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Mathematical Problem-Solving Skills in Solving PISA Model Questions on Space Content for Prospective Teacher Students

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Abstract: This research aims to identify and describe the mathematical problem-solving abilities of prospective mathematics teacher students in solving PISA model questions related to space content at levels 4, 5, and 6. The approach used is a qualitative research approach. The subjects of this study are mathematics education students who are currently enrolled in the Mathematics Education Study Program at Tanjungpura University, classes VA1 and VA2, totaling 19 were test takers and, and 6 of them were interviewed. The data collection tools descriptive tests in the form of PISA model questions related to space content at levels 4, 5, and 6.The data analysis technique employed is Miles and Huberman's data analysis technique, which includes data reduction, data presentation, and conclusion drawing. The research results indicate the mathematical problem-solving ability of prospective mathematics teacher students in solving PISA model questions in the space content at levels 4, 5, and 6 achieved an overall percentage of 61.99% in the medium category. The achievement percentages at levels 4, 5, and 6 were 82.89% in the high category, 65.35% in the medium category, and 37.72% Students needs to be an adaptation in solving PISA by using good and systematic mathematical problem-solving stages.

Keywords: Mathematical; Problem solving skills; PISA; Space content

Introduction

Problem-solving skills are part of 21st century skills known as critical thinking and problemsolving skills (Trilling & Fadel, 2009). This ability is expected to help individuals in facing various problems now and in the future (Kurniawati et al., 2019). The aspect of the problem that cannot be separated from the ability to solve problems is the aspect of education. In education, problem solving ability is one of the goals to be achieved in the learning process based on curriculum components (Cahyani & Setyawati, 2017). More specifically, problem solving ability is included in the competencies to be achieved in the school mathematics curriculum (Cahyani & Setyawati, 2017; Vicente et al., 2022). Thus, problem solving ability in the process of learning mathematics is known as mathematical problem solving ability.

In relation to this, mathematical problem solving ability has an important role for mathematics learning in the interpretation of goals, processes, and skills (Netriwati, 2016; Roebyanto & Harmini, 2017; Maftukhah, 2018; Ningsih, 2018). Furthermore et al. (2022) argued that mathematical problem-solving ability is an important part of mathematics learning because in this ability there is a meaningful application. Meaningful application of mathematical problem solving skills can encourage the formation of thinking power, the creation of intellectual abilities, and familiarising students in dealing with problems, as well as a means of connecting the learning process of mathematics with everyday life (Kurino, 2018). Through this application, students are directed to be able to determine the solution of various

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problems, including problems that cannot be achieved with routine steps, but need more processes in the form of non-routine steps (Polya, 1973; Agustami et al., 2021). In addition, it requires a process of combining aspects of students' knowledge and skills that have been previously obtained so that their mathematical problem solving abilities can be well formed (Rusdianti, 2020). Therefore, good cooperation between students and teachers is needed in the learning process so that students' mathematical problem solving skills can be well trained in dealing with a variety of problems, both in learning and complex real life (Kurniawati et al., 2019).

The National Research Council (USA) even identified problem-solving skills as one of the crucial 21st century skills. In this regard, mathematical problem solving skills should be instilled and familiarised in prospective teacher students (Dewi, 2013). This can happen because problem solving skills are the main focus in learning mathematics at the university level (Samo, 2017). There needs to be a self-preparation process to develop this ability so that students can face various problems that are not only related to mathematics, but related to other fields of knowledge and daily life (Ningsih, 2017; Sumarni et al., 2019; Anisah et al., 2019). This preparation is intended as a form of responsibility for students who will become prospective teachers in the future to be able to shape and guide students' mathematical problem solving skills properly (Triyani & Pujiastuti, 2020).

Furthermore, the formation of mathematical problem solving skills in students can be measured by working on contextual-based problems (Zubaidah, 2017). One of the international assessments that is a means of assessing mathematical problem solving ability on these contextual questions is the Programme for International Student Assessment (PISA) (Sari et al., 2020). Students who are the target of PISA implementation are students aged 15 years. PISA questions are designed in the context of everyday life, so students are challenged to apply mathematical knowledge in real situations, not just answer routine questions. This reflects the problem-solving skills that are essential in modern life PISA assesses the extent to which 15-year-old students can apply their knowledge and skills to real-life problems and situations, not just textbook exercises (OECD, 2019). The PISA model does not only measure memorization or algorithmic procedures, but demands the ability to think critically, reason, and solve complex problems. This is very important in the development of 21st century competencies. Tasks in PISA are designed to require students to transfer and apply their knowledge to unfamiliar problems" (Stacey, 2011).

PISA is carried out every three years to each country in the world that is incorporated into PISA participants. One of the countries is Indonesia. Indonesia has been a PISA participant from 2000 until the last year of implementation in 2018 (Lessy, 2022). Indonesia's involvement in the PISA test is to find out how far the achievements of Indonesian students in reading, mathematics, and science when compared to other world countries. Furthermore, Indonesian students who are 15 years old as the target of PISA implementation are students who are in junior high school and senior high school (Suprayitno, 2019). From the seven periods of Indonesia's participation in the implementation of PISA, the achievements of Indonesian students in the field of mathematics can be seen in the table 1.

Table 1. Indonesia's PISA Results in Mathematics (OECD, 2019)

Year	Average Score Indonesia	Average International Score	Indonesia Ranking	Participants
2000	367	500	39	41 Countries
2003	360	500	38	40 Countries
2006	391	500	50	57 Countries
2009	371	496	61	65 Countries
2012	375	494	64	65 Countries
2015	386	490	63	72 Countries
2018	379	489	73	79 Countries

Based on table 1, it can be seen that the average PISA achievement by Indonesian students in the field of Mathematics is still low from the average international score and still puts Indonesia at the bottom level when compared to other countries, such as Singapore, Malaysia, and Brunei Darussalam (OECD, 2019). Purnomo et al. (2015) stated that the factor causing the low PISA results in Indonesia in mathematics is due to the lack of practice for students in solving various PISA-based problems that require the process of mathematical problem solving skills in it. This can be seen in the process of learning mathematics in Indonesia where students are only fixated on the delivery given by the teacher, without developing their abilities to the application stage as a form of follow-up to the understanding they have gained.

In relation to the mathematics assessment carried out by PISA, OECD describes the level of mathematical

ability from level 1 to level 6 and the content of the material tested consists of four main contents, namely change and relationship, space and shape, quantity, and uncertainty and data. In PISA 2012, the space and shape content is the content that has low achievement compared to other contents (Purnomo, 2016). Most students were only able to reach level 3 and very few of the students were able to reach level 4 and 5. In fact, there were no students who were able to reach the highest level, namely level 6 in the PISA level. Based on this, it can be concluded that the thinking ability of Indonesian students is still in the low category. This is supported by the statements of Setiawan et al. (2014) and Dinni (2018) which state that levels 1 to 3 of PISA are classified as Low Order Thinking Skill (LOTS) levels while levels 4 to 6 of PISA are classified as High Order Thinking Skill (HOTS). Therefore, this study will examine in depth the space and shape content at level 4 to level 6, especially on space content.

Space and shape content is one of the important materials for students to learn because this content tests the ability of students to recognise shapes, find similarities or differences from various dimensions and representations of shapes, and recognise the characteristics of an object related to its position (Oktaviana, 2017). More specifically, the space and shape content is related to a pattern, the nature of the object, the position of the object, and the representation of the object in a real form. Based on this, the space and shape content is related to geometry material studied in mathematics learning at school. Thus, mastery of space and shape content becomes something fundamental to be instilled in students because many applications of geometry are used in other mathematical materials, such as algebraic materials, calculus materials, and arithmetic materials that require support from mastery of this space and shape content material. This statement is supported by Van De Walle (2008) who states that it is important to learn geometry material because the exploration contained in geometry has a major role in other mathematical materials. Furthermore, Van De Walle (2008) also states that geometry material is important to learn because in everyday life there are many applications of shape and space and there is a challenge in learning the material. In addition, through learning geometry can encourage the formation of abilities owned by students, one of which is the ability to solve mathematical problems (Kennedy, 2008).

The importance of mastering geometry material on the content of space and shape is supported by the Indonesian education curriculum which compiles geometry material coherently based on the cognitive level of students. This can be seen in the arrangement of geometry materials at the level of education in which the shape material focus taught at the level of Junior High School (SMP) equivalent and space material began to be taught at the level of Junior High School (SMP) equivalent and refocused at the level of Senior High School (SMA) equivalent. Geometry material on the space content studied at the junior high school level includes flat-sided spaces and curved-sided spaces. Meanwhile, the geometry material in the space content studied at the Senior High School level includes the third dimension. However, in the implementation there are obstacles for students in learning this space content. These obstacles occur because in solving geometry problems required the ability to visualise or represent the right and accurate to the abstract objects contained in the problem. This is in line with the opinion of Sulistiowati et al. (2019) which states that in solving problems in geometry material students tend to have difficulty in understanding the given problem, determining the appropriate solution and connecting geometry concepts with the appropriate solution steps.

Furthermore, to find out the ability of prospective mathematics teacher students in solving PISA questions on the content of space, the researchers conducted a pre-run to 4 students of the 3rd semester of Mathematics Education at FKIP Tanjungpura University. The pre-test was conducted on 8 September 2022 by giving 2 PISA questions in 2012 that have different levels of difficulty. The results obtained from the pre-research were that in solving problem number 1 there was one subject who could not answer the question correctly, while problem number 2 with a higher level of difficulty obtained that all subjects could not answer the question correctly.

In addition, the researcher also conducted interviews with students who were the subjects of the pre-research. Based on these interviews, information was obtained that question number 1, pre-recess subjects generally did not experience difficulties, but there was one subject who made a mistake due to not being careful in analysing the image in the problem. Whereas in problem number 2, pre-research subjects generally had difficulty in determining the strategy that must be done to determine the components that would be used to calculate the volume of the beam being sought, especially in determining the height of the beam. The difficulty in determining the strategy resulted in the pre-test subjects not being able to use the correct concept in solving the problem.

Based on this, the researcher realises that there is a need for an in-depth study of the mathematical problem solving skills of prospective mathematics teachers as an evaluation material as well as self-preparation in carrying out their profession as prospective teachers later to transfer mathematical problem solving skills to students by getting used to studying PISA model questions so that the mathematical problem solving skills of students are equivalent to other world countries.

Research that is relevant to this study is as follows. First, research conducted by Sulastri et al. (2014) on the ability of mathematics education students in solving PISA Most Difficult Level questions. The results showed that students' ability to solve PISA questions was still lacking. 14.3% of students were able to solve PISA questions correctly, 42.85% of students were able to solve PISA questions but less precise and 42.86% of students were unable to solve PISA questions. Second, research conducted by Jamco (2022) on the mathematical problem solving ability of mathematics education students at Sanata Dharma University in solving PISA-type questions on uncertainty and data content. The results showed that the mathematical problem solving ability of mathematics education students at Sanata Dharma University with an average of 50.00 was in the insufficient category with the achievement of IDEAL problem solving ability indicators, namely 32% of students were able to fulfil the problem identification stage, 10% of students were able to fulfil the stage of determining goals, 95% of students were able to fulfil the stage of determining emerging strategies, 94% of students were able to fulfil the stage of implementing strategies, and 50% of students were able to fulfil the stage of evaluating results and checking back. Third, research conducted by Novitasari (2019) on students' mathematical problem solving ability on space and shape content. The results showed that students in the high category were able to understand the problem and plan a solution, students in the medium category were able to understand the problem and students in the low category were unable to fulfil all problem solving indicators.

Based on the description that has been presented about the PISA test as one of the main assessments to measure the mathematical problem solving skills possessed by students, the low mathematical problem solving skills possessed by students, the importance of space content in mathematics material and in its application in everyday life and the influence of teacher ability on the ability of students, the researcher is interested in conducting a study entitled Analysis of Mathematical Problem Solving Ability of Prospective Mathematics Teacher Students in Solving Space Content PISA Model Questions.

Method

The research approach used in this study is a qualitative approach. The type of research used is a case study. The subjects in this study were prospective mathematics teacher students who are currently studying at the Tanjungpura University Mathematics Education study programme, class VA1 and VA2, totalling 19 students. The determination of the subject was carried out by purposive sampling technique. The object of this research is the mathematical problem solving ability in solving PISA model questions on space content at levels 4, 5, and 6. In this case, there are 3 (three) stages of research procedures, namely the preparation, implementation, and final stages. The techniques used in this research are test and interview techniques. The preparation of instruments in this study requires an instrument preparation procedure consisting of making grids, writing items, instrument validity, and instrument trials. In this study, the data analysis technique used adopted the interactive analysis model presented by Miles and Huberman. The data validity checking technique used in this research is triangulation technique.

Result and Discussion

Based on the research results conducted regarding the mathematical problem-solving abilities of prospective mathematics teachers in solving PISA model questions in the content area of space at levels 4, 5, and 6, it was found that overall they fall into the moderate category with a percentage achievement of 61.99%. This result indicates that prospective mathematics teachers still encounter several obstacles in the problem-solving process, from the stage of understanding the problem to the stage of checking their work.

This result is in line with research conducted by Sulastri et al. (2014) which stated that only 14.3% of students were able to solve PISA questions correctly, indicating that students' abilities to solve international standard non-routine problems like PISA questions are very concerning and require special attention. Furthermore, in the research by Darma et al. (2019), it was stated that the mathematical problem-solving ability of students is still low. This can be seen from the results of the tests which indicate that 70.59% of students are in the low category and none of the students fall into the high category. Furthermore, research conducted by Akbarita (2018) states that mathematics students lack the ability to solve geometry problems. This is because most students are only capable at the stage of understanding the problem with a percentage of 76%. Meanwhile, students are still unable to proceed to the next stages: the stage of devising a plan has a percentage of 52.4%, the stage of carrying out the plan has a percentage of 13.22%, and the stage of looking back has a percentage of 10.15%. Meanwhile, Nissa et al. (2015) and Hendroanto (2018) state that there are various difficulties experienced by students in solving PISA questions, which consist of difficulty in formulating problems, low understanding in comprehending information in the questions, and a

lack of creativity in determining strategies to solve problems.

Furthermore, the mathematical problem-solving abilities of prospective mathematics teacher students in solving PISA model questions related to space content at levels 4, 5, and 6 will be discussed in detail as follows.

Mathematical Problem-Solving Abilities in PISA Model Questions Related to Space Content at Level 4

The mathematical problem-solving ability of prospective mathematics teacher students in solving PISA model questions on the content of space at level 4 has an achievement percentage of 82.89%, thus categorized as high. The percentage obtained indicates that most prospective mathematics teacher students are capable of solving PISA model questions on the content of space at level 4. In other words, this achievement percentage shows that the mathematical problem-solving skills possessed by prospective mathematics teacher students meet the activities at level 4 of PISA, which are related to concrete and complex situations, solved by selecting and integrating different procedures, requiring a transformation process from real situations into mathematical models, and also being able to provide reasons for the procedures undertaken (OECD, 2019).

The results are not much different from the research conducted by Bana et al. (2021), which indicated that 68.75% of students were able to correctly solve PISA model questions at level 4 based on the indicators used in their study. Additionally, the scores obtained by students in the study by Bana et al. (2021) reached a maximum score of 92 and a minimum score of 31. This can be interpreted that the majority of students already possess good problem-solving techniques in tackling PISA model questions at level 4. The explanation regarding the indicators of mathematical problem-solving abilities at level 4 is as follows.

Understanding the Problem

The indicator for understanding problems at level 4 overall has an achievement percentage of 94.74%, thus it can be classified in the high category. From the 6 selected students, it was found that all subjects met the indicator for understanding problems at level 4 and did not experience any difficulties in writing down all the important information known and asked in the questions.

Planning the Resolution

The indicator for planning completion at level 4 overall has a percentage of achievement of 92.11%, so it can be classified as high category. From the 6 selected students, it was found that 2 students have not met the indicator for planning completion at level 4, while the other 4 students have met the indicator. The factors that cause students to not meet the indicator for planning completion at level 4 include: Difficulty in utilizing information to plan the strategies and formulas used and incorrect use of formulas due to forgetfulness.

Implementing the Resolution Plan

The indicator of implementing the resolution plan at level 4 overall has an achievement percentage of 88.16%, thus it can be classified in the high category. Out of 6 selected students, it was found that 2 students did not meet the indicator of planning the resolution at level 4, while the other 4 students were able to meet the indicator of planning the resolution at level 4. The factors causing the students to not meet the indicator of implementing the resolution plan at level 4 include: not meeting the indicator of planning the resolution; difficulties in operating decimal numbers; and forgetting to interpret the results obtained according to the problem's request.

The indicator rechecking for reviewing at level 4 overall has an achievement percentage of 42.11%, which can be classified as low. Among the 6 students selected, it was found that 4 students did not meet the review indicator at level 4, while the other 2 students were able to meet the review indicator at level 4. The factors that cause students to not meet the review indicator at level 4 include: confidence or assurance in the results they have obtained; not knowing the appropriate examination method to use; not finding errors in the problem-solving process they have undertaken, even after conducting a review; and running out of time.

Mathematical Problem Solving Ability of PISA Model Questions Content Space at Level 5

The mathematical problem-solving ability of prospective mathematics teacher students in completing PISA model questions content space at level 5 has a percentage of achievement of 65.35%, categorizing it as moderate. Furthermore, the OECD (2019) outlines activities at level 5 related to complex situations, solved by selecting, comparing, and evaluating various strategies, working with broad reasoning and appropriate representational skills, as well as reflecting and communicating them. In relation to the percentage results obtained in this study, it can be stated that prospective mathematics teacher students have not yet been able to carry out activities at level 5 effectively.

The results obtained in this study are not much different from the research conducted by Astusi et al. (2020), which stated that only 7 students or 43.75% were able to meet all the indicators on the PISA level 5 questions. This can be interpreted to mean that the majority of students have not yet been able to develop broad thinking and reasoning skills and work with

models in complex situations, cannot identify constraints, and accurately explain assumptions, as well as are not yet accustomed to connecting mathematical knowledge and skills with the situations faced in the study. The explanation regarding the indicators of mathematical problem-solving abilities at level 5 is as follows.

Understanding the Problem

The indicator of understanding problems at level 5 overall has an achievement percentage of 89.47%, thus it can be classified as high. Out of the 6 selected students, it was found that 1 student has not met the indicator of understanding problems at level 5, while the other 5 students are able to meet the indicator of understanding problems at level 5. The factor causing the student not to meet the indicator of understanding problems at level 5 is running out of time during the working process.

Planning for Resolution

The indicator for planning completion at level 5 has an overall achievement percentage of 73.68%, thus it can be classified as moderate. Out of 6 selected students, it was found that 3 students have not met the indicator for planning completion at level 5, while the other 3 students can meet the indicator for planning completion at level 5. The factors that cause students not to meet the indicator for planning completion at level 5 include: the use of incorrect strategies and formulas; not knowing the formulas that should be used; and running out of time.

Implementing the Resolution Plan

The completion at level 5 overall has an achievement percentage of 60.53%, thus it can be categorized as medium. Out of 6 selected students, it was found that 3 students have not met the indicators of implementing the completion plan at level 5, while the other 3 students are able to meet the indicators of implementing the completion plan at level 5. The factors that cause students not to meet the indicators of implementing the completion plan at level 5 include: Not meeting the planning indicators for completion and incorrectly operating calculations.

Verify Again

The indicator of rechecking at level 5 overall has an achievement percentage of 34.21%, which can be categorized as low. Out of the 6 selected students, it was found that 4 students have not met the rechecking indicator at level 5, while 2 other students were able to meet the rechecking indicator at level 5. The factors causing the students not to meet the rechecking indicator at level 5 include: Running out of time; not knowing the proper checking methods to use; not finding errors in the problem-solving process they have undertaken, although they have already rechecked; being confident or certain with the results they obtained; and not carrying out the problem-solving process.

Mathematical Problem Solving Ability of PISA Model Questions Content Space at Level 6

The mathematical problem-solving abilities of prospective mathematics teacher students in solving PISA model questions on content space at level 6 have a percentage of achievement of 37.72%, which is classified as low. Compared to the percentages at other levels, the achievement percentage at level 6 is the lowest. The results obtained are not much different from the study conducted by Putriyani et al. (2018), which stated that the mathematical abilities of students were lowest at level 3 and highest at level 5. This means that none of the students reached level 6 for PISA mathematical abilities in that study.

In addition, the OECD (2019) states that activities at level 6 are related to using high-level thinking skills in the mathematical reasoning process, applying knowledge and understanding accompanied by mastery of operational techniques and mathematical relationships, as well as developing new approaches and strategies to solve new situations. In relation to the percentage results obtained, it can be stated that prospective mathematics teacher students are not yet able to perform activities at level 6 well. The explanations regarding the indicators of mathematical problem-solving abilities at level 6 are as follows.

Understanding the Problem

The indicator for understanding problems at level 6 overall has an achievement percentage of 52.63%, which can be classified as low. From the 6 selected students, it was found that only 1 student was able to meet the indicator for understanding problems at level 6, while the other 5 students had not met the indicator for understanding problems at level 6. The factors causing students to not meet the indicator for understanding problems at level 6 include: (1) inability to interpret the meaning of the questions; (2) running out of time; and (3) inability to connect important information found in the questions due to not understanding the questions. Additionally, it was also found that students who did not meet the indicator for understanding problems at level 6 were not thorough in reading the questions given. However, these students were capable of identifying the important information contained in the questions.

Planning for Resolution

The indicator for planning completion at level 6 overall has an achievement percentage of 42.11%, which can be classified as low. Among the 6 selected students, only 1 student was able to meet the indicator for planning completion at level 6, while the other 5

students had not yet met this indicator. The factors that caused the students to not meet the indicator for planning completion at level 6 include: Using incorrect formulas; running out of time; and having difficulty utilizing information to plan strategies and the formulas used.

Implementing the Resolution Plan

The indicator for implementing the resolution plan at level 6 overall has an achievement percentage of 34.21%, placing it in the low category. Among the 6 selected students, only 1 student was able to meet the indicator for implementing the resolution plan at level 6, while the other 5 students had not met the indicator for implementing the resolution plan at level 6. The factors causing the students to not meet the indicator for implementing the resolution plan at level 6 include: facing difficulties in operating calculations; lack of diligence in analyzing the components present in the image representation; and (3) not meeting the indicator for planning the resolution.

Rechecking

The indicator for reviewing at level 6 overall has a completion percentage of 21.05%, which can be categorized as low. From the 6 selected students, it was found that none of the students had met the indicator for reviewing at level 6. The factors causing the students to not meet the indicator for reviewing at level 6 include: Forgetting to write down the method of examination used; not finding errors in the problem-solving process they have completed, even after re-checking; not knowing the appropriate method of examination that should be used; and not carrying out the problem-solving process.

Conclusion

Based on the results of the research and discussion, it can be concluded that the mathematical problem solving ability of prospective mathematics teachers in solving PISA model questions on space content is generally classified as moderate, with an achievement percentage of 61.99% and an average score of 22.32 out of a total of 36. This shows that students have not been able to fully fulfill all indicators of mathematical problem solving ability used in this study. The specific conclusions based on PISA levels are as follows: Level 4 (High Category - 82.89%): At this level, most students were able to understand the problem, but some still did not meet the indicators of solution planning due to difficulties in utilizing information, choosing the right strategy and formula, and forgetfulness of the formula. Failure in implementing the solution plan was caused by weaknesses in the planning stage, difficulty in operating decimal numbers, and inability to interpret the results according to the context of the problem. The non-fulfillment of the checking indicator was caused by high self-confidence and ignorance of how to check the results. Level 5 (Medium Category - 65.35%): Students who have not understood the problem at this level are generally caused by time constraints. Failure in planning the solution is related to the use of incorrect or unknown strategies and formulas. The implementation of the solution plan is disrupted by calculation errors and weaknesses in the planning stage. The failure in checking occurred because they did not know the checking method, did not realize there was an error, or did not carry out the completion process completely. Level 6 (Low Category - 37.72%): At this highest level, many students failed to understand the meaning of the problem because of difficulties in interpreting, linking important information, and not being careful when reading the problem. Errors in planning the solution were caused by inappropriate formula selection and inability to design strategies. Obstacles in implementing the solution plan were related to difficulties in performing calculation operations and analyzing visual representations. Meanwhile, failures in checking were caused by forgetfulness, ignorance of checking methods, or no checking process at all. Overall, the mathematical problem solving skills of prospective mathematics teachers still need to be improved, especially in terms of understanding complex problems, planning solution strategies, and reflective skills to check their work.

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Conceptualization; methodology; validation; formal analysis.: investigation; resources; data curation: writing—original; draft preparation: writing—review and editing; visualization: Muhammad Mahendra Kurniawan.

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Conflicts of Interest

The authors declare no conflict of interest.

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