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DESIGN THINKING IN MATHEMATICS EDUCATION FOR PRIMARY SCHOOL: A SYSTEMATIC LITERATURE REVIEW

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***Abstract*:**
Design Thinking is a knowledge as a thriving innovation practice and an approach to creative problem solving. The main purpose of this study is to review existing studies which are related to the Design Thinking in Mathematics Education for primary school. The search terms were used by inserting the suitable keywords based on the main topic such as "design thinking", "mathematics education", "mathematics", "primary school" and "elementary school". Systematic Literature Review (SLR) was conducted to gain information for better understanding regarding our topic. This SLR was performed through two search engines which were SpringerLink and Scopus. In reporting this study, the PRISMA guidelines were followed. We identified and screened 1123 articles published between 2017 until 2021 in SpringerLink and Scopus. After elimination of duplicates and non-relevant topics, there were 23 articles remained based on the inclusion and exclusion criteria. The limited number of studies on the main topic as design thinking for primary school caused the small numbers of articles were selected. This is because there are many articles about teachers and post-graduate. Our findings indicated that the year of 2021 was mostly research conducted, followed by the year of 2020, 2019 and 2017 meanwhile there is no research conducted in 2018. Concerning the geographical distribution of the authors, the findings indicated that the predominant authors that developing the design thinking were in Germany, Australia, USA, Singapore and Switzerland, and only a few research conducted in Hong Kong, Sweden, Cyprus, Israel, Turkey, UK, Spain, Canada, Netherlands, Malaysia, and mixed countries. From the results, we can see that this design thinking should be practiced by teachers in their teaching regardless of whether it is mathematics or any other subject. In conclusion, design thinking among the students, especially primary school students nowadays, is indispensable to ensure that our country is always moving forward in the era of globalization.

Keywords: Design Thinking, Mathematics Education, Primary School, SLR, Springer Link, Scopus

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INTRODUCTION

Design thinking is acknowledged as a thriving innovation practice plus something more, something in the line of a deep understanding of innovation processes (Thienen, Clancey, Corazza, & Meinel, 2018). Design thinking will create some other thinking such as creative thinking, mathematical thinking and so on. While problem-solving abilities in mathematics are essential for success in the twenty-first century, many learners who struggle with mathematics do not develop these skills throughout their primary grades (Xin, 2019). Interestingly, design thinking could be employed in primary school context (Freiman, Polotskaia, & Savard, 2017; Isaksen & Akkermans, 2011; van Hooijdonk, Mainhard, Kroesbergen, & van Tartwijk, 2020). From the students' view, especially in primary school students, nowadays it is indispensable to ensure that our country is always moving forward in the era of globalization. van Hooijdonk et al. (2020) states that students in elementary school were able to pick their most innovative ideas. This implies that students are frequently encouraged to come up with various innovative ideas to address an issue instead of engaging in procedures that need both divergent and convergent thinking, such as fact gathering, problem solving, and solution seeking (Isaksen & Akkermans, 2011).

To date, existing literature proves that there are several literature analyses in design thinking in mathematics education but more focus on creative thinking and mathematical thinking (Noh, Jeong, & Shin, 2021; Painter, 2018; Severino, Petrovich, Mercanti-Anthony, & Fischer, 2021). For example, van Hooijdonk et al. (2020) did a literature review on creative problem solving in primary education, looking at the function of fact seeking, problem solving, and solution finding across problems. According to their findings, it is useful to use scores as the number of various knowledge aspects and the quality of the recognized problem when working with primary school children, especially when seeking for more and unique ideas before engaging in: fluency, originality, completeness, and practicality. However, limited research has been conducted by using systematic literature review (SLR) in design thinking. Therefore, we synthesize studies on design thinking in mathematics education for primary school. Our study included four main objectives which are to investigate the Design Thinking in Mathematics Education distributed in 2017 to 2021, to investigate the Design Thinking in Mathematics Education distributed in different countries, to identify the reported research methodologies and outcomes in existing literature and to explore the focus and trends in existing literature. The following research questions (RQ) were defined to attain the purpose.

RQ1 : How are the design thinking in mathematics education distributed in terms of publication year?
RQ2 : How are the design thinking in mathematics education distributer in different countries?
RQ3 : What are the reported research methodologies in existing literature?
RQ4 : What were the focus and trends in existing literature?
RQ5 : What topics in mathematics are involved in design thinking in existing literature?

LITERATURE REVIEW

Design thinking is both a successful innovation approach and something more, something along the lines of a comprehensive grasp of innovation processes (Thienen et al., 2018). It's a method of problem-solving that's widely acknowledged as a viable path to human-centered innovation (Plattner, 2009). Empathy, group ideation or brainstorming, and testing are all used in the design thinking process to solve problems and create new solutions. It has been stated that design thinking provides a flexible, accessible structure to lead and scaffold educators' creativity in dealing with practical difficulties (Rauth, Schlapschy, & Skerra, 2010). According to (Pendleton-Jullian & Brown, 2015), design thinking abilities are key literacies for 21st century creativity. In the business realm, the application has shown to be successful in offering real-world solutions with a focus on the user (Kelley & Kelley, 2013).

Design thinking has been applied in a variety of disciplines for creativity and value creation, encompassing business, law, elementary school education, science, and medicine. According to (Liu & Group, 1996), design thinking refers to how designers see themselves and how they think as a result. It's a collaborative approach in which designers connect ideas to address an issue. According to (Braha & Reich, 2003), design thinking is a general process in which designers should adapt their present design depending on new knowledge. When it comes to design, there are several different types of thinking that can be observed (Horn & Dorner, 1999). For example, designs begin with a hazy vision of how the design or product should look and function. Pavie & Carthy (2015) illustrates the impact of Design Thinking on the transformation of goods, services, processes, and strategy.

Design thinking has been widely used in education across a wide range of subjects and stages of education, including primary school, graduate and post-graduate studies, Engineering and Management Studies, Entrepreneurship, and so on (Pande & Bharathi, 2020). (Withell & Haigh, 2013) focuses on the students' learning and teaching experiences, as well as the curriculum's impact on their development of Design Thinking expertise. Design Thinking, Experiential Learning, Bloom's Learning Domains, Constructivism, and Constructive Alignment are among the key theories advocated for inclusion in the curriculum. According to Kolb's experiential learning theory, there are four stages of experiential learning which are concrete learning, reflective observation, abstract conceptualization and active exploration. Cognitive, emotional, and psychomotor areas of educational activity were established by (Cooper & Higgins, 2015). Before beginning instruction, constructive alignment is a teaching method in which the goals for what learners know and how they should communicate their learning are explicitly stated (Biggs & Collis, 2014). Constructivism is a learning philosophy that asserts that people actively construct or create their own knowledge, and that reality is shaped by the learner's experiences (Gordon, 2009).

Oxman (2004) proposes and demonstrates Think-Maps for Teaching Design Thinking in Design Education, a pedagogical model for design education and design instruction. In this method, domain knowledge became an essential component that was prepared and included into design education. Going beyond by using Design Thinking as a pedagogy, work is done by focusing on how design-creativity can be enabled via design education (Rauth et al., 2010). Sheer, Swarts, & Ghadiali

(2012) found that design educators that used Design Thinking in their classrooms were able to develop innovation, creativity, problem-solving skills, and strong teamwork among their students. Empathy, define, ideation, prototype, and test are the five primary phases that Design Thinking entails. Empathy is the process of identifying difficulties or issues among stakeholders. Define is the process of assessing the information gathered during the empathy stage and determining the problem statement. Ideation is the process of coming up with a solution. Through the research process, the prototype collects feedback from stakeholders on the intended solution, whereas the test finalizes the design after studying the inputs at the feedback stage.

Design Thinking is useful in solving open and complex problems. Design Thinking helps to develop creative confidence among individuals to help them develop a new idea. Every student or designer should attain such confidence to help them engage successfully in the creative process of designing. More importantly, when used in the creative process, Design Thinking has been shown to have a significant beneficial influence on an individual 's desire (Balakrishnan, 2021). The confidence instilled in pupils by Design Thinking during the creative process encourages them to push the boundaries of their creativity and invention (Thienen et al., 2018). According to (Rauth et al., 2010), Design Thinking is a structured way to help produce and develop ideas since its structured approach offers designers creative confidence. Design Thinking, according to (Sheer et al., 2012), facilitates team-based learning, which supports the practice and holistic modalities of constructivist learning in any project assignments. Cooperation and various individual views increase learning through teamwork, which is one of the essential pillars of Design Thinking.

According to Callahan et al. (2019), using Design Thinking in the design classroom teaches undergraduates the value of idea generation and critical thinking. Design Thinking aided the pupils' creative process, allowing them to think in new ways. Developing creative thinking abilities in design students has proven to be a difficult undertaking for many design educators (Crilly & Cardoso, 2017). Students may build creative abilities and creative confidence to solve issues successfully in a variety of scenarios by participating in the Design Thinking process. In a nutshell, Design Thinking has sparked students' imaginations and increased their creativity, as well as motivating them to design, solve problems, and think creatively.

RESEARCH METHODS

The methodology used is systematic literature review. The guidelines are followed from Preferred Reporting Items for Systematics Review and Meta-Analyses (PRISMA). The PRISMA figure in this study was modified (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The method used to find articles related to design thinking in Mathematical Education in primary school is Systematic Literature Review (SLR). The search engine used to find articles such as Scopus and Springer. These search engines were used to make a systematic review, eligibility and exclusion criteria, steps of the review process such as identification, screening and eligibility and data abstraction and analysis.

The review process was performed in October 2021. The first step is identifying the keyword of the title. Some of the articles found were used as samples to find another article. The search results were discussed with the team to avoid bias and to find the best article. As the keyword were confirmed, we widened the strategies to identify any eligible studies as possible. The keyword uses as shown in Table 1 for Scopus and Springer.

Table 1. The keyword uses for Scopus and Springer

Database	Keyword Used
Scopus and Springer	TITLE-ABS- KEY ((“Design Thinking” AND (“Mathematics Education” OR “mathematics”) AND (“Primary School” OR “elementary school”))

In this process, a multiple set of eligibility and exclusion criteria was applied. First, the literature type was selected were journal articles. The journal articles possess empirical data, excluding systematic review articles and conference proceeding. Second, we only choose the English Journal articles to make it easier for us to understand the content of the articles. Third, the reviewers only take the articles that were published within the last five years between 2017 to 2021. This criteria was chosen because the reviewers want the latest and current issues about design thinking in mathematical education in primary school. There is no specific country were excluded. Final step in inclusion and exclusion process which is the reviewers concentrated on articles that deal in the title area at least mathematical domain. The final phase of the review process produced 23 articles.

We used the selection criteria such as timeline, document type, language and subject area after gathering all identified resources. This is because to filter out the articles that not relevant or not used to our research. The inclusion and exclusion criteria should be clearly defined to make sure the sources selected are relevant to the primary research purpose. The table below shows the inclusion and exclusion criteria for the research. It was determined that 23 articles were relevant, selected and the full-text articles of these publications were obtained.

Table 2. The inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Published between 2017 until 2021	Less than 2017
Indexed journal	Non-indexed journals, review journals, chapter in book, book, conference proceeding, master dissertation, thesis, prefaces, blog and opinion.
English language	Non-English Language
Specific to the mathematics education	General application for professional learning such as medical, public health and engineering.

The 23 articles were studied, examined and selected. The reviewers were identified appropriately the article abstracts and also read full articles to make sure the themes and sub-themes were appropriate. Themes were identified in 23 articles related to design thinking in mathematical education in primary school then organized by authors in form of typology around the main themes.

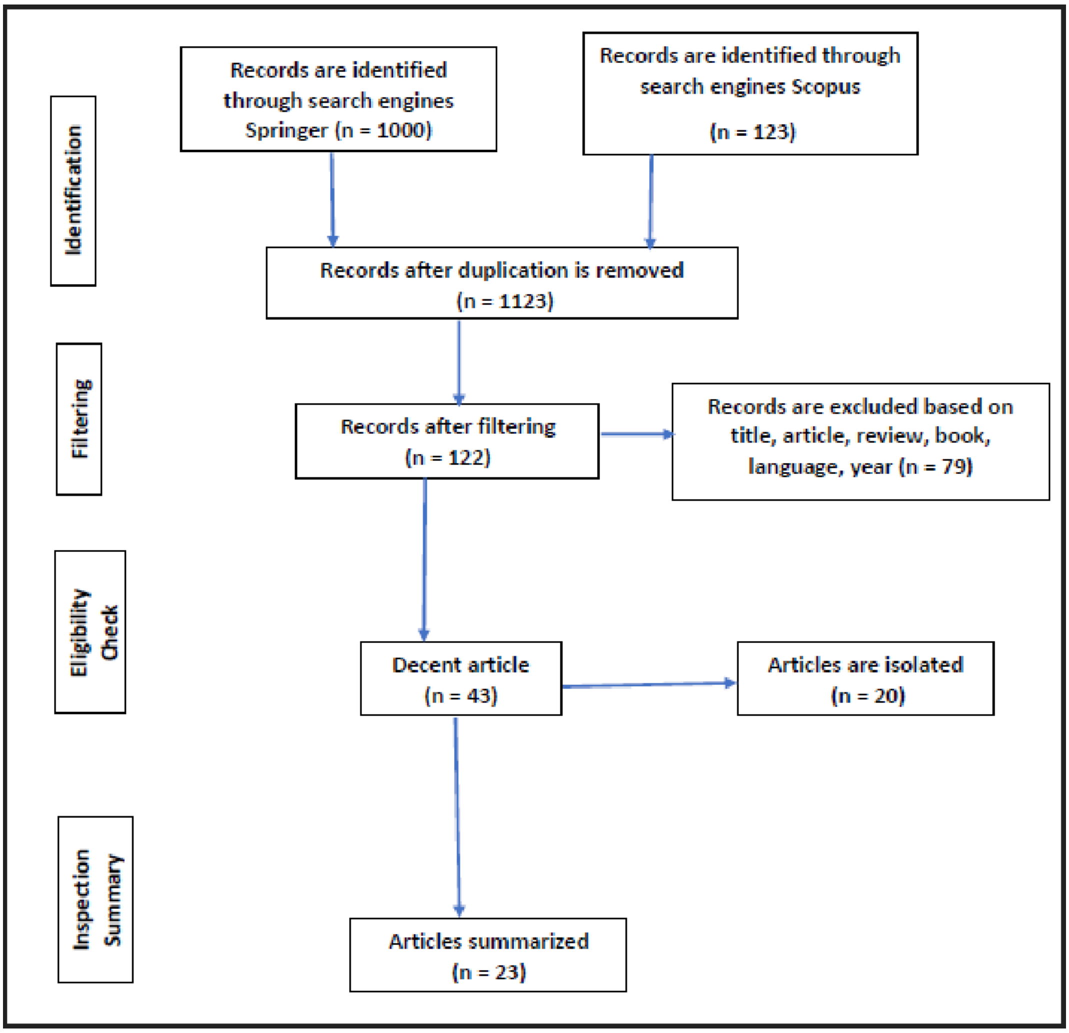

Figure 1. Prisma Protocol

RESULTS

A total of 23 papers were chosen for the systematic analysis after being screened using the Systematic Literature Review (SLR). The main Systematic Literature Review (SLR) were reviewing existing studies which are related to the Design Thinking in Mathematics Education (using existing literature) for primary school. The guidelines are followed from Preferred Reporting Items for Systematics Review and Meta-Analyses (PRISMA). This study used five research questions to guide its review of the selected articles. Table 1 summarizes and compares the papers that were chosen, which included the inclusion criterion of a systematic review of the literature, namely research years from 2017 until 2021, geographical distribution of the authors, research method used for investigating design thinking, types of focus and trends related to design thinking in Mathematics education context, and types of topics in Mathematics are involved in design thinking. Each of these research questions is further discussed in the subsections that follow.

The first research question was concerned with the research years from 2017 until 2021. The population years of the research were also examined in this review research (Figure 2). There has been a significant growth of research in years 2021. Most of the research (30%) recruited in years 2021 (Balakrishnan, 2021; Eriksson & Sumpter, 2021; Herbert & Williams, 2021; Irakleous et al., 2021; Leong, 2021; Ng & Cui, 2021; Pielsticker et al., 2021). 7 of research years in 2021 were from Australia, Cyprus, Germany, Hong Kong, Malaysia, Singapore and Sweden. Followed by years of 2020 (26%) (Ayala-Altamirano & Molina, 2020; Can & Yetkin, 2020; Fujita et al., 2020; Ott, 2020; Price et al., 2020; Hooijdonka et al., 2020). 6 of research years in 2020 were from Netherlands, Mixed Country (UK, Japan, England), Spain, Switzerland, Turkey and UK. Only a few investigations were conducted in years 2017 (22%) (Blanton et al., 2017; Freiman et al., 2017; Jorgensen & Larkin, 2017; Savard & Polotskaia, 2017; Shahbari & Peled, 2017). 5 of research years in 2017 were from Australia, Canada, Germany, Israel and USA. In years 2019 (22%) (Kaur, 2019; Miller, 2019; Li et al., 2019; Rottman et al., 2019; Xin, 2019). 5 of research years in 2019 were from Australia, Germany, Singapore, Switzerland and USA. Lastly, no investigations were conducted in years 2018 (0%).

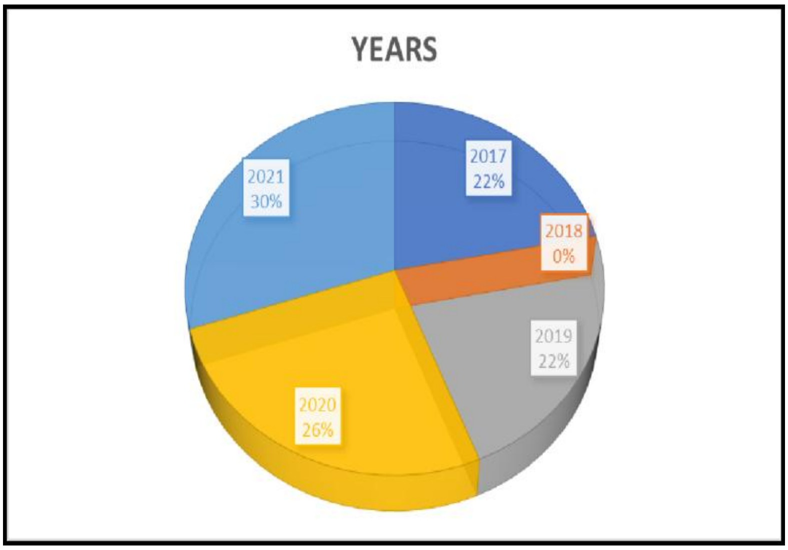

Figure 2. Research years in the reviewed article

The second research question was concerned with geographical distribution of the authors (Figure 3). Our systematic review only included papers published in English; nevertheless, the investigations were done in a variety of cultural contexts across the world. With the most empirical investigations, Germany had dominated the outcomes (13%) (Pielsticker et al., 2021; Rottman et al., 2019;

Savard & Polotskaia, 2017). Australia also had dominated the outcomes (13%) (Herbert & Williams, 2021; Jorgensen & Larkin, 2017; Miller, 2019). Followed by USA (9%) (Blanton et al., 2017; Xin, 2019), Singapore (9%) (Kaur, 2019; Leong, 2021) and Switzerland (9%) (Li et al., 2019; Ott, 2020). Only a few investigations were conducted in Hong Kong (4%) (Ng & Cui, 2021), Sweden (4%) (Eriksson & Sumpter, 2021), Cyprus (4%) (Irakleous et al., 2021), Israel (4%) (Shahbari & Peled, 2017), Turkey (4%) (Can & Yetkin, 2020), UK (4%) (Price et al., 2020), Spain (4%) (Ayala-Altamirano & Molina, 2020), Canada (4%) (Freiman et al., 2017), Netherlands (4%) (Hooijdonka et al., 2020), Malaysia (4%) (Balakrishnan, 2021) and Mixed Country which are UK, Japan and England (4%) (Fujita et al., 2020).

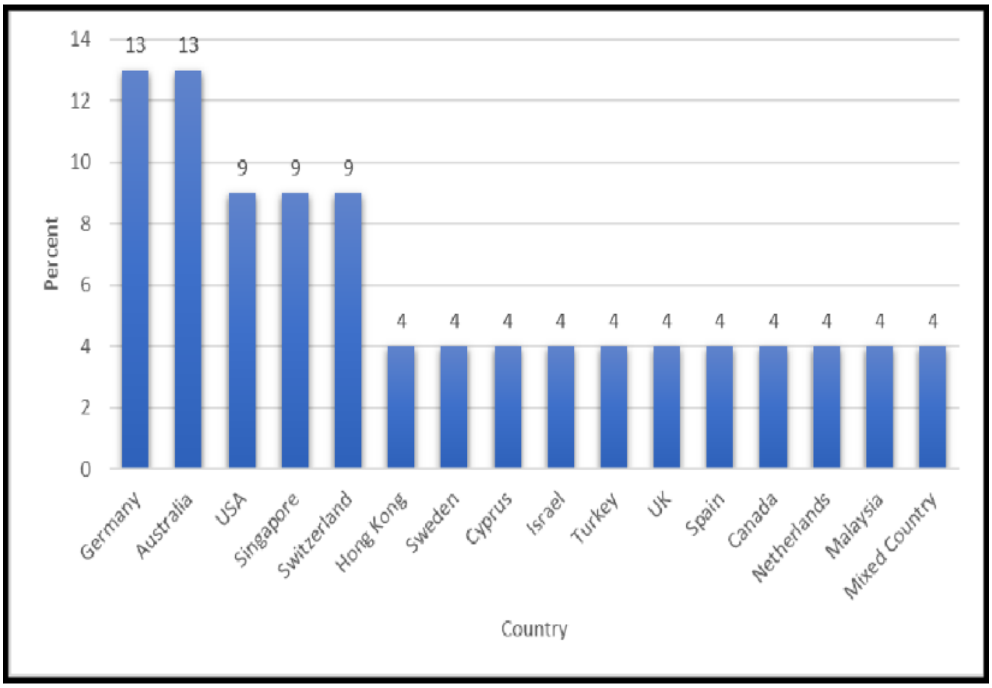

Figure 3. Distribution of published articles by geographical distribution

The third research question was concerned with research methodologies (qualitative research, quantitative research and both methodology). Figure 4 depicts the distribution of research methodologies used in this research. It was revealed that the qualitative research (48%) (Ayala-Altamirano & Molina, 2020; Balakrishnan, 2021; Freiman et al., 2017) and quantitative research research (48%) (Can & Yetkin Özdemir, 2020; Eriksson & Sumpter, 2021; Irakleous, Christou, & Pitta-Pantazi, 2022; Kaur, 2019; Leong, 2021; Ng & Cui, 2021; Pielsticker, Witzke, & Vogler, 2021; Savard & Polotskaia, 2017; Shahbari & Peled, 2017) have the equal methodology number. This was followed by the research that employed combination of quantitative and qualitative method (4%) (Miller, 2019). Based on the data obtained, this indicated that qualitative and quantitative approach with case study design was the most to be adopted for measuring design thinking in Mathematics education for primary school. The adoption of a case study methodology would improve the results and give more meaningful interpretations in design thinking.

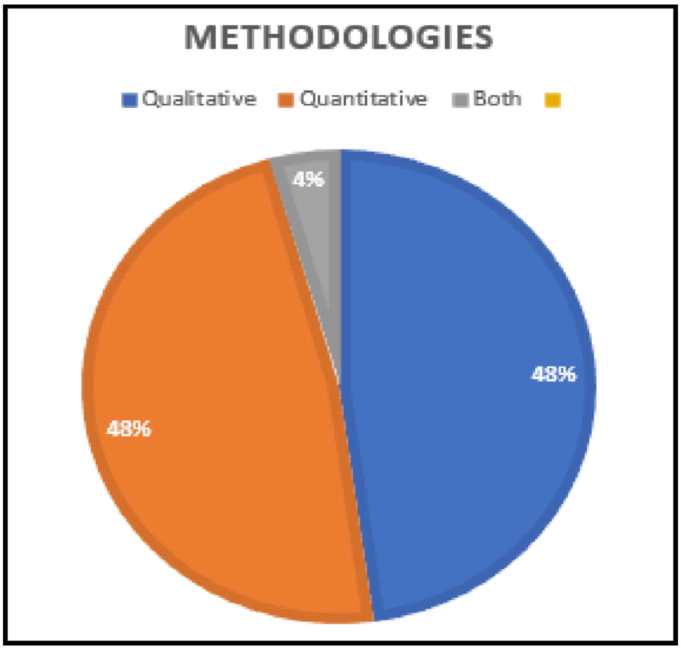

Figure 4. Distribution of published articles by research methodologies

The fourth research question was concerned with focus and trends related to design thinking in mathematics education in primary school (develop a model, problem-solving, concept or knowledge and experience). The figure show that, concept or knowledge are the most focus or trend for the research (48%) (Blanton, Brizuela, Gardiner, Sawrey, & Newman-Owens, 2017; Li et al., 2019; Miller, 2019; Savard & Polotskaia, 2017). Next place were problem-solving (31%) (Ng & Cui, 2021; van Hooijdonk et al., 2020; Xin, 2019). Followed by develop a model (17%) (Jorgensen & Larkin, 2017; Ott, 2020; Pielsticker et al., 2021; Rottmann, Haberzettl, & Krämer, 2020). Last is experience (4%) (Leong, 2021). Based on the data obtained, most of the article using the concept or existing knowledge to focus on the design thinking. This indicated that using concept or existing knowledge with case study design was effective for focus and trends towards design thinking in mathematics education for primary schoo

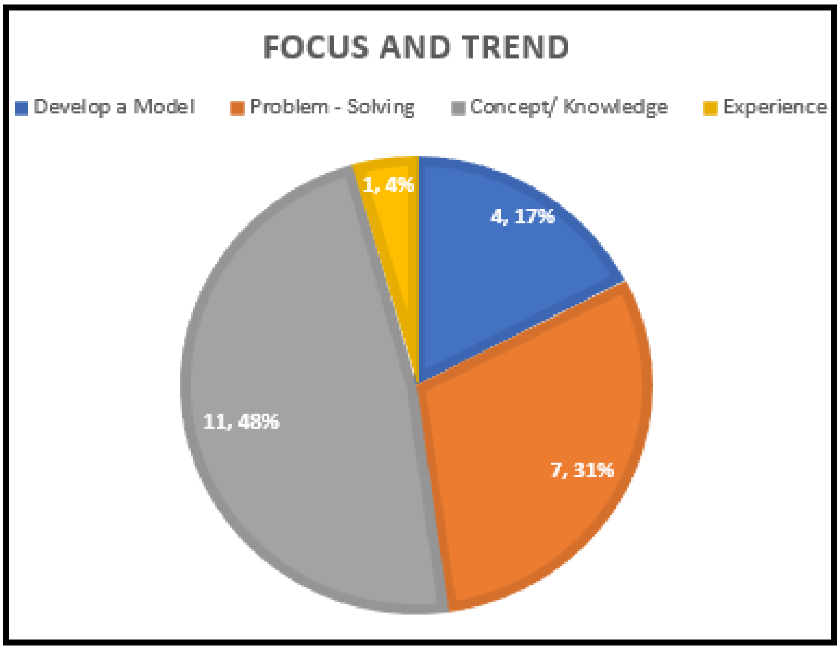

Figure 5. Distribution of published articles by types of focus and trends

The fifth research question was concerned with the types of topics in Mathematics are involved in design thinking (Geometry, Algebra, Arithmetic, Trigonometry, Statistic and Fraction). The Figure 6 shows that, there is four out of twenty-three articles not specifies or mention the topic (18%) (Balakrishnan, 2021; Jorgensen & Larkin, 2017; Miller, 2019). Next, Geometry topic (26%) (Fujita, Kondo, Kumakura, Kunimune, & Jones, 2020; Ng & Cui, 2021; Ott, 2020; Pielsticker et al., 2021; Price, Yiannoutsou, & Vezzoli, 2020) and Algebra topic (26%) (Ayala-Altamirano & Molina, 2020; Blanton et al., 2017; Eriksson & Sumpter, 2021; Freiman et al., 2017; Xin, 2019) share the same number of topic in research articles research. This was followed by the research that employed Arithmetic topic (13%) (Kaur, 2019; Rottmann et al., 2020; Savard & Polotskaia, 2017) and Fraction topic (9%) (Can & Yetkin Özdemir, 2020; Shahbari & Peled, 2017). Furthermore, Statistic (4%) (van Hooijdonk et al., 2020) and Trigonometry (4%) (Leong, 2021) also shared the same number of topic in the research article. Based on the data obtained, Geometry and Algebra topic were the most topic used in the research article. This indicated that Geometry and Algebra topic were the most suitable to apply in design thinking in Mathematics education in primary school. The use of topic diversity in case studies will improve the results and provide more meaningful in design thinking.

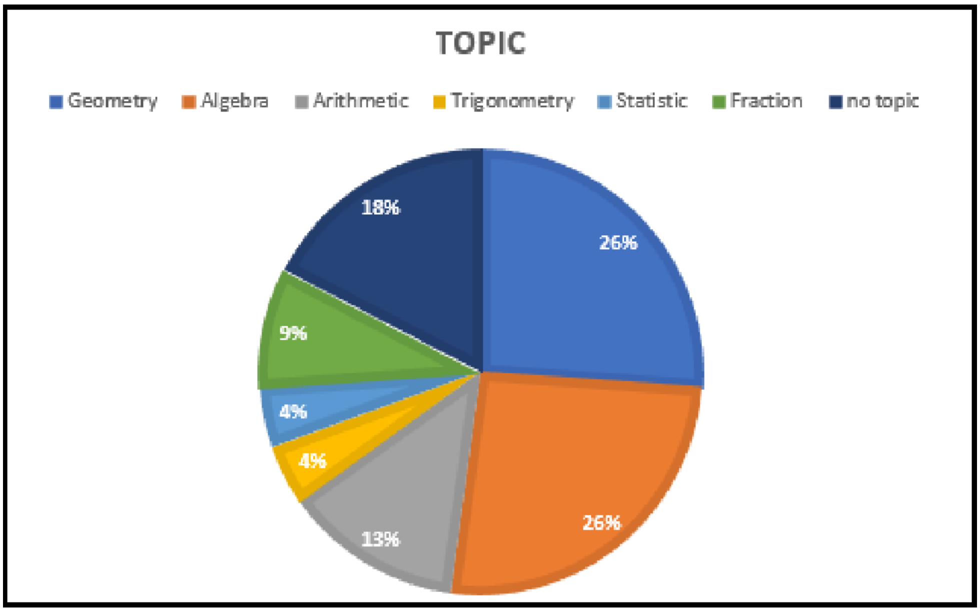

Figure 6. Distribution of published articles by types of topics

DISCUSSION

Our findings indicated that the year of 2021 was mostly research conducted, followed by the year of 2020, 2019 and 2017 meanwhile there is no research conducted in 2018. In general, it can be noticed that there is an improvement of publications started on 2017 till 2021. The reason behind the increase of publications could lie in the fact that design thinking research has been highly investigated due to the increased popularity of this field, while this was not the case in 2018, in which no articles were published. Since design thinking is based on the approach used for practical and creative problem solving, the increasing interest in design thinking publications could also refer to the increasing popularity of educational software, design thinking tool or model and concept or knowledge of design thinking, like mathematical knowledge and algebraic thinking in recent years and how such software, tool and concept had facilitated the procedure of design thinking approach. For example, design thinking will create some other thinking such as creative thinking, mathematical thinking and so on, these support with research from Irakleous et al. (2022) that investigated empirically the structure and relationships among mathematical imagination, mathematical knowledge and mathematical mindset. Therefore, this topic needs to be examined further in another year, especially improving design thinking for primary school students.

Concerning the geographical distribution of the authors, the findings indicated that the predominant authors that developing the design thinking were in Germany, Australia, USA, Singapore and Switzerland, and only a few research conducted in Hong Kong, Sweden, Cyprus, Israel, Turkey, UK, Spain, Canada, Netherlands, Malaysia, and mixed countries. This finding may explain why academics in Germany and Australia were keen to improve design thinking starting from primary school students. The result also showed that there was a lack of a diversity of countries especially in the Asian context to develop the design thinking for primary school students. For example, although design thinking has been applied in Malaysia's mathematics subject for primary school, Balakrishnan (2021) found that the use of design thinking in design classrooms in the context of developing students' creativity and motivation to think creatively is not a well-researched area, as Henriksen, Mishra, & Fisser (2016) assert that the majority of the current research in the area of creativity in education in primarily concerned with individual creative processes. Likewise, Hong Kong primary mathematics has shown that digital tools can fruitfully enrich students' modeling processes by supporting multiple, dynamic representations of concepts especially in geometry (Ng & Cui, 2021). Therefore, this topic must be examined further in other nations, especially improving design thinking for primary school students.

Our findings indicated that qualitative research methods were used in most of the examined studies, followed by quantitative and mixed method research. This work partially supported research conducted by Miller (2019) which employs a teaching experiment methodology by using both quantitative and qualitative methods which focused on mathematical knowledge and thinking. The fact that the reviewed research employed a wide range of data gathering methodologies was encouraging such as pretest, posttest and questionnaire. According to (Hankeln, Adamek, & Greefrath, 2019), the qualitative examination of the students' responses allowed for the identification of potential coding challenges, which resulted in minor formulation revisions. For example, Balakrishnan (2021), using the qualitative approach, found that most of the students stated that the design thinking tool had facilitated their creative thinking and design thinking is a structured approach to help them to generate and evolve ideas. Furthermore, Ott (2020) using the qualitative approach which is Ethnography Research, found that the most students of the 3rd grade first generated their own graphic representations for a given word problem. Moreover, this finding opened a new research avenue, with future studies focusing on mixed techniques to capture the entire design thinking of primary school students.

Most of the authors from the studies reviewed did not show any specific focus or trend, however there are few similarities in their writing where they use model-based problems in mathematics that require creative and critical thinking skills. Some also use 2D and 3D geometric models as their problems. Fujita et al. (2020), for example, have studied and analyzed how students in grades 4 through 9 use their skills to solve problems involving 2D representations of 3D geometric shapes. Moreover, as discussed earlier where creative thinking is part of design thinking. There are writers who explain about creative problem solving where it requires gradual thinking or ideas and of course it needs to be creative. van Hooijdonk et al. (2020) stated that since primary school, interest in promoting creative problem solving (CPS) has increased. However, integrating CPS into education seems to be a difficult task. One issue is that the process of generating creative ideas (idea finding) is often taught separately from other processes such as examining knowledge (fact finding), describing problems (problem finding), and comparing ideas to determine the most creative (solution finding). So, they studied how elementary school students can find solutions and how they choose the most creative ideas. As for design thinking itself, there are several studies that focus on design thinking yet still emphasize on creative skills. For example, Balakrishnan (2021), who studied related importance in leveraging thought design learning strategies to produce creative skills and motivation to think creatively. So, most of the writings reviewed do not have too much focus or trend yet there are still some similarities between the studies.

Concerning the mathematical topics involved in design thinking in the existing literature, most of the identifiable topics are topics concerning geometry (Fujita et al., 2020; Ng & Cui, 2021; Pielsticker et al., 2021) and the rest such as algebra (Ayala-Altamirano & Molina, 2020; Eriksson & Sumpter, 2021; Freiman et al., 2017; Xin, 2019) and arithmetic (Kaur, 2019; Savard & Polotskaia, 2017). Most of the article involved mathematics or computational problem-solving involving such as programming, graphics and 3D geometrical shapes. For example, Ott (2020) made a related study of how children take into account mathematical structures in self-generated graphic representations, the way they obtain mathematical matches with word problems, and the level of abstraction they choose. All of that will generate their thinking towards a more critical and deeper direction. There are also statements related to computer-based learning and mathematical relationships involving algebra.

IMPLICATIONS

From the results, we can see that this design thinking should be practiced by teachers in their teaching regardless of whether it is mathematics or any other subject. This design thinking trains a lot of thinking where students need to think more systematically and effectively to solve a complex problem. Various subjects or topics that can use this design thinking such as the findings of our study, namely geometry and algebra. So, teachers need to encourage their students to think more effectively in appropriate ways so that ideas can always be generated by them. In addition, based on our research, design thinking is rarely found in Malaysia. Most of the countries that study and practice design thinking are like Germany, Australia and the USA. So, we hope that this design thinking will be used frequently in Malaysia, especially for teachers who will teach in the future. Next, we hope that many research articles related to design thinking in Malaysia will be published so that it can be used as a guide in the future.

Furthermore, the design thinking process may seem a bit overwhelming initially but it usually begins at home. Parents should be aware that design thinking starts with empathy and usually opens up newer ways for their children and for them as well to explore a situation in a way they might have not thought about. Design thinking can transform and enhance a child's creativity in more ways than one. Parents should foster and nurture design thinking in their children at a very early age by urging them to come up with creative solutions. Part of parenting like a designer is teaching kids to create. For example, asking a kid to design a car. They will probably get excited about it and come up with the coolest car designs that ever existed. As Margaret Mead said, “Children must be taught how to think, not what to think”.

CONCLUSION

Design Thinking is an approach used for practical and creative problem solving. The study of design thinking has raised in recent years. In our systematic review, the study about design thinking in mathematics education for primary school from 2017 until 2021 was mostly recruited in the year of 2021. We also found that the predominant authors that developed the design thinking were in Germany, Australia, USA, Singapore and Switzerland, and only a few researches conducted in Hong Kong, Sweden, Cyprus, Israel, Turkey, UK, Spain, Canada, Netherlands, Malaysia, and mixed countries. The current systematic review also revealed that almost a half of the published papers employed the qualitative approach as a data collection method. Moreover, most of the articles used the concept or existing knowledge as a type of focus and trends used in design thinking. Finally, in the existing literature, geometry and algebra are the most identifiable topics involved in design thinking in mathematics education for primary school.

FUTURE DIRECTIONS/LIMITATIONS

The improvement of publications from 2017 until 2021 about design thinking in mathematics education for primary school should be encouraged in the future. Especially with geographical distribution of the authors, more research in design thinking in mathematics education for primary school is needed in the Asian context. In addition, it is a good idea to include more research design in quantitative approach and mixed methods. Concerning the types of focus and trends in design thinking, concept or knowledge is the most focus and trend for the research. The emphasis on model or tools, software, and problem-solving should be more employed in the future research for enhancing design thinking development. Finally, although most research types of topics are about geometry and algebra, the other topics are also needed in the upcoming research especially in improving design thinking in mathematics education for primary school students. These lead the primary school students to think outside the box hence improve their ability to explicit their own ideas.

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REFERENCES

Ayala-Altamirano, C., & Molina, M. (2020). Meanings attributed to letters in functional contexts by primary school students. *International Journal of Science and Mathematics Education*, *18*(7), 1271–1291. https://doi.org/10.1007/s10763-019-10012-5

Balakrishnan, B. (2021). Exploring the impact of design thinking tool among design undergraduates: a study on creative skills and motivation to think creatively. *International Journal of Technology and Design Education*, 1–14. https://doi.org/10.1007/s10798-021-09652-y

Biggs, J. B., & Collis, K. F. (2014). *Evaluating the quality of learning: The SOLO taxonomy (Structure of the Observed Learning Outcome)*. Academic Press.

Blanton, M., Brizuela, B. M., Gardiner, A. M., Sawrey, K., & Newman-Owens, A. (2017). A progression in first-grade children's thinking about variable and variable notation in functional relationships. *Educational Studies in Mathematics*, *95*(2), 181–202. https://doi.org/10.1007/s10649-016-9745-0

Braha, D., & Reich, Y. (2003). Topological structures for modeling engineering design processes. *Research in Engineering Design*, *14*(4), 185–199. https://doi.org/10.1007/s00163-003-0035-3

Callahan, B. J., Wong, J., Heiner, C., Oh, S., Theriot, C. M., Gulati, A. S., … Dougherty, M. K. (2019). High-throughput amplicon sequencing of the full-length 16S rRNA gene with single-nucleotide resolution. *Nucleic Acids Research*, *47*(18), e103–e103. https://doi.org/10.1093/nar/gkz569

Can, D., & Yetkin Özdemir, İ. E. (2020). An examination of fourth-grade elementary school students' number sense in context-based and non-context-based problems. *International Journal of Science and Mathematics Education*, *18*(7), 1333–1354. https://doi.org/10.1007/s10763-019-10022-3

Cooper, D., & Higgins, S. (2015). The effectiveness of online instructional videos in the acquisition and demonstration of cognitive, affective and psychomotor rehabilitation skills. *British Journal of Educational Technology*, *46*(4), 768–779. https://doi.org/10.1111/bjet.12166

Crilly, N., & Cardoso, C. (2017). Where next for research on fixation, inspiration and creativity in design? *Design Studies*, *50*(1), 1–38.

Eriksson, H., & Sumpter, L. (2021). Algebraic and fractional thinking in collective mathematical reasoning. *Educational Studies in Mathematics*, *108*(3), 473–491. https://doi.org/10.1007/s10649-021-10044-1

Freiman, V., Polotskaia, E., & Savard, A. (2017). Using a computer-based learning task to promote work on mathematical relationships in the context of word problems in early grades. *ZDM*, *49*(6), 835–849. https://doi.org/10.1007/s11858-017-0883-3

Fujita, T., Kondo, Y., Kumakura, H., Kunimune, S., & Jones, K. (2020). Spatial reasoning skills about 2D representations of 3D geometrical shapes in grades 4 to 9. *Mathematics Education Research Journal*, *32*(2), 235–255.

https://doi.org/10.1007/s13394-020-00335-w

Gordon, M. (2009). Toward a pragmatic discourse of constructivism: Reflections on lessons from practice. *Educational Studies*, *45*(1), 39–58. https://doi.org/10.1080/00131940802546894

Hankeln, C., Adamek, C., & Greefrath, G. (2019). Assessing sub-competencies of mathematical modelling—Development of a new test instrument. In *Lines of inquiry in mathematical modelling research in education* (pp. 143–160). https://doi.org/10.1007/978-3-030-14931-4_8

Henriksen, D., Mishra, P., & Fisser, P. (2016). Infusing creativity and technology in 21st century education: A systemic view for change. *Journal of Educational Technology & Society*, *19*(3), 27–37. Retrieved from https://www.jstor.org/stable/jeductechsoci.19.3.27

Horn, B. W., & Dorner, J. W. (1999). Regional differences in production of aflatoxin B1 and cyclopiazonic acid by soil isolates of Aspergillus flavus along a transect within the United States. *Applied and Environmental Microbiology*, *65*(4), 1444–1449. https://doi.org/10.1128/AEM.65.4.1444-1449.1999

Irakleous, P., Christou, C., & Pitta-Pantazi, D. (2022). Mathematical imagination, knowledge and mindset. *ZDM–Mathematics Education*, *54*(1), 97–111. https://doi.org/10.1007/s11858-021-01311-9

Isaksen, S. G., & Akkermans, H. J. (2011). Creative climate: A leadership lever for innovation. *The Journal of Creative Behavior*, *45*(3), 161–187. https://doi.org/10.1002/j.2162-6057.2011.tb01425.x

Jorgensen, R., & Larkin, K. (2017). Analysing the relationships between students and mathematics: A tale of two paradigms. *Mathematics Education Research Journal*, *29*(1), 113–130. https://doi.org/10.1007/s13394-016-0183-1

Kaur, B. (2019). The why, what and how of the 'Model'method: A tool for representing and visualising relationships when solving whole number arithmetic word problems. *ZDM*, *51*(1), 151–168. https://doi.org/10.1007/s11858-018-1000-y

Kelley, T., & Kelley, D. (2013). *Creative confidence: Unleashing the creative potential within us all*. Currency.

Leong, Y. H. (2021). Contours of self-efficacy across nested mathematical domains: a case of a Singapore student with a history of low performance in mathematics. *Mathematics Education Research Journal*, 1–22. https://doi.org/10.1007/s13394-021-00394-7

Li, Y., Schoenfeld, A. H., DiSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and design thinking in STEM education. *Journal for STEM Education Research*, Vol. 2, pp. 93–104. https://doi.org/10.1007/s41979-019-00020-z

Liu, Y.-T., & Group, A. (1996). Is designing one search or two? A model of design thinking involving symbolism and connectionism. *Design Studies*, *17*(4), 435–449. https://doi.org/10.1016/S0142-694X(96)00018-X

Miller, J. (2019). STEM education in the primary years to support mathematical thinking: Using coding to identify mathematical structures and patterns. *ZDM*, *51*(6), 915–927. https://doi.org/10.1007/s11858-019-01096-y

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Ng, O.-L., & Cui, Z. (2021). Examining primary students' mathematical problem-solving in a programming context: towards computationally enhanced mathematics education. *ZDM–Mathematics Education*, *53*(4), 847–860. https://doi.org/10.1007/s11858-020-01200-7

Noh, J. Y., Jeong, H. W., & Shin, E.-C. (2021). SARS-CoV-2 mutations, vaccines, and immunity: implication of variants of concern. *Signal Transduction and Targeted Therapy*, *6*(1), 1–2. https://doi.org/10.1038/s41392-021-00623-2

Ott, B. (2020). Learner-generated graphic representations for word problems: an intervention and evaluation study in grade 3. *Educational Studies in Mathematics*, *105*(1), 91–113. https://doi.org/10.1007/s10649-020-09978-9

Oxman, R. (2004). Think-maps: teaching design thinking in design education. *Design Studies*, *25*(1), 63–91. https://doi.org/10.1016/S0142-694X(03)00033-4

Painter, D. L. (2018). *Using design thinking in mathematics for middle school students: a multiple case study of teacher perspectives*. Retrieved from https://digitalcommons.csp.edu/cup_commons_grad_edd/192/

Pande, M., & Bharathi, S. V. (2020). Theoretical foundations of design thinking–A constructivism learning approach to design thinking. *Thinking Skills and Creativity*, *36*, 100637. https://doi.org/10.1016/j.tsc.2020.100637

Pavie, X., & Carthy, D. (2015). Leveraging uncertainty: a practical approach to the integration of responsible innovation through design thinking. *Procedia-Social and Behavioral Sciences*, *213*, 1040–1049. https://doi.org/10.1016/j.sbspro.2015.11.523

Pendleton-Jullian, A. M., & Brown, J. S. (2015). *Design unbound: Evolving design literacy pathways of efficacy*. CreateSpace (distributor).

Pielsticker, F., Witzke, I., & Vogler, A. (2021). Edge Models with the CAD Software: Creating a New Context for Mathematics in Elementary School. *Digital Experiences in Mathematics Education*, *7*(3), 339–360. https://doi.org/10.1007/s40751-021-00092-w

Plattner, H. (2009). A common database approach for OLTP and OLAP using an in-memory column database. *Proceedings of the 2009 ACM SIGMOD International Conference on Management of Data*, 1–2. Retrieved from https://dl.acm.org/doi/abs/10.1145/1559845.1559846

Price, S., Yiannoutsou, N., & Vezzoli, Y. (2020). Making the body tangible: Elementary geometry learning through VR. *Digital Experiences in Mathematics*

Education, *6*(2), 213–232. https://doi.org/10.1007/s40751-020-00071-7

Rauth, S., Schlapschy, M., & Skerra, A. (2010). Selection of antibody fragments by means of the filter-sandwich Colony screening assay. In *Antibody Engineering* (pp. 255–266). https://doi.org/10.1007/978-3-642-01144-3_17

Rottmann, T., Haberzettl, N., & Krämer, M. (2020). Inclusive assessment of whole number knowledge—development and evaluation of an assessment interview for children with visual impairments in the primary grades. *Mathematics Education Research Journal*, *32*(1), 147–170. https://doi.org/10.1007/s13394-019-00296-9

Savard, A., & Polotskaia, E. (2017). Who's wrong? Tasks fostering understanding of mathematical relationships in word problems in elementary students. *Zdm*, *49*(6), 823–833. https://doi.org/10.1007/s11858-017-0865-5

Severino, L., Petrovich, M., Mercanti-Anthony, S., & Fischer, S. (2021). Using a design thinking approach for an asynchronous learning platform during COVID-19. *IAFOR Journal of Education*, *9*(2), 145–162. Retrieved from https://eric.ed.gov/?id=EJ1291892

Shahbari, J. A., & Peled, I. (2017). Modelling in primary school: Constructing conceptual models and making sense of fractions. *International Journal of Science and Mathematics Education*, *15*(2), 371–391. https://doi.org/10.1007/s10763-015-9702-x

Sheer, F. J., Swarts, J. D., & Ghadiali, S. N. (2012). Three-dimensional finite element analysis of Eustachian tube function under normal and pathological conditions. *Medical Engineering & Physics*, *34*(5), 605–616. https://doi.org/10.1016/j.medengphy.2011.09.008

Thienen, J., Clancey, W. J., Corazza, G. E., & Meinel, C. (2018). Theoretical foundations of design thinking. In *Design thinking research* (pp. 13–40). https://doi.org/10.1007/978-3-319-60967-6_2

van Hooijdonk, M., Mainhard, T., Kroesbergen, E. H., & van Tartwijk, J. (2020). Creative problem solving in primary education: Exploring the role of fact finding, problem finding, and solution finding across tasks. *Thinking Skills and Creativity*, *37*(1), 1–32. https://doi.org/10.1016/j.tsc.2020.100665

Withell, A. J., & Haigh, N. (2013). *Developing design thinking expertise in higher education*. Retrieved from https://openrepository.aut.ac.nz/handle/10292/6326

Xin, Y. P. (2019). The effect of a conceptual model-based approach on 'additive'word problem solving of elementary students struggling in mathematics. *ZDM*, *51*(1), 139–150. https://doi.org/10.1007/s11858-018-1002-9

Table 3. The content analysis on reviewed articles

Author	Research Question 1	Research Question 2	Research Question 3	Research Question 4	Research Question 5
Felicitas Pielsticker	2021	Germany	Quantitative approach	Develop a model	Geometry
Yan Ping Xin	2019	USA	Quantitative approach	Problem solving	Algebra
Jodie Miller	2019	Australia	Quantitative & Qualitative approach	Concept/ Knowledge	No topic
Oi-Lam Ng	2021	Hong Kong	Quantitative approach	Problem solving	Geometry
Robyn Jorgensen	2017	Australia	Qualitative approach	Develop a model	No topic
Helena Eriksson	2021	Sweden	Quantitative approach	Concept/ Knowledge	Algebra
Thomas Rottman	2019	Germany	Qualitative approach	Develop a model	Arithmetic
Yew Hoong Leong	2021	Singapore	Quantitative approach	Experience	Trigonometry
Panayiota Irakleous	2021	Cyprus	Quantitative approach	Concept/ Knowledge	Geometry
Sandra Herbert	2021	Australia	Qualitative approach	Concept/ Knowledge	Algebra
Juhaina Awawdeh Shahbari	2017	Israel	Quantitative approach	Concept/ Knowledge	Fraction
Derya Can	2020	Turkey	Quantitative approach	Concept/ Knowledge	Fraction
Annie Savard	2017	Germany	Quantitative approach	Concept/ Knowledge	Arithmetic
Maria Blanton	2017	USA	Qualitative approach	Concept/ Knowledge	Algebra
Sara Price	2020	UK	Qualitative approach	Concept/ Knowledge	Geometry
Berinderjeet Kaur	2019	Singapore	Quantitative approach	Problem solving	Arithmetic
Cristina Ayala-Altamirano	2020	Spain	Qualitative approach	Concept/ Knowledge	Algebra
Viktor Freimen	2017	Canada	Qualitative	Problem	Algebra

Author	Research Question 1	Research Question 2	Research Question 3	Research Question 4	Research Question 5
			approach	solving	
Taro Fujita	2020	UK, Japan, England	Qualitative approach	Problem solving	Geometry
Barbara Ott	2020	Switzerland	Qualitative approach	Develop a model	Geometry
Mare Van Hooijdonk	2020	Netherlands	Quantitative approach	Problem solving	Statistic
Yeping Li	2019	Switzerland	Qualitative approach	Concept/ Knowledge	No topic
Balamuralithara Balakrishnan	2021	Malaysia	Qualitative approach	Problem solving	No topic