www.ijemst.net

Research on Mathematics Problem Solving in Elementary Education Conducted from 1969 to 2021: A Bibliometric Review

Menaga Suseelan
Universiti Sains Malaysia, Penang, Malaysia

Cheng Meng Chew
Universiti Sains Malaysia, Penang, Malaysia

Huan Chin
Universiti Sains Malaysia, Penang, Malaysia

To cite this article:

Suseelan, M., Chew, C.M., & Chin, H. (2022). Research on mathematics problem solving in elementary education conducted from 1969 to 2021: A bibliometric review. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 10*(4), 1003-1029. https://doi.org/10.46328/ijemst.2198

International Journal of Education in Mathematics, Science and Technology

2022, Vol. 10, No. 4, 1003-1029 https://doi.org/10.46328/ijemst.2198

Research on Mathematics Problem Solving in Elementary Education Conducted from 1969 to 2021: A Bibliometric Review

Menaga Suseelan, Cheng Meng Chew, Huan Chin

Article Info

Article History

Received:
12 November 2021
Accepted:
14 July 2022

Keywords

Bibliometric analysis
Elementary school
Mathematics
Problem-solving
Word problems

Abstract

This study focused on capturing the research landscape of past studies related to mathematics problem solving in elementary education from 1969 to 2021 through a bibliometric analysis. All the 159 bibliographic data involved were extracted from the Scopus database. The findings show an increasing trend in publication and citation over the years. The publications were distributed over six continents, namely North America, South America, Europe, Asia, Oceania, and Africa. The United States emerged as the most productive country with the highest number of publications, g-index, and h-index. The foci of the research are (i) problem solving involving arithmetic and mathematical representations, (ii) mathematics teaching and learning based on word problems, (iii) cognition of pupils and affective domains in mathematics problem solving, and (iv) problem solving involving algebra and teachers' role in problem solving learning. The findings of this study serve as a guideline for researchers to understand the niche area and set forth pathways for future research.

Introduction

Problem solving is regarded as the heart of mathematics teaching and learning (Liljedahl et al., 2016) which helps to bridge the mathematical concepts learnt with the real-world application (Verschaffel et al., 2010). In the mathematics classroom, problem solving is introduced to pupils in elementary school. They will engage in solving word problems at the end of each chapter. Through this activity, the pupils will learn to translate the problem situations into mathematical sentences with the appropriate arithmetic operation. In other words, the mathematics problem solving activity would engage students in rationalising the use of the mathematics concepts learned in various problem situations. Hence, mathematics problem solving would deepen students' mathematical understanding (Lithner, 2008).

Moreover, engaging students in solving non-routine word problems supports the sense-making of mathematics concepts learned in modelling the contextual problem situation through mathematising the real-life numerical data (Chamberlin et al., 2022). Thus, problem solving serves as the foundation of mathematical modelling which is highly emphasised in secondary and tertiary education (Evans, 1980). In fact, the development of mathematics problem solving ability is initiated through the early learning of basic mathematics concepts, followed by solving routine word problems as an exercise as well as solving non-routine word problems as an enrichment activity (English & Sriraman, 2010). Thus, problem solving is emphasized in the mathematics curriculum since primary school.

Problem solving is one of the major research domains in mathematics education (Liljedahl et al., 2016). Various research has been conducted to deepen the educational stakeholders' understanding of problem solving and relevant pedagogical issues (Cai et al., 2005). Despite the strong consensus among the mathematics education community on recognizing the development of students' mathematics problem solving ability as the main goal in the classroom, Lester and Cai (2016) noted that the consensus on effective instruction for developing students' problem solving ability is yet to be reached. Following this, Hansen (2021) urged the researchers to conduct more research on mathematics problem solving. Nonetheless, it is argued that the lack of accumulation of problem solving research is the main issue to be addressed for avoiding the recycling of flawed conjectured problem solving instructions in future research (English & Sriraman, 2010) Thus, it is warranted to conduct a review of the past-related studies for identifying the research gaps (Cason et al., 2019).

Various literature review methods are used to accumulate the existing knowledge and hence capture the state of the arts of the research. The evidence reported in past studies could be summarized comprehensively in a systematic literature review to address the research questions on a specific niche area (Donthu et al., 2021; Taufik et al., 2019; Xiao & Watson, 2019). While the content of the literature is analysed manually by the researchers using the qualitative technique following the research questions formed, the systematic literature review tends to include a small number of past studies (Snyder, 2019). Unlike systematic literature review, the empirical evidence in past studies is summarised quantitatively in meta-analysis. Specifically, the descriptive and inferential data from several studies on the specific topic of interest could be merged in a meta-analytic review (Mengist et al., 2020) for determining the combined direction and strength of effects and relationships among variables of the past studies (Donthu et al., 2021), and hence generate more general statements about the entire set of studies (Xiao & Watson, 2019). Although meta-analysis can synthesise the findings of many past studies, Aguinis et al. (2011) argued that the literature included in a meta-analytic review tend to be less diverse.

Bibliometric analysis has the same advantages as meta-analysis whereby a large amount of literature could be included in the reviewing process. In fact, the bibliometric analysis could be a more promising method for conducting the review because the use of scientific mapping could unveil the cumulative scientific knowledge and evolutionary nuances of the research by including a diverse collection of relevant studies (Donthu et al., 2021). The extensive analysis of bibliometric data would portray the research trends in elementary mathematics problem solving. Specifically, the findings of publication and citation trend would suggest the research growth, while the geographical distribution of publication would pinpoint the areas that lack relevant research. Thus, conducting a bibliometric review would benefit the researchers in identifying the research gaps and shaping the research focus (Chen et al., 2019). In this regard, we sought to conduct a bibliometric analysis to capture the research landscape of past studies related to mathematics problem solving in elementary education from 1969 to 2021.

Literature Review

Mathematics Problem Solving

Problem solving has been identified as one of the five important strands of school mathematics (National Council of Teachers of Mathematics [NCTM], 2000). Instead of standing alone as a sole topic, problem solving is embedded in every chapter because it is a process of applying the learnt mathematics concept to solve the problem (Gökkurt & Soylu, 2013). In primary school, pupils would be engaged solving word problems, which required them to apply the arithmetic operations to the numerical information available in the text description of problem situations (Verchaffel et al, 2020). Recently, teachers are urged to develop pupils' problem solving competency by exposing them to non-routine problems which cannot be solved using the known algorithm (Jader et al., 2020).

Empirical studies on problem solving have been conducted widely in the past. These studies were conducted to identify pupils' problem solving difficulties (Tambychik & Meerah, 2010), and to determine the factors that affect pupils' problem solving ability (Herbert & Williams, 2021; Öztürk et al., 2020; Passolunghi et al., 2019; Vondrova, 2020), examine the problem solving teaching and learning process (Copur-Gencturk & Doleck, 2021; Csíkos & Szitányi, 2020; Masingila et al., 2018), and evaluate the problem solving interventions (Asigigan & Samur,2021; Goulet-Lyle et al., 2020; Lee, 2017).

To synthesise the findings of past-related studies, several researchers (e.g, Cook et al., 2020; Lei et al., 2020; Peltier & Vannest, 2017) have conducted meta-analyses of the literature on problem solving interventions. For example, Lei et al. (2020) have conducted a meta-analysis of 10 single-subject case studies to determine the magnitude of the effect of interventions in improving the word problem solving performance of English Learners with learning disabilities and mathematics difficulties. Besides, Cook et al. (2020) have reviewed 10 relevant articles to determine the evidence base classification of schema-based instruction for improving word problem solving abilities of students with learning disabilities in Grades K–12. Rather than solely focusing on students with learning disabilities, Peltier and Vannest, (2017) conducted a meta-analysis of 21 relevant articles to determine the effect of schema instruction on elementary school students' problem solving performance.

Instead of reviewing articles quantitatively by performing a meta-analysis, several studies have also conducted an exploratory systematic review to synthesise the knowledge reported in past related studies. For instance, Lambert and Tan (2017) reviewed 139 articles on problem solving to determine the differences between the problem solving research involving students with and without learning disabilities in the theoretical orientations and research methodologies used. On the other hand, Olivares et al. (2021) reviewed 78 relevant articles to conceptualize the role and characteristics of problem solving in the mathematics curriculum (Olivares et al., 2021).

Whist the past-related research syntheses were conducted by reviewing the relevant literature to address the highly specific research questions formulated, this study sought to portray the research trends by conducting a bibliometric analysis. The findings of this study would deepen the understanding of the researchers on the state-of-the-art research on mathematics problem solving among primary pupils from 1969 to 2021 and hence support them in shaping their research focus.

Purpose of the Study

This study aimed to profile the research landscape on mathematics problem solving in elementary education from the year 1969 to 2021. The research questions addressed by this study are:

1) What is the current publication trend of research related to problem solving involving primary pupils?
2) What is the citation trend of research related to problem solving involving primary pupils?
3) What is the geographical distribution of the publication and the collaboration pattern among countries in research related to problem solving involving primary pupils?
4) What are the foci of the research on problem solving involving primary pupils?

Methodology

Data Collection Method

The data collection process is summarized in Figure 1. The process of document search and refinement was done based on four stages, namely identification, screening, eligibility, and inclusion, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al. 2009). The data relating to the topic 'Mathematics Problem Solving in Elementary Education' were extracted from the Scopus database due to its wide interdisciplinary coverage.

The first stage involved the identification of relevant publications using the search string and the removal of duplicates. While the research topic focused on 'Mathematics Problem Solving in Elementary Education', the commonly presented keywords in the literature, such as *'problem solving', 'word problems' and 'mathematics problems'* were identified for performing the search. The double quotation marks (" ") were used in the search to ensure the search result includes the approximate phrases such as 'word problem', 'word problems', 'word-problem' and 'word-problems' ("How Do I", 2022). To perform a more effective document search, the advanced search was conducted by limiting the search scope based on the subject area.

Specifically, the search was limited to subject areas of '*mathematics'* and *'social science'* because problem solving is the research domain in the field of mathematics education, and '*education'* is the research field under the subject area of *'social* science*'*. In other words, only the articles with the presence of the words *'problem solving', 'word problems' or 'mathematics problems'* in the title, which were categorised under both subject areas of *'mathematics'* and *'social sciences'* would be shortlisted during the advanced search. A total of 688 publications had been identified using the search string '*TITLE ("problem solving" OR "problem-solving" OR "word problem" OR "mathematics problem") AND SUBJAREA (soci) AND SUBJAREA (math)'* and no duplicates were identified.

In the second stage, screening was conducted to limit the documents to the required language and document type. Only English publications were included because it is the most widely used language in scientific communication. For document type, only articles, book chapters and reviews were taken into consideration. The publications in the form of erratum and notes were excluded because they only consisted of very minimal research information. After the screening process, 197 articles were removed because they do not satisfy the basic screening criteria. With this, only 491 publications remained.

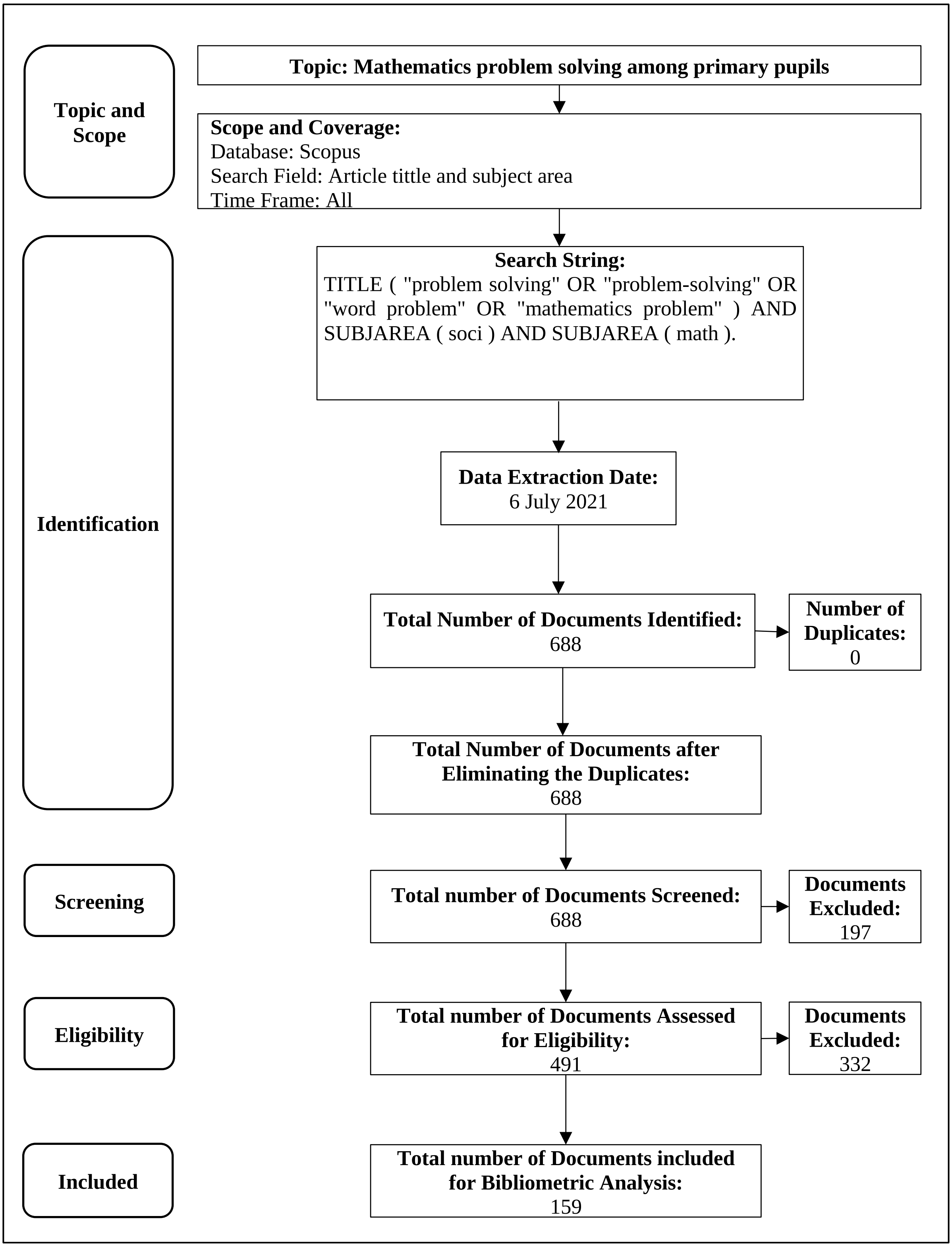

Figure 1. Data Collection Process

In stage three, the documents were assessed for eligibility. The title and abstract of the records were assessed manually by the researchers to identify the records that satisfied the inclusion criteria, which is the research involved mathematics problem solving in elementary education. Only the publications that satisfied this criterion were included in the analysis following the research topic. At the end of stage three, 332 records were removed with the reason that the research involved mathematics problem solving in secondary school and higher education contexts. As such, 159 records remained.

While the study aimed to capture the research trends and landscapes, all records were included regardless of the publication years to ensure the objectivity of the results and interpretation (Donthu et al., 2021). These records were extracted on 6 July 2021 during the inclusion stage. The titles of the 159 publications could be accessed through the URL: https://tinyurl.com/2p836bfj

Data Analysis Method

The current publication trend of publications related to problem solving among primary pupils was determined by performing descriptive analysis on the bibliometric data retrieved from the Scopus database. The graphs representing the number of publications and the cumulative number of publications in each year were generated using Microsoft Excel 2016.

To study the citation trend of publications related to problem solving among primary pupils, the data extracted from Scopus was segregated by year. The average citation per publication and the average citation per cited publication was calculated using Microsoft Excel 2016. Then, the g-index and h-index of the documents published by year were obtained using Harzing's Publish or Perish software.

To capture the geographical distribution of the publication, Microsoft Excel 2019 was used to generate a world map with the distribution of the publication. The average citation per publication, the average citation per cited publications, the g-index and the h-index were calculated using the same method used for citation trend analysis. Then, the VOSviewer was used to generate the network visualization and overlay visualization map that shows the collaboration pattern among the countries.

Lastly, the keywords co-occurrence analysis was conducted to determine the foci of the research on mathematics problem solving involving primary pupils. The author and index keywords were extracted from the database. Before the analysis process, data pre-processing was conducted.

The keywords presented as spelling variants (e.g., 'problem-solving' & 'problem solving'), singular or plural forms (e.g., 'word problems' & 'word problem'), and synonyms (e.g., 'elementary school' & 'primary school') were standardized. Then, the keyword co-occurrence network was generated using VOSviewer. As such, the foci of the research could be determined based on the keywords which cluster together in the network (Chen et al., 2016).

Results

Based on the 159 shortlisted records, the publication years spanned the years from 1969 to 2021. The majority of the records were articles (96.23%), followed by book chapters (2.52%) and reviews (1.26%).

Publication Trend

Figure 2 shows a bar graph representing the distribution of annual publications over the years from 1969 to 2021. During this time frame, the maximum number of records published was in 2020 (11.95%) followed by the year 2007 (8.18%). Before 2007, the number of publications remained below four every year. After 2007, almost every year recorded at least four publications except 2008 (n = 0) and 2009 (n = 3).

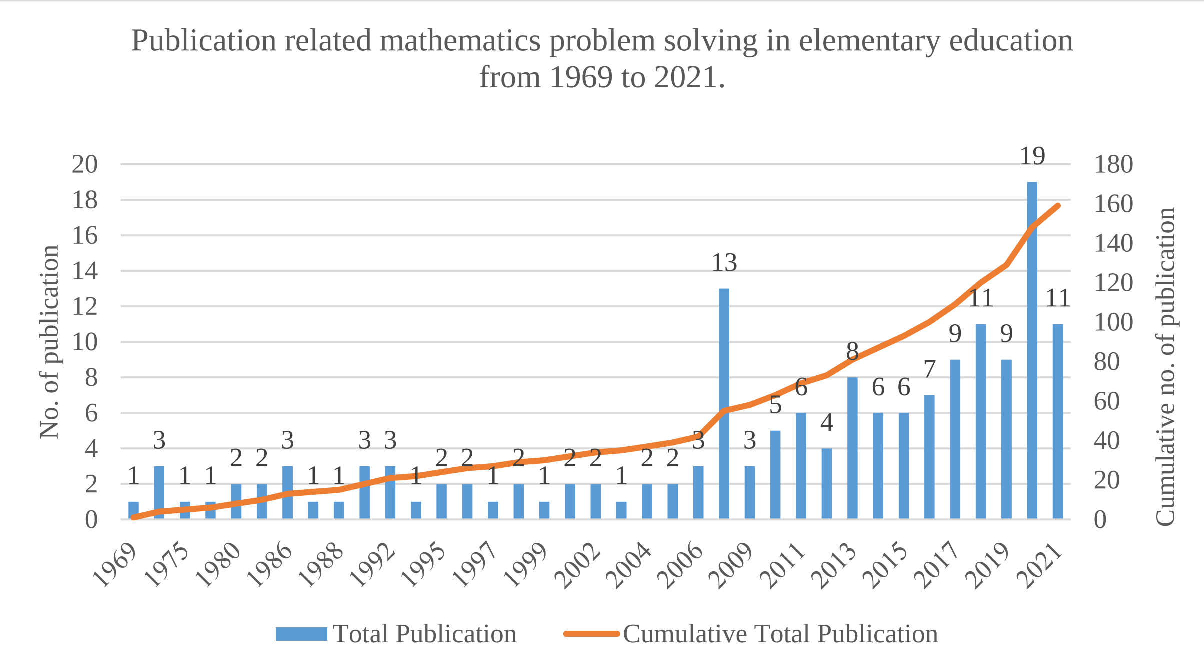

Figure 2. Publication from 1969 to 2021

There was a big increase in the number of publications from 2019 to 2020. The number of publications in 2020 (n = 19) was more than double the number of publications in the previous year, 2019 (n = 9). A cumulative frequency graph was plotted to capture the growth pattern of the publications. The curve is concave upwards, and this indicates an increasing publication trend over the years with a sharper slope from 2007 to 2021 compared to 1969 to 2006. This indicates that the growth of research on problem solving in elementary education was quite slow from the year 1969 to 2006. However, there was a rapid research growth since 2007.

Citation Trend

The citation analysis of mathematics problem solving in elementary education from 1969 to 2021 is summarized in Table 1.

Table 1. Citation Analysis of Publications

Year	TP (%)	NCP	TC	C/P	C/CP	*h*	*g*
2021	11 (6.92%)	6	8	0.73	1.33	1	2
2020	19 (11.95%)	17	61	3.21	3.59	4	6
2019	9 (5.66%)	8	28	3.11	3.50	4	4
2018	11 (6.92%)	9	71	6.45	7.89	5	8
2017	9 (5.66%)	9	70	7.78	7.78	6	8
2016	7 (4.40%)	7	51	7.29	7.29	4	7
2015	6 (3.77%)	6	66	11.00	11.00	4	6
2014	6 (3.77%)	6	82	13.67	13.67	5	6
2013	8 (5.03%)	8	100	12.50	12.50	6	8
2012	4 (2.52%)	4	44	11.00	11.00	4	4
2011	6 (3.77%)	4	69	11.50	17.25	3	4
2010	5 (3.14%)	5	81	16.20	16.20	4	5
2009	3 (1.89%)	3	123	41.00	41.00	3	3
2007	13 (8.18%)	11	173	13.31	15.73	8	11
2006	3 (1.89%)	3	228	76.00	76.00	3	3
2005	2 (1.26%)	2	26	13.00	13.00	2	2
2004	2 (1.26%)	2	5	2.50	2.50	1	2
2003	1 (0.63%)	1	47	47.00	47.00	1	1
2002	2 (1.26%)	2	71	35.50	35.50	2	2
2001	2 (1.26%)	2	14	7.00	7.00	2	2
1999	1 (0.63%)	1	27	27.00	27.00	1	1
1998	2 (1.26%)	2	23	11.50	11.50	2	2
1997	1 (0.63%)	1	16	16.00	16.00	1	1
1996	2 (1.26%)	2	12	6.00	6.00	2	2
1995	2 (1.26%)	2	19	9.50	9.50	2	2
1994	1 (0.63%)	1	4	4.00	4.00	1	1
1992	3 (1.89%)	3	29	9.67	9.67	3	3
1990	3 (1.89%)	3	47	15.67	15.67	3	3
1988	1 (0.63%)	1	6	6.00	6.00	1	1
1987	1 (0.63%)	1	8	8.00	8.00	1	1
1986	3 (1.89%)	3	104	34.67	34.67	2	3
1983	2 (1.26%)	1	38	19.00	38.00	1	1
1980	2 (1.26%)	2	85	42.50	42.50	2	2
1976	1 (0.63%)	1	2	2.00	2.00	1	1
1975	1 (0.63%)	1	67	67.00	67.00	1	1
1974	3 (1.89%)	3	21	7.00	7.00	3	3
1969	1 (0.63%)	1	18	18.00	18.00	1	1

Notes. *TP*=total number of publications, *NCP*=number of cited publications, *TC*=total citations, *C/P* =average citations per publication, *C/CP*=average citations per cited publication, *h*=h-index, *g*=g-index

Based on Table 1, the number of cited papers (NCP) was the highest in the year 2020 (NCP = 17) followed by 2007 (NCP = 11), with the NCP value exceeding 10. Despite the low publication rate recorded before 2007, nearly all publications produced in each year were cited publications, except the year 1983. Only one out of two papers published in 1983 has been cited.

The total citations were the highest in the year 2006 although it only recorded a total publication of three. Each publication in 2006 received 76.00 citations on average. Even though a small number of publications was produced in 2006, some of these publications had great research impact and hence were being cited frequently. The total citations after 2006 decreased gradually until 2013 in which a sudden hike was observed with a total citation of 100. Thereafter, the total citations remained below 100 until 2021.

The highest g-index and h-index were recorded in the year 2007 with a value of '11' and '8' respectively. This indicates that publications in 2007 had the highest impact within the time frame of 1969 to 2021. With the h index of eight, and g index of 11, at least eight publications in 2007 had been cited sixty-four (64) times in total and at least 11 publications in 2007 had been cited at least 11 times each. The g-index was noticeably higher than the h-index as it permits citations from papers with a lower number of citations to be bolstered by papers with higher citations to meet the required threshold (Egghe, 2006). It is worth noting that the g-index and h-index were at most three before 2007.

On the other hand, the g-index and h-index were at least three after 2007, except for 2021 (g index = 2, h index = 1). This trend is in line with the increase in research growth since 2007. While there is a positive research growth since 2007, the research impact of publications was still warranted.

Geographical Distribution of the Publications

The geographical distribution of the publications is illustrated in Figure 3. The countries were identified based on the author's affiliations. The colour coding of the map explains the distribution based on the number of publications in each country. The highest number of publications is indicated by the darkest shade and as the number of publications decreases, the shade gets lighter. The publications were distributed over different continents.

Based on the map as shown in Figure 3, a total of 39 countries from North America (n=3), South America (n=1), Europe (n=19), Oceania (n=2), Africa (n=3), and Asia (n=11) were stained with colours with different intensities. With the darkest shade, the United States is the country with the highest contributions to publications on mathematics problem solving in elementary education. Nearly one-quarter of the publications were produced by institutions in the United States (TP=41). This was followed by Australia (TP=16) with the second darkest shade.

The countries with at least three publications are listed in Table 2. As shown in Table 2, there were 22 countries with at least 3 publications on mathematics problem solving in elementary education. The top five most productive countries fall on three continents namely North America (United States and Canada), Europe (Belgium and United

Kingdom) and Oceania (Australia). The total publications from these five countries comprise more than half (55.98%) of the total publications published from 1969 to 2021. The publications from these countries recorded a high citation rate. All publications from Canada are categorized as cited publications, while more than 90 percent of publications from Australia, Belgium, Canada, and the United Kingdom, each has been cited at least once.

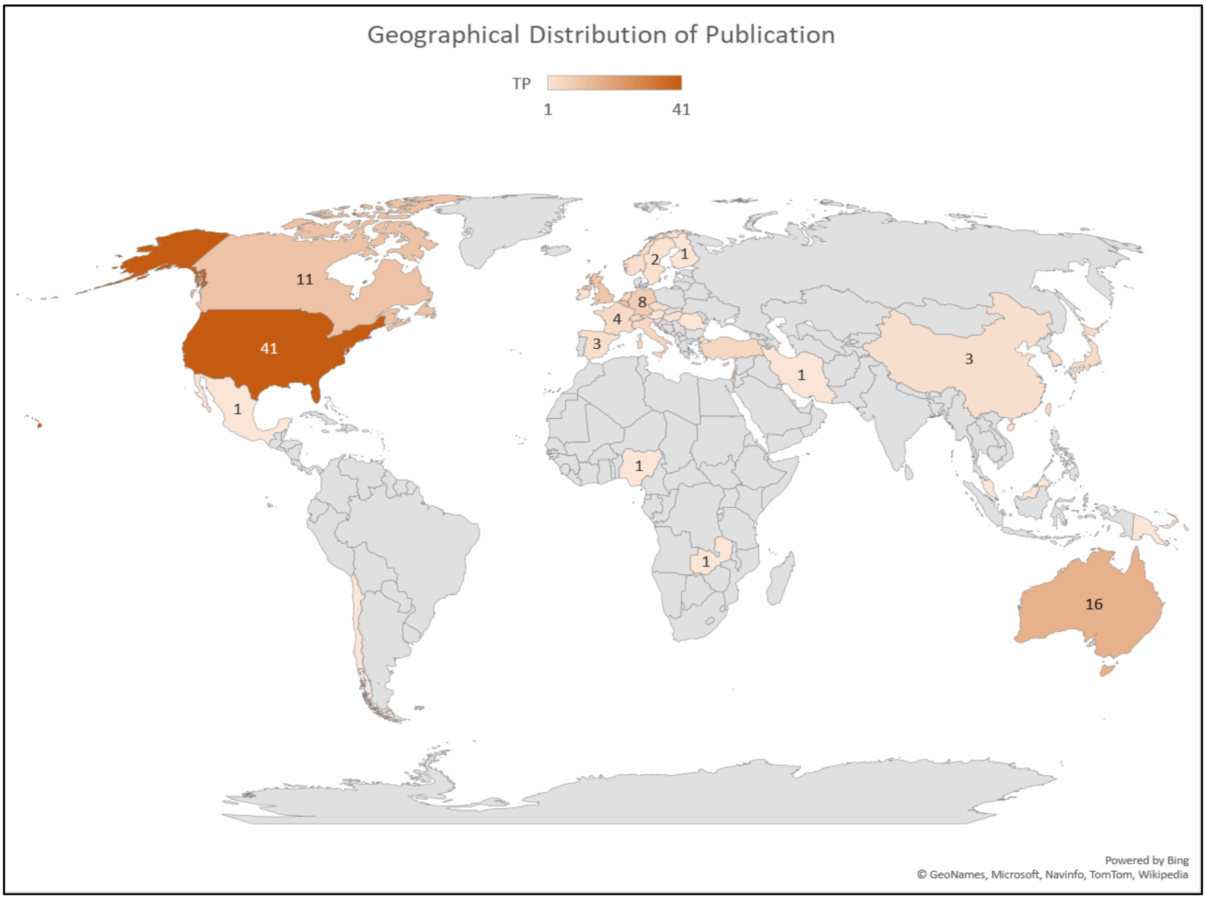

Figure 3. Geographical Distribution of Publications

With the highest number of publications, the United States was recorded as the most cited country with the greatest research impact (g-index =12; h-index=22). This indicates that the publications from the United States had the highest impact among the countries included in the dataset. Nearly 90 percent of the published research works caught the attention of other researchers and had been cited in their studies 537 times in total.

Out of the 37 cited publications distributed in the United States, at least 12 of them had been cited at least 12 times each. At least 22 cited publications from the United States had contributed to a minimum of 484 (222) total citation counts. Next to the United States, Australia recorded a high g-index and h-index with a value of 15 and eight respectively. This was followed by Belgium with an h-index of seven and a g-index of 10. Even though the number of cited publications from Canada (NCP=11) was higher than that of Belgium (NCP=10), the h-index of Canada (h-index=5) was lower than that of Belgium (h-index=7). This is because the number of highly cited publications from Canada is less than that from Belgium. At least seven publications from Belgium received at least seven citations each, while only five publications from Canada received at least five citations each.

Table 2. Countries with more than Two Publications

Country	TP(%)	NCP	TC	C/P	C/CP	*h*	*g*
United States	41(25.79%)	37	537	13.10	14.51	12	22
Australia	16(10.06%)	15	229	14.31	15.27	8	15
Belgium	11(6.92%)	10	170	15.45	17.00	7	10
Canada	11(6.92%)	11	181	16.45	16.45	5	11
United Kingdom	10(6.29%)	9	105	10.50	11.67	6	9
Germany	8(5.03%)	8	116	14.50	14.50	5	8
Israel	6(3.77%)	6	78	13.00	13.00	5	6
Italy	5(3.14%)	5	51	10.20	10.20	4	5
Netherlands	5(3.14%)	5	84	16.80	16.80	4	5
Singapore	5(3.14%)	5	103	20.60	20.60	4	5
Turkey	5(3.14%)	2	26	5.20	13.00	2	2
Cyprus	4(2.52%)	4	91	22.75	22.75	4	4
France	4(2.52%)	4	18	4.50	4.50	3	4
Japan	4(2.52%)	3	28	7.00	9.33	3	3
Switzerland	4(2.52%)	3	8	2.00	2.67	2	2
Taiwan	4(2.52%)	3	32	8.00	10.67	3	3
China	3(1.89%)	3	35	11.67	11.67	3	3
Czech Republic	3(1.89%)	2	5	1.67	2.50	1	2
Hungary	3(1.89%)	3	28	9.33	9.33	3	3
Norway	3(1.89%)	2	15	5.00	7.50	2	2
South Korea	3(1.89%)	3	8	2.67	2.67	2	2
Spain	3(1.89%)	3	3	1.00	1.00	1	1

Notes. TP=total number of publications, *NCP*=number of cited publications, *TC*=total citations, *C/P*=average citations per publication, *C/CP*=average citations per cited publication, *h*=h-index, *g*=g-index

Global Collaboration Pattern

To study the global collaboration pattern, the co-authorships were analysed with the country as the unit of analysis. The VOSviewver software was used to visualize the collaboration between countries with at least one related publication. As shown in Figure 4, the collaboration pattern of the 39 countries which surpassed the minimum publication threshold was represented by the incomplete network with 16 isolated components.

The largest component of the incomplete network consisted of 20 nodes. The rest of the components are relatively small. There was an isolated component (yellow component) with three nodes and two isolated components (light blue and orange components) with two nodes each. The other isolated components are presented as a single node. Except for Japan, the rest of the single-node component is not clearly presented because they were hidden behind other larger nodes. While the nodes and edges in the network represent the countries and the collaboration among the countries respectively, the isolated component with single nodes indicates the country with no research collaboration in mathematics problem solving involving elementary education recorded.

In general, the incomplete network as shown in Figure 4 indicates the fragmentation of the global collaboration pattern. Despite nearly half of the countries (n=20, 51.28%) being interconnected with collaboration ties, another half of the countries with relevant publications were poorly interconnected. In fact, no research collaboration in mathematics problem solving involving elementary education was recorded in nearly one-third of the countries (n=12, 30.77%).

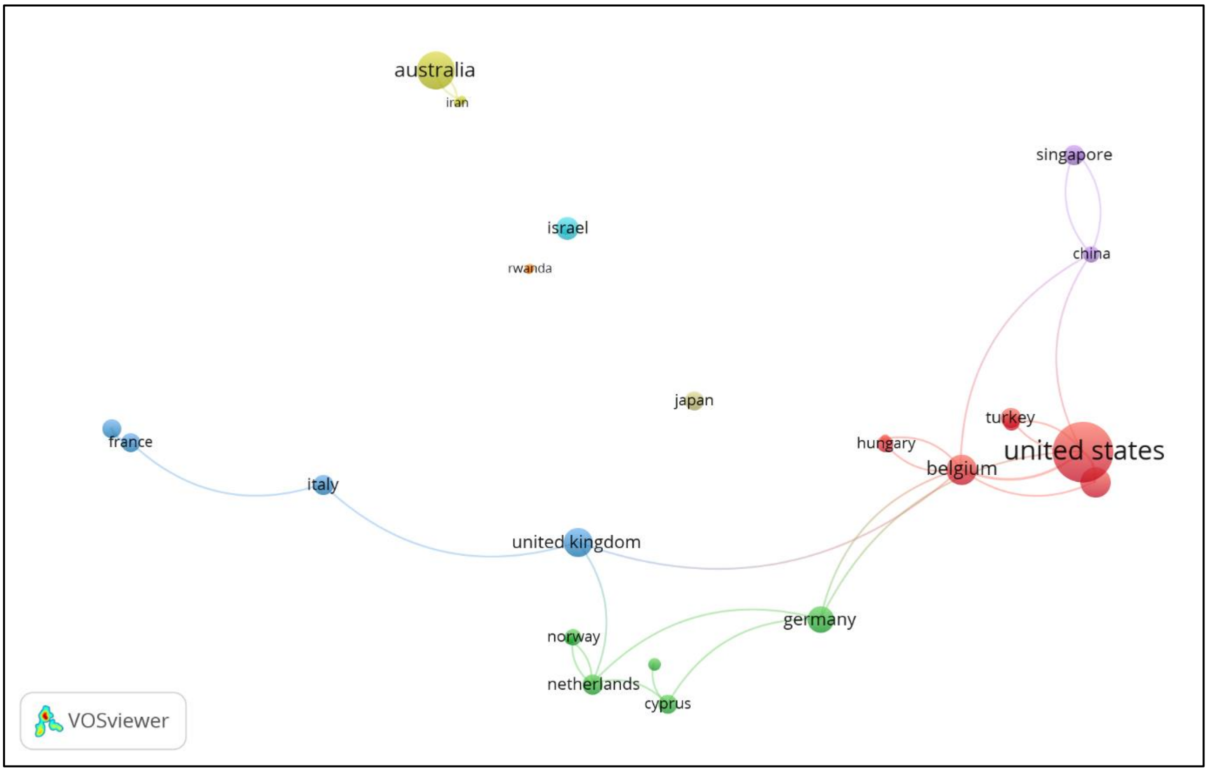

Figure 4. The Collaboration between Countries

Based on the network, the United States is the largest node. This indicates the United States has a higher number of publications related to mathematics problem solving involving primary pupils. There were six edges connected to this largest node (i.e., United States). This indicates the United States has collaborated with six different countries. Although Belgium has a lower number of publications compared to the United States, it was the most active country in collaborating with others. It has collaborated with seven different countries. However, there is not much difference in the thickness of the edges among the various collaborations. This scenario might be due to an almost equal number of collaborations among any two countries.

The 39 countries were grouped into 20 clusters in the global collaboration network. However, only eight of the clusters were visible in the network shown in Figure 4. These invisible clusters were the isolated components with a single node, which were hidden behind the larger nodes. The largest component consisted of four clusters coded with different colours (i.e., blue, green, red, and purple). The red cluster shows an inter-continent collaboration. This cluster consisted of two North American Countries (i.e., the United States and Canada) and three European

Countries (i.e., Turkey, Belgium, and Hungary).

Research Foci

The foci of the research on mathematics problem solving in elementary education were determined by conducting keywords co-occurrence analysis. A total of 38 keywords which surpassed the co-occurrence threshold of two were included in the analysis. To generate the network with a clear clustering result, the keywords with total link strength of less than five were removed from the list. By setting the minimum cluster size as six nodes, the co-occurrence network of the remaining 34 keywords was generated. As shown in Figure 5, the nodes and edges in the map represent the keywords and the co-occurrence of the keywords respectively. As shown in Figure 5, Problem solving is represented by the largest node followed by word problems (the largest green node), cognition (the largest blue node) and primary (the largest red node) with almost equal size with the largest blue node. The relatively thick edges between keyword pairs such as problem solving and mathematics learning, problem solving and reasoning, as well as problem solving and affective domain (blue node adjacent to mathematics learning) denote a high co-occurrence between them (Chen et al.,2016).

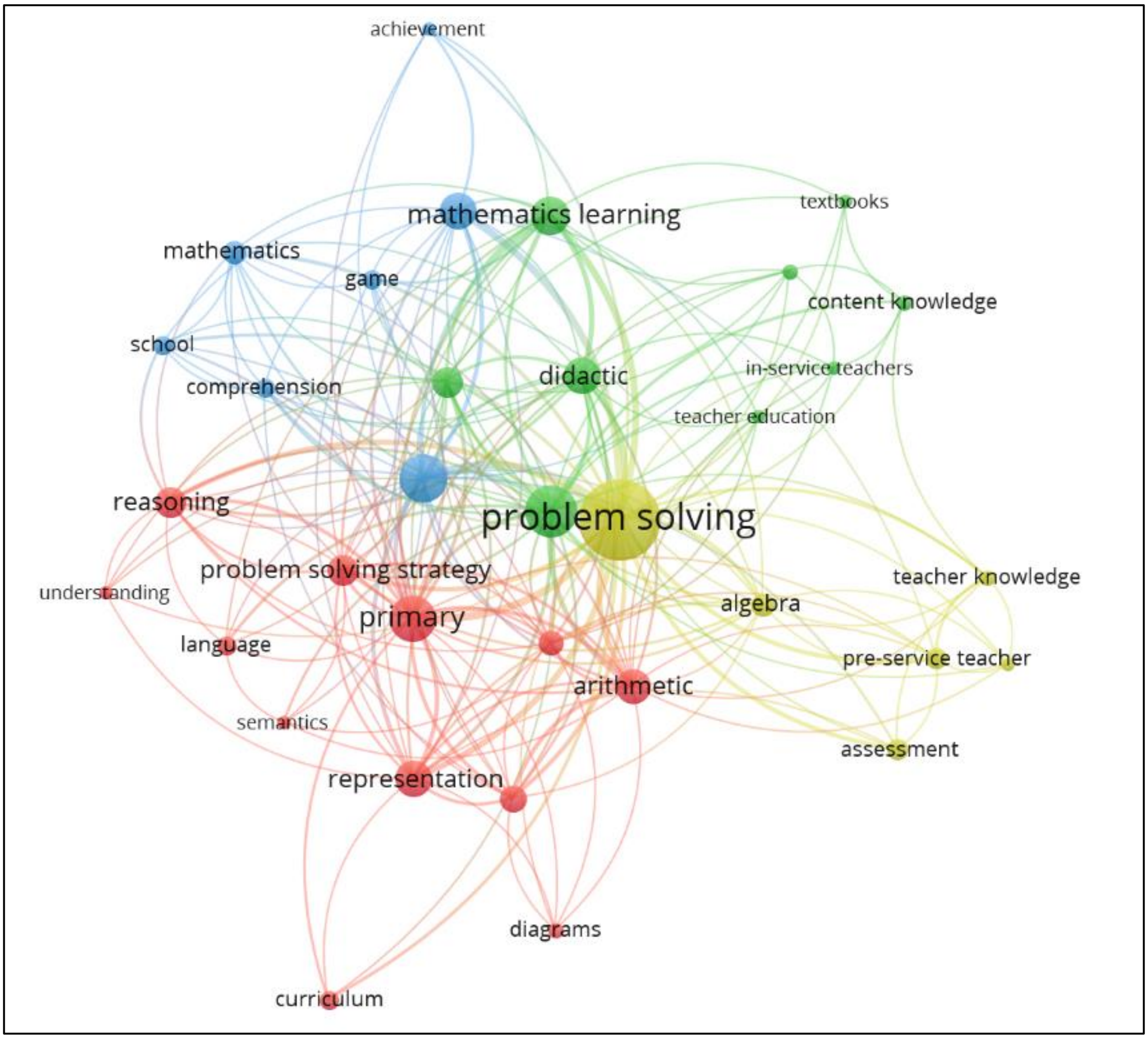

Figure 5. Keyword Co-Occurrence Network (Occurrence Threshold ≥ 2)

The 34 keywords were grouped into clusters which are represented with different colours in the network displayed in Figure 5. Each cluster reflects a research focus. The red cluster is the largest cluster with 12 keywords. The node size of ‘primary’, ‘representation’ and ‘reasoning’ are relatively large compared to other nodes in the cluster. Thus, these keywords reflect the research focus named ‘problem solving involving arithmetic and mathematical representations.’ The green cluster consisted of nine keywords, in which ‘word problems’, ‘mathematics learning’ and ‘didactic’ were the three keywords with the largest node size. Following this, the green cluster reflects the research focus named ‘mathematics teaching and learning based on word problem’. The blue cluster consisted of seven keywords, whereby 'cognition', 'affective domain', and 'mathematics' are the three largest nodes in the cluster. Thus, the blue cluster reflects the research focus named 'cognitive and affective domains in mathematics problem-solving. The yellow cluster is the smallest cluster which only consists of seven keywords. 'Problem-solving' is the node with the largest size, followed by 'algebra'. Notably, the size of the nodes labelled with 'assessment', 'pre-service teacher', and 'teacher knowledge' are slightly smaller than the node 'algebra'. In other words, these keywords are almost equivalent to 'algebra' in terms of their relevance to the research focus. Thus, the yellow cluster represents the research focus named 'problem solving involving algebra and teachers' role in problem solving learning'.

Discussion

This study intended to capture the research landscape related to mathematics problem solving in elementary education from the year 1969 to 2021. The discussion of the findings corresponding to each research question is presented in the following sections.

What is the current publication trend of research related to problem solving in elementary education?

The findings indicate an increased number of publications related to problem solving in elementary education from the year 1969 to 2021. This is in line with the analysis conducted by Ozkaya (2018) in which an increase in the number of mathematics education publications was observed from the year 1980 to 2018. According to McLeod and Adams (2012), Ozkaya (2018) as well as Tjoe (2019), mathematics problem solving is the key research field in mathematics education and it is emphasised in every International Congress of Mathematics Education (ICME) (Liljedahl et al., 2016). Problem solving is established as the main reform goal in mathematics education and it drew great attention from the researchers upon the introduction of the Principles and Standards of School Mathematics in 2000 (Gökce & Güner, 2021). Thus, the research work related to problem solving in elementary school increases over time.

In this study, a steeper increase was noticed after the year 2007. This finding was supported by Ramirez and Devesa (2019) in which research publications in mathematics increased drastically after 2007. The rapid growth of research in 2007 could be due to more research projects that had been conducted to address the unsatisfactory mathematics problem solving performance of the students aged 15 to 16 years old in PISA 2003 globally (OECD, 2004). As documented in the International PISA 2003 Report published by OECD (2004), there were only 31 percent of the participating students who were able to understand the multiple representations of the simple problems involving real-world context and solve the problems involving real-life contexts by carrying out multistep or sequential calculation processes. In other words, only nearly 30 percent of the students aged 15 to 16 years old were able to apply their mathematical knowledge to solve simple problems involving real-life contexts. This worrisome situation prompted the researchers to conduct more relevant research in the subsequent years so that the students' mathematics problem solving skills could be enhanced. Notably, there was a surge of publications in 2007 and 2020. This was because the two thematic issues focused on mathematics problem solving had been published in the journal named 'ZDM- Mathematics Educations' in 2007 and 2020. It is worth noting that, 10 out of 13 of the publications in 2007 as listed in Table 3 were the invited articles published in the thematic issue entitled 'Problem Solving Around the World: Summing Up the State of the Art'.

Table 3. List of Documents Published in 2007

Documents		Citation
[1]	Cai, J., & Nie, B. (2007). Problem solving in Chinese mathematics education: Research and practice. *ZDM*, *39*(5), 459-473.	55
[2]	Bonotto, C. (2007). How to replace word problems with activities of realistic mathematical modelling. In W. Blum et al. (Eds.),*: The 14th ICMI Study: Modelling and applications in mathematics education* (pp. 185-192). Springer, Boston, MA.	23
[3]	Fan, L., & Zhu, Y. (2007). From convergence to divergence: The development of mathematical problem solving in research, curriculum, and classroom practice in Singapore. *ZDM*, *39*(5), 491-501.	17
[4]	Reiss, K., & Törner, G. (2007). Problem solving in the mathematics classroom: The German perspective. *ZDM*, *39*(5), 431-441.	16
[5]	Hino, K. (2007). Toward the problem-centered classroom: trends in mathematical problem solving in Japan. *ZDM*, *39*(5), 503-514.	15
[6]	Santos-Trigo, M. (2007). Mathematical problem solving: an evolving research and practice domain. *ZDM*, *39*(5), 523-536.	15
[7]	Arcavi, A., & Friedlander, A. (2007). Curriculum developers and problem solving: the case of Israeli elementary school projects. *ZDM*, *39*(5), 355-364.	10
[8]	Artigue, M., & Houdement, C. (2007). Problem solving in France: didactic and curricular perspectives. *ZDM*, *39*(5), 365-382.	8
[9]	Clarke, D., Goos, M., & Morony, W. (2007). Problem solving and working mathematically: An Australian perspective. *ZDM, 39*(5), 475-490.	6
[10]	Burkhardt, H. & Bell, A. (2007). Problem solving in the United Kingdom. *ZDM*, *39*(5), 395-403.	6
[11]	Boero, P., & Dapueto, C. (2007). Problem solving in mathematics education in Italy: dreams and reality. *ZDM*, *39*(5), 383-393.	1
[12]	Pratt, N., & Woods, P. (2007). Changing PGCE students' mathematical understanding through a community of inquiry into problem solving. *Research in Mathematics Education*, *9*(1), 79-94.	0
[13]	Natsusaka, S. (2007). The Problem solving Oriented Teaching Methods and Examples. In M. Isoda et al. (Eds.), *Japanese Lesson Study in Mathematics: Its Impact, Diversity and Potential for Educational Improvement* (pp. 92-101). World Scientific, Singapore.	0

Meanwhile, nearly half of the publications (8 out of 19) in 2020 as listed in Table 4 were invited articles published in the thematic issue entitled 'Mathematical word problem solving: Psychological and educational perspectives. Instead of publishing regular research articles, 'ZDM- Mathematics Educations' only publishes research articles based on the invitation of the editorial board (Kaiser, 2019). Thus, the publication of thematic issues that focused on problem solving might lead to the surge of publications in 2007 and 2020.

Table 4. List of Documents Published in 2020

Documents		Citation
[1]	Verschaffel, L., Schukajlow, S., Star, J., & Van Dooren, W. (2020). Word problems in mathematics education: A survey. *ZDM*, *52*(1), 1-16.	18
[2]	Csíkos, C., & Szitányi, J. (2020). Teachers' pedagogical content knowledge in teaching word problem solving strategies. *ZDM*, *52*(1), 165-178.	5
[3]	Pongsakdi, N., Kajamies, A., Veermans, K., Lertola, K., Vauras, M., & Lehtinen, E. (2020). What makes mathematical word problem solving challenging? Exploring the roles of word problem characteristics, text comprehension, and arithmetic skills. *ZDM*, *52*(1), 33-44.	5
[4]	Goulet-Lyle, M. P., Voyer, D., & Verschaffel, L. (2020). How does imposing a step-by-step solution method impact students' approach to mathematical word problem solving?. *ZDM*, *52*(1), 139-149	4
[5]	Powell, S. R., Berry, K. A., & Barnes, M. A. (2020). The role of pre-algebraic reasoning within a word-problem intervention for third-grade students with mathematics difficulty. *ZDM*, *52*(1), 151-163.	4
[6]	Alghamdi, A., Jitendra, A. K., & Lein, A. E. (2020). Teaching students with mathematics disabilities to solve multiplication and division word problems: the role of schema-based instruction. *ZDM*, *52*(1), 125-137.	2
[7]	Gvozdic, K., & Sander, E. (2020). Learning to be an opportunistic word problem solver: Going beyond informal solving strategies. *ZDM*, *52*(1), 111-123.	2
[8]	van Lieshout, E. C., & Xenidou-Dervou, I. (2020). Simple pictorial mathematics problems for children: locating sources of cognitive load and how to reduce it. *ZDM*, *52*(1), 73-85.	1
[9]	Ng, O. L., & Cui, Z. (2020). Examining primary students' mathematical problem solving in a programming context: Towards computationally enhanced mathematics education. *ZDM*. Article in press. https://doi.org/10.1007/s11858-020-01200-7	1
[10]	Harris, D., Logan, T., & Lowrie, T. (2021). Unpacking mathematical-spatial relations: Problem solving in static and interactive tasks. *Math. Educ. Res. J.*, *33*(3), 495-511.	1
[11]	Ramírez, R., Brizuela, B. M., & Ayala-Altamirano, C. (2020). Word problems associated with the use of functional strategies among grade 4 students. *Math. Educ. Res. J*, 1-25.	1
[12]	Reid O'Connor, B., & Norton, S. (2020). Supporting indigenous primary students' success in problem-solving: learning from Newman interviews. *Math. Educ. Res. J*, 1-24.	0
[13]	Scheibling-Sève, C., Pasquinelli, E., & Sander, E. (2020). Assessing conceptual knowledge through solving arithmetic word problems. *Educ. Stud. Math*, *103*(3), 293-311.	2
[14]	Ott, B. (2020). Learner-generated graphic representations for word problems: an intervention	0

Documents		Citation
	and evaluation study in grade 3. *Educ. Stud. Math*, *105*(1), 91-113.	
[15]	Ke, F., & M Clark, K. (2020). Game-based multimodal representations and mathematical problem solving. *Int. J. Sci. Math. Educ.*. *18*(1), 103-122.	5
[16]	Cho, M. K., & Kim, M. K. (2020). Investigating elementary students' problem solving and teacher scaffolding in solving an ill-structured problem. *Int J Math Educ Sci Technol.*, *8*(4), 274-289.	3
[17]	Dröse, J., & Prediger, S. (2020). Enhancing fifth graders' awareness of syntactic features in mathematical word problems: A Design Research study on the variation principle. *J. fur Math.-Didakt.*, *41*(2), 391-422.	2
[18]	Öztürk, M., Akkan, Y., & Kaplan, A. (2020). Reading comprehension, Mathematics self-efficacy perception, and Mathematics attitude as correlates of students' non-routine Mathematics problem solving skills in Turkey. *Int. J. Math. Educ. Sci. Technol.*, *51*(7), 1042-1058.	4
[19]	Vondrová, N. (2020). The effect of an irrelevant number and language consistency in a word problem on pupils' achievement and reasoning. *Int. J. Math. Educ. Sci. Technol.*, Article in press. https://doi.org/10.1080/0020739X.2020.1782497	1

What is the citation trend of research related to problem solving in elementary education?

Over the years, there is a smooth increase in the cumulative number of citations. This suggests that problem solving is still an active and impactful research domain (Drijvers et al., 2020) although it started to be documented in the Scopus database starting from 1969. Specifically, the year 2020 witnessed the highest number of cited papers. This further bears witness to its impactful status in mathematics education because many research works published at the latest in 2020 had been cited to date. According to Leydesdorff et al. (2016), citation counts accumulate over time. However, the bibliometric analysis conducted in 2021 recorded a high number of cited publications recorded in 2020. The research publications on mathematics problem solving in elementary education as recorded in 2020 have received great attention from the researcher community. For instance, nearly half of the publications (8 out of 19) in 2020 as listed in Table 4 were invited articles published in the thematic issue in ZDM. While these articles were written by the scholars, they received great attention from the research community and hence were being cited in the latest relevant research work.

Even though there were only three publications documented in Scopus in 2006, the average number of citations per publication is high. This might be due to the papers published having rich content and providing rich literature for studies that cited those papers. Among the three publications, the article written by Debellis and Goldin (2006) received the highest citation. In fact, this article is also the highest cited publication within the data set. This article reflected the 15-year reflection of the research collaborations among Debellis and Goldin as well as their colleagues on the affective domain in the context of individual mathematical problem solving.

As the articles accumulate the findings of the research collaboration for 15 years, it might have caused a huge impact on the research field. For instance, the theoretical framework related to pupils' affective domain in mathematical problem solving might have been used by many researchers to support their studies thereafter. The articles written by Chapman (2006) as well as Wu and Adams (2006) also received high citation counts. Chapman (2006) accumulated the conceptions and practices of the 14 experienced teachers from elementary, junior high and senior high schools on mathematics problem solving. This article is essential for the reader for enhancing mathematics word problem teaching practices for various grade levels. In addition, Wu and Adams (2006) fitted students' responses to the psychometric model, named Item Response Theory to explore students' cognitive process in solving word problems. Notably, these three articles were published in open-access mode, and they are available for all which in turn attract more attention, downloads, and citations.

The year 2007 recorded the highest *g*-index (g-index = 11) and *h*-index (h-index = 8) of all time which also indicates that most of the documents produced in that year are of high impact (Costas & Bardons, 2008). The documents published in 2007 is as listed in Table 3. Notably, 10 out of 13 publications are invited articles published in the special issue of ZDM, entitled 'Problem Solving Around the World: Summing Up the State of the Art'. The invited articles were written by prominent researchers from various countries to address the three research questions: "(i) What are the major ideas in research? (ii) What are the main themes in curricula?; (iii) What are the relationships between research and curricula, as mediated by politics?" (Törner et al., 2007, p. 353). These invited articles which outlined the major research directions in problem solving in each country received great attention from researchers because they might support the researchers in determining the research gaps besides providing foundational information of problem solving research over the whole world. In addition, one of the highly cited publications in 2007 was the research work presented in the International Congress of Mathematics Education (ICMI) which was published as an open-access book chapter. Specifically, the research work was conducted by an international team of leading scholars and practitioners in that domain, thus the result of the study has a high impact on the field of mathematics education.

What is the geographical distribution of the publication and the collaboration pattern among countries in research related to problem solving in elementary education?

The top five countries in the production of publications related to mathematics problem solving involving primary pupils are the United States, Australia, Belgium, Canada, and United Kingdom. The distribution of these countries is spread throughout three main continents, namely North America, Europe, and Oceania. The United States emerged as the most productive country which contributed more than a quarter of the total publications over the years with the highest number of total citations, *g*-index, and *h*-index. This is in line with the record stating that the United States, United Kingdom and Australia are the countries with the best performance and highest publication rate in the field of mathematics education. (Ozkaya, 2018; Ramirez & Devesa, 2019).

The collaboration pattern also indicates that the United States collaborated with various countries from the same and different continents and continues to produce the highest number of publications yearly, especially after 2010. Besides being in the list of top countries with the most publications, Australia also emerges as a pioneer country in publications involving mathematics problem solving in elementary education. This might be due to the emphasis and initiatives of the Australian government in improving the mathematics performance of the country (Anderson, 2014; Clarke et al., 2007; Stacey, 2001). Specifically, problem solving involving real-world context has emerged as the main curricular goal in mathematics as early as the 1980s and continues until current times (Clarke et al., 2007). Parallel with this main curricular goal, a lot of research on elementary mathematics word problems have been conducted by researchers affiliated with Australia in the past.

Countries such as Switzerland and Rwanda are relatively new in publications related to mathematics problem solving in elementary education because those countries might have given importance to mathematics problem solving slightly later (Kizito et al., 2019) or might have published in other languages that were not covered in this study (van Leeuwen et al., 2001). As the least developed country in East Africa (UNDESA, UNCTAD, ECA, ECE, ECLAC, ESCAP, & ESCWA, 2022), Rwanda might have a limited number of researchers in mathematics education. This might restrict the number of publications related to mathematics problem solving in elementary education.

What are the foci of the research on problem solving in elementary education?

The foci of the research work related to mathematics problem solving involving primary pupils identified are (i) problem solving involving arithmetic and mathematical representations, (ii) mathematics teaching and learning based on word problems, (iii) cognition of pupils and affective domains in mathematics problem solving, and (iv) problem solving involving algebra and teachers' role in problem solving learning.

The most prominent focus is problem solving involving arithmetic and mathematical representations. The finding is consistent with the curriculum in elementary education, which is dominated by numeracy and arithmetic operations (Verschaffel et al., 2007). The pupils are expected to master arithmetic first before any other mathematical branches such as algebra and geometry (Somasundram, 2017). Thus, majority of elementary mathematics problem solving studies are based on arithmetic and representations (Copur-Gencturk & Doleck, 2021; Pongsakdi et al., 2020). As advocated by Verschaffel et al. (2007), the elementary students' institutive mathematics idea emerges when they actively constructed the knowledge using manipulatives such as based-10 blocks. Likewise, the manipulatives could also serve as tools representing the mathematics ideas underneath the problem situation presented in the text. Following this, the students could understand the relationship between the numerical information given in the word problems. As the research hotspot, problem solving involving arithmetic and mathematical representations have been rigorously studied by researchers. Nonetheless, inconsistent findings were reported in the literature (Verschaffel et al., 2020). This suggests the need for relevant studies to confirm the effectiveness of mathematical representations on elementary students' word problem solving performance.

The second focus is on mathematics teaching and learning based on word problems. This is in line with the primary instructional goal in the mathematics classroom which emphasises developing students' problem solving ability (NCTM, 2000; Liljedahl & Santos-Trigo, 2019). Traditionally, the elementary students will engage in solving one-step word problems after learning the mathematics concept so that they can make sense of the concept learned and applied it in a real-life context (Ramírez et al., 2020; Verschaffel et al., 2020). Following this, the notion 'mathematics learning through problem-solving' emerges. Rather than teaching problem solving as an isolated topic, problem solving serves as the integral compartment of mathematics learning across content areas (Lester & Cai, 2016). Nonetheless, word problems are still a big challenge for mathematics learners, especially primary pupils due to various factors such as linguistic difficulties, learning difficulties and failure to comprehend or transform word problems correctly (Fatmanissa & Kusnandi, 2017; Gooding, 2009; Mancl, 2011; Martiniello, 2008). This urges more research on elementary word problem solving to identify and rectify issues involving word problems.

The third focus is cognitive and affective domains in elementary mathematics problem-solving. The word problem solving is illustrated as a four-step process which begins from (i) understanding the word problems; (ii) devising a plan; (iii) carrying out the plan; and (iv) looking back (Polya, 2004). After understanding the problem situation described in words, the students need to formulate the mathematical sentences to solve the problems, perform the calculation to obtain the answer, and lastly check the reasonability of the answer obtained. In fact, solving word problems involve several cognitive skills such as verbal, arithmetic, spatial, and general reasoning skills (Strohmaier et al., 2022). Nonetheless, Álvarez et al. (2016) argued that success in solving word problems also relies on students' metacognition. This is because the last step in solving word problems (i.e., look back) is a monitoring and self-regulation process. Thus, solving word problems is related to students’ cognitive domain. However, researchers (i.e., Hansen, 2021; Öztürk et al. 2020; Passolunghi et al., 2019) found that students' mathematics problem solving is influenced by affective factors. In fact, several emotional changes were captured in the study conducted by O’Dell (2018). While the complex word problems are treated as puzzles, the students solved them with enthusiasm at the beginning (McLeod, 2012).

Due to the lack of mathematics knowledge, engaging in solving complex word problems might induce productive struggle of students. Following this, the emotion shifted from positive to negative after several unsuccessful attempts. Once the students persist through the struggle, their emotions switch from frustration to joy and pride in their work. However, the students’ willingness to persist through struggle is influenced by affective factors (McLeod, 2012). Thus, the current research calls upon the focus on students' feelings, emotions, and attitudes towards mathematical problem solving (Ignacio et al., 2006; Marchis, 2013; Passolunghi et al., 2019), besides their thought process, to support the development of students’ problem solving ability.

The last focus is problem solving involving algebra and the teacher's role in problem solving learning. Algebra is the mathematics content domain which is introduced to students after they have learned the number concepts and arithmetic. The basic concepts of algebra are introduced to students as early as elementary school (Powell & Fuchs, 2014). Like arithmetic instruction, problem solving is the ultimate goal for elementary algebraic learning. Thus, students will engage in word problem solving activities in mathematics lessons so that they can connect the algebraic concepts learned with real life.

However, the abstractness of the algebraic concepts creates a barrier to concept mastery (van Dooren et al., 2003). This eventually hindered the students from solving algebraic word problems which required the application of the concepts. Thus, more studies should be conducted to address this issue. Moreover, studies conducted by

Fitzmaurice et al. (2019) and Powell (2019) found that teachers have a great influence on students' mathematics problem solving ability. Thus, the role of teachers in supporting elementary students' productive struggle in solving word problems is also another current research focus.

Conclusion

The gradual increase in the trends of publications related to mathematics problem solving in elementary education shows that a continuous increase will be witnessed in the upcoming years. The research on problem solving in elementary education has substantial wide geographical distribution and the publication has a high impact on the field of mathematics education. The scientific mapping of bibliographic data reveals the four research domains:

(i) arithmetic and mathematical representations;

(ii) mathematics teaching and learning based on word problems;

(iii) cognitive and affective domains in elementary mathematics problem solving; and

(iv) problem solving involving algebra and teacher's role in problem solving learning.

While the research gaps are presented in the four research foci, researchers are encouraged to conduct studies on the four research foci. Perhaps the findings of this study could provide insights into the research landscapes and serve as a guide for future researchers to conduct relevant research to enhance elementary students' word problem solving ability.

Limitations and Suggestions for Future Studies

Several limitations of the present study should be addressed. The data for this analysis were extracted only from the Scopus database and this might omit part of the total publications. Moreover, since the data were retrieved on 6 July 2021, the documents published after that date were not taken into consideration. Thus, the findings of this study might be subjected to some minor errors due to the increment of relevant literature in recent years and thereby should be interpreted with caution. Future research on this topic is recommended to include the recent literature from more databases.

Acknowledgements

Acknowledgement to “Ministry of Higher Education for Fundamental Research Grant Scheme with Project Code: FRGS/1/2019/SS109/USM/02/13”.

References

Aguinis, H., Pierce, C. A., Bosco, F. A., Dalton, D. R., & Dalton, C. M. (2011). Debunking myths and urban legends about meta-analysis. *Organizational Research Methods*, *14*(2), 306-331.

Álvarez, J. A. M., Rhoads, K., & Campbell, R. C. (2019). Toward Designing and Developing Likert Items to Assess Mathematical problem solving. In P. Liljedahl and M. Santos-Trigo (eds.), *Mathematical Problem Solving* (pp. 231-260). Springer.

Anderson J. (2014). Forging New opportunities for problem solving in Australian mathematics classrooms through the first national mathematics curriculum. In Li Y. & Lappan G. (Eds), *Mathematics Curriculum in School Education. Advances in Mathematics Education* (pp. 209-229). Springer.

Asigigan, S. I. & Samur, Y. (2021). The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem solving skills. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 9*(2), 332-352.

Cai, J., Mamona-Downs, J., & Weber, K. (2005). Mathematical problem solving: What we know and where we are going. *The Journal of Mathematical Behavior, 24*(3-4), 217–220.

Cason, M., Young, J., & Kuehnert, E. (2019). A meta-analysis of the effects of numerical competency development on achievement: Recommendations for mathematics educators. *Investigations in Mathematics Learning, 11*(2), 134-147.

Chamberlin, S., Payne, A. M., & Kettler, T. (2020). Mathematical modeling: a positive learning approach to facilitate student sense making in mathematics. *International Journal of Mathematical Education in Science and Technology*, *54*(4), 858-871.

Chapman, O. (2006). Classroom practices for context of mathematics word problems. *Educational Studies in Mathematics*, *62*(2), 211-230.

Chen, X., Chen, J., Wu, D, Wie, Y. & Li, J. (2016). Mapping the research trends by co-word analysis based on keywords from funded project. *Procedia Computer Science, 91*, 547 – 555.

Chen, X., Wang, S., Tang, Y., & Hao, T. (2019). A bibliometric analysis of event detection in social media. *Online Information Review, 43*(1), 29-52.

Clarke, D., Goos, M. & Morony, W. (2007). Problem solving and working mathematically: An Australian perspective. *ZDM Mathematics Education, 39*, 475–490.

Cook, S. C., Collins, L. W., Morin, L. L., & Riccomini, P. J. (2020). Schema-based instruction for mathematical word problem solving: An evidence-based review for students with learning disabilities. *Learning Disability Quarterly, 43*(2), 75-87.

Copur-Gencturk, Y., & Doleck, T. (2021). Strategic competence for multistep fraction word problems: An overlooked aspect of mathematical knowledge for teaching. *Educ Stud Math, 107*, 49–70.

Costas, R. & Bardons, M. (2008). Is g-index better than h-index? An exploratory study at the individual level. *Scientometrics, 77*(2), 267-288.

Csíkos, C., & Szitányi, J.(2020). Teachers' pedagogical content knowledge in teaching word problem solving strategies. *ZDM Mathematics Education*, 52, 165–178.

Debellis, V. A., & Goldin, G. A. (2006). Affect and meta-affect in mathematical problem solving: A representational perspective. *Educational Studies in Mathematics, 63*(2), 131-147.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285-296.

Drijvers, P., Grauwin, S., & Trouche, L. (2020). When bibliometrics met mathematics education research: The case of instrumental orchestration. *ZDM - Mathematics Education, 52*, 1455-1469.

Egghe, L. (2006). Theory and practise of the g-index. *Scientometrics, 69*(1), 131–152.

English, L., & Sriraman, B. (2010). Problem solving for the 21 st century. In B. Sriraman, L. English (eds.), *Theories of Mathematics Education, Advances in Mathematics Education* (pp. 263-290). Springer.

Evans, J. R. (1980). Solving word problems and elementary mathematical modelling. *International Journal of Mathematical Educational in Science and Technology, 11*(4), 517-522.

Fatmanissa, N., & Kusnandi, K. (2017). The linguistic challenges of mathematics word problem solving: A research and literature review. *Malaysian Journal of Learning and Instruction, Special Issue on Graduate Students' Research on Education*, 73-92.

Fernandez, M.L., Hadaway, N., & Wilson, J.W. (1994). Problem solving: Managing it all. *The Mathematics Teacher, 87*, 195-199.

Ferrini-Mundy, J., & Schmidt, W. H. (2005). International comparative studies in mathematics education: Opportunities for collaboration and challenges for researchers. *Journal for Research in Mathematics Education, 36*(3), 164–175.

Fitzmaurice, O., Walsh, R. & Burke, K. (2019). The 'Mathematics Problem' and preservice post primary mathematics teachers – Analyzing 17 years of diagnostic test data. *International Journal of Mathematical Education in Science and Technology, 52*(2), 259-281.

Gökçe, S., & Guner, P. (2021). Forty years of mathematics education: 1980-2019. *International Journal of Education in Mathematics, Science and Technology, 9*(3), 514-539.

Gökkurt, B., & Soylu, Y. (2013). Levels of students' use of semantic knowledge in problem solving process. *Kastamonu Education Journal, 21*(2), 469–488.

Gooding, S. (2009). Children's difficulties with mathematical word problems. In M. Joubert (Ed.), *Proceedings of the British Society for Research into Learning Mathematics* (pp. 31-36). BSRLM.

Goulet-Lyle, M.P., Voyer, D. & Verschaffel, L.(2020). How does imposing a step-by-step solution method impact students' approach to mathematical word problem solving?. *ZDM Mathematics Education*, 52, 139–149.

Hansen, E.K.S. (2021). Students' agency, creative reasoning, and collaboration in mathematical problem solving. *Math Ed Res J*. [Advance Online Publication]. https://doi.org/10.1007/s13394-021-00365-y

Herbert, S., Williams, G. (2021). Eliciting mathematical reasoning during early primary problem solving. *Math Ed Res J*. [Advance Online Publication]. https://doi.org/10.1007/s13394-021-00376-9

How Do I Search for A Document? (2022, April 1) Scopus: Access and use Support Center. https://service.elsevier.com/app/answers/detail/a_id/11213/supporthub/scopus/?utm_medium=LibGuide&utm_campaign=SC_LibGuide&dgcid=RN_AG_Program_400001714

Ignacio, N.G., Nieto, L.J.B., & Barona, E.G. (2006). The affective domain in mathematics learning. *International electronic Journal of Mathematics Education, 1*(1), 16-32.

Jader, J., Lithner, J., & Sidenvall, J. (2020). Mathematical problem solving in textbooks from twelve countries. *International Journal of Mathematical Education in Science and Technology, 51*(7), 1120-1136.

Kaiser, G. (2019). ZDM Mathematics Education—Its Development and Characteristics. In G. Kaiser & N. Presmeg, *Compendium for Early Career Researchers in Mathematics Education* (pp. 481-492). Springer.

Kizito, N., Telesphore, H. H. & Claude, R. J.(2019). Rwandan new competence base: Curriculum implementation and issues; sector-based trainers. *LWATI: A Journal of Contemporary Research*, *16*(1), 24-41.

Lai, Y., Zhu, X., Chen, Y., & Li, Y. (2015). Effects of mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. *PLoS ONE, 10*(6), Article 0130570. https://doi.org/10.1371/journal.pone.0130570

Lambert, R., & Tan, P. (2017). Conceptualizations of students with and without disabilities as mathematical problem solvers in educational research: A critical review. *Education Sciences*, *7*(2), Article 51. https://doi.org/10.3390/educsci7020051

Lee, C.I. (2017). An appropriate prompts system based on the Polya method for mathematical problem-solving. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(3), 893 – 910.

Lei, Q., Mason, R. A., Xin, Y. P., Davis, J. L., David, M., & Lory, C. (2020). A meta-analysis of single-case research on mathematics word problem-solving interventions for English learners with learning disabilities and mathematics difficulties. *Learning Disabilities Research & Practice, 35*(4), 201-217.

Lester, F. K., & Cai, J. (2016). Can mathematical problem solving be taught? Preliminary answers from 30 years of research. In P. Felmer, E, Pehkonen, & J. Kilpatrick (Eds.), *Posing and solving mathematical problems. Advances and New Perspectives* (pp. 83-108). Springer.

Leydesdorff, L., Bornmann, L., Comins, J. A., & Milojević, S. (2016). Citations: Indicators of quality? The impact fallacy. *Frontiers in Research metrics and Analytics, 1*(1).

https://doi.org/10.3389/frma.2016.00001

Liljedahl, P., & Santos-Trigo, M. (Eds.) (2019). *Mathematical Problem Solving*. Springer.

Liljedahl, P., Santos-Trigo, M., Malaspina, U., & Bruder, R. (2016). *Problem Solving in Mathematics Education. ICME-13 Topical Surveys.* Springer.

Lithner, J. (2008). A research framework for creative and imitative reasoning. *Educational Studies in Mathematics, 67*(3), 255–276

Mancl, D. B. (2011). *Investigating the effects of a combined problem solving strategy for students with learning difficulties in mathematics* [Doctoral dissertation, University of Nevada]. UNLV Theses, Dissertations, Professional Papers, and Capstones. http://dx.doi.org/10.34917/2268935

Marchis, I. (2013). Relation between students' attitude towards Mathematics and their problem solving skils. *PedActa, 3*(2), 59-66.

Martiniello, M. (2008). Language and the performance of English language learners in math word problems. *Harvard Educational Review, 78*, 333–368.

Masingila, J.O., Olanoff, D. & Kimani, P.M. (2018). Mathematical knowledge for teaching teachers: Knowledge used and developed by mathematics teacher educators in learning to teach via problem solving. *J Math Teacher Educ, 21*, 429–450.

McLeod, D. B. (2012). The role of affect in mathematical problem solving. In D. B. McLeod, & V. M. Adams (Eds.), *Affect and mathematical problem solving: A new perspective* (pp. 20-36). Springer.

McLeod, D. B., & Adams, V. M. (Eds.). (2012). *Affect and mathematical problem solving: A new perspective*. Springer.

Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX*, *7*, Article 100777.

http://dx.doi.org/10.1016/j.scitotenv.2019.134581

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & The PRISMA Group (2009). Preferred eeporting items for systematic reviews and meta-analyzes: The PRISMA statement. *PLoS Med*, *6*(7), Article e1000097. https://doi.org/10.1136/bmj.b2535

Morgan, C., Craig, T., Schuette, M., & Wagner, D. (2014). Language and communication in mathematics education: an overview of research in the field. *ZDM - Mathematics Education, 46*(6), 843–853.

National Council of Teachers of Mathematics [NCTM] (2000). *Principles and Standard of School Mathematics.* NCTM.

O'Dell, J. R. (2018). The Interplay of Frustration and Joy: Elementary Students' Productive Struggle When Engaged in Unsolved Problems. In Hodges, T.E., Roy, G. J., & Tyminski, A. M. *(Eds.), Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Educatio* (pp. 938-945). University of South Carolina & Clemson University.

OECD (2004a). Learning for tomorrow's world; first results from PISA 2003. OECD.

Olivares, D., Lupiáñez, J. L., & Segovia, I. (2021). Roles and characteristics of problem solving in the mathematics curriculum: A review. *International Journal of Mathematical Education in Science and Technology, 52*(7), 1079-1096.

Ozkaya, A. (2018). Bibliometric analysis of the studies in the field of mathematics education. *Educational Research and Reviews, 13*(22), 723-734.

Öztürk, M., Akkan, Y. & Kaplan, A. (2020). Reading comprehension, mathematics self-efficacy perception, and mathematics attitude as correlates of students' non-routine mathematics problem solving skills in Turkey, *International Journal of Mathematical Education in Science and Technology, 51*(7), 1042-1058.

Passolunghi, M.C., Cargnelutti, E. & Pellizzoni, S.(2019). The relation between cognitive and emotional factors and arithmetic problem-solving. *Educ Stud Math*, *100,* 271–290.

Peltier, C., & Vannest, K. J. (2017). A meta-analysis of schema instruction on the problem solving performance of elementary school students. *Review of Educational Research*, *87*(5), 899-920.

Polya, G. (2004). *How to solve it: A new aspect of mathematical method* (No. 246). Princeton University Press.

Pongsakdi, N., Kajamies, A., Veermans, K. (2020). What makes mathematical word problem solving challenging? Exploring the roles of word problem characteristics, text comprehension, and arithmetic skills. *ZDM - Mathematics Education, 52*, 33–44.

Powell, S. R., & Fuchs, L. S. (2014). Does early algebraic reasoning differ as a function of students' difficulty with calculations versus word problems?. *Learning Disabilities Research & Practice*, *29*(3), 106-116.

Powell, S.R., Berry, K.A. & Barnes, M.A. (2020). The role of pre-algebraic reasoning within a word-problem intervention for third-grade students with mathematics difficulty. *ZDM - Mathematics Education*, *52*, 151–163.

Radford, L., & Barwell, R. (2016). Language in mathematics education research. In A. Gutiérrez, G. Leder, & P. Boero (Eds.), *The Second Handbook of Research on The Psychology of Mathematics Education. The Journey Continues*. Sense.

Ramirez, M.C., & Devesa, R. A. R. (2019). A scientometric look at mathematics education from Scopus database. *The Mathematics Enthusiast, 16*(1), 37-46.

Ramírez, R., Brizuela, B.M. & Ayala-Altamirano, C. (2020). Word problems associated with the use of functional strategies among grade 4 students. *Math Ed Res J*, *33*(1), 1-35.

Rickard, A. (2005). Evolution of a teacher's problem solving instruction: A case study of aligning teaching practice with reform in middle school mathematics. *RMLE Online*, *29*(1), 1-15.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104,* 333-339.

Somasundram, P., Akmar, S., & Eu, L. (2017). Year five pupils' understanding of generalised arithmetic. *New*

Educ. Rev., 49, 176– 188.

Stacey, K. (2001). Trends in researching and teaching problem solving in school mathematics in Australia: 1997–2000. In E. Pehkonen (Ed.), *Problem Solving around the World* (pp. 45–53). University of Turku, Finland.

Strohmaier, A. R., Reinhold, F., Hofer, S., Berkowitz, M., Vogel-Heuser, B., & Reiss, K. (2022). Different complex word problems require different combinations of cognitive skills. *Educational Studies in Mathematics*, *109*(1), 89-114.

Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: What do they say?. *Procedia Social and Behavioral Sciences, 8,* 142-151.

Tawfik, G. M., Dila, K. A. S., Mohamed, M. Y. F., Tam, D. N. H., Kien, N. D., Ahmed, A. M., & Huy, N. T. (2019). A step by step guide for conducting a systematic review and meta-analysis with simulation data. *Tropical Medicine and Health*, *47*(1), 1-9.

Tjoe, H. (2019). "Looking Back" to Solve Differently: Familiarity, Fluency, and Flexibility. In P. Liljedahl & M. Santos-Trigo (Eds.), *Mathematical Problem Solving* (pp. 3-20). Springer.

Törner, G., Schoenfeld, A. H., & Reiss, K. M. (2007). Problem solving around the world: summing up the state of the art. *ZDM*, *39*(5), 353-353.

UNDESA, UNCTAD, ECA, ECE, ECLAC, ESCAP, & ESCWA (2022). World economic situation and prospects 2022. Retrieved from
https://desapublications.un.org/file/728/download?_ga=2.77738388.1253796096.1654092543-37254835.1654092543

Van Dooren, W., Verschaffel, L., & Onghena, P. (2003). Pre-service teachers' preferred strategies for solving arithmetic and algebra word problems. *Journal of mathematics teacher education*, *6*(1), 27-52.

Van Leeuwen, T. N., Moed, H. F., Tijssen, R. J. W., Visser, M. S., & van Raan, A. F. J. (2001). Language biases in the coverage of the Science Citation Index and its consequences for international comparisons of national research performance. *Scientometrics*, *51*(1), 335–346.

Verschaffel, L., Greer, B., & De Corte, E. (2007). Whole number concepts and operations. In F. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (pp. 557-628). Information Age Publishing Inc.

Verschaffel, L., Schukajlow, S., Star, J. & Van Dooren, W. (2020). Word problems in mathematics education: a survey. *ZDM - Mathematics Education, 52*(1), 1-16.

Verschaffel, L., Van Dooren, W., Greer, B., & Mukhopadhyay, S. (2010). Reconceptualising word problems as exercises in mathematical modelling. *Journal für Mathematik-Didaktik, 31*(1), 9-29.

Vondrova, N. (2020). The effect of an irrelevant number and language consistency in a word problem on pupils' achievement and reasoning. *International Journal of Mathematical Education in Science and Technology.* [Advance Online Publication]. https://doi.org/10.1080/0020739X.2020.1782497

Wu, M., & Adams, R. (2006). Modelling mathematics problem solving item responses using a multidimensional IRT model. *Mathematics Education Research Journal*, *18*(2), 93-113.

Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research*, *39*(1), 93-112.

Zimmermann, B. (2016). Improving of mathematical problem-solving: Some new ideas from old resources. In P.

Felmer, E, Pehkonen, & J. Kilpatrick (Eds.), *Posing and solving mathematical problems. Advances and New Perspectives* (pp. 83-108). Springer.

Author Information

Menaga Suseelan
https://orcid.org/0000-0002-9319-8284
School of Educational Studies
Universiti Sains Malaysia, Penang
Malaysia

Cheng Meng Chew
https://orcid.org/0000-0001-6533-8406
School of Educational Studies
Universiti Sains Malaysia, Penang
Malaysia
Contact e-mail: *cmchew@usm.my*

Huan Chin
https://orcid.org/0000-0003-0991-7299
School of Educational Studies
Universiti Sains Malaysia, Penang
Malaysia