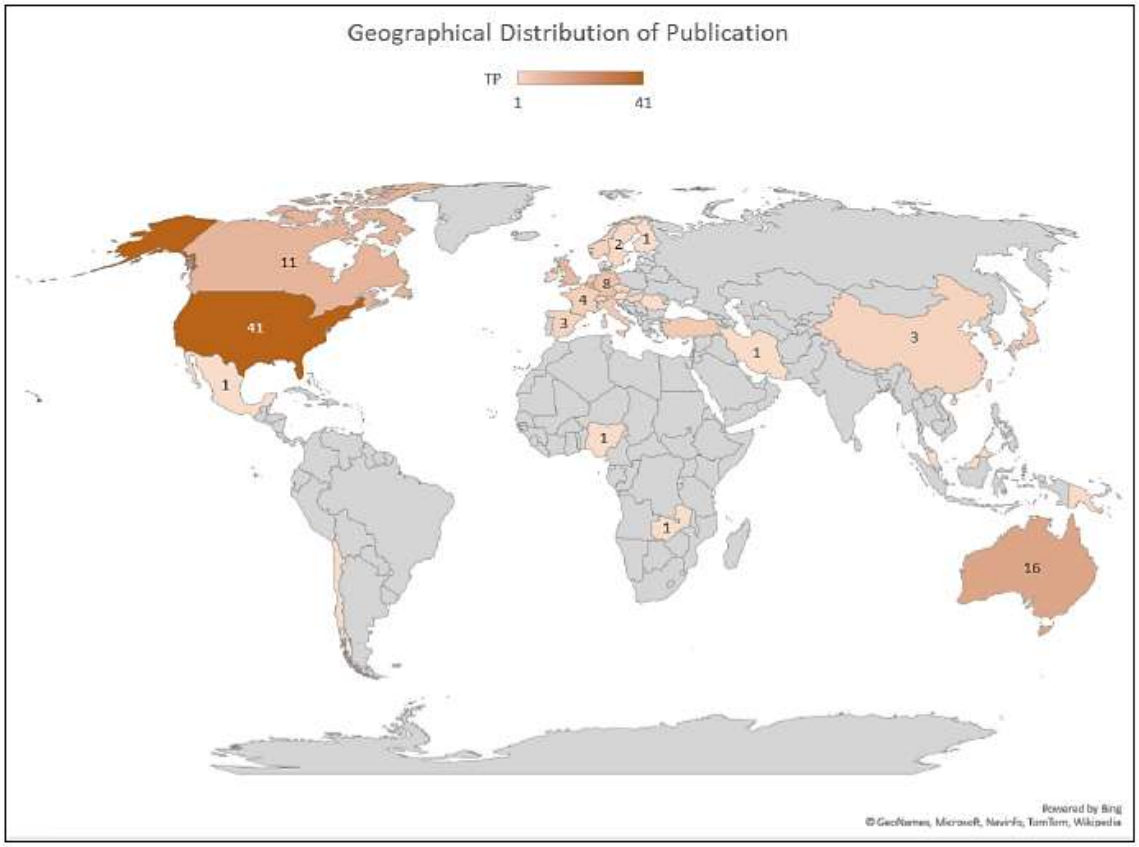

Figure 5. Geographical Distribution of Publications (Seseelan, Chew, & Chin, 2022)

The discussion on problem-solving is indeed endless, undergoing changes to adapt to every given period and condition. It is not surprising that in several countries, problem-solving becomes a notably interesting topic. Despite a decline in research studies in recent years, problem-solving remains relevant to the needs of education, particularly in the field of mathematics.

According to Liljedahl, dkk (2016) “Problem solving is regarded as the heart of mathematics teaching and learning”. This implies that problem-solving is likened to the heart of mathematics education. If the heart is a vital organ in the human body, then problem-solving becomes an element of utmost importance for mathematics. The ability to solve problems cannot be separated from mathematics; therefore, every student needs to train themselves to possess this particular skill. Apart from being necessary for solving math problems based on real-life situations, this skill is highly relevant in daily life.

According to Lithner (2008), solving mathematical problems will deepen students' understanding of mathematics. Problem-solving is introduced to students in elementary school when they are learning mathematical material and engaging in solving problems presented in the form of word problems. Through this activity, students learn to interpret problem situations into mathematical language with appropriate arithmetic operations. In other words, mathematical problem-solving activities involve students in the rationalization process of applying learned mathematical concepts in various problem situations (Seseelan, Chew, & Chin, 2022).

The mathematical problem-solving ability plays an increasingly significant role in the lives of children outside the classroom, enabling students to grasp more challenging concepts and fostering peer collaboration. Therefore, modern education recommends that teachers integrate learning approaches aimed at enhancing students' mathematical problem-solving skills. This is because the ability to solve mathematical problems is crucial for education, particularly considering that the use of this skill can improve the quality of

the teaching and learning process and provide opportunities for innovation in presenting material at various educational levels.

Researchers identified trends from 2020 to 2024, revealing several articles on problem-solving, with subjects tailored to their respective educational levels. During this period, the publication of articles on problem-solving was least common at the junior and senior high school levels, with five articles. This was followed by six articles at the university level, nine articles for primary school (SD) level, and fifteen articles for studies involving teachers or prospective teachers. The researcher compiled these facts from two database sources, Scopus and ERIC, which are further presented in the following figure:

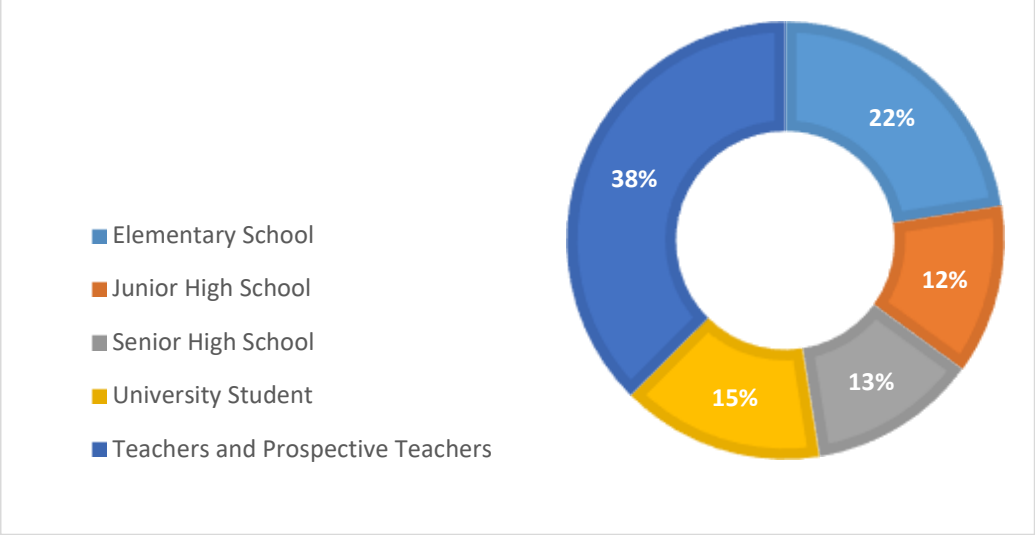

Figure 6. Distribution of articles based on research subjects

4.2 Characteristics of Students' Problem-Solving Abilities

In this research, one of the study's focal points is the characteristics of students' mathematical problem-solving abilities. The researcher contends that a fundamental need in the learning process is understanding the character of a learner. The success of a teacher in achieving learning targets is obtained by presenting material in line with the students' characteristics in the classroom. This highlights the importance of understanding students' characteristics, including the characteristics of problem-solving abilities in mathematics learning.

The researcher analyzed students' mathematical problem-solving abilities from the most basic level (elementary school) to the senior high school level. With carefully collected and analyzed data from 40 articles, only 25 articles discuss the characteristics of students' mathematical problem-solving abilities, as detailed in the following table:

Table 2. Characteristics of Students' Mathematical Problem-Solving

Problem Solving Components	Educational level	Student Characteristics
Understanding the problem	Elementary School	Note down the teacher's explanation through friends' notes
	Junior High School	Understand the problem by reading the questions and looking for keywords
	Senior High School	Form images in the mind
Devising a plan	Elementary School	Using mathematical knowledge to discover concepts or methods

	Junior High School	Connect previous experiences with information obtained from the questions
	Senior High School	Develop plans, organize information and work towards solutions
Carrying out the plan	Elementary School	Collaborate with friends to complete challenges in the form of assignments from the teacher
	Junior High School	Solve the problems faced with techniques that are considered the most effective for solving a problem
	Senior High School	Carry out solutions by paying attention to the main questions of the problem at hand
Looking back	Elementary School	Ask questions about questionable matters
	Junior High School	Verify the answer by looking at the results of your work again
	Senior High School	Verifying their ideas, reviewing what has been implemented and achieved

4.3 Factors Influencing Students' Mathematical Problem-Solving Abilities

Students' mathematical problem-solving abilities vary in levels, categorized as low, moderate, and high. This variability arises due to several factors influencing the differences in the level of mathematical problem-solving abilities. In general, students' mathematical problem-solving abilities are influenced by two factors, that is internal factors and external factors. An explanation of these factors is provided in the following table:

Table 3. Factors Affecting Students' Mathematical Problem-Solving Abilities

Factor Type	Description	Author
Internal	Lack of mathematical literacy	(Purnomo, Sukestiyarno, Junaedi, & Agoestanto, 2022)
	Independent learning	(Seepiwsiw & Seehamongkon, 2023)
	Fear and doubt	(Ersoy & Dağyar, 2022)
	High self-confidence	(Sutama, et al., 2021)
External	Delivery of material that is incomplete and lacking in depth	(Purnomo, Sukestiyarno, Junaedi, & Agoestanto, 2022)
	The teacher's role is to explore students' abilities	(Ozpinar & Arslan, 2023)
	Approach to organizing activities and developing learning innovation from teachers	(Seepiwsiw & Seehamongkon, 2023)
	The process of student mathematical interaction	(Baiduri, Putri, & Alfani, 2020)

CONCLUSION

The study on mathematical problem-solving abilities addresses the importance of teachers understanding these characteristics at each educational level. Research findings reveal that students at the elementary school level exhibit different problem-solving characteristics compared to students at the equivalent junior high school level, including those at the senior high school level. This understanding broadens the perspective of mathematics teachers to deliver learning and formulate problems suitable for their students' characteristics.

Throughout this article, the researcher identifies various studies on students' mathematical problem-solving abilities within the timeframe of 2020 to 2024. Most studies during this period focus on their relevance to teachers and prospective teachers, with 15 published articles. The remaining articles delve into the mathematical problem-solving abilities related to students according to their respective educational levels. There are 5 publications related to the elementary school level, 5 publications for the junior high school level (n = 5 articles), 5 publications for the senior high school level (n = 5 articles), and 9 publications for the higher education level.

Furthermore, the researcher identifies factors influencing students' mathematical problem-solving abilities. It is found that these abilities are influenced by internal factors (i.e., factors originating from individuals), such as the fear experienced by students when teachers are about to present problems in class. Additionally, external factors (i.e., factors originating from outside individuals) play a role, such as a lack of mathematical interaction with peers when facing difficulties with assigned problems or possibly due to the less engaging teaching methods of their instructors. Addressing these factors is crucial to effectively deliver instruction and enhance students' mathematical problem-solving abilities.

LIMITATIONS

While this review has identified some trends in article studies and important objectives for discussing problem-solving, this research has several limitations. Firstly, concerning the data sources used in this article study, it is limited to the Scopus and ERIC databases. Additionally, the publication timeframe chosen by the researcher, between 2020 and 2024, narrows the analyzed data. Various other databases, such as SAGE, Springer, Web of Science, can be employed in future article studies. Furthermore, this review only encompasses research in the form of scholarly articles. Future reviews could include a broader range of data sources, such as papers, theses, dissertations, and conference proceedings, providing researchers the opportunity to delve deeper into problem-solving studies. Therefore, the discussion and conclusions here are only a limited review of some studies implicitly illustrating their findings. The researcher hopes that this study serves as a reference for future researchers to comprehend the scope of problem-solving studies and set the direction for future research.

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