

Exploring Mathematical Creative Thinking with Design Thinking in Mathematics Learning Innovation

Fauzi Bhustomi¹, Supandi¹, Muhtarom¹

¹ Universitas PGRI Semarang, Indonesia

ARTICLE INFO

Keywords:

Mathematical Creative Thinking;
Design Thinking;
Mathematics Learning Innovation

Article history:

Received 2025-11-07

Revised 2026-01-15

Accepted 2026-03-12

ABSTRACT

This study aims to explore innovation in mathematics learning through the application of the design thinking approach to support students' mathematical creative thinking skills. The research employed an exploratory mixed-method approach based on the design thinking framework, focusing on the empathize, define, and ideate stages. The study involved 160 students and 11 mathematics teachers from four madrasahs in Kendal Regency, Indonesia. Data were collected through questionnaires and in-depth interviews and analyzed using descriptive qualitative analysis supported by triangulation techniques. In addition, a meta-analysis of 11 relevant studies was conducted using the OpenMEE application to examine the effectiveness of several proposed learning solutions. The results of the empathize stage showed that 67% of students had positive emotional responses toward mathematics learning, while 65% experienced difficulties in remembering formulas and 57.5% had difficulty understanding mathematical concepts. At the define stage, the main problems identified were students' difficulties in understanding abstract mathematical concepts, low learning motivation, and the need for more interactive and differentiated learning approaches. The ideate stage generated several potential solutions, including the development of differentiated learning supported by interactive media such as H5P and Edpuzzle as well as the implementation of the REACT learning model. The meta-analysis results indicated a large and statistically significant effect of these learning innovations on improving students' mathematical abilities, with an estimated effect size of 1.683 ($p < 0.001$; 95% CI = 1.022–2.345). These findings suggest that integrating design thinking with evidence-based learning innovations can provide effective strategies for improving students' mathematical creative thinking skills and creating more interactive and student-centered mathematics learning environments.

This is an open access article under the [CC BY-NC-SA](https://creativecommons.org/licenses/by-nc-sa/4.0/) license.



Corresponding Author:

Supandi

Universitas PGRI Semarang, Indonesia; supandi@upgris.ac.id

1. INTRODUCTION

Recent international assessments indicate that Indonesian students still face significant challenges in developing higher-order thinking skills in mathematics. The Programme for International Student Assessment (PISA) 2022 reported that Indonesia obtained an average mathematics score of 366, which is considerably below the OECD average of 472 (OECD, 2024). Similarly, the Trends in International Mathematics and Science Study (TIMSS) 2019 showed that Indonesian students achieved an average mathematics score of 397, far below the international benchmark of 500 (Mullis et al., 2020). These results indicate that students still experience difficulties in solving non-routine problems that require reasoning, creativity, and conceptual understanding. In mathematics learning, the ability to think creatively plays an important role because it enables students to generate various strategies, connect mathematical concepts, and produce innovative solutions when solving complex problems (Andiyana et al., 2018; Putri & Awalludin, 2024; Rahmawati et al., 2024; Wahyuni & Palupi, 2022). Therefore, the development of mathematical creative thinking skills becomes an important aspect that needs to be strengthened in mathematics education.

Previous studies have shown that innovative learning approaches play an important role in developing students' mathematical creative thinking skills (Mayasari & Harahap, 2022; Pajrin et al., 2025; Utami et al., 2020). Several studies have explored the use of design thinking and innovative learning models to support students' higher-order thinking skills in mathematics. For example, Riti et al. (2021) reported that the implementation of design thinking in project-based learning can improve students' critical thinking and problem-solving abilities. Similarly, Kinley et al. (2022) emphasized that design thinking can create a collaborative learning environment that encourages students to actively generate ideas and explore alternative solutions to problems. In addition, Muhtarom et al. (2025) found that the integration of design thinking in the development of educational games can significantly improve students' mathematical thinking skills.

In the context of mathematics education, several innovative learning strategies have also been implemented to support creative thinking. Komarudin et al. (2022) demonstrated that the REACT learning strategy can improve students' mathematical communication and creative thinking skills. Meanwhile, Deswita et al. (2024) revealed that differentiated learning can enhance students' creative thinking and learning independence. The use of digital learning media, such as H5P and Edpuzzle, has also been reported to improve student engagement and support interactive learning environments (Saadah et al., 2024; Madani et al., 2025).

However, most previous studies primarily focused on implementing specific learning models or media to improve learning outcomes. Research that explores learning problems from the perspective of students and teachers using the design thinking framework is still relatively limited. In addition, previous studies on design thinking in education tend to emphasize the prototyping and product development stages, while fewer studies investigate the early stages of design thinking, such as empathize and define, which aim to deeply understand users' needs in the learning process. Furthermore, studies that integrate design thinking with meta-analysis as a method for validating solution ideas in mathematics learning research are still rarely conducted.

Therefore, this study aims to explore the needs and problems experienced by students and teachers in mathematics learning using the design thinking approach, particularly through the empathize, define, and ideate stages. In addition, this study integrates meta-analysis to evaluate and strengthen the proposed learning solutions based on empirical evidence from previous studies. This approach is expected to provide a more comprehensive and evidence-based strategy for improving students' mathematical creative thinking skills.

However, in reality, students' mathematical creative thinking skills are still at a low level (Chairunnissa et al., 2022; Sari et al., 2013). This is evidenced by the results of a survey conducted by the international institution Programme for International Student Assessment (PISA), which showed that Indonesia scored very low in 2022, when compared to the international average. In addition, in the 2019 Trends in International Mathematics and Science Study (TIMSS), Indonesia recorded an average mathematics ability score of 397, which is far below the international average of 500 (Nurhayati et al.,

2022). The results of TIMSS and PISA reflect the low level of students' creative thinking skills, considering that the questions in both assessments are contextual and require reasoning, argumentation, and creativity in solving problems. This condition is in line with other studies showing that junior high school students have very limited creative thinking skills. They tend to solve problems by repeating procedures that have been taught in class (Hadayana et al., 2023).

Based on preliminary observations conducted in several madrasahs in Kendal Regency, namely MTs NU 02 Al Ma'arif Boja, MTs NU 11 Kisabariman, MTs NU 17 Kyai Jogoreso, and MTs NU 22 Singorojo, it was found that mathematics learning has not optimally encouraged the development of students' mathematical creative thinking skills. Classroom observations and interviews with mathematics teachers indicated that the learning process is still predominantly teacher-centered, where teaching and learning activities are mainly carried out through lecture methods. This approach tends to make students passive and highly dependent on teachers as the primary source of learning. Furthermore, interviews with teachers revealed several challenges during the learning process, such as students' lack of focus, difficulties in solving mathematical problems, and classroom conditions that are less conducive to active learning. As a result, students tend to solve problems by repeating procedures previously taught by teachers rather than developing their own strategies. Consequently, students' creative thinking skills are not optimally developed due to limited opportunities to explore ideas and construct their own understanding. In this context, the use of open-ended mathematical problems can be an effective strategy to encourage students to express ideas, explore various solution strategies, and develop creative thinking skills in solving mathematical problems (Supandi et al., 2021).

In order to improve students' creative thinking skills, innovation is needed in the learning process, both through approaches and supporting learning models. One approach that can be applied is design thinking. This approach is based on solutions designed to solve problems creatively. With design thinking, learning can be more effective, helping students think critically and creatively, and maximizing their potential in understanding and applying mathematical concepts (Riti et al., 2021). The design thinking approach can be said to be a relatively new concept in the world of education. However, this approach is considered very relevant to teaching 21st century skills (Charles, 2022).

This study seeks to explore students' experiences during the learning process, including the difficulties they face, the extent to which they feel involved, and their motivation in learning. The purpose of the study is to understand the application of the design stages. thinking, such as understanding problems, defining needs, generating ideas, prototyping, and testing solutions, effectively in mathematics learning. In addition, this study also aims to analyze the effect of this approach on improving students' mathematical creative thinking skills, including the ability to generate new ideas, connect concepts, and find innovative solutions in solving mathematical problems. It is hoped that this study can produce more effective and relevant learning strategies to help students develop their potential in mathematics learning.

2. METHODS

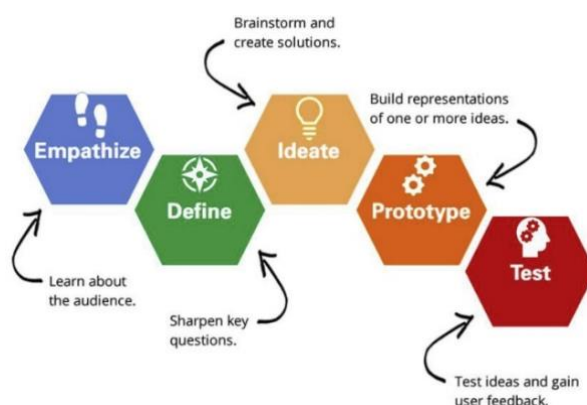
This study employed an exploratory mixed-method design using the design thinking framework to explore problems and generate innovative solutions in mathematics learning. The design thinking approach was used as the main framework to understand users' needs (teachers and students) and develop potential learning innovations. In this study, the research focused on three initial stages of design thinking, namely empathize, define, and ideate, which aim to identify learning problems, formulate problem statements, and generate possible solution ideas.

The research was conducted in four madrasahs located in Kendal Regency, Central Java, Indonesia, namely MTs NU 02 Al Ma'arif Boja, MTs NU 11 Kisabariman, MTs NU 17 Kyai Jogoreso, and MTs NU 22 Singorojo during the 2024/2025 academic year. These madrasahs are Islamic junior secondary schools with diverse student backgrounds and learning characteristics. The research subjects consisted of 160 students and 11 mathematics teachers selected using purposive sampling to obtain relevant information related to mathematics learning experiences.

Data were collected through questionnaires and semi-structured interviews. The questionnaire was distributed to students to identify their learning experiences, difficulties, and needs in mathematics learning, while interviews were conducted with several mathematics teachers to obtain deeper information regarding classroom learning practices and challenges.

Data analysis was carried out using qualitative and quantitative approaches. Qualitative data from interviews were analyzed through three stages: data coding, data categorization, and theme identification to interpret the main issues experienced by students and teachers. Data validity was ensured through triangulation techniques by comparing information obtained from questionnaires and interviews. Meanwhile, quantitative data from the questionnaire were analyzed descriptively to identify the distribution of students' responses.

In addition, a meta-analysis approach was conducted at the ideate stage to evaluate the effectiveness of several proposed learning solutions based on previous empirical studies. The meta-analysis was performed using the OpenMEE application to calculate the effect size of selected studies related to differentiated learning, the REACT learning model, and interactive learning media such as H5P and Edpuzzle.



Source: Hoover (2018)

Figure 1. Design Thinking Process

The stages of the design thinking approach applied by researchers are as follows: (1) The Empathize stage is a process where researchers approach users directly to gather information and understand their desires. In this phase, researchers conduct observations and interviews to identify user needs (Wijaya et al., 2022). (2) The Define stage is a continuation of the Empathize stage, where after understanding the needs and problems of users (teachers and students), it is important to emphasize these problems in order to determine the priority of the issues faced. This process is carried out by combining and categorizing the results of the observations that have been collected. The results of this categorization are then summarized into a *Point of View* (POV) and *How Might We* (HMW), which aims to make it easier for researchers to formulate solutions in the next stage (Tsamara et al., 2023). (3) The Ideate stage is a transition stage from problem formulation to finding solutions. In this process, the main focus is to generate ideas or ideas that will form the basis for creating a prototype design that will be developed (Sari et al., 2020).

The ideas developed in the ideate stage are further strengthened through a systematic meta-analysis. The selection of subjects in the meta-analysis study is adjusted to the ideas generated from the ideate phase, so that it remains in line with the direction and focus of the research. The data analysis process is carried out interactively through three main stages, which are data reduction, data presentation, and drawing conclusions. Data validity is ensured using triangulation techniques by comparing and testing the consistency of the results from questionnaires and interviews, and strengthening the findings through effect size calculations using the meta-analysis method. The calculation of effect sizes is carried out with the help of the OpenMEE application. (Sihombing et al., 2019) explain that the OpenMEE application is intuitive and open-source software, specifically

designed for meta-analysis based on fixed-effect and random-effect models. Its use allows researchers to input data systematically, calculate effect sizes, and display results in the form of forest plots, and funnel plots which are useful for detecting potential publication bias. The results of the analysis are shown with a significance value of $p < 0.005$, the estimation model used meets the eligibility criteria for use in calculating effect size, thus supporting the validity of the research ideas generated in the ideate phase.

This research was conducted in several madrasahs from three sub-districts, they are Boja, Singorojo, and Limbangan sub-districts located in Kendal district during October - November 2024 involving students and mathematics teachers from four madrasahs, which are MTs NU 02 Al Ma'arif Boja, MTs NU 11 Kisabariman, MTs NU 17 Kyai Jogoreso, and MTs NU 22 Singorojo, located in Kendal district in the 2024/2025 academic year. Data collection in this study in the form of a questionnaire used includes a closed questionnaire that is limited by answer choices that allow respondents to choose more than one answer and is distributed in the form of a google form and direct interviews with several respondents. The sample used in this study consisted of 160 students and 11 teachers with the following details:

Table 1. Number of Student Respondents

Madrasah	Number of Student Respondents	Percentage (%)
MTs NU 02 Al Ma'arif Boja	71	44.4
MTs NU 11 Kisabariman	27	16.9
MTs NU 17 Kyai Jogoreso	35	21.9
MTs NU 22 Singorojo	27	16.9
Amount	160	100

Table 2. Number of Teacher Respondents

Madrasah	Number of Student Respondents	Percentage (%)
MTs NU 02 Al Ma'arif Boja	4	36.3
MTs NU 11 Kisabariman	3	27.3
MTs NU 17 Kyai Jogoreso	2	18.2
MTs NU 22 Singorojo	2	18.2
Amount	11	100

3. FINDINGS AND DISCUSSION

The results of the questionnaire indicate that most students show positive emotional responses toward mathematics learning. A total of 47% of students reported feeling happy and 20% reported feeling very happy during the learning process, indicating that 67% of students experienced positive emotions toward mathematics learning. Meanwhile, 31% of students reported feeling neutral and only 2% stated that they were not happy.

These findings indicate that although the learning environment has been able to create relatively positive emotional engagement among students, there are still several challenges related to students' deeper cognitive involvement in the learning process. Emotional engagement is an important factor in supporting meaningful learning because positive learning experiences can increase students' motivation and willingness to participate actively in classroom activities. However, positive emotions alone do not automatically guarantee the development of higher-order thinking skills.

From the perspective of creative thinking theory, the development of students' creative thinking skills requires learning environments that allow students to explore ideas, generate multiple solution strategies, and express their own mathematical reasoning (Silver, 1997; Siswono et al., 2022). In this context, the design thinking approach, particularly the empathize stage, plays an important role in

understanding students' learning experiences and identifying obstacles faced during the learning process. By identifying students' emotional responses, learning difficulties, and learning needs, teachers can design more student-centered learning strategies that support the development of mathematical creative thinking skills.

These findings also support the constructivist learning perspective, which emphasizes that knowledge is actively constructed through meaningful learning experiences and student participation (Silver, 1997; Siswono et al., 2022). Therefore, understanding students' learning experiences through the empathize stage becomes an important foundation for designing innovative learning strategies that can improve students' creative thinking skills in mathematics.

As for the results of this study, the researcher arranged them based on the stages of the design method. thinking as follows:

3.1 Empathize

At the Empathize stage, a questionnaire was distributed that had been consulted and validated by experts from the Semarang PGRI University lecturers. The results of the questionnaire on the student's feelings aspect, it can be concluded that the majority of students have a positive emotional response to the learning provided. As many as 47% of students stated that they felt happy and 20% felt very happy, so that a total of 67% of students showed positive feelings. Meanwhile, 31% of students felt normal, and only 2% of students admitted that they were not happy. There were no students who stated that they were very unhappy. These results indicate that the learning carried out was able to create a pleasant atmosphere for most students. This shows that more than half of the students have a positive attitude towards learning mathematics, although there are still a small number who feel less enthusiastic. The difficulties or obstacles experienced by students in learning mathematics are very diverse and are caused by various factors.

Based on the results of a questionnaire from 160 students, it was found that 65% of students had difficulty remembering formulas, 57.5% had difficulty understanding mathematical concepts, 18.8% felt that mathematics was difficult because of the abstract nature of mathematics, 14.4% were influenced by the learning environment, 10% were caused by less interesting learning methods, and 8.8% were related to minimal support. The rest considered mathematics less relevant to everyday life or were caused by other factors. In overcoming or handling these obstacles/difficulties, what students do is described in the following diagram:

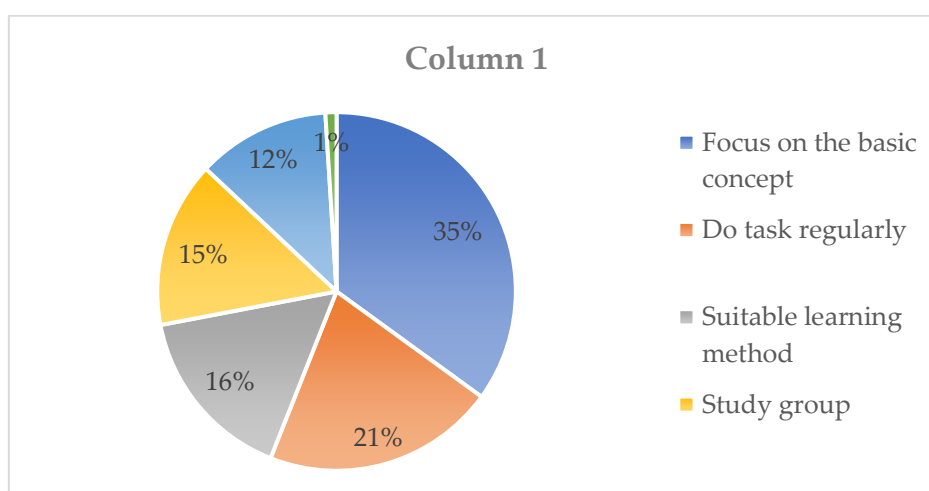


Figure 2. Results of the Questionnaire on Aspects of How Students Overcome Difficulties in Learning Mathematics

This shows that understanding basic concepts and collaborating with others are dominant strategies in helping students overcome difficulties in learning mathematics. The mathematics material

that is considered the most difficult by students usually includes topics that require deep understanding and high analytical skills, such as algebra and geometry. The results of the questionnaire on aspects of the material that students find difficult show that most students consider number material (such as integers, fractions, and so on) to be the most difficult material, with a percentage of 40%. Furthermore, 31% of students stated that they had difficulty with algebra material, followed by 27% of students who found it difficult with geometry material (flat shapes, solid shapes, and the like). Meanwhile, only 2% of students found it difficult with data analysis and probability material. These results show that number and algebra material are the most challenging topics for students, so they need special attention in learning planning, such as the use of interactive media or a contextual approach to facilitate understanding of concepts. Conversely, the low percentage of data analysis and probability material indicates that the material is relatively easier for students to understand.

Moreover, from the aspect of students' needs and desires in learning mathematics, the results showed that 60% (96 students) wanted interesting learning media, 52.5% (84 students) expected learning methods that support student involvement, 36.9% (59 students) wanted varied learning resources, and the remaining 21.9% (35 students) wanted innovative learning models.

Meanwhile, the results of a questionnaire involving 11 teachers from four different madrasas showed that all respondents chose a learning method that could be adjusted to the abilities and learning styles of each student or differentiated learning. The results of the questionnaire on aspects of teacher needs in mathematics learning showed that the aspect most prioritized by teachers was differentiated learning, with 12 respondents (21.8%). Furthermore, 10 respondents (18.2%) prioritized contextual learning. Meanwhile, aspects of learning methods, learning media, and formative assessment each received the same number of respondents, which are 7 people (12.7%).

These data show that the majority of teachers feel the need to strengthen the application of differentiated and contextual learning in the mathematics teaching and learning process. This reflects the importance of an approach that adapts to the needs and characteristics of students, as well as the use of real contexts to make learning more meaningful. Although other aspects have lower percentages, they are still important to note in order to improve the quality of learning as a whole.

Based on the survey results, researchers analyzed the problems that emerged in mathematics learning using empathy maps from the perspective of students and teachers. Empathy The map aims to visualize, open, and better understand the emotional experiences of target users (teachers and students). The parts of the empathy map are Says & Does, which is what users say and how users behave in mathematics learning, and Think & Feels, which is what users think and feel while using mathematics learning (Pratama et al., 2024). The following is an empathy map compiled based on questionnaire and interview analysis:

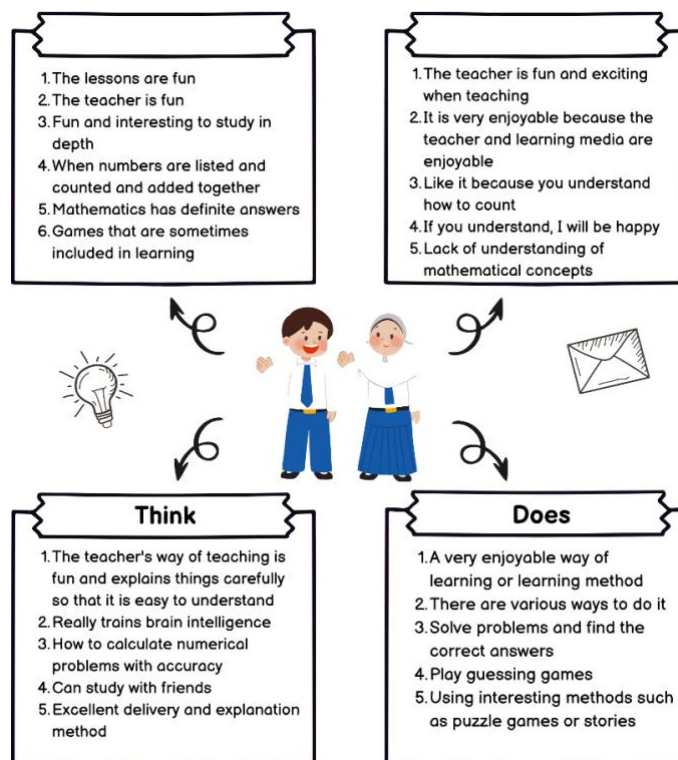


Figure 3. Student Empathy Map

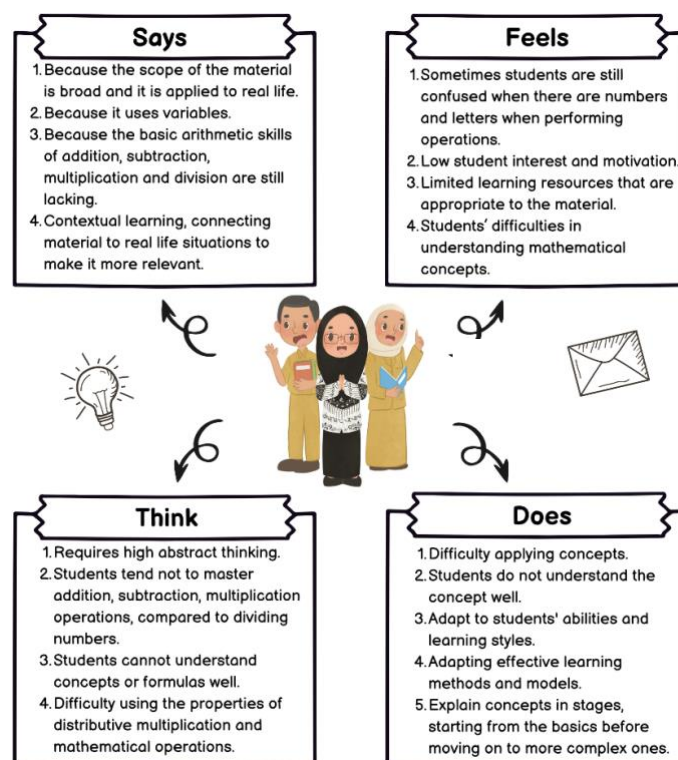


Figure 4. Teacher Empathy Map

From empathy map that has been compiled, several major problems in learning mathematics can be identified. One problem is when students have to learn complex and abstract concepts, such as the use of variables or mathematical operations with numbers and letters. In addition, the need for high abstract thinking in mathematics often makes it difficult for students to understand these concepts.

Students' interest and motivation in learning mathematics also tend to be low. This can be caused by various factors, including limited learning resources that are relevant to the material being taught. Students find it difficult to obtain additional references that can help them understand concepts in depth. Low motivation is also exacerbated by the challenges in applying mathematical concepts to real situations.

Students also face obstacles in understanding and applying mathematical concepts. This shows that the learning methods and models used are not fully effective or are not in accordance with the students' learning styles. In addition, the learning approach that is not fully optimal is one of the causes of students' difficulty in understanding the material. Learning that does not adapt to students' learning styles makes it difficult for them to follow and apply what is learned. Therefore, a more varied, effective, and student-oriented learning method is needed to help them overcome difficulties in learning mathematics.

3.2 Define

At this stage, the researcher has compiled the user problems (students and teachers) into a problem statement to gain a deeper understanding of the needs or constraints faced by users, and to develop relevant solutions. After all the problems and needs of users are summarized in the form of problem statement, the researcher then broadens his perspective by defining user needs in more detail through points of the designer's view of the problem. The results of this process are summarized in the form of how questions might we to guide solution development (Tsamara et al., 2023).

Point of view is a method for obtaining information from users with the aim of producing solution design ideas that are in accordance with the user's point of view. This method functions to formulate problem statements based on information expressed by users, which are then used as a basis for designing solution ideas (Riza et al., 2022). The point of view is of The view that has been formulated by the researcher can be seen in the following image:

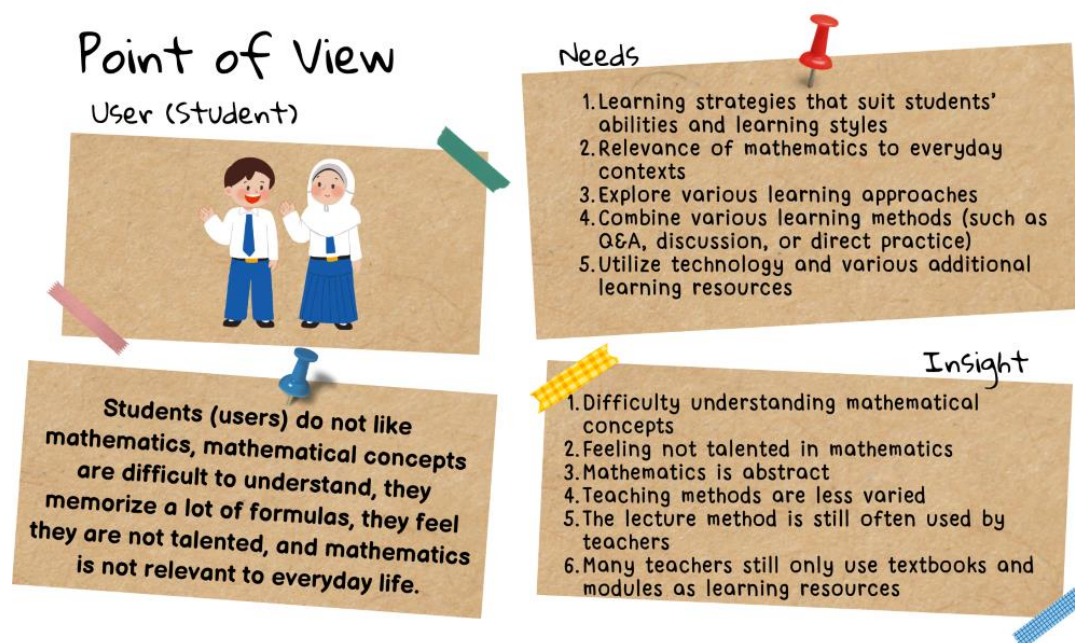


Figure 5. Student Point of View

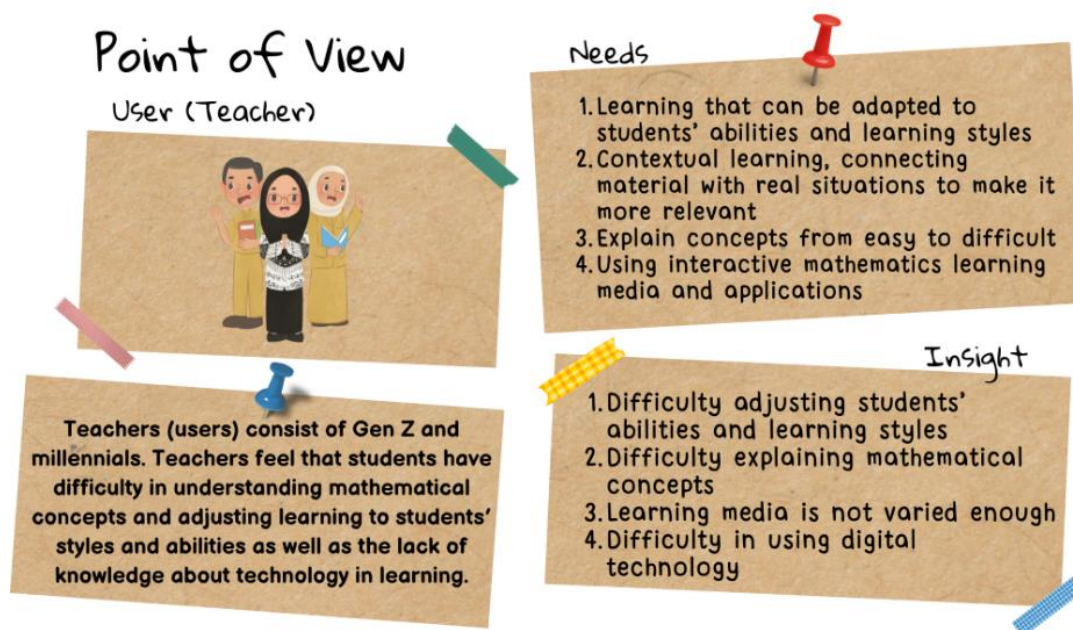


Figure 6. Teacher's Point of View

Both students and teachers need a more varied, interactive, and contextual learning approach to overcome the difficulties faced. Improving teacher competence in using technology and a variety of learning methods, as well as providing relevant learning media, can be a solution to create a more effective and enjoyable mathematics learning experience.

How might we (HMW) in this method, the designer changes the statement into a question as a step to obtain clearer information regarding how to provide solutions to each identified problem. This method aims to focus the solution search process systematically and in a directed manner (Tsamara et al., 2023). Here is how might we which has been formulated can be seen in the following table:

Table 3. How Might We

No	Question	Solution
1.	How can we make abstract mathematical concepts more concrete and easier to visualize for students?	Using visual media or teaching aids and relating mathematical concepts to real life
2.	How can we encourage students to be actively involved in the mathematics learning process?	Using interactive methods such as group discussions, quizzes, or math games that involve students directly
3.	How can we make learning mathematics more fun and interesting for students?	Learning with interactive methods and game systems or educational activities
4.	How can we help students who have difficulty understanding mathematical concepts?	Using different learning approaches and delivering from the simple.
5.	How can we create a learning environment with different abilities and learning styles of students?	Implementing a differentiated learning approach to content, process, and product.

3.3 Ideate

This stage is the process where ideas begin to form. All ideas that emerge will be considered to solve the problems that have been identified at the define stage. At the ideate stage, it is important to generate as many ideas or solutions as possible at the beginning, so that the best way to solve the

problem or provide the elements needed to prevent similar issues in the future can be chosen (Aisah & Widodo, 2024). At this stage, the process of collecting several ideas is carried out through Brainstorming which aims to get ideas from a solution to an existing problem.

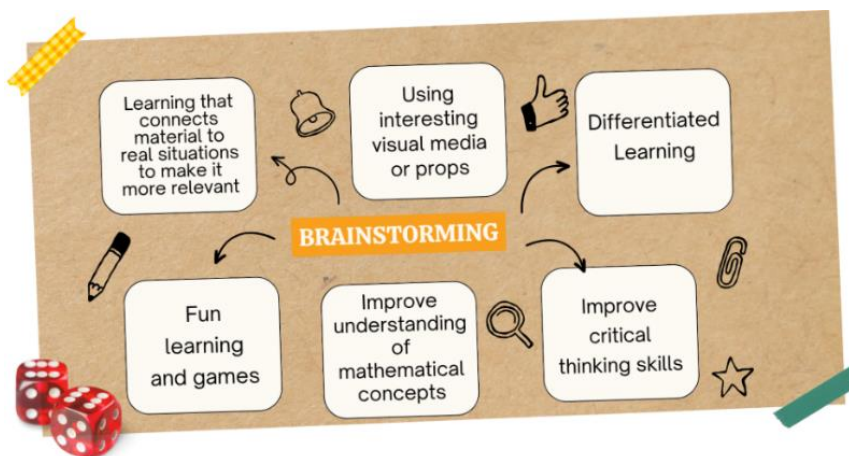


Figure 7. Brainstorming

The results of the brainstorming are then described in the form of mind maps. map, which presents all ideas and concepts in one organized visualization.

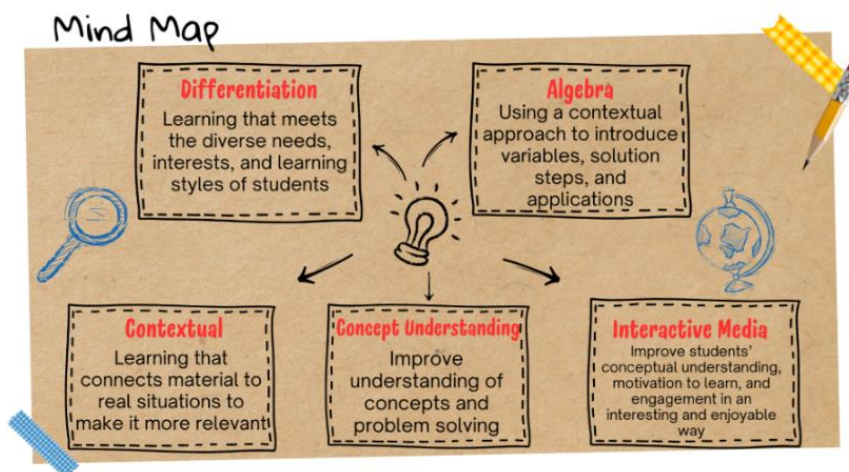


Figure 8. Mind Map

Based on the problems that have been previously defined by students and teachers, the researcher then provides several ideas and solutions based on the results of brainstorming and mind mapping. map. Successful solution ideas that were defined to overcome the problem can be seen in the following table:

Table 4. Ideate

No	Idea
1.	Developing Interactive Learning Media Based on H5P Edukati in Differentiated Learning to Improve Mathematical Creative Thinking Skills
2.	REACT Learning Activities Using Edpuzzle Media to Improve Mathematical Creative Thinking Skills
3.	Designing Interactive Learning Media Based on H5P in the REACT Framework to Improve Mathematical Creative Thinking Skills

3.4 Meta-Analysis

The purpose of this meta-analysis is to evaluate the ideate stage solution in the context of the influence of the differentiation approach, the REACT model, and the use of H5P-based interactive media, and Edpuzzle on improving students' mathematical creative thinking skills. (Juandi & Tamur, 2020) refer to meta - analysis as a systematic quantitative approach that is useful for integrating results from various studies, including the identification of effect sizes and publication bias control techniques. Effect size calculations are carried out to determine the extent to which the application of approaches, models and media contributes significantly to the solution at the ideate stage. In this process, 11 selected articles were analyzed to obtain the appropriate effect size. The results of these calculations were then further analyzed using a meta-analysis approach to present comprehensive and measurable findings based on the available data.

Table 5. Article Data, Effect Size, and Variance

Studies	Treatment	ES	V
(Cindyana et al., 2022)	Differentiation	0.679	0.099
(Deswita et al., 2024)	Differentiation	1,000	0.090
(Hartini et al., 2024)	Differentiation	2.625	0.207
(Ananda et al., 2022)	REACT	1,926	0.091
(Komarudin et al., 2022)	REACT	1,077	0.076
(Sofyan et al., 2022)	REACT	2,447	0.105
(Hidayat et al., 2023)	Edpuzzle	0.638	0.075
(Hidayat et al., 2023)	Edpuzzle	0.632	0.058
(Saadah et al., 2024)	Edpuzzle	0.666	0.067
(Madani et al., 2025)	H5P	0.888	0.064
(Sukmawati et al., 2023)	H5P	7,399	0.448

The collected data was then subjected to meta-analysis using the OpenMEE application, which produced data as presented in the following table.

Table 6. Meta-Analysis Results

Estimate	Lower bound	Upper bound	Std. error	p-Value
1.683	1.022	2.345	0.338	<0.001

Based on table 6, the results of the meta-analysis using OpenMEE obtained an estimated value of 1,683 with a 95% confidence interval ranging from 1,022 to 2,345. This value indicates that learning interventions such as the differentiation approach, the REACT model, and the use of interactive media based on H5P and Edpuzzle as a whole have a large and significant influence on improving student learning outcomes, especially in the aspect of mathematical problem-solving abilities. A p-value <0.001 indicates that the effect obtained is very statistically significant and does not occur by chance.

3.5 Discussion

The findings of this study were analyzed based on the three main stages of the design thinking framework, namely empathize, define, and ideate combined with meta-analysis. These stages provide a comprehensive understanding of the learning problems experienced by students and teachers, as well as potential solutions based on empirical evidence.

3.6 Empathize Stage: Understanding Students' and Teachers' Needs

The empathize stage revealed several important aspects related to students' learning experiences and difficulties in mathematics learning. The questionnaire results showed that although most students demonstrated positive emotional responses toward mathematics learning, many students still

experienced difficulties in understanding mathematical concepts and remembering formulas. These findings indicate that emotional engagement alone is not sufficient to support the development of higher-order thinking skills.

From the perspective of creative thinking theory, students need learning environments that allow them to generate multiple ideas, explore different problem-solving strategies, and express their reasoning in flexible ways (Silver, 1997; Siswono et al., 2022). Creative thinking in mathematics involves several indicators, including fluency, flexibility, originality, and elaboration in generating mathematical ideas (Manurung et al., 2024; Mursidik et al., 2015). However, the learning practices identified in the empathize stage indicate that students still have limited opportunities to develop these abilities due to the dominance of teacher-centered instruction.

These findings are also consistent with the constructivist learning perspective, which emphasizes that knowledge is actively constructed through meaningful learning experiences and active student participation (Piaget, 1970). When learning activities are dominated by teacher explanations, students tend to become passive recipients of information rather than active problem solvers. Therefore, understanding students' needs and learning difficulties through the empathize stage becomes an important foundation for designing learning innovations that support the development of creative thinking skills.

3.7 Define Stage: Identifying Key Problems in Mathematics Learning

The define stage focuses on identifying and formulating the main problems experienced by students and teachers during the learning process. Based on the empathy map and questionnaire results, several key issues were identified, including students' difficulties in understanding abstract mathematical concepts, low learning motivation, and limited learning resources that support interactive learning.

These problems indicate that the current learning approach has not fully accommodated students' diverse learning needs. In mathematics education, learning should provide opportunities for students to actively construct knowledge and explore mathematical ideas through meaningful experiences. However, when learning is primarily focused on procedural instruction, students tend to rely on memorizing formulas rather than understanding concepts.

The findings in this stage emphasize the importance of implementing innovative learning approaches that can create more interactive and student-centered learning environments. In the context of design thinking, the define stage plays a crucial role in transforming users' needs and experiences into clearly formulated problem statements that guide the development of potential solutions.

3.8 Ideate Stage and Meta-Analysis: Evidence-Based Learning Solutions

At the ideate stage, several potential learning solutions were generated based on the problems identified in the previous stages. These solutions include the implementation of differentiated learning approaches, the use of the REACT learning model, and the integration of interactive learning media such as H5P and Edpuzzle.

To strengthen the proposed solutions, a meta-analysis of relevant studies was conducted to evaluate the effectiveness of these learning strategies in improving students' mathematical abilities. The results of the meta-analysis showed an estimated effect size of 1.683 with a significance value of $p < 0.001$, indicating that the implementation of differentiated learning, REACT learning strategies, and interactive digital media has a strong and significant impact on students' learning outcomes.

These findings are consistent with previous studies that reported positive effects of innovative learning strategies on students' mathematical thinking skills. For example, Komarudin et al. (2022) found that the REACT learning strategy can significantly improve students' creative thinking and mathematical communication skills. Similarly, Deswita et al. (2024) reported that differentiated learning can enhance students' creative thinking abilities and learning independence.

From the perspective of design thinking theory, the ideate stage encourages the generation of multiple solution ideas that are centered on users' needs. By combining design thinking exploration with meta-analysis validation, this study provides a more comprehensive approach to developing evidence-based learning innovations in mathematics education.

3.9 Research Contribution

This study contributes to the field of mathematics education by integrating the design thinking approach with meta-analysis as a strategy for developing learning innovations. While previous studies on design thinking in education often focus on product development or learning prototypes, this study emphasizes the exploration of users' needs through the empathize and define stages and strengthens the proposed solutions through empirical evidence from meta-analysis. This approach provides a more systematic and evidence-based framework for developing learning innovations aimed at improving students' mathematical creative thinking skills.

4. CONCLUSION

This study aimed to explore innovation in mathematics learning through the design thinking approach to support the development of students' mathematical creative thinking skills. The findings show that the design thinking framework can effectively identify learning problems and generate potential solutions based on students' and teachers' real needs.

At the empathize stage, the results indicate that although most students show positive emotional responses toward mathematics learning, many still experience difficulties in understanding mathematical concepts and remembering formulas. These findings highlight the need for learning strategies that provide greater opportunities for students to actively construct knowledge and explore multiple problem-solving strategies.

At the define stage, several key problems in mathematics learning were identified, including the dominance of teacher-centered instruction, students' limited opportunities to develop creative thinking skills, and the need for more interactive and differentiated learning approaches.

At the ideate stage, several potential learning innovations were generated, including the implementation of differentiated learning, the REACT learning model, and the use of interactive digital media such as H5P and Edpuzzle. The meta-analysis results show that these learning strategies have a large and statistically significant effect on improving students' mathematical abilities, with an estimated effect size of 1.683 ($p < 0.001$).

The main contribution of this study lies in integrating the design thinking approach with meta-analysis as a strategy to develop evidence-based learning innovations in mathematics education. This approach provides a systematic framework for identifying learning problems and validating potential solutions based on empirical evidence.

Future research is recommended to continue the design thinking stages into the prototype and test phases in order to evaluate the effectiveness of the proposed learning innovations in real classroom implementations.

REFERENCES

- Aisah, A., & Widodo, S. (2024). Perancangan User Interface Game Edukasi Android pada Mata Pelajaran Operasi Hitung Matematika dengan Metode Design Thinking. *Sudo Jurnal Teknik Informatika* *Jurnal Teknik Informatika*, 3(1), 9–18. <https://doi.org/10.56211/sudo.v3i1.462>
- Ananda, S. T., Saryantono, B., & Noviyana, H. (2022). Pengaruh Strategi Relating, Experiencing, Applying, Cooperating, Transferring (REACT) Terhadap Kemampuan Pemecahan Masalah Matematika Siswa Kelas VIII Semester Ganjil UPT SMP Negeri 7 Bandar Lampung Tahun Pelajaran 2021/2022. *Jurnal Ilmiah Mahasiswa Pendidikan Matematika*, 1–11.

- Andiyana, M. A., Maya, R., & Hidayat, W. (2018). Analisis Kemampuan Berpikir Kreatif Matematis Siswa Smp Pada Materi Bangun Ruang. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, 1(3), 239. <https://doi.org/10.22460/jpmi.v1i3.p239-248>
- Chairunnissa, A., Anriani, N., & Santosa, C. A. H. F. (2022). Analisis Kemampuan Berpikir Kreatif Siswa Melalui Pembelajaran Dengan Pendekatan Stem Pada Materi Statistika Kelas VIII SMP. *Jurnal Penelitian Dan Pembelajaran Matematika*, 15(2), 275. <https://doi.org/10.30870/jppm.v15i2.16196>
- Charles, S. (2022). Design Thinking, a Novel Approach for an Effective and Improved Educational System—A Review. *International Journal of Professional Development, Learners and Learning*, 4(1), ep2205. <https://doi.org/10.30935/ijpdll/12010>
- Cindyana, E. A., Alim, J. A., & Noviana, E. (2022). Pengaruh Pembelajaran Berdiferensiasi Berbantuan Materi Ajar Geometri Berbasis Rme Terhadap Kemampuan Penalaran Matematis Siswa Kelas 3 Sekolah Dasar. *JURNAL PAJAR (Pendidikan Dan Pengajaran)*, 6(4), 1179. <https://doi.org/10.33578/pjr.v6i4.8837>
- Deswita, D., Hasnawati, H., & Yumiati, Y. (2024). Penerapan Pembelajaran Berdiferensiasi Terhadap Kemampuan Berpikir Kreatif Dan Kemandirian Belajar Matematis Murid Sekolah Dasar. *Dharmas Education Journal (DE_Journal)*, 5(1), 1–14. <https://doi.org/10.56667/dejournal.v5i1.1207>
- Hadayana, N. I., Mirza, A., Hamdani, H., & Pasaribu, R. L. (2023). Kemampuan Berpikir Kreatif Matematis Siswa Dalam Menyelesaikan Soal Bangun Datar Ditinjau dari Self-Regulated Learning. *Jurnal Education and Development*, 11(2), 438–443. <https://doi.org/10.37081/ed.v11i2.4487>
- Hartini, Putri; Wahyuningsih, Sri ; Prasrihamni, M. (2024). Pengaruh Pembelajaran Berdiferensiasi Terhadap Kemampuan Bernalar Kritis Siswa Kelas V Di SD Negeri 223 Palembang. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, 9(3), 458–469.
- Juandi, D., & Tamur, M. (2020). *Pengantar Analisis Meta. Pers UPI*. (December 2020).
- Kinley, K., Dorji, U., Chopel, S., & Rai, R. (2022). Introducing the Design Thinking Approach for Teaching and Learning at Tendruk Central School in Samtse Dzongkhag. *Bhutan Journal of Research and Development*, 11(2). <https://doi.org/10.17102/bjrd.rub.11.2.035>
- Komarudin, K., Mutia, M., Putri, D. P., Masykur, R., Suherman, S., & Astuti, A. D. (2022). Effect of REACT learning strategy on creative thinking and mathematical communication skills. *Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah Di Bidang Pendidikan Matematika*, 8(1), 48–61. <https://doi.org/10.29407/jmen.v8i1.16839>
- Madani, S. F., Sutiarsa, S., & Triana, M. (2025). The Effect of Using H5P Interactive Media on Students' Mathematical Critical Thinking Ability. *Journal of Innovation and Research in Primary Education*, 4(2), 128–135. <https://doi.org/10.56916/jirpe.v4i2.1210>
- Manurung, A. S., Halim, A., & Nur, S. M. (2024). Model of Mathematical Creative Thinking Ability Based on Character Education for Elementary School Students Jakarta. *Asatiza: Jurnal Pendidikan*, 5(1), 45–60. <https://doi.org/10.46963/asatiza.v5i1.1727>
- Mayasari, L., & Harahap, N. A. (2022). Peningkatan Kemampuan Berpikir Kreatif Matematis Siswa Menggunakan Metode Quantum Teaching pada Kelas VIII SMP N 1 Merbau. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, 6(2), 1741–1750. <https://doi.org/10.31004/cendekia.v6i2.1316>
- Muhammad Syarif Hidayat, Nana, & Makiyah, Y. S. (2023). Efektivitas Penggunaan Media Pembelajaran Edpuzzle Berbasis Video Terhadap Hasil Belajar Peserta Didik pada Materi Suhu dan Pemuaian. *JIPFRI (Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah)*, 7(2), 72–81. <https://doi.org/10.30599/jipfri.v7i2.2183>
- Muhtarom, M., Sugiyanti, S., Zuhri, M. S., Mutiara, N. L. D., Adrillian, H., & Baldemor, M. (2025). Development of Educational Games Based on Design Thinking to Improve Mathematical Thinking Skills. *QALAMUNA: Jurnal Pendidikan, Sosial, Dan Agama*, 17(1), 337–350. <https://doi.org/10.37680/qalamuna.v17i1.6203>
- Mullis, I. V. S., Martin, M. O., Ruddock, G., O'Sullivan, C. Y., & Preuschoff, C. (2020). *TIMSS 2019 assessment frameworks*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

- Mursidik, E. S. M., Samsiyah, N., & Rudyanto, H. E. (2015). Kemampuan Berpikir Kreatif Dalam Memecahkan Masalah Matematika Open-Ended Ditinjau Dari Tingkat Kemampuan Matematika Siswa Sekolah Dasar. *Pedagogia: Jurnal Pendidikan*, 4(1), 23–33. <https://doi.org/10.21070/pedagogia.v4i1.69>
- Nurhayati, N., Asrin, A., & Dewi, N. K. (2022). Analisis Kemampuan Numerasi Siswa Kelas Tinggi dalam Penyelesaian Soal Pada Materi Geometri di SDN 1 Teniga. *Jurnal Ilmiah Profesi Pendidikan*, 7(2b), 723–731. <https://doi.org/10.29303/jipp.v7i2b.678>
- OECD. (2024). *PISA 2022 Results (Volume III): Creative Minds, Creative Schools*. OECD Publishing. <https://doi.org/10.1787/765ee8c2-en>
- Pajrin, N. F., Pujiastuti, E., & Sugiman, S. (2025). Berpikir Kreatif Siswa Melalui Teknologi Abad-21: Berpikir Kreatif Dengan Teknologi. *De Fermat: Jurnal Pendidikan Matematika*, 7(1), 22–34. <https://doi.org/10.36277/deferemat.v7i1.294>
- Pratama, I. P. A. A., Paramitha, A. A. I. I., & Satwika, I. P. (2024). Penerapan Metode Design Thinking Dalam Implementasi User Interface Berbasis Website Studi Kasus JRO Sandat Property. *JTKSI (Jurnal Teknologi Komputer Dan Sistem Informasi)*, 7(1), 73–86.
- Putri, R. A., & Awalludin, S. A. (2024). Analisis Kemampuan Berpikir Kreatif Matematis Ditinjau dari Self Efficacy Dalam Menyelesaikan Soal Berbasis Literasi dan Numerasi. *FIBONACCI: Jurnal Pendidikan Matematika Dan Matematika*, 10(1), 51–64. <https://doi.org/10.24853/fbc.10.1.51-64>
- Rahmawati, D., Huda, N., & Marlina, M. (2024). Kemampuan Berpikir Kreatif Matematis Berdasarkan Self-confidence pada Materi Barisan dan Deret Bilangan. *JKPM (Jurnal Kajian Pendidikan Matematika)*, 9(2), 209. <https://doi.org/10.30998/jkpm.v9i2.22396>
- Riti, Y. U. R., Degeng, I. N. S., & Sulton, S. (2021). Pengembangan Model Pembelajaran Berbasis Proyek dengan Menerapkan Metode Design Thinking untuk Meningkatkan Keterampilan Berpikir Kritis Siswa Dalam Mata Pelajaran Kimia. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, 6(10), 1581. <https://doi.org/10.17977/jptpp.v6i10.15056>
- Riza, A., Sidharta, A., Rokhmawati, R. I., & Priharsari, D. (2022). Perancangan Learning Management System menggunakan Metode Design Thinking (Studi Kasus: SMK Prajnaparamita Malang). *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer*, 6(2), 838–847.
- Saadah, N., Sapti, M., & Kurniasih, N. (2024). Pengaruh Model Pembelajaran Blended Learning Berbantuan Edpuzzle Terhadap Hasil Matematika Siswa SMP. *Jurnal Pendidikan Kreativitas Pembelajaran*, 6(4).
- Sari, I. M., Sumiati, E., & Siahaan, P. (2013). Analisis Kemampuan Berpikir Kreatif Siswa Smp Dalam Pembelajaran Pendidikan Teknologi Dasar (PTD). *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam*, 18(1), 60. <https://doi.org/10.18269/jpmipa.v18i1.258>
- Sari, I. P., Kartina, A. H., Pratiwi, A. M., Oktariana, F., Nasrulloh, M. F., & Zain, S. A. (2020). Implementasi Metode Pendekatan Design Thinking dalam Pembuatan Aplikasi Happy Class Di Kampus UPI Cibiru. *Edsence: Jurnal Pendidikan Multimedia*, 2(1), 45–55. <https://doi.org/10.17509/edsence.v2i1.25131>
- Sihombing, P. robinson, Arsani, A. M., Mahfirah, T. F., Krisdianto, B. F., & Lameky, V. Y. (2019). Meta Analysis dalam Berbagai Software. In *Tanggerang: Minhaj Pustaka* (Vol. 11, Issue 1).
- Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *Zentralblatt Für Didaktik Der Mathematik*, 29(3), 75–80. <https://doi.org/10.1007/s11858-997-0003-x>
- Siswono, T. Y. E., Rosyidi, A. H., Kohar, A. W., Hartono, S., Nisa, K., & Uripno, G. (2022). *Integrasi Teknologi dalam Pembelajaran Matematika Upaya Meningkatkan Kemampuan Berpikir Kreatif Matematis Siswa*. CV Literasi Nusantara Abadi.
- Sofyan, D., Sugandi, A. I., Linda, L., Sari, D. R., & Bernard, M. (2022). Penerapan Strategi React Berbantuan Geogebra Dalam Meningkatkan Kemampuan Berpikir Kritis Matematis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 11(3), 1668. <https://doi.org/10.24127/ajpm.v11i3.4995>

- Sukmawati, I., Prajoko, S., & Alamsyah, M. R. N. (2023). Pemahaman Konsep Mahasiswa pada Pembelajaran Biologi Berdiferensiasi yang Menerapkan E-PjBL Berbantuan Media H5P. *Bioed : Jurnal Pendidikan Biologi*, 11(2), 161. <https://doi.org/10.25157/jpb.v11i2.12235>
- Supandi, S., Suyitno, H., Sukestiyarno, Y. L., & Dwijanto, D. (2021). Learning barriers and student creativity in solving math problems. *Journal of Physics: Conference Series*, 1918(4), 042088. <https://doi.org/10.1088/1742-6596/1918/4/042088>
- Tsamara, A., Raf, A., & Rani, S. (2023). Perancangan Antarmuka Aplikasi Belajar Matematika dari Rumah untuk Sekolah Dasar menggunakan Pendekatan Design Thinking. *Automata*, 4, 1–8.
- Utami, R. W., Endaryono, B. T., & Djuhartono, T. (2020). Meningkatkan Kemampuan Berpikir Kreatif Matematis Siswa Melalui Pendekatan Open-Ended. 7(1).
- Wahyuni, D., & Palupi, B. S. (2022). Analisis Kemampuan Berpikir Kreatif Matematis Siswa Kelas V Sekolah Dasar Melalui Soal Open-Ended. *Jurnal Kiprah Pendidikan*, 1(2), 76–83. <https://doi.org/10.33578/kpd.v1i2.30>
- Wijaya, V., Fadli, M., Dharma, Y. A., & Pribadi, M. R. (2022). Pengembangan UI/UX pada aplikasi Go-Print Dengan menggunakan metode design thinking. *MDP Student Conference (MSC)*, 1(1), 298–305.

