ISSN 2087-8885
E-ISSN 2407-0610

Journal on Mathematics Education
Volume 12, No. 2, May 2021, pp. 313-330

ON CREATIVITY THROUGH MATHEMATIZATION IN SOLVING NON-ROUTINE PROBLEMS

Sujinal Arifin[1], Zulkardi[2], Ratu Ilma Indra Putri[2], Yusuf Hartono[2]

[1]Universitas Islam Negeri Raden Fatah, Jl. Prof. K.H. Zainal Abidin Fikri, Palembang, Indonesia
[2]Sriwijaya University, Jalan Raya Palembang Prabumulih, Ogan Ilir, Indonesia
Email: zulkardi@unsri.ac.id

Abstract

This study aimed to describe and compare the students' fluency, flexibility, and originality in solving non-routine problems in the Palembang context. They were depicted from the student's fluency, flexibility, and originality of solving the horizontal and vertical mathematization forms. This qualitative study employed. The subjects of this study were 30 students of grade nine of junior high schools in Palembang. The instruments used were tests and interviews. The tests were employed to investigate the written horizontal and vertical mathematizations forms. Meanwhile, the interviews were to explore the students' ideas with inadequately detailed answers. Then, the test and interview data were reduced and grouped based on the indicators of creativity. The reduced data were presented in a descriptive form for conclusions. The results of the data analysis showed that the high-ability students were the most fluent and flexible in solving the problems. Still, the provided solutions were less original and tended to use formal mathematics in the forms of formulas, symbols, and operations. Meanwhile, the moderate-ability students tended to start to solve problems by simplifying them, then presenting them in visual images. The answer sheets of the moderate-ability students revealed their fluency in understanding the problems and solutions, flexibility, and originality of thinking. This study obtained different results from the low-ability students who tended to have difficulties understanding the problems and made many errors in solving them. Such a condition showed their inability to write the known data and relate the data to other facts they had already learned. As a result, their answers did not represent fluency, flexibility, and originality.

Keywords: Mathematization, Creativity, Problem-Solving, Non-routine

Abstrak

Penelitian ini bertujuan untuk menggambarkan dan membandingkan kelancaran, fleksibilitas dan orisinalitas dalam menyelesaikan masalah non rutin berkonteks "Palembang". Hal ini tergambar dari kelancaran, fleksibilitas dan orisinalitas siswa dalam membuat matematisasi horizontal dan matematisasi vertikal. Penelitian ini merupakan penelitian kualitatif. Subjek penelitian ini adalah siswa kelas IX SMP di kota Palembang. Instrumen yang digunakan adalah tes dan wawancara. Tes dilakukan untuk melihat bentuk matematisasi horizontal dan vertikal secara tertulis. Wawancara dilakukan untuk menggali ide dari siswa yang jawabannya kurang detail. Data hasil tes dan wawancara, selanjutnya direduksi dan dikelompokkan sesuai indikator kreativitas. Data hasil reduksi tersebut disajikan dalam bentuk deskriptif untuk selanjutnya digunakan dalam pengambilan kesimpulan. Berdasarkan hasil analisis data diperoleh bahwa siswa berkemampuan tinggi lebih lancar dan fleksibel dalam menyelesaikan masalah tetapi penyelesaian yang diberikan dikategorikan kurang original dan cenderung menggunakan matematika formal berupa rumus, simbol dan operasi matematika. Sedangkan siswa berkemampuan sedang cenderung memulai pekerjaan dengan menyederhanakan masalah dan menampilkannya dalam bentuk gambar visual. Dari lembar jawaban tampak originalitas berpikir, fleksibelitas dan kelancaran siswa baik dalam memahami persoalan maupun penyelesaiannya. Hasil yang berbeda diperoleh dari siswa berkemampuan rendah. Mereka cenderung mengalami kesulitan dalam memahami permasalahan sehingga banyak terjadi kesalahan-kesalahan di dalam menyelesaikan soal yang tampak dari ketidakmampuan siswa dalam menuliskan data-data yang diketahui dan mengaitkannya dengan fakta lain yang sudah mereka pelajari sehingga aspek kelancaran, fleksebilitas, dan originalitas tidak muncul di dalam jawaban mereka.

Kata kunci: Matematisasi, Kreativitas, Pemecahan Masalah, Non-Rutin

How to Cite: Arifin, S., Zulkardi, Putri, R.I.I., & Hartono, Y. (2021). On Creativity through Mathematization in Solving Non-Routine Problems. *Journal on Mathematics Education, 12*(2), 313-330. http://doi.org/10.22342/jme.12.2.13885.313-330

Problem-solving skill is very fundamental in this changing world (Malik, 2018; Nufus, Duskri, &

Bahrun, 2018; Marchetti, 2018). The skill plays important roles in the mathematics classroom and a real-world situation. Moreover, to solve mathematical problems, students are frequently demanded to be creative and use various strategies. Therefore, creativity is an important skill to develop (Puccio, 2017). Problem-solving skill is one reason why these two competencies become the focus of mathematics curriculum in Indonesia. The focus of mathematics class in Indonesia is to develop competencies based on non-routine, open, and real-world problems (Cai & Ding, 2015; Maulana & Yuniawati, 2018; Chong, Shahrill, Putri, & Zulkardi, 2018; Minarni, Napitupulu, & Husein, 2016).

The problem-solving ability is related to solving non-routine problems (Celebioglu, Yazgan, & Ezentas, 2010). Non-routine problems refer to things challenging and encouraging students to use different heuristic approaches in their solution (Dendane, 2009, Heffernan & Teufel, 2018; Sudia & Lambertus, 2017). Therefore, the solution process needs mental and intellectual processes to find solutions based on accurate data and information and drawing precise and accurate conclusions. These complex situations often cause students to solve non-routine problems difficultly (Murdiyani, 2018; Hartono, 2014).

Problem-solving has six principles. First, successful problem-solving can be achieved if the idea of the problem is recognized (Carson, 2007). Second, problem-solving uses existing data or information (Csapó & Funke, 2017). Third, the starting point of problem-solving is to discover possible solutions (Fischer, Greiff, & Funke, 2012). Fourth, realizing the core of the problem comes before trying to solve it. Fifth, ideas that create innovation should be separated from the process of evaluating ideas because the evaluation process will inhibit the idea creation (Madzík, 2019). Sixth, selected situations should be converted into a problem situation that is sometimes necessarily changed to a choice situation.

When facing a difficult or complex problem, the first step to solve it is to analyze and describe it in simpler ways, such as a sketch or a more detailed paragraph; thus, the problem is more easily solved (Miller & Ranum, 2013). Furthermore, the problem-solving process is continued by looking for some possible ways to finally find the best, most appropriate, and easiest solution (Fischer, Greiff, & Funke, 2012). This process allows students to design a problem-solving strategy that they will utilize during the calculation. The process of problem-solving lets students freely use their ideas or create new ideas without being bound or associated with old ideas (AlMutairi, 2015).

There are four factors influencing problem-solving: motivation, beliefs, habits, and emotions (Ozturk & Guven, 2016). Therefore, the ability to solve problems is measured not only by students' ability to find solutions, but also by the problem-solving process. Students who can solve problems will have understood what they solve and why the solution is chosen. The problem-solving ability is measured and focuses not only on the truth of substantial mathematical solutions and procedures performed but also on the coherence and wrinkling of ideas or mathematical procedures to support these solutions. Related to this, problem-solving is a process of communicating ideas or mathematical thoughts coherently and clearly.

Chamberlin (2010) points out that one of the keys to successfully solve problems is representing the problem correctly. For example, representing all mathematical ideas related to the problem in concisely can more simplify the process, operation, and discovery of the solutions. These steps can be represented in models, schemes, and symbols. In a realistic mathematical view, the process of conveying ideas in models, schemes, and symbolizations is called the mathematization process.

Mathematization is divided into two: horizontal and vertical mathematization. The activities of the horizontal mathematization include (1) identifying specific mathematics in general contexts, (2) scheming, (3) formulating and visualizing problems in different ways, (4) finding relationships, (5) finding regularity, (6) introducing isomorphic aspects in different problems, (7) turning daily problems into mathematical problems, and (8) turning daily problems into a familiar mathematical model. Meanwhile, the activities of vertical mathematization are (1) expressing a relationship in a formula, (2) proving regularity, (3) improving and adjusting the model, (4) using different models, (5) combining and integrating models, (6) formulating a new mathematical concept, and (7) generalizing formal form (Menon, 2013; Loc & Hao, 2016).

The most important aspect of a problem-solving ability needs not only the mastery of factual and procedural knowledge relevant to the problem but also high creativity by noticing the problem from various points of view (Cropley & Cropley, 2009). Creativity will emerge if someone can know the relationship of the existing elements and provide new ideas to create innovation (Diyanni, 2016). On the other hand, creativity is defined as the ability to offer fresh ideas and apply them in problem-solving (Siswono, 2010). Moreover, it can be defined as the ability to combine, solve, or answer problems and reflect creative children's operational abilities in various possible answers or problem-solving based on the provided information, including triggering many ideas for a problem (DeHaan, 2009). Creative thinking and creativity come from sharply thinking with intuition, moving imagination, and uncovering all amazing and inspiring possibilities and new ideas (Barnard & Herbst, 2018). In addition, creativity usually arises because of habits, such as curiosity, enjoyment of asking questions, and constant search for new experiences (Diyanni, 2016).

Three of four Indicators reflecting someone's creativity are fluency, flexibility, and originality (Torrance, 1972; Siswono, 2010). The fluency in thinking is reflected in generating many relevant ideas or answers. Therefore, fluency in thinking is emphasized more on quantity, not quality. Fluency is defined as the ability to produce several ideas and various answers or questions, investigate a problem from different points of view, find alternatives or different directions, and successfully use various approaches or ways of thinking in formulating, demonstrating, and communicating strong mathematical ideas (Tjoe, 2019). The flexibility in thinking is reflected from likely different results of ideas and the ability to change a way or approach of problem-solving quickly. The originality is usually reflected in answers or unusual solutions and the tendency to differ from other students' answers. A student with creativity and the ability to think in high divergence does not have much difficulty in solving problems.

As defined by experts, creativity is always related to thinking and behaving abilities (Starko, 2013). Therefore, to develop their creativity, students need internal and external impulses. The external impulses include tasks and teaching materials that can facilitate students to develop their creativity. The teaching materials with problem-solving questions about everyday life situations or phenomena can develop students' creativity (Novita & Putra, 2016).

Non-routine tasks and problems that are not well-structured refer to activities that potentially develop student's creativity (Novita & Putra, 2016). Thus, creativity in solving mathematical problems can be defined as students' ability to formulate mathematical problems freely, inventively, and currently (Saragih & Habeahan, 2014). The raising ideas result from compiling information and producing divergent answers following the flexibility and fluency concepts that exist in creativity (Benedek, Könen, & Neubauer, 2012). Creativity always involves imagination, intuition, and invention by developing divergent, original, and curious thoughts making predictions and guesses, and likely employing trial and error strategies (Gilhooly, 2016). Many studies in mathematics education (Celebioglu, Yazgan, & Ezentas, 2010; Mabilangan, Limjap, & Belecina, 2011; Villareal, 2014; Yazgan, 2015) have shown that non-routine problems most effectively improve mathematical problem-solving skills.

Moreover, Pitta-Pantazi and Christou (2009) believe that the use of non-routine problems most effectively improves students' mathematical creativity. Yazgan (2015) has analyzed the role of strategy in solving non-routine problems and finds that high ability students' success in solving problems is different from low ability students' success. Another investigation shows that students find solutions when given free will to solve; they employed seven of the eight problem-solving strategies to solve non-routine problems (Mabilangan, Limjap, & Belecina; 2011).

Research related to creative thinking shows that non-routine problems positively influence students' mathematical creativity. The use of non-routine contextual problems potentially affects students' thinking skill improvement in real-life situations. Therefore, this study employed contextual non-routine problems. Based on the description above, it was assumed that the investigation on using non-routine problems in the Palembang context would discover many strategies and representations of solutions to produce positive effects on students' mathematical creativity. Thus, this study aimed to describe and compare the fluency, flexibility, and originality in solving non-routine problems in the Palembang context. This study illustrated the students' creativity from their fluency, flexibility, and originality in making horizontal and vertical mathematization.

METHOD

Design

This study employed a descriptive design because the study aimed to describe the existing phenomena taking place at this time or in the past. Moreover, the study aimed to describe and compare the fluency, flexibility, and originality in solving non-routine problems in the Palembang context. The creativity was reflected in the students' fluency, flexibility, and originality in making horizontal and vertical mathematization.

The research procedure consisted of three stages: the preparation, implementation, and data analysis stages. The preparation stage covered three activities. They were (1) assessing theories and components of creativity to measure students' creativity in solving mathematical problems, (2) arranging non-routine problems in the Palembang context, and (3) preparing interview instruments. This stage was implemented through (1) distributing test questions containing non-routine problems in the Palembang context to students to explore the emergence and forms of horizontal and vertical mathematization, and (2) interviewing the research subjects. Meanwhile, the data analysis stage included (1) data reduction, (2) data presentation, and (3) conclusion.

Subject

The subjects of this study were 30 grade 9.b students of SMP Negeri 3 Palembang. The students' characteristics were categorized as heterogeneous because they consisted of high-ability, moderate-ability, and low-ability students.

Instruments

The data-collecting instruments of this study were tests and interviews. The test consisted of two questions of non-routine problems in the Palembang context. The tests were employed to describe students' creativity and referred to three components: fluency, flexibility, and originality in making horizontal and vertical mathematization in solving non-routine problems in the Palembang context. This study employed a semi-structured interview because the questions could be developed as needed. The interviews aimed to gain more explicit information on the students' creativity in solving mathematical problems, particularly to explore deeper flexibility aspects.

Data Analysis

The data analysis techniques were divided into two parts: data analysis of written test results and data analysis of interview results. The data of written test result were reduced by grouping and separating the boundaries between horizontal and vertical mathematizations and calculating how many students were categorized in each aspect. These aspects are presented in Table 1 and then in tabular forms. The results of the reduced data were employed to describe the students' creativity components, including fluency, flexibility, and originality in horizontal and vertical mathematization.

Meanwhile, the data analysis of the interview began with transcribing the conversations between teachers and students. Next, the transcript was reduced, and each information categorized as important data was selected. The results of this reduction were presented descriptively to juxtapose with the test result data. The conclusion phase was the process of compiling the information obtained from the results of the tests and interviews. Then, all of the data were compared with the theories that form the basis of this study.

Table 1. Creativity Indicators

Creativity Aspects	Description
Fluency	Fluency emphasized the ability to produce several ideas and multiple answers or questions, investigate a problem from different points of view, find alternatives or different directions, and successfully apply various approaches or ways of thinking.
Flexibility	The flexibility in thinking was reflected from the likely different ideas and ability to change the way or approach of problem-solving quickly.
Originality	The originality was usually reflected in the unusual answers or solutions and the tendency to have different answers from other students. A student with creativity and the ability to think in high divergence did not have much difficulty in solving the problems.

RESULTS AND DISCUSSION

Creativity in mathematization means the fluency, flexibility, and authenticity in displaying horizontal and vertical mathematization forms when solving non-routine problems in the Palembang context. Figure 1 shows the problems employed in this study.

Pagoda Roof
(Problem 1)

There is a pagoda on Kemaro Island. When viewed from above, it appears that the roof of the pagoda is an octagonal shape. If the diameter of the lowest floor of the pagoda (on the ground) is 13 m, and the distance of each adjacent octagon is 50 cm, predict the diameter of the pagoda's roof and the area of the pagoda's roof. Explain the strategy you use!

Monpera
(Problem 2)

Monpera consists of eight floors. The five lower floors are filled and turned into a museum. The museum has various collections serving as the witness to the five-day-and-five-night war in Palembang. On the 1st floor, there is a collection of weapons. On the 2nd floor, there are various documents and photos of the war period. On the 3rd floor, there is a collection of old money. Meanwhile, on the 4th and 5th floors, there are statues and clothes of the heroes. If the Monpera officers want to rearrange all the existing collections by placing them on different floors, determine how many possible ways the officers can organize the collections.

Figure 1. Non-Routine Problems in the Palembang Context

The fluency was shown by the students' ability to produce several ideas and various answers or questions, investigate a problem from different points of view, find alternatives or different directions, and successfully apply various approaches or ways of thinking. Flexibility was illustrated by the students' ability to display other forms or strategies. Meanwhile, the originality was seen from the peculiarities in the students' answers. This study presented fluency, flexibility, and originality when the students transformed real-world problems into mathematical symbols and changed symbols to other more abstract mathematical symbols. The test obtained the data as presented in Table 2.

Table 2. Fluency, Flexibility and Originality

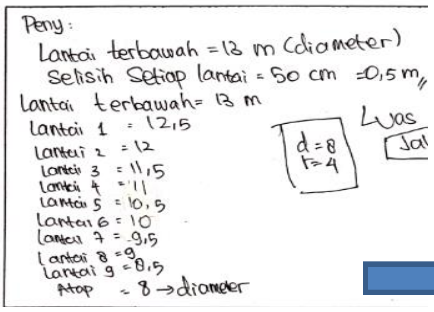
Problem	Horizontal Mathematization			Vertical Mathematization		
	Fluency	Flexibility	Originality	Fluency	Flexibility	Originality
1	7	5	4	7	3	3
2	14	14	4	14	10	4

Horizontal Mathematization on the First Problem

Table 2 shows that seven students are categorized as fluent in performing the horizontal mathematization. They were fluent in identifying aspects of mathematics in context, making schematics, formulating problems to other forms, visualizing problems, seeking connection of information, finding regularity, turning everyday problems into mathematical symbols, or changing everyday problems into a known mathematical model. Some of the students' answers are presented in Figure 2.

Moreover, Table 2 presents that the students' horizontal mathematization forms vary. The first type was visualizing form. The second type was written in numbers 1, 2, up to 9 to indicate that there were nine floors in the building. The written numbers 13 m, 12.5 m, etc., were to mark the diameters. The third type was sketch and numbers.

The interview results showed that the students confidently wrote their answers. Besides answering the question correctly, they did not do any streaks or other forms of correction. The test results showed that the other students' answers were also relatively similar to the first type.



Type 1

Solution:

Ground (lowest floor) = 13 m (diameter)

difference of floors = 50 cm = 0.5 m

Ground (lowest floor) = 13 m

1st Floor = 12.5

2nd Floor = 12

3th Floor =11.5

4th Floor =11

5th Floor =10.5

6th Floor =10

7th Floor = 9.5

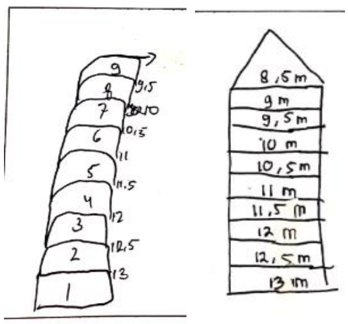
8th Floor =9

9th Floor = 8.5

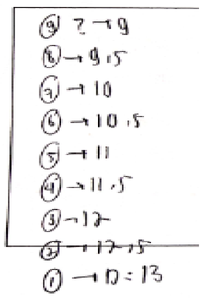
Roof = 8 (diameter)

d = 8
r =4

Type 1



Type 2



Type 3

Figure 2. Students' Answers on Horizontal Mathematization

This study explored flexibility during the interview. In addition to telling the solutions written on the answer sheet, the students were also delivered other strategies possibly applied to answer the first problem.

Researcher : *Can you explain this answer? (pointing SA's solution of problem 1)*

SA : *There are nine floors, and each consecutive floor has a 0.5 m difference, so I make this detailed floor because I don't know any specific formula for this problem.*

Researcher	:	*Interesting. What do you mean by specific formula?*
SA	:	*I think there must be some formulas for this problem. But I don't know. Maybe not (looking hasitate).*
Researcher	:	*Very well. Do you think you can apply other strategies, besides your answer?*
SA	:	*hmmm… I don't know. hmmm… I'll try. (SA wrote the solution on the paper. She drew a picture to help her explain the problem). What about this? (showing her work)*
Researcher	:	*Very good. Can you explain?*
SA	:	*Because the pagoda is an octagon, so I drew some octagons with their respective measures. Hence, it's going to be easier for me to calculate.*

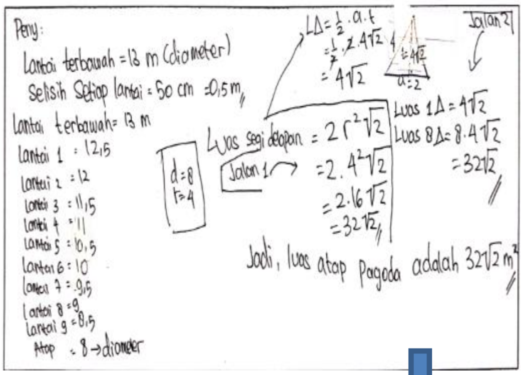
The results of the interviews showed that only high-ability students could display horizontal mathematization in other forms. Another alternative strategy demonstrated by SA showed one of the forms as presented in Figure 2. The students' answer sheets revealed that only five students were categorized as flexible.

The originality in horizontal mathematization was depicted from the students' unique representation form. Producing unique answers considered as an original form is indeed quite complex. The originality of the students' written answers was seen from their distinctive answer forms (once the student's answer was totally or nearly similar to that of other students). This phenomenon indicated that there was little difference in the students' answers.

Vertical Mathematization in the First Problem

Fluency in vertical mathematization forms were characterized by the students' ability to produce several ideas and various answers or questions, investigate a problem from different points of view, find alternatives or different directions, and successfully apply various approaches or ways of thinking. The students' fluency was discovered from their ability to write mathematical symbols and the mastery of applying mathematical concepts and procedures for changing one symbol into another more abstract mathematical symbol. Specifically, fluency in a verbal-mathematical form was illustrated by the students' ability to express a relationship in a formula, show the regularity of using different models, combine and integrate models, and generalize to formal form. Moreover, the students' fluency was also discovered from the detailed strategy described in each step.

This study revealed that there were three levels of vertical mathematization. The first level showed fluency and proficiency in expressing the concept of diameter, radius, and the application of an octagon as a sum of eight triangles. The second level showed using incompleteness and wrong concepts caused wrong assumptions. The third level showed the absence of sufficient concept knowledge caused a fatal mistake. During the interview, the students were asked to think of other strategies possibly applied to answer the first problem. The interview results found that only three students could display another vertical mathematization form while the others did not have another idea to solve this problem. These results are presented in Figure 3.



Solution:

Ground (lowest floor) = 13 m (diameter)

difference of floors = 50 cm = 0.5 m

Ground (lowewt floor) = 13 m

1st Floor = 12.5

2nd Floor = 12

3th Floor =11.5

4th Floor =11

5th Floor =10.5

6th Floor =10

7th Floor = 9.5

8th Floor =9

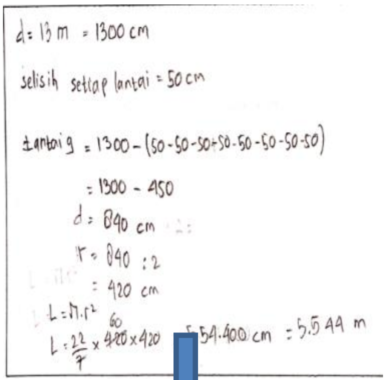
9th Floor = 8.5

Roof = 8 (diameter)

d = 8
r =4

Area triangle $= \frac{1}{2}.a.t$
$= \frac{1}{2}.2.4\sqrt{2}$
$= 4\sqrt{2}$
Area one triagle = $4\sqrt{2}$
Area 8 triagle = $8.4\sqrt{2}$
$= 32\sqrt{2}$
Octagonal area is $32\sqrt{2}$ m^2.

Type 1



d = 13 m = 1300 cm

difference of floors = 50 cm

9th Floor = 1300 - (50 – 50 - 50 – 50 -50 – 50 – 50 - 50)

= 1300 – 450

d = 840 cm

r = 840 : 2

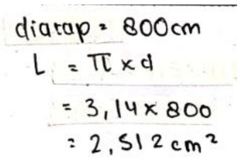
= 420 cm

L = π. r^2

L $= \frac{22}{7} x420x420$ = 554.400 cm

= 5.544 m

Type 2



On roof = 800 cm

L = π x d

= 3.14 x 800

= 2.512 cm^2

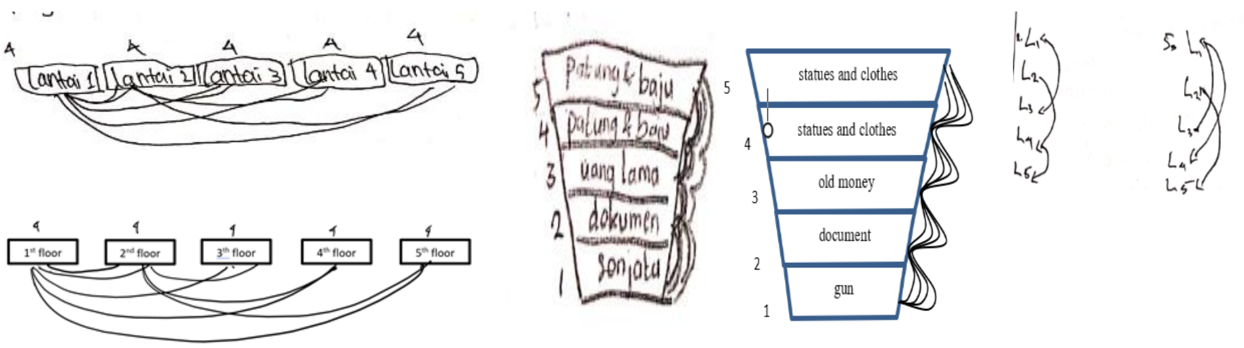
Type 3

Figure 3. Students' Answers to the Vertical Mathematization

The originality in horizontal mathematization forms was drawn from the students' unique form of representation. Producing a unique answer is indeed difficult because the vertical mathematization forms contained the use of concepts, procedures, and other mathematical operations. However, if the students could show distinctively different use of symbols and change them into other forms, their answers were categorized as original. This study revealed that only three students could deliver original answers.

Horizontal Mathematization on the Second Problem

The students applied the same method as that in the first problem to solve the second problem. This study revealed three types of horizontal mathematization. The first type was visualizing a problem using a rectangle. The second type is applying visualization sightly different from the three images made. This type utilized the visualizing shape as five floors. The third type did not apply shape as horizontal mathematization. The curved lines represented the movement from one floor to another. The horizontal mathematization is shown in Figure 4.



Type 1 Type 2 Type 3

Figure 4. Horizontal Mathematization on the Second Problem

The flexibility was explored during the interview. In addition to telling the solution written on the answer sheets, the students delivered other strategies possibly used to answer the second problem.

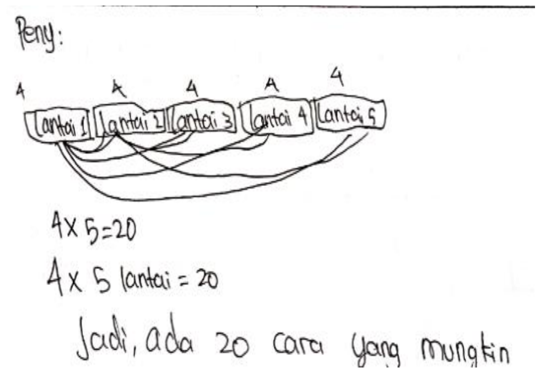
Researcher	:	*Can you explain this form? (pointing at student's graphic, type 1). Because I think this is really interesting.*
JM	:	*well, for example, they want to move the weapons from the 1st floor. Then it is up to them to move the weapons either to the 2nd, 3rd, 4th, or 5th floor, right? Then these lines represent the movements. And these lines are similar in other cases.*
Researcher	:	*What about the 4th and 5th floor? Why is there no line between them?*
JM	:	*Because they contain the same thing.*
Researcher	:	*I see. Besides this answer, do you think you can use another strategy to solve the problem?*
JM	:	*I think I can. (started to write down another strategy).*

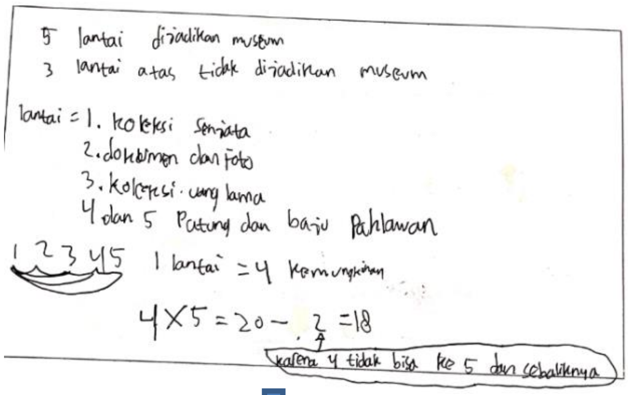
The interviews and answer sheets revealed that 14 students could display horizontal mathematization form in other forms. Although they could make other alternative strategies, they still led to draw one of the forms as shown in Figure 4.

The originality in horizontal mathematization forms was drawn from the students' unique form of representation. Producing unique answers considered as the original form is quite difficult. The students' written answers discovered that the originality was derived from the not common form. This phenomenon indicated that there was a little difference in the students' answers. The students' answer sheets discovered only four students were categorized as original.

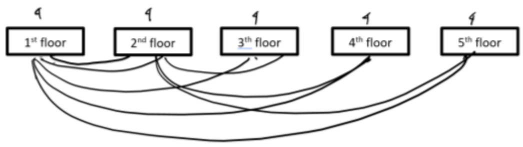
Vertical Mathematization on the Second Problem

The fluency was discovered from the ability to write mathematical symbols and mastery of applying mathematical concepts and procedures for changing one symbol into another more abstract mathematical symbol. The students only applied two nearly similar strategies to solve the second problem (see Figure 5). However, only a few students applied mathematical symbols and operations to solve the second problem.





Solution:



4 x 5 = 20

4 x 5 floor = 20

So, there are 20 possible ways

5 floors as museum

3 floors not as museum

1st Floor = gun collection

2nd Floor = document and photo collection

3th Floor = old money collection

4th and 5th = statue and clothes of heroes

1 floor = 4 possibility

4 x 5 = 20 – 2 = 18

Because 4 cannot move to 5 and the opposite applies

Type 1 Type 2

Figure 5. Vertical Mathematization on the Second Problem

The analysis revealed 14 students were categorized as fluent in operating vertical mathematization forms. Meanwhile, the interviews discovered that ten students were categorized as flexible. They generally stated that they applied the form of '4 + 4 + 4 + 4 + 4' for two reasons. First, one floor had four-item possibilities to fill. Second, because the Monpera building has five floors to reorganize, the students used the '4 + 4 + 4 + 4 + 4' strategy (see Figure 5). The second problem was the most difficult one to determine the originality in vertical mathematization forms because almost all of the students likely applied identical strategy to answer the problem. During the interview, the students stated that the second problem was not too complicated even though some deception elements were found.

The main objective of this study was to describe the students' creativity in solving the non-routine problems. The results of this study implied that the non-routine problems in the Palembang context could be solved not only by high-ability students but also by medium and low-ability students. High-ability students likely applied short strategies and directly used formal mathematical symbols. This finding agrees with Minarni, Napitupulu, and Husein (2016), who suggest that students with formal understanding likely employed symbols to represent mathematics. Students who were fluent in vertical mathematization were automatically fluent in the horizontal mathematization form. This finding agrees with Siswono (2010), stating that people's ability to think creatively is higher if they can show many possible answers for a problem. Moreover, they can process knowledge better than others, combine their ideas, and create ideas from the knowledge they have learned. This study discovered that high-ability students tend to be more flexible than moderate-ability students. However, they likely displayed not original answers. This finding agrees with Siswono (2010), who opines that students' capability to math subject can solve problems clearly but are unable to use more than one alternative solution and do not provide an element of novelty.

The students employed their strategies and likely started with informal forms, such as describing the situation of the problem in the horizontal mathematization form. This finding agrees with Arcavi (2005) pointing out that students used informal forms, such as pictures and schemes, as an effort to understand a problem. The students were fluent in horizontal mathematization forms but not in vertical mathematization one. They could understand the problem but are confused in choosing and using the procedures. This finding agrees with Yimer and Ellerton (2009) assert that many students can understand a problem but lack the skills to create procedures that will guide them to the right direction. The moderate-ability students in this study displayed fluency, flexibility, and originality. This phenomenon agrees with Siswono (2010), stating that creative thinking has two assumptions. First, everyone can be creative to a certain degree in a certain way. Second, the ability to think creatively is a learnable skill. In other words, each individual has a different creativity degree and distinctive way to realize their creativity. When someone can have the ability (higher or lower degree) to produce new work according to their fields, he is considered as creative.

Meanwhile, the moderate-ability students could understand problems but did not know what procedures they had to apply to solve the problems. This finding agrees with Tambychik and Meerah (2010) pointing out that students who lack heuristic knowledge in problem-solving will have difficulty solving mathematical problems and providing incorrect answers, conclusions, and recommendations. Moreover, some of them cannot get points because they fail to find the correct answers for some problems and difficultly estimate the solution to the problems. İncebacak and Ersoy (2016) state that such failures result from the fact that the students do not have enough knowledge to solve problems. Moreover, their solutions seem incomplete and unclear. Dendane (2009) emphasizes that students should learn mathematical contents and the use of mathematical contents to develop thinking skills and solve mathematical problems.

CONCLUSIONS

The high-ability students had the most fluent and flexible solving-problem skills. However, they provided less genuine-solutions and likely used formal mathematics in formulas, symbols, and mathematical operations. Meanwhile, moderate-ability students tended to start their work by simplifying problems and displaying them in visual images. Their answer sheets presented their originality of thinking, flexibility, and fluency in understanding the problems and solutions. Meanwhile, the low-ability students had difficulties understanding problems. Moreover, they created many errors when solving the problems because they could not write the familiar data and relate them to other facts they had already learned. Consequently, their answers did not represent the aspects of fluency, flexibility, and originality.

ACKNOWLEDGMENTS

We deeply express our gratitude to the Rector of Universitas Islam Negeri Raden Fatah Palembang and the Dean of the Teacher Training and Education Faculty who funded and supported this study. We also express our gratitude to the principal, teachers, and students of SMP Negeri 3 Palembang for providing the research site.

REFERENCES

AlMutairi, A. N. M. (2015). The Effect of Using Brainstorming Strategy in Developing Creative Problem-Solving Skills among Male Students in Kuwait: A Field Study on Saud Al-Kharji School in Kuwait City. *Journal of Education and Practice*, *6*(3), 136-145. https://files.eric.ed.gov/fulltext/EJ1083780.pdf

Arcavi, A. (2005). Developing and using symbol sense in mathematics. *For the Learning of Mathematics*, *25*(2), 42-47. https://flm-journal.org/Articles/4B432EC08630646B693621E55ECA5C.pdf

Barnard, & Herbst. (2018). Entrepreneurship, Innovation and Creativity: *The Creative Process of Entrepreneurs and Innovator*. http://dx.doi.org/10.2139/ssrn.3195912

Benedek, M., Könen, T., & Neubauer, A. C. (2012). Associative abilities underlying creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(3), 273–281. https://doi.org/10.1037/a0027059

Cai, J & Ding, M. (2015). On mathematical understanding: perspectives of experienced Chinese mathematics teachers. *Journal of Mathematics Teacher Eduacation*, *18*(5), 5-29. http://dx.doi.org/10.1007/s10857-015-9325-8

Carson, J. (2007). A Problem with Problem Solving: Teaching Thinking without Teaching Knowledge. *The Mathematics Educator*, *17*(2), 7-14. https://ojs01.galib.uga.edu/tme/article/view/1912

Celebioglu, B, Yazgan, Y & Ezentas, R. (2010). Usage of non-routine problem-solving strategies at first grade level. *Procedia - Social and Behavioral Sciences*, *2*(2), 2968–2974. https://doi.org/10.1016/j.sbspro.2010.03.449

Chamberlin, S. A. (2010). Mathematical problems that optimize learning for academically advanced students in grades K-6. *Journal of Advanced Academics*, *22*(1), 52–76. https://doi.org/10.1177/1932202X1002200103

Chong, M. S. F, Shahrill, M, Putri, R. I. I, & Zulkardi. (2018). Teaching Problem Solving Using Non-Routine Tasks. *AIP Conference Proceedings*, *1952*(1), 020020. http://dx.doi.org/10.1063/1.5031982

Cropley, A., & Cropley, D. (2009). *Fostering creativity: A diagnostic approach for education and organizations*. Cresskill, NJ: Hampton Press.

Csapó, B. & Funke, J. (Eds.) (2017). The Nature of Problem Solving. *Using research to inspire 21st century learning*. Paris: OECD Publishing.

DeHaan, R. L. (2009) Teaching creativity and inventive problem solving in science. *CBE Life Science Education*, *8*(3), 172–181. https://doi.org/10.1187/cbe.08-12-0081

Dendane, A. (2009) *Skills Needed for Mathematical Problem Solving*, [Online], Available: http://www.analyzemath.com/ math_problems/paper_7.html

Diyanni, R. (2016). *Critical and Creative Thinking*: *A Brief Guide for Teachers*. West Sussex: John Wiley & Sons, Inc. https://download.e-bookshelf.de/download/0003/6422/56/L-G-0003642256-0007213179.pdf

Fischer, A., Greiff, S., & Funke, J. (2012). The process of solving complex problems. Journal of Problem Solving, *4*(1), 19-42. http://hdl.handle.net/10993/3184

Gilhooly, K. J. (2016). Incubation and Intuition in Creative Problem Solving. *Frontiers in Psychology*, *7*, 1076. https://doi.org/10.3389/fpsyg.2016.01076

Hartono, Y. (2014). *Problem Solving Strategy* [in Bahasa]. Yogyakarta: Graha Ilmu.

Heffernan, K., & Teufel, S. (2018). Identifying Problems and Solutions in Scientific Text. *Scientometrics*, *116*, 1367–1382. https://doi.org/10.1007/s11192-018-2718-6

İncebacak, B. B., & Ersoy, E. (2016). Problem Solving Skills of Secondary School Students. *China-USA Business Review*, *15*(6), 275-285. https://doi.org/10.17265/1537-1514/2016.06.002

Loc, N. P., & Hao, M. H. (2016). Teaching Mathematics Based On “Mathematization” of Theory of Realistic Mathematics Education: A Study of the Linear Fungtion Y=Ax+B. *The International Journal of Engineering and Science (IJES)*, *5*(6). 20-23. http://www.theijes.com/papers/v5-i6/D050602023.pdf

Mabilangan, R. A., Limjap, A. A., & Belecina, R. R. (2011). Problem solving strategies of high school students on non-routine problems: A case study. *Alipato: A Journal of Basic Education*, *5*, 23-46. https://www.journals.upd.edu.ph/index.php/ali/article/download/2759/2580

Madzík, P. (2019) Capture and evaluation of innovative ideas in early stages of product development. *TQM* J, *31*(6), 908–927. https://doi.org/10.1108/TQM-02-2019-0050

Malik, R. S. (2018). Educational Challenges In 21 St Century and Sustainable Development. *Journal of Sustainable Development Education and Research*, *2*(1), 9-20. https://doi.org/10.17509/jsder.v2i1.12266

Maulana, F., & Yuniawati, N. T. (2018). Students' Problem-Solving Ability in Non-routine Geometry Problem. *International Journal of Information and Education Technology*, *8*(9), 661-667. http://www.ijiet.org/vol8/1118-SK012.pdf

Marchetti, G. (2018) Consciousness: a unique way of processing information. *Cognitive Processing*, *19,* 435–464 (2018). https://doi.org/10.1007/s10339-018-0855-8

Menon, U. (2013). Mathematization – Vertical and Horizontal. Conference: epiSTEME 5 International Conference to Review Research on Science, Technology and Mathematics Education, *Conference Proceedings*., At Mumbai, India. http://episteme.hbcse.tifr.res.in/index.php/episteme5/5/paper/view/168/52

Miller, B., & Ranum, D. (2013) *Problem solving with algorithms and data structures*, 3rd edn. Franklin: Beedle & Associates.

Minarni, A., Napitupulu, E. E., & Husein, R. (2016). Mathematical understanding and representation ability of public junior high school in north sumatra. *Journal on Mathematics Education*, *7*(1), 43-56. http://dx.doi.org/10.22342/jme.7.1.2816.43-56

Murdiyani, N. M. (2018). Developing non-routine problems for assessing students' mathematical literacy. *Journal of Physics: Conference Series*, *983*(1), 012115. https://doi.org/10.1088/1742-6596/983/1/012115

Novita, R., & Putra, M. (2016). Using task like PISA's problem to support student's creativity in mathematics. *Journal on Mathematics Education*, *7*(1), 31-42. https://doi.org/10.22342/jme.7.1.2815.31-42

Nufus, H., Duskri, M., & Bahrun. (2018). Mathematical creative thinking and student self-confidence in the challenge-based learning approach. *Journal of Research and Advances in Mathematics Education*, *3*(2), 57-68. https://doi.org/10.23917/jramathedu.v3i2.6367

Ozturk, T., & Guven, B. (2016). Evaluating Students' Beliefs in Problem Solving Process: A Case Study. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(2), 411–429. https://doi.org/10.12973/eurasia.2016.1208a

Pitta-Pantazi, D., & Christou, C. (2009). Cognitive Styles, Dynamic Geometry and Measurement Performance. *Educational Studies in Mathematics*, *70*(1), 5-26. https://doi.org/10.1007/s10649-008-9139-z

Puccio, G. (2017). From the dawn of humanity to the 21st century: Creativity as an enduring survival skill. *The Journal of Creative Behavior*, *51*(4), 330-334. https://doi.org/10.1002/jocb.203

Saragih, S., & Habeahan, W. L. (2014). The Improving of Problem-Solving Ability and Students' Creativity Mathematical by Using Problem Based Learning in SMP Negeri 2 Siantar. *Journal of*

Education and Practice, *5*(35), 123-132. https://www.iiste.org/Journals/index.php/JEP/article/viewFile/17463/17722

Siswono, T. Y. E. (2010). Levelling students’ creative thinking in solving and posing mathematical problem. *Journal on Mathematics Education*, *1*(1), 17–40. https://doi.org/10.22342/jme.1.1.794.17-40

Starko, A. J. (2013). *Creativity in the classroom: Schools of curious delight*. Mahwah, NJ: Lawrence Erlbaum.

Sudia, M., & Lambertus. (2017). Profile of High School Student Mathematical Reasoning to Solve the Problem Mathematical Viewed from Cognitive Style. *International Journal of Education and Research*, *5*(6), 163-174. https://www.ijern.com/journal/2017/June-2017/14.pdf

Tambychik, T., & Meerah, T. S. M. (2010). Students’ Difficulties in Mathematics Problem-Solving: What do they Say? *Procedia - Social and Behavioral Sciences*, *8*, 142–151. https://doi.org/10.1016/j.sbspro.2010.12.020

Tjoe, H. (2019). “Looking Back” to Solve Differently: Familiarity, Fluency, and Flexibility. In P. Liljedahl, & M. Santos-Trigo (Eds). *Mathematical Problem Solving*. *ICME-13 Monographs* (pp. 3-20). Cham: Springer. https://doi.org/10.1007/978-3-030-10472-6_1

Torrance, E. P. (1972). Predictive validity of the Torrance Tests of Creative Thinking. *The Journal of Creative Behavior*, *6*(4), 236–252. https://doi.org/10.1002/j.2162-6057.1972.tb00936.x

Villareal, I. (2014). Heuristics in solving non-routine problems of selected students in a city science high school. *Master’s Thesis*. Manila: Philippine Normal University.

Yimer, A., & Ellerton, N. F. (2009). Cognitive and Metacognitive Aspects of Mathematical Problem Solving: An Emerging Model. *Identities, Cultures, and Learning Spaces*, 575-582. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=736B460ACDD8EADC7F5BE63B11DA5704?doi=10.1.1.554.9923&rep=rep1&type=pdf

Yazgan, Y. (2015). Sixth graders and non-routine problems: Which strategies are decisive for success? *Educational Research and Reviews*, *10*(13), 1807-1816. https://doi.org/10.5897/ERR2015.2230