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Students' Mathematical Creative Thinking: A Systematic Literature Review with Bibliometric Analysis

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Abstract

This study aims to determine the trend of publications on creative thinking in mathematics learning published on Google Scholar in the 2017-2021 period, as well as describe opportunities and directions for research on creative thinking with themes related to future mathematics learning. This research is a systematic literature review study with bibliometric analysis. This research method uses PRISMA 2020 steps. The study results show that the most productive authors are Asikin, Mulyono and Tohir, each publishing two articles. The paper that gets the most citations is by Hasanah and Surya, which discusses students' creative thinking skills in mathematics using cooperative and problem-solving learning. Research themes such as students, creative thinking, problems and mathematics, and mathematical domains such as numbers, algebra and geometry have been widely used. This allows future research paths that can be studied, including the domain of mathematics in the material of statistics and opportunities, students' creative thinking in 7th and 9th-grade students gender, and the use of technological media to improve or measure students' mathematical creative thinking processes. However, the domains and topics that have been studied are still possible to be reviewed as an effort to maximize students' mathematical creative thinking abilities.

Keywords: *creative thinking, mathematics, student, bibliometric*

A. Introduction

One of the high-order thinking skills empowered in 21st-century learning is creative thinking. Creative thinking is a mental activity associated with considering new ideas, perspectives, approaches, or ways of solving problems. Creative thinking is marked by creating something new from the results of various ideas, concepts or knowledge possessed by students (Dinawati & Siswono, 2020). The development of creative thinking is needed to prepare students to face future challenges and help them solve problems while in society and the world of work (Fauzi et al., 2019; Schoevers et al., 2019).

A person's ability to think creatively is influenced by individual personality, motivation, social context, intellectual and cultural (Sternberg & Sternberg, 2012). Hilal et al., (2013) emphasized that a person's barriers to creative thinking are learning and habits, rules and traditions, perceptual and cultural, emotional, and resource barriers. Therefore, it is necessary to have practice and habits to use creative thinking skills to be more imaginative, flexible, and original in solving everyday problems. Hayes states that creativity can be increased by developing basic knowledge, creating the right atmosphere for creativity and looking for analogies (Solso et al., 2014).

Creative thinking is distinguished from other types of thinking because creative thinking generates new and original ideas or solutions to problems. Creative thinking refers to the originality and uniqueness of ideas or solutions that did not exist before. Wallas (Solso et al., 2014) explains that there are 4 stages in the creative process: preparation, incubation, illumination and verification. Preparation is done by formulating a problem and making an initial effort to solve it. Incubation is the period when no effort is made directly to solve the problem and attention is momentarily diverted to something else. Illumination is gaining insight (deep understanding) of the problem. Verification is testing the understanding that has been obtained and making solutions.

Creative thinking can be trained through learning mathematics (Sternberg in Choifah et al., 2022). The ability to think creatively in learning mathematics is the ability to express ideas creatively in solving mathematical problems. The ability to think creatively mathematically is a way of thinking that is measured through thinking fluency, thinking flexibility, thinking originality, and elaboration. Fluency is shown by the ability of students to express more than one idea to solve problems, ask lots of questions that show mastery of the material, and give many suggestions that might be solutions to problems. Flexibility is shown by the ability of students to see a problem from many different perspectives and then find alternative strategies for solving approaches and ways of thinking. Originality is a person's ability to think uniquely to produce new thoughts that may not be commonplace, although the truth still needs to be tested. Elaboration is shown by students' ability to parse again, and develop existing ideas in more detail to become a more complete and interesting unit of thought (Septiani et al., 2018). Mathematical creative thinking can help students devise various solutions to a problem. Therefore, students need to have the ability to think creatively and mathematically.

The fact is that there are still many junior high school students who have relatively low mathematical creative thinking abilities (Buyung, 2021). Cahyani et al., (2019) stated that students' creative thinking was low because the teacher only gave routine questions. Teachers do not provide creative thinking practice questions to students, so students are not familiar with mathematical creative thinking skills questions (Hudanagara & Anita, 2018). Students think less/not creatively because students find it difficult to understand problems (Siregar et al., 2018) and have low mathematical abilities (Febrianingsih, 2022). In addition, students are more likely to enjoy learning with almost the same questions, so students have difficulty generating new solutions (Pasaribu, 2020).

Arifah & Asikin (2018) argued that students' low creative thinking skills were influenced by several factors, one of which was the learning process. Several other studies have provided alternative solutions to improve junior high school students' creative thinking skills by applying appropriate learning models/approaches. Students' mathematical creative thinking increases

after applying open-ended learning (Cahyani et al., 2019; Utami et al., 2020). The ability to think creatively and mathematically develops after learning with a problem-posing approach (Lutfi, 2016; Setiyani, 2020). The ability to think creatively mathematically increases after learning using the Search, Solve, Create and Share learning model (Sujiarto & Sukmiati, 2017). There is also an increase in the average ability of students to think creatively mathematically after being taught contextual mathematics learning (Ruhiyat & Sugandi, 2017) and realistic mathematics education (RME) approach (Utami & Ilyas, 2019).

In addition, some research on creative thinking is also related to other mathematical hard skills or soft skills. Creative thinking influences self-confidence and self-efficacy (Septiani et al., 2018), mathematical disposition (Ruhiyat & Sugandi, 2017), problem-solving (Desti et al., 2018), and mathematics learning outcomes for junior high school students (Sahwari & Dassucik, 2021). Dinawati & Siswono (2020) states that math anxiety harms junior high school students' mathematical creative thinking.

The study of mathematical creative thinking has been studied and contributed to various aspects of research, a literature review related to mathematical creative thinking is needed further to strengthen the relevance of learning mathematics. A literature review on research themes related to students' creative thinking in learning mathematics can be done using bibliometric analysis. Bibliometric analysis is needed to update research information in mathematics education (Julius et al., 2021). The results of our search, research on bibliometric analysis for the term creative thinking in mathematics, has only been carried out by (Rahayu et al., 2022). Rahayu used Google Scholar data sources in the 1957-2020 range in his research. Researchers need to conduct a bibliometric analysis to reveal more about the trend of creative thinking in mathematics, especially in recent years. The purpose of this study is to find out the trend of publications on creative thinking in mathematics learning which are published on Google Scholar in the last 5 years (authors, articles and themes) and to describe opportunities and directions for research on creative thinking with related themes in learning mathematics in the future.

This research can be a reference and starting point for other researchers who are interested in research on creative thinking in learning mathematics. The results of this study can provide knowledge and experience to see opportunities for research trend trends in finding novelty and avoiding repetition of research in the future.

B. Methodology

This research is a systematic literature review (SLR) study. SLR was performed by bibliometric analysis. Bibliometric analysis is one of the literature's most detailed and intelligent data research. This subject review is directed at literature material by applying numerical and measurable strategies (Karim & Soebagyo, 2021). Bibliometric analysis is often carried out as part of a systematic review because it can clarify information regarding the progress of knowledge creation based on quantitative metrics of scientific production (Oliveira et al., 2015). Therefore, bibliometric analysis can be used to reveal emerging trends in articles and journals.

This research method uses the steps in Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 for databases and registers (Haddaway et al., 2022). The steps consist of: (1) identifying the topics for relevant studies; (2) screening documents; and (3) including the documents for analyzing, synthesizing, and describing studies. Searching and selecting articles through the PRISMA steps is presented in Figure 1.

The identification step is carried out by searching for the article's title from the Google Scholar database using the Publish or Perish (PoP) software, which includes the keyword "creative thinking in mathematics". This research focuses on articles and proceedings published in English, national and international, with publications ranging from 2017 to 2021. Search results based on keywords obtained 121 articles. There were 21 articles removed because 4 were duplicate articles and the others were not articles but research statements (type citations). After a sample of 100 articles has been determined, the next step is screening.

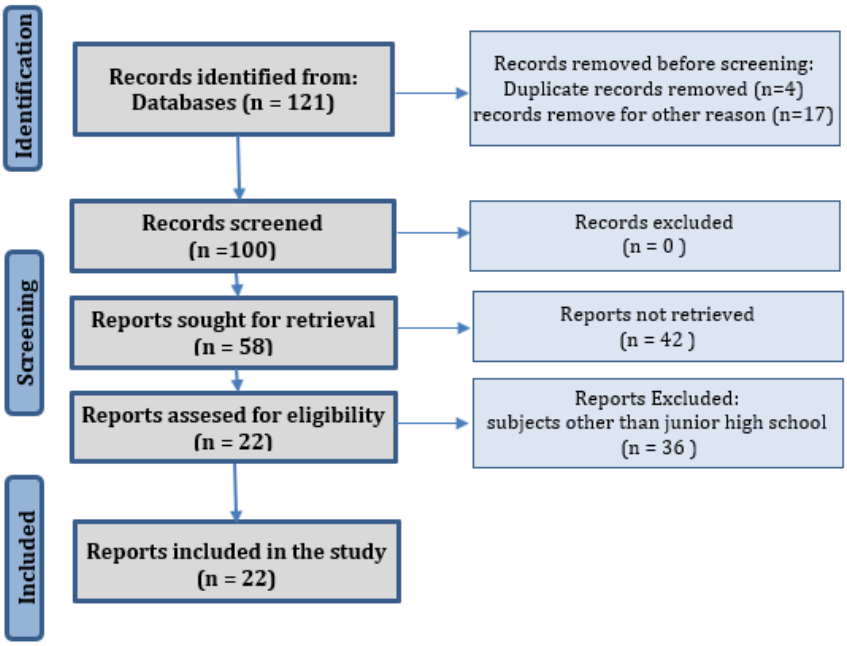

Figure 1. PRISMA flow diagram

In the screening application, all titles were relevant, it was sought to retrieve articles per the research objectives, resulting in a sample of 58 articles (articles issued were articles other than Indonesia). After verifying suitability with the specified theme, 22 articles were obtained following the subject to be studied, namely junior high school students. The main reason for the other articles being excluded is because the subjects of the articles are elementary, high school, vocational and university students. Thus, the results of selecting articles at this stage were 22 articles because they met the two predetermined criteria.

The selected articles are then saved in CSV and RIS formats. CSV is used to process table and graphic data that provides information on the title, author's name, journal name, year of publication and number of article citations. Meanwhile, RIS was used for bibliometric analysis using VOSviewer software. VOSviewer can do mapping in creating different co-authorship and co-occurrence of keywords. VOSviewer visualization provides data representation through network visualization, overlay visualization and density visualization. Network visualization presents linkages and research theme clusters related to keywords. Overlay Visualization is used to identify the year of implementation of related research themes. Density visualization is used to analyze research themes that are frequently and rarely researched.

C. Findings and Discussion

1. Number of Publications

The search results for "creative thinking in mathematics" document data for junior high school students in Indonesia show that there were as many as 22 research documents in the 2017-2021 period. The number of articles published during this period is presented in Figure 2.

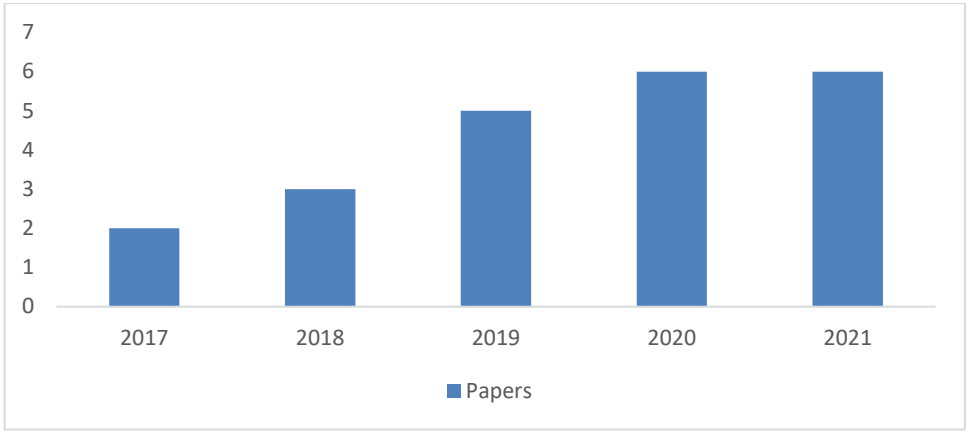

Figure 2. Total of creative thinking in mathematics articles in 2017-2022 (n=22)

The number of papers per year is presented in Figure 2. which shows that the number of papers has increased in the last five years. In 2017 there were 2 articles; in 2018, there were 3 articles; in 2019, there were 5 articles; in 2020, there were 6 articles; in 2021, there were 6 articles.

2. The most productive authors and articles

After the RIS data was entered into the VOSviewer software, 41 authors were obtained, with authors who had at least 2 documents found 3 authors. The network visualization of these findings is presented as shown in Figure 3.

Figure 3. Network visualization of co-author. Source: VOSviewer

Figure 3 shows that the network does not have interconnected lines with the same magnitude. This shows that the contribution of the three authors regarding mathematical creative thinking is similar to each of the 2 articles. Askin's article discusses the quality of mathematics learning settings challenge-based learning on student's creative thinking skills and belief in math (Ardiansyah et al., 2018) and describes student's creative thinking skills viewed by adversity quotient and mathematics anxiety (Wahyuningtyas et al., 2020). Mulyono, in his article, examines students' mathematical creative thinking skills based on field-independent and field-dependent cognitive styles (Yulianto et al., 2021) and the effectiveness of the MiC learning model with an open-ended approach to mathematical creative thinking ability (Dwidayati et al., 2020). Tohir discusses students' creative thinking skills in solving math Olympiad problems based on

metacognition levels (Tohir, 2019) and students' creative thinking skills in solving Olympic problems Based on Problem-Solving Polya and Krulik-Rudnick Models (Tohir et al., 2018).

The selected articles were also analyzed for the number of citations per paper to determine which articles were the most productive. The number of paper citations is shown in Table 1 below

Table 1. Total Number of paper citations

Author	Judul	Quantity	Frequency(%)
Hasanah & Surya (2017)	Differences in the Abilities of Creative Thinking and Problem Solving of Students in Mathematics by Using Cooperative Learning and Learning of Problem Solving	103	35,4
Maharani, et al. (2017)	Creative Thinking Process based on Wallas Model in Solving Mathematics Problem	57	19,59
Tohir et al. (2018)	Students' Creative Thinking Skills in Solving Mathematics Olympiad Problems Based on Problem-Solving Polya and Krulik-Rudnick Model	33	11,34
Ardiansyah et al (2018)	Student's Creative Thinking Skill and Belief in Mathematics in Setting Challenge-Based Learning Viewed by Adversity Quotient	25	8,59
Sari et al. (2018)	The development of learning instruments using the creative problem-solving learning model to improve students' creative thinking skills in mathematics	21	7,22
Sya'roni et al. (2020)	Students' creative thinking skills in the flipped classroom-blended learning of mathematics based on lesson study for learning community	14	4,81
Wahyuningtyas (2020)	Student's Creative Thinking Skills Viewed by Adversity Quotient and Mathematics Anxiety in Grade VIII	9	3,09
Tohir (2019)	Students' Creative Thinking Skills in Solving Mathematics Olympiad Problems Based on Metacognition Levels	9	3,09
Hidajat (20201)	Students' Creative Thinking Profile as a High-Order Thinking in the Improvement of Mathematics Learning	5	1,72
Samura et al. (2021)	Improving the Creative Thinking Ability of Junior High School Students Through GeoGebra Assisted Learning Community in Mathematics	4	1,37
Bahrudin & Siswono (2020)	Mathematics Anxiety and Students' Creative Thinking Process in Solving Number Patterns Problems	4	1,37
Mellawaty et al. (2019)	Creative thinking ability on the integrating mathematical habits of mind in Missouri mathematics project learning	3	1,03
Muttaqin et al. (2021)	Students' creative thinking skills in solving mathematics higher order thinking skills (HOTS) problems based on online trading arithmetic	2	0,69
Pratama & Budiarto (2017)	Creative Thinking Ability Of Students In Grade VIII JHS To Solve Higher Order Thinking Problem Considered by Mathematics Ability	2	0,69
Total		**291**	**100**

Table 1 presents the 14 papers cited on creative thinking in mathematics. The most cited paper is Hasanah & Surya (2017) paper, with 103 citations (35,4%). The next paper is Maharani et al. (2017) paper, with 57 citations (19,59%), Tohir et al. (2018) with 33 citations (11,34%), Ardiansyah et al. (2018) with 25 citations (8,59%), Sari et al. (2018) with 21 citations (7,22%) and Sya'roni et al. (2020) with 14 citations (4,81%). Other papers get citations under 10 citations. Citation trends will continue to increase in line with the level of publication. This addition is expected to continue because research on creative thinking in learning mathematics is a field of research that is enough to increase the interest of researchers. Many issues can be studied further to develop processes or provide alternative solutions to improve creative thinking abilities and skills in learning mathematics.

3. Clusters, Themes and Future Research

Based on cluster analysis using the binary calculation method, 80 terms appear. Only 70 items are connected with 11 clusters and 251 links. The network visualization display is presented as shown below.

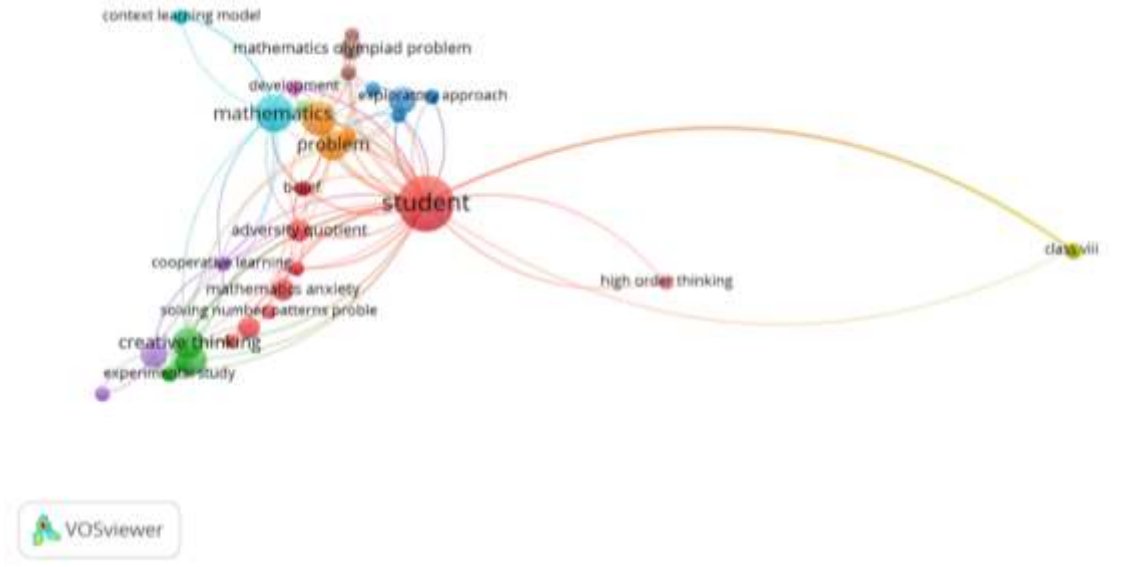

Figure 5. Network Visualization of Co-occurrence. Source: VOSviewer

The results of the network visualization show that there are items with larger nodes so that they are more clearly visible from other items. These nodes are student (cluster 1, shown in red), creative thinking (cluster 2, shown in green), mathematics (cluster 6, shown in turquoise) and problem (cluster 7, shown in orange). The big node illustrates that students, creative thinking, problems and mathematics are widely studied simultaneously. This is possible because in this study, the subjects used were students. Likewise, creative thinking is a keyword because it is the central theme used in this study. Creative thinking is a mental activity used when students want new ideas. Creative thinking allows one to produce several solutions to solve problems (Bahrudin & Siswono, 2020). Creative thinking can be developed and trained through learning mathematics. Based on this, it indicates that problems and mathematics are important parts of creative thinking.

The following shows the occurrence data with the author's keywords with an overlay visualization in Figure 6.

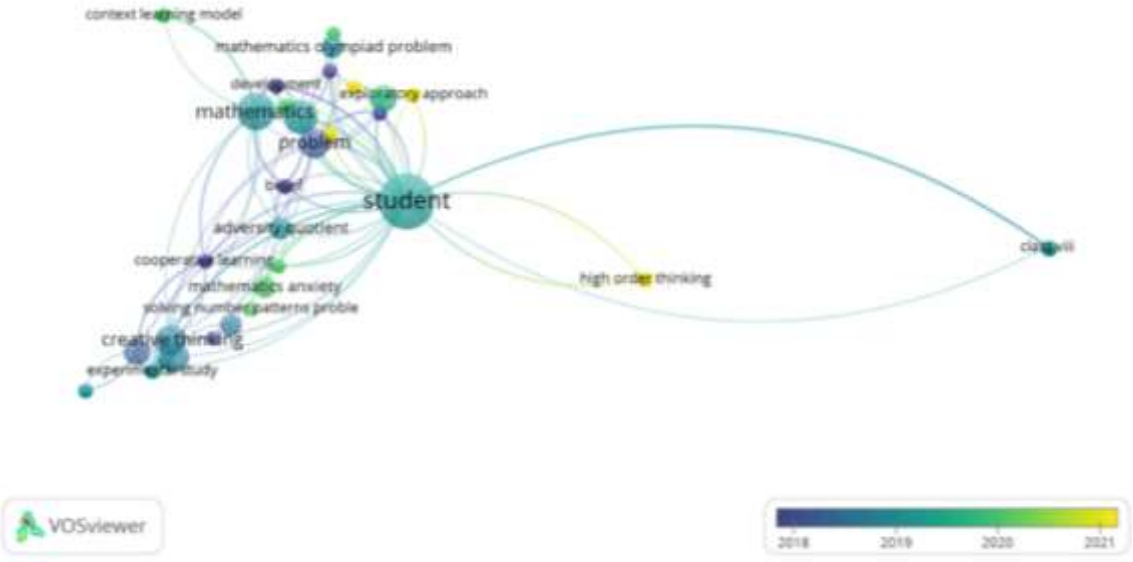

Figure 6. Overlay Visualization of Co-occurrence. Source: VOSviewer

In Figure 6, the student item overlay network has the most connections. Student, creative thinking, and mathematics items were widely published between 2018-2020. The problem item was made the centre of research in 2018. The yellow colour is the item with the latest publication (in 2021), namely high-order thinking skills, explanatory approach and the use of GeoGebra.

Density Visualization of the Co-occurrence of creative thinking in mathematics can be seen in the distribution in Figure 7 below.

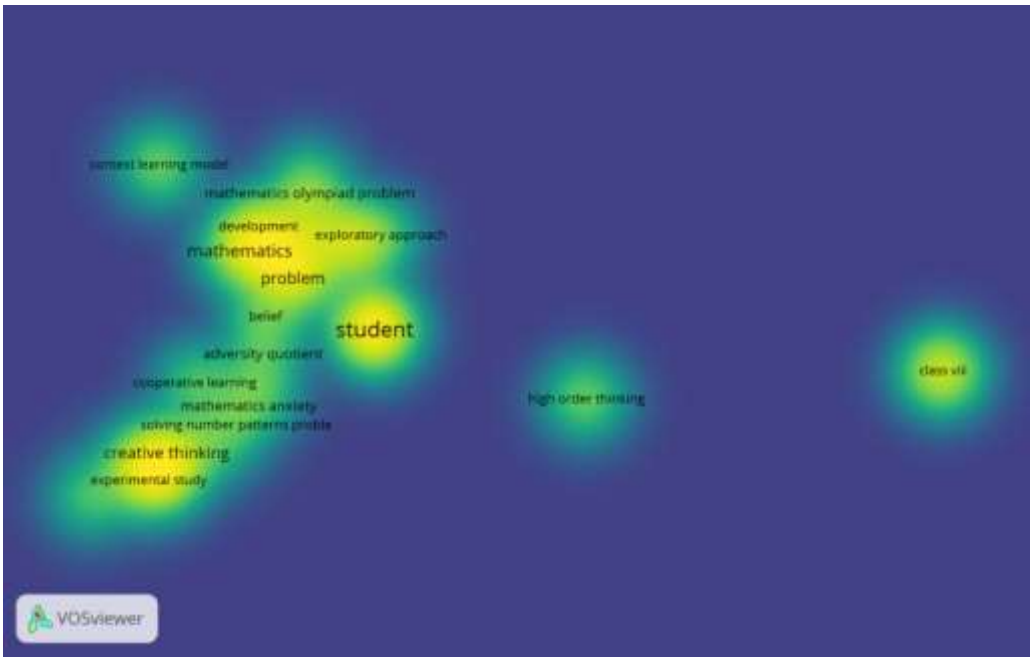

Figure 7. Density Visualization of Co-occurrence. Source: VOSviewer

Figure 7 shows that student, creative thinking, problem and mathematics items have the brightest light. This shows that these themes are widely used in research on creative thinking mathematics in junior high school students in Indonesia. While other themes such as experimental study, explanatory approach, class VIII, high order thinking, belief, mathematics anxiety, solving number patterns, cooperative learning, development and adversity quotient are still little researched and can be developed into future research to support the ability to think creatively mathematically student.

The visualisation results show that most previous research focused on 8th grades students. Furthermore, it can be studied further related to the ability to think creatively in 7th and 9th-grade students. It can even be explored further by considering the gender differences. Research on students' creative thinking still needs to be improved in involving technology. Some of the technology applications used include flipped classroom-blended learning (Sya'roni et al., 2020), the use of GeoGebra (Samura, 2019) and online trading arithmetic (Muttaqin et al., 2021). Therefore research is needed regarding developments in media-related technology or tools to improve or measure students' mathematical creative thinking processes or skills.

In the content analysis of the article, information was also obtained that the content domains discussed were numbers, algebra, and geometry. Some specific materials from numbers, algebra, and geometry have been studied to review students' creative thinking processes. The materials used include number patterns (Bahrudin & Siswono, 2020), social arithmetic (Dwidayati et al., 2020), relations and functions (Sya'roni et al., 2020), algebraic operations (Yulianto et al., 2021), circles (Hasanah & Surya, 2017), triangles (Mellawaty et al., 2019), and the volume of flat side space (Ardiansyah et al., 2018). Domains that are still limited to research are statistics and probability. Statistics and probability can be studied as future research by considering the learning approach and student character. Research conducted by Fadlilah et al. (2021) showed that students with a visual learning style were more creative than those with a visual-kinesthetic

learning style in solving statistical problems. However, the previously researched domains and topics are still worthy of being considered for review as an effort to maximize students' mathematical creative thinking abilities.

D. Conclusion

A systematic literature review through bibliometric analysis was conducted to provide a reliable, consistent and up-to-date review of research on creative thinking in mathematics learning. Specifically, an analysis of the co-authorship and co-occurrence of keywords was performed, followed by an in-depth analysis of 22 documents published between 2017 and 2021. This review offers a comprehensive overview of creative thinking in mathematics learning. The review describes the research publication trends of the last 5 years (authors, articles and themes), thus forming the basis for offering possible future research pathways. The findings show that the number of research papers on creative thinking in mathematics learning increased in 2017-2021. The most productive authors then were Mohammad Asikin, Mulyono and Mohammad Tohir who each published 2 articles. The most influential paper on creative thinking research is by Hasanah and Surya, which states that STAD is better than problem-solving learning in increasing students' creative thinking with 103 citations. Research themes such as student, creative thinking, problem and mathematics, and mathematical domains such as numbers, algebra and geometry have been widely used in research on creative thinking mathematics among junior high school students in Indonesia. This allows future research paths that can be studied, including the domain of mathematics in the material of statistics and probability, creative thinking in 7th and 9th-grade students, gender, and research related to technological developments related to media or tools to improve or measure students' mathematical creative thinking processes or skills. However, apart from this, the domains and topics that have been previously researched are still worthy of consideration and are being reviewed again to maximize students' mathematical creative thinking abilities. Therefore, this study can guide researchers and contribute to developing research on creative thinking in learning mathematics.

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