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CHARACTERISTICS OF STUDENTS' MATHEMATICAL PROBLEM SOLVING ABILITIES IN OPEN-ENDED-BASED VIRTUAL REALITY GAME LEARNING

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ABSTRACT

This research is motivated by the problem-solving ability of students is still low, and the teaching materials used cannot be studied independently. The purpose of this study was to determine students' profiles about students' problem-solving abilities seen from indicators of choosing and implementing the problem-solving strategies to solve mathematical and outside mathematics using open-ended-based virtual reality games. A virtual reality game through open-ended-based learning media is made with the concept of moving the situation of learning mathematics in the real world into a virtual world displayed through a computer. This research used a qualitative method with a case study design. The research instrument used is a question of mathematical problem-solving ability through open-ended-based and interview transcripts. The research subjects were six eighth grade Junior High School students consisting of two students with high knowledge, two with moderate knowledge, and two with common knowledge. The result showed that students have different mathematical problem-solving abilities from each indicator, namely 1) identifying the adequacy of data for problem-solving, 2) making mathematical models from everyday situations or problems, 3) selecting and implementing strategies to solve math and math problems outside of using virtual reality games through open-ended based.

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1. INTRODUCTION

Based on the national education curriculum in Indonesia, the learning process is required not only to be oriented to the ability of understanding and knowledge but also the ability of students to think at a high level (High Order Thinking). According to Brookhart (2010), high-level thinking is a combination of several abilities such as combining concepts into new concepts, creative, critical, systematic thinking, which caused someone can solve problems in all aspects. According to Abdullah et al. (2015), high level capabilities can be

developed, one of them with problem-solving strategies. Therefore, in the learning process, it must be created by looking at indicators that are suitable for mastering high-level abilities. If an evaluation or problem given only memorizing the formula or only applies the formula to the question, then the students will not have good problem-solving abilities.

Problem-solving according to Muir et al. (2008), was one of the goals that must be achieved in mathematics. According to Branca (1980), problem-solving was a process that prioritizes strategic steps taken to solve problems and finally find answers to those problems. Therefore, the problem-solving ability must be possessed by students to train solving problems inside and outside mathematics (Harisman et al., 2017). In solving the problems, students need to know the procedure or stages that are used to find out the right solution. Balta and Asikainen (2019) said that what students must have in the process of problem-solving is to use their qualitative understanding to get a quantitative solution. Thus, the ability of problem-solving can be interpreted as the students' ability to solve a given problem through steps and the right strategy to get a solution to a given problem.

Mathematics problem-solving was very important to be owned by students in mathematics learning. According to Pehkonen (1997), the ability to solve mathematical problems can develop the cognitive ability and a part of the mathematical application process. Valdez and Bungihan (2019) revealed that problem-solving ability is not only useful for mathematics but also other science lessons even very important for daily life. However, the students' mathematical problem-solving ability in Indonesia is still low, especially in the step of choosing and using strategies that were appropriate with the given problem. Based on the experience of researcher teaching in the PPL (Teaching Practice Program), many students did the task as in the example given only. Many students were still confused about the steps of completing it and did not know the strategies they have to use to answer the problem of the task. This was because students have not been trained since elementary and middle school to solve the problem of the task. Students prefer to answer questions using practical formulas, thus they do not need to think hardly to answer them.

The students from elementary until high school have low problem-solving abilities and there were also difficulties for teachers in teaching them. One of the materials that was considered difficult by students was the cube (solid figure), because it took the imagination of the space and parts of the building. The hardest part in this cube material was that it has not mastered optimally in terms of the nature of solid figure and plane figure, looking for area and volume, and solving routine problems in solid figure (Pertiwi et al., 2021; Wahyuni et al., 2020). Thus, it impacted to students' difficulty in solving the solid figure material's problem. Based on the interview results, the teaching materials used were still in the form of modul. The modul used cannot be studied independently by students, because they were not accompanied by illustrations supported and did not stimulate students to think openly or open mind.

Nowadays, there are many approaches that can improve problem-solving ability. One of them was an open-ended approach. The open-ended approach allowed students to choose to improve problem-solving abilities appropriate with the level of ability and interest of their students (Hwang et al., 2014; Kosyvas, 2016; Mann, 2006). The open-ended approach made students think openly, but in the right path of solving problems because students are given open questions. According to Hino (2007) learning mathematics by giving open questions was a good approach in improving problem-solving ability.

The open-ended approach was an approach that emphasizes students to think openly about a problem of the task. The open-ended approach can develop students' thinking about a problem, because the given problem was open. Setiawan and Harta (2014) stated the open-ended approach was a learning approach that gave students the opportunity to solve problems in a variety of ways and more than one correct answer then discussed to compare work

results. According to Pehkonen (1997) the open-ended approach was a method of using open-ended questions in the classroom to generate discussion activities. To support learning that used the open-ended approach in today's technology was very important.

Information and communication technology has increasingly developed. The benefits of Smartphone have been felt by all members of society including teachers and students. Based on interview with teachers at Majalengka Junior High School, 70% of teachers have a Smartphone device and all students in one class have a Smartphone. However, the use of Smartphone was only limited for gaming and chatting. Game that many manufactured in the market was the kind of game that was only for entertainment purposes, such as adventure, strategy of war, violence, and others. Through technology will be very useful when combined between students' skill and students' cognitive ability. This was in line with the statement of Suwanroj et al. (2019) that students' digital competence will emerge when their cognitive ability and skill are combined with technology.

To solve the problems above and take advantage of technological improvement, researcher will create learning media in the form of real-world simulation games on space building material. According to Pramuditya et al. (2017) the game was an entertainment media that used by someone to eliminate physical happiness and spend free time. In addition, based on previous research conducted by Pramuditya, Noto and Purwono (2018), learning media in the form of RPG (Role Playing Game) educational games for mathematics lessons have been made valid and practical. However, it is limited only to the materials giving and simple evaluation tools not to be made based on real-world situations that allow users to think open-ended with the material and questions given. Hence, the learning media in the form of educational games can be used to overcome the difficulties and boredom of students in mathematics and can be used in classroom learning.

Educational game that is designed was a game in the form of virtual reality (VR). Sahulata et al. (2016) stated that VR generally presents a visual experience that can be felt directly by its users displayed through a computer or through a media viewer such as Google cardboard glasses. VR can be made to make the users felt the learning situation in the game directly, thus it made the students gain experience and new knowledge that useful for improving their mathematical problem-solving abilities.

This study was conducted to answer the research questions; (1) How are the characteristics of the high ability students in problem-solving ability using virtual reality game through open-ended based? (2) How are the characteristics of the moderate ability students in problem-solving ability using virtual reality game through open-ended based?, (3) How are the characteristics of the low ability students in problem-solving ability using virtual reality game through open-ended based?

2. METHOD

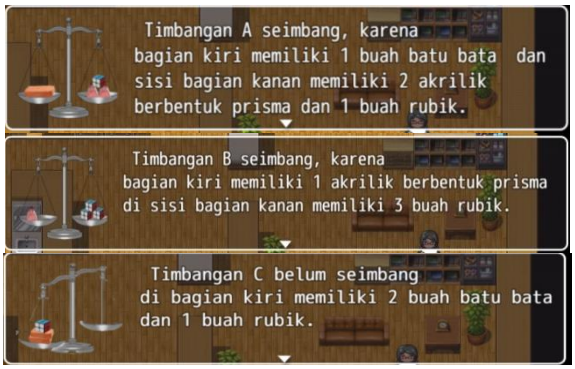
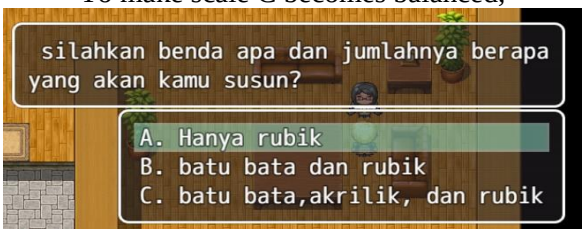
The research method used is qualitative research, in which the researcher acts as the main instrument in this research and the data collected is not in the form of numbers but the results of interviews towards the research subjects continuously. Qualitative research is done to examine the problems faced deeply by the research subjects, therefore, it can explore the selection and the implementation of problem-solvingstrategies used. As Creswell (2014) stated that qualitative research is interpretive research, it means that researchers are involved in ongoing and continuously experience with the participants.

The research design used was a case study of 3 students at Majalengka Junior High School. The case that is examined in this research is the ability of students to solve mathematical problems that is seen from the selection and implementation of problem-solving strategies used with the help of educational games. Algozzine and Hancock (2017)

argued that case study research is a research in exploring a system that is bound or cases that occur within a certain time from deep and reliable data sources.

The example of an open-ended question for the problem-solvingability used (see Table 1).

Table 1. An example of an open-ended problem-solving question

Open-ended problem-solving question	Questions display in the game
There are 3 known objects, namely: - block bricks where height = 2 cm width = 4 cm, and length = 7 cm, - Rubik, a cube in which the ribcage is 2 cm long - Acrylic with prism shaped. Then Mr. Roni scaled the objects above, the following results of the scales are: Scales A has perfect balance because the left side has 1 block-shaped object and the right side has two prism-shaped objects and one cube-shaped object. Scales B also has perfect balance because the left side has 1 prism shaped object and the right side has 3 cube shaped objects. Scales C on the left has 2 block-shaped objects and 1 cube-shaped object. Therefore, in order to make scale C balanced, which objects that might be arranged on the right side?	Mr. Roni has 3 types of items like in the game,  then Mr. Roni scaled it.  To make scale C becomes balanced, 

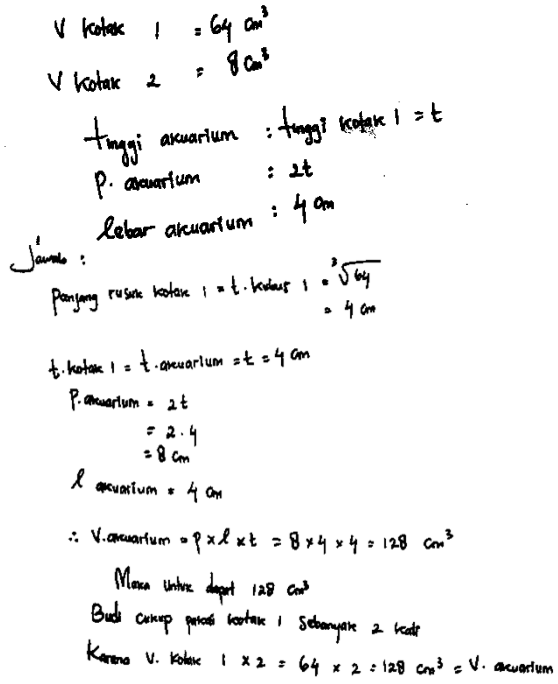
The total number of students who were the subjects of the study were 6 students of Majalengka Junior High School. The selection of these 6 students is based on the teacher's consideration by observing the students' basic mathematics ability. The selected students consisted of 2 students with high basic mathematical ability, 2 students with moderate basic mathematical ability, and 2 students with low basic mathematical ability. The initials of the research subjects can be seen in the following Table 2.

3. RESULT AND DISCUSSION

3.1. Result

Table 2 presents one of the answers of high ability students on the indicator identifying the data adequacy for problem-solving using virtual reality games with open-ended based.

Table 2. Analysis of students' high ability answers to indicator 1

Students' answers	Analysis of answers
	Students can identify the data that is known in the question completely: students write the volume of box 1 and volume of box 2 correctly. Students also write down the data that is known from the exact size of the aquarium such aquarium height = height of box 1 even though the size of the aquarium is no specified directly in the form of numbers. Students also know what problems are asked in question number 1. Although what is asked is not directly written, but it can be seen from the final answers of students who show how much to take water using the box provided that is 2 times using box 1. While for aspects of data sufficiency, students understand that to get the final results, it is required aquarium height and length data. students search for insufficient data first, that is aquarium height = box height 1 = 4 cm and aquarium length = 8 cm

This research is motivated by the importance of mathematical problem-solving ability in mathematics learning, but the students' problem-solving ability is still low and the teaching materials used cannot be studied independently. The purpose of this study was to determine students' profiles about students' problem-solving abilities seen from indicators of choosing and implementing problem-solving strategies to solve mathematical problems and/or outside mathematics using virtual reality games through open-ended based. Virtual reality game through open-ended based is a learning media that is made with the concept of moving the situation of learning mathematics in the real world into a virtual world that is displayed through a computer.

This research used qualitative method with case study design. The research instrument used is question of mathematical problem-solving ability through open-ended based and interview transcripts. The research subjects were 6 eighth grade Junior High School students consisting of 2 high ability students, 2 moderate ability students, and 2 low ability students. Data analysis in this research was carried out with the data reduction stage, the data presentation stage, and the conclusion drawing stage. The result showed that the indicators of identifying the data adequacy for problem-solving, the high ability and the

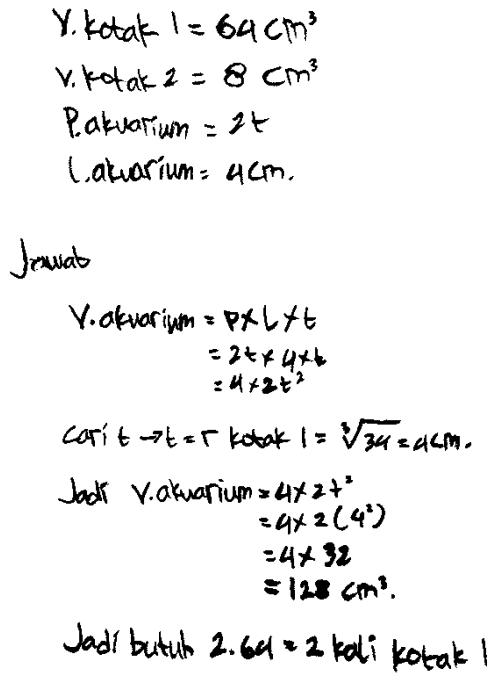
moderate ability students were able to solve the mathematical problem well, but the low ability students are not able to solve mathematical problem well.

Moreover, based on the results of interviews, it is obtained that students can mention all the known data correctly including the height of the aquarium. To understand the problem, students understand what is asked about the question even though it is not written on the answer sheet but students can answer according to what was asked on the question 2 times using box 1. It can be seen from the following interview script:

Researcher : Please state what is known in the question?
Researcher : What is the answer?
Student : Use box 1 twice, but don't know whether it's right or wrong.
Students : volume of box 1 is 64 cm^3, volume of box 2 is 8 cm^3, aquarium height is the same as box 1 height, aquarium width is 4cm, and aquarium length is twice its height.

In addition, students also know that the data in question number 1 is not sufficiently visible when students say they must look for the height and length of the aquarium. One of the moderate ability students' answers on indicator identifying the data adequacy for problem-solving using virtual reality game through open-ended based (see Table 3).

Table 3. Analysis of students' moderate ability answer on indicator 1

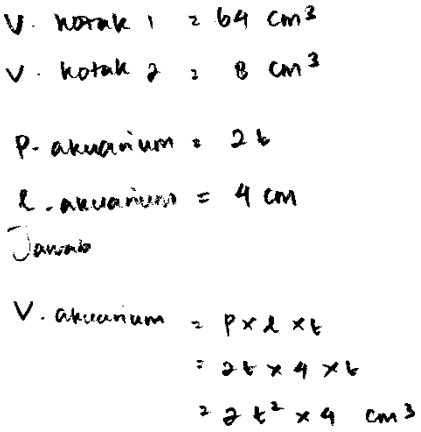
Students' answers	Analysis of answers
	Students can identify the data that is known in the question but there is one point missed. Students write volume in box 1 and volume in box 2 correctly. Students also write the data that is known from the size of the aquarium that is the length and width of the aquarium but do not write the height of the aquarium = height of box 1. Students also know what the problem is asked in question number 1. Even though what is asked is not directly written, but it can be seen from the students' final answer which show how much to take water using the box provided that is 2 times using box 1. While for the aspect of data sufficiency, students understand that to get the final result, it needs aquarium height data. When the student look for aquarium volumes, student seems to find the height of the aquarium first, that is the height of the aquarium = height of box 1 = 4 cm

Moreover, based on the results of interviews, students can mention all the known data correctly including the height of the aquarium. To understand the problem, students understand what is asked about the question even though it is not written on the answer sheet but students can answer according to what was asked. When they are asked what is the answers to question number 1, students answer with box 1, 2 times. Seen from the following interview script:

Researcher : Please mention what is known on the question?
Student : volume of box 1 is 64 cm^3, the volume of box 2 is 8 cm^3, the width of the aquarium is 4 cm, and the length of the aquarium is 2 times higher.
Researcher : what is the answer?
Student : Use box 1 twice

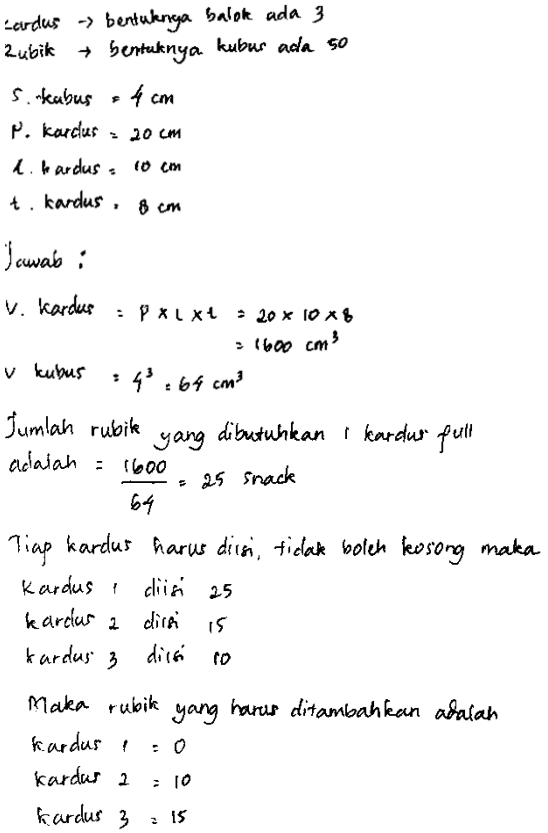
In addition, students also know that the data in question number 1 has not been seen enough when students say it is not enough, because they have to find the height of the aquarium first. One of the low ability students' answers on indicators identifying the data adequacy for problem-solving using virtual reality games with through open-ended based (see Table 4).

Table 4. Analysis of low ability students' answers to indicator 1

Students' answers	Analysis of answers
	Students can identify the data that is known in the question but there is one point missed. Students write volume in box 1 and volume in box 2 correctly. Students also write down the data that is known from the size of the aquarium that is the length and width of the aquarium but students do not write the height of the aquarium = height of box 1. Students do not know what the problem asked in question number 1, it is seen that it is not written what is known and from the final answer also shows the aquarium volume is inaccurate, the aquarium volume = $2t^2$ x 4 cm^3. While for the aspect of data sufficiency, students do not understand that to get the final result, aquarium height data is needed. When Students look for aquarium volume, students do not write height data and do not look for aquarium height.

Moreover, based on the results of interviews, it is obtained that students cannot mention the data that is known correctly. Students did not mention the known data regarding aquarium height. Students also do not know the data known about the height of the aquarium seen from the students' conversation stated that it is difficult to find height value. For the data adequacy in the questions, students knew that the data is not enough but the reason is because they can't find the volume of the aquarium. In addition, students cannot solve the problems correctly until they finish. When they are asked what the answers is to question number 1, students feel stuck when looked for the aquarium volume. Therefore students know the data that is asked, but do not know the data adequacy requirements and cannot mention the data that is known completely and correctly. One of students' answers with high ability on indicators creating mathematical models of a situation or daily problem and solving them using virtual reality game with through open-ended based (see Table 5).

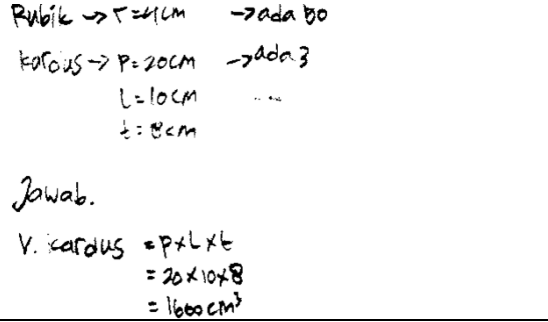
Table 5. Analysis of high ability student answers to indicator 2

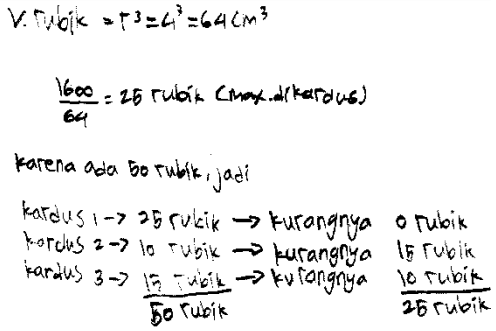
Students' answers	Analysis of answers
	Students write the mathematical model of the question's problem correctly, that is $\frac{V.Cardboard}{V.Rubik}$, Therefore, students get the maximum score of Rubik in 1 cardboard box correctly which is 25 Rubik. Another mathematical model written correctly by students is to fill in how many Rubik in the box and the remaining Rubik should be added to the cardboard. In addition, students are able to complete the mathematical model they have made until writing the final answer correctly.

Furthermore, based on the results of the interview it was found that students understood the problem from this question. Students mention the mathematical model of the question correctly that is the volume of cardboard divided by the volume of Rubik = maximum Rubik in 1 cardboard ($\frac{V.Cardboard}{V.Rubik} = maks.rubik$). Hence, students get the maximum score of Rubik in 1 cardboard box correctly which is 25 Rubik. In addition, students are able to complete the mathematical models that they have made, it can be seen from students' conversations that they can solve until they get the final results.

Table 6 shows one of students' moderate ability answers on indicators creating mathematical models of a situation or daily problem and solving them using virtual reality games through open-ended based.

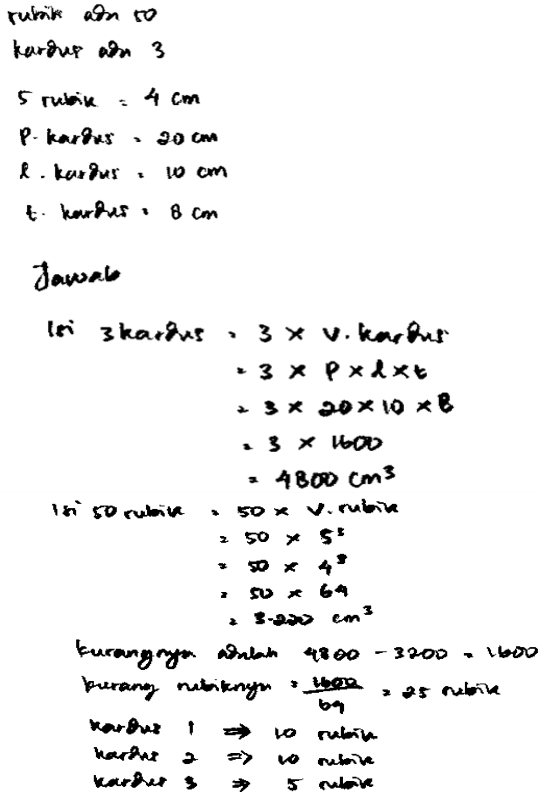
Table 6. Analysis of moderate ability students' answers to indicator 2

Students' answers	Analysis of answers
	Students write the mathematical model of the question's problem correctly, that is $\frac{V.Cardboard}{V.Rubik}$, Therefore, students get the maximum score of Rubik in 1 cardboard box correctly which is 25 Rubik. Another mathematical model written correctly by students is to fill in how many Rubik in the box and the remaining Rubik should be added to

Students' answers	Analysis of answers
	the cardboard. In addition, students are able to complete the mathematical model they have made until writing the final answer correctly.

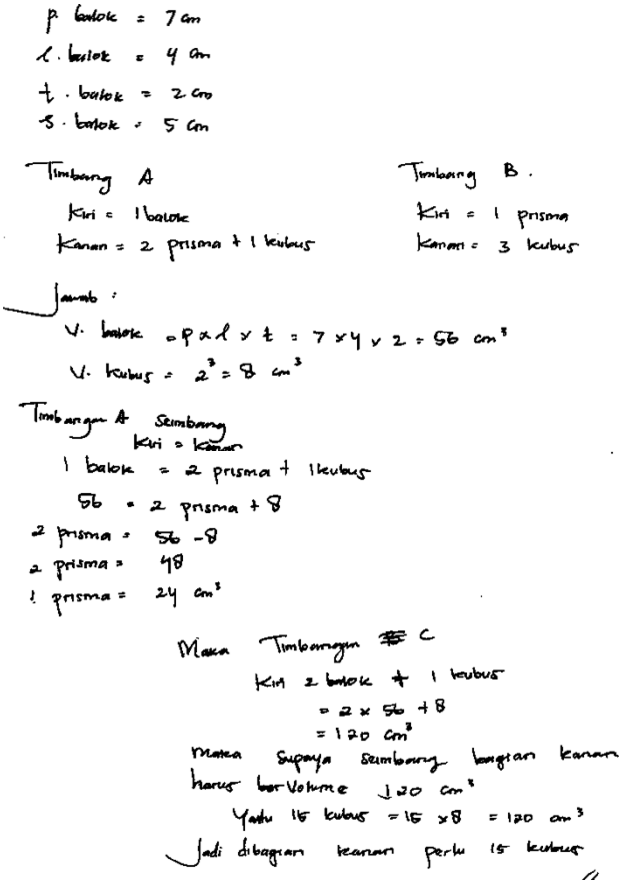
Based on the results of the interview, it was found that students understood the problem from this question. Students mention the mathematical model of the question's problem correctly, that is the volume of cardboard divided by the volume of Rubik = maximum Rubik in 1 cardboard ($\frac{V.Cardboard}{V.Rubik} = maks.rubik$). Hence, students get a maximum score of Rubik in 1 cardboard correctly which is 25 Rubik. In addition, students are able to complete the mathematical model that they have made, it can be seen from the students' conversation that they can solve until they get the final result. One of the low ability students' answers on indicators to make mathematical models of a situation or daily problems and solving them using virtual reality games through open-ended based (see Table 7).

Table 7. Analysis of low ability students' answers to indicator 2

Students' answers	Analysis of answers
	Students write a mathematical model of the question's problem but it is not quite right. Students write mathematical models to find the remaining Rubik in 3 boxes. Although in the final answer the students write down the lack of Rubik in each cardboard but the maximum Rubik and the number of Rubik that must be entered into each cardboard are not written down.

Meanwhile, the results of interviews obtained that students understand the problem from this question. Students mention the mathematical model of the question's problem correctly, that is the volume of cardboard divided by the volume of Rubik = maximum Rubik in 1 cardboard ($\frac{V.Cardboard}{V.Rubik} = maks.rubik$). Therefore, students get a maximum score of Rubik in 1 cardboard correctly which is 25 Rubik. In addition, students are able to complete the mathematical model that they have made, it can be seen from the students' conversation that they can solve until they get the final result. One of the answers of high ability students on indicators of choosing and implementing strategies to solve mathematical problems and or outside mathematics using virtual reality games through open-ended based (see Table 8).

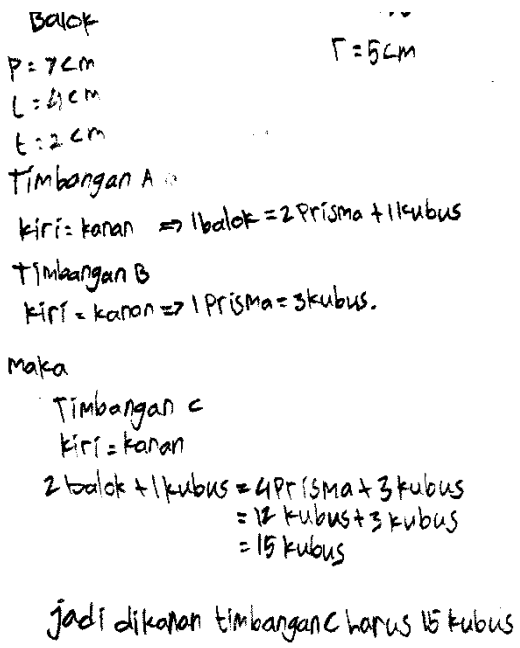
Table 8. Analysis of high ability student answers to indicator 3

Students' answers	Analysis of answers
	Student answered the questions by collecting data on scales A and scales B, therefore to obtain the prism volume that is value Prism Volume = 24 cm^3. Then students use the volume of prism to obtain objects that must be in the scale C. Thus the student has chosen the right way or strategy to answer the problem in the question that is the strategy of organizing data. In the final answer to the question's problem, students write the correct answer that is on the right side of the C scale, 15 cubes are needed hence the scales are balanced. Therefore, students are able to solve the problem using the strategy.

Besides, based on the results of interviews, students answer the questions by collecting data on scales A and scales B to obtain the prism volume value that is Prism Volume = 24 cm^3. Therefore, the strategy used by students is to process or organize data from existing data. In the conversation, it appears that students collect the known data from scales A and B afterwards, looking for prism volumes based on these data. Then we get the objects needed, so, the scale C is balanced. Thus, students have chosen the right way or strategy to answer the problem in the question. In the final answer to the question's problem, students said the correct answer is that on the right side of the scale C, 15 Rubik are needed hence the scale is balanced.

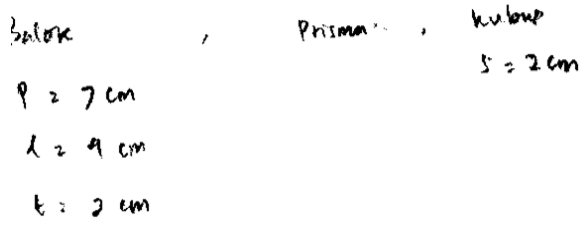
Table 9 shows one of the answers of moderate ability students on indicators of choosing and implementing strategies to solve mathematical problems and or outside mathematics using virtual reality games through open-ended based.

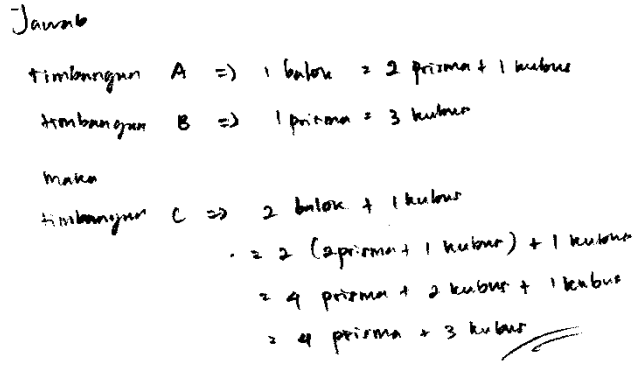
Table 9. Analysis of students' answers to the ability being on indicator 3

Students' answers	Analysis of answers
	Students answer the questions by looking for patterns from scale A and scale B thus they get the right pattern. Then students substitute the patterns of the scales A and B, namely 1 beam = 2 prisms + 1 cube and 1 prism = 3 cubes into the C scale. Hence using the pattern, the student writes the final answer correctly that is to the right of the C scale we need 15 objects cube shaped thus the scales are balanced.

Meanwhile, based on the results of interviews obtained that students answer the questions by collecting data on scales A and scales B thus obtain the items needed on the scale C to be balanced. Therefore the strategy used by students is to look for patterns from known data. In the conversation it appears that students look for patterns from the scales A and B. After knowing the pattern enters into the scales C. Then objects obtained for the scales C. Thus, the student has chosen the right way or strategy to answer the problem in the question. In the final answer to the question problem, students said the correct answer is that on the right side of the scale C, 15 cubes are needed thus the balance is balanced. Therefore, students are able to solve question's problem using these strategies. One of the answers of students with low ability on indicators to choose and implement strategies to solve mathematical problems and or outside mathematics using virtual reality games through open-ended based (see Table 10).

Table 10. Analysis of low ability student answers to indicator 3

Students' answers	Analysis of answers
	Students answer the questions by looking for patterns from scale A and scale B thus they get the right pattern. Then students substitute the pattern of the scale A, namely 1 beam = 2 prisms + 1 cube into the scale C. Hence, using the pattern, students write the final answer correctly, that is to the right of

Students' answers	Analysis of answers
	the scale C, it takes 15 cube-shaped objects thus the scales are balanced.

Moreover, based on the results of the interview it was found that students answered the questions by looking for a balanced pattern of scales A and B thus obtain the items needed on the C balance to be balanced. Thus the strategy used by students was to find patterns from known data. In conversation shows that, the students look for patterns of scales A and B. After knowing the pattern, then obtained any object for scales C. Thus students have chosen the right way or strategy to answer the problem in the question. In the final answer to the question problem, students said the correct answer that is to the right of the scale C requires 4 prisms and 3 cubes thus the scales are balanced. Therefore students are able to solve problem problems using these strategies.

3.2. Discussion

Students have good or not good mathematical problem-solvingabilities, there are indicators or aspects to assess them. There are many kinds of indicators for assessing students' mathematical problem-solving abilities. The questions made by researchers, namely: 1) identifying the adequacy of data for problem-solving, 2) making mathematical models of daily situations or problems and how to solving them, 3) choosing and implementing strategies to solve mathematical problems and/or outside mathematics using virtual reality games through open-ended based (Widodo et al., 2021). Based on data taken from the results of students' answers and interviews, it can be seen the differences in the characteristics of students in solving problem question using virtual reality games through open-ended based.

3.2.1. Characteristics of students' low problem-solving abilities using virtual reality games through open-ended based

When students are given a problem-solving question that is presented in virtual reality games through open-ended-based, students are only able to know the data adequacy requirements and the data being asked. But students were not able to mention data that is known to be complete and correct. Therefore, the two low-ability students have not been able to identify the adequacy of the data for problem-solving in the game.

The problem-solving was a difficult process for students, one of which is at the problem understanding step and planning a problem. But when problems that contain indicators make a mathematical model of a situation or daily problem and solve it, students are able to make a mathematical model of a situation or daily problem and solve it. It can be seen that all students can write mathematical models of problem questions in the game correctly. This is because students are helped by illustrating problems in the game, thus it is

easier to make mathematical forms of the problem (Harisman et al., 2021; Hutajulu et al., 2022; Kariadinata, 2021). This is in line with Pramuditya, Noto and Syaefullah (2018) that the mathematics RPG educational game is interesting, fun, and educated, because of illustrations. Students can also solve problem questions using models or plans that they have previously made. This is in line with Prihandika and Saputro (2021) states that students are able to draw up a completion plan or make a mathematical model and implements a completion plan. While the questions that contain indicators choose and implement strategies to solve mathematical problems and/or outside mathematics that all students studied are able to choose and implement strategies to solve mathematical problems and/or outside mathematics from the questions in the game. It can be seen that all students use a way of solving it by choosing the right problem-solving strategy. All students also get the correct final answer by using a solution to the strategy they have made before. This is in line with Karlimah et al. (2021) which stated that in making a settlement plan in this case choosing and implementing a problem-solving strategy, look for the relationship between the information provided and the unknown exactly hence it is possible to obtain unknown results.

3.2.2. Characteristics of students' moderate problem-solving abilities using virtual reality games through open-ended based

Based on the data taken from the results of students' answers and interviews, it can be seen that moderate-able students are able to identify the adequacy of the data for problem-solving in the game. It can be seen that students can understand the problem in the game well. This is because students feel the illustrations in the game help in remembering what is known, therefore they can understand the problem question. Based on research by Akbar et al. (2018) which stated that students more often finish directly and feel no need to write it down, because they feel they are wasting time. But in this study, students write the data that is known and the steps to solve them, which are not written only the data that is asked. Students are also able to know the adequacy of the data as a condition for answering questions.

It can be seen that students can write mathematical models of problem questions that exist in the game correctly. This is because students are helped by illustrating problems in the game, hence it is easier to make mathematical forms of the problem. This is in line with Pramuditya, Noto and Syaefullah (2018) that the mathematics RPG educational game is interesting, fun, and educational because of illustrated illustrations. Students can also solve problem problems using models or plans that they have previously made. This is in line with research Prihandika and Saputro (2021) states that students are able to draw up a completion plan or make a mathematical model and implements a completion plan. That all students studied are able to choose and implement strategies to solve mathematical problems and / or outside mathematics from the problems in the game. It can be seen that all students use a way of solving it by choosing the right problem-solving strategy. All students also get the correct final answer by using a solution to the strategy they have made before. This is in line with Karlimah et al. (2021) which stated that in making a settlement plan in this case choosing and implementing a problem-solving strategy, look for the relationship between the information provided and the unknown exactly hence it is possible to obtain unknown results.

3.2.3. Characteristics of students' high problem-solving abilities using virtual reality games through open-ended based

Based on data taken from the results of students' answers and interviews, it can be seen that high-ability students have been able to identify the adequacy of data for problem-solving in the game. It can be proven that students can understand the problem in the game as well. This is because students feel the illustrations in the game help in remembering what is known. Therefore they can understand the problem question. Based on research by Akbar et al. (2018) which stated that students more often finish directly and feel no need to write it down because they feel they are wasting time. However, in this study, students write the data that is known and the steps to solve them, which are not written only the data that is asked. Students are also able to know the adequacy of the data as a condition for answering questions.

It can be seen that students can write mathematical models of question's problems that exist in the game correctly. This is because students are helped by illustrating problems in the game so that it is easier to make mathematical forms of the problem. This is in line with Pramuditya, Noto and Syaefullah (2018) that the mathematics RPG educational game is interesting, fun, and educational because of illustrated illustrations. Students can also solve problem problems using models or plans that they have previously made. This is in line with research Prihandika and Saputro (2021) states that students can draw up a complete plan or make a mathematical model and implements a completion plan. That all students studied can choose and implement strategies to solve mathematical problems and/or outside mathematics from the problems in the game. It can be seen that all students use a way of solving it by choosing the right problem-solving strategy. All students also get the correct final answer by using a solution to the strategy they have made before. This is in line with Karlimah et al. (2021) which stated that in making a settlement plan in this case choosing and implementing a problem-solving strategy, look for the relationship between the information provided and the unknown exactly hence it is possible to obtain unknown results.

Muir and Beswick (2005) stated that the process of thinking in combining some knowledge in problem-solving is an important factor in whether students can solve a problem. Every student who has different abilities have different problem-solving thinking processes. According to Muir et al. (2008) that someone's ability to understand a mathematical problem structure is an important element in problem-solving.

The following findings are presented about the characteristics of students ranging from low, moderate, and high abilities found during this study (see Table 11).

Table 11. Characteristic of students' problem-solving abilities

No	Low ability students	Moderate ability students	High ability students
1	Guessing when choosing answers in the game.	Answering questions with a strategy that students can then choose the correct answer	Choose the answer then adjust the solution strategy according to the answer choice
2	Students are only able to choose one problem-solving strategy	Students are only able to choose one problem-solving strategy	Students can choose more than one problem-solving strategy in the game

No	Low ability students	Moderate ability students	High ability students
3	Students are only able to work on problems with one completion strategy	Students are only able to work on problems with one completion strategy	Students can answer questions in a variety of ways
4	Some steps are not yet right in the problem-solving process	Students can answer correctly at each stage of completion	Students can answer correctly at each stage of completion
5	Students are not able to interpret known data from game illustrations	Students can interpret known data from game illustrations	able to interpret known data from game illustrations

4. CONCLUSION

Based on the analysis and discussion of the Mathematical problem-solving of 6 students of Majalengka Junior High School can be concluded that students have mathematical problem-solving abilities different from each indicator. For indicators identifying the adequacy of data for problem-solving, high-ability students and moderate-ability students can solve mathematical problem-solving well. Students with low ability have not been able to solve mathematical problem-solving well. The indicators make a mathematical model of a situation or daily problem and solve it that students with high, moderate, and low abilities are able to solve mathematical problems well. While there are indicators for choosing and implementing strategies to solve mathematical problems and/or outside mathematics for in-game problems, those students with high, moderate, and low abilities can solve mathematical problem-solving well.

REFERENCES

Abdullah, A. H., Abidin, N. L. Z., & Ali, M. (2015). Analysis of students' errors in solving higher order thinking skills (HOTS) problems for the topic of fraction. *Asian Social Science*, *11*(21), 133-142. https://doi.org/10.5539/ass.v11n21p133

Akbar, P., Hamid, A., Bernard, M., & Sugandi, A. I. (2018). Analisis kemampuan pemecahan masalah dan disposisi matematik siswa kelas XI SMA Putra Juang dalam materi peluang [Analysis of problem solving ability and mathematical disposition of class XI Putra Juang high school students in probability materials]. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *2*(1), 144-153. https://doi.org/10.31004/cendekia.v2i1.62

Algozzine, B., & Hancock, D. (2017). *Doing case study research: A practical guide for beginning researchers* (third edition ed.). Teachers College Press.

Balta, N., & Asikainen, M. (2019). Introductory students' attitudes and approaches to Physics problem solving: Major, achievement level and gender differences [Physics education, problem solving in physics, AAPS survey, attitudes, gender]. *Journal of Technology and Science Education*, *9*(3), 378-387. https://doi.org/10.3926/jotse.666

Branca, N. A. (1980). Problem solving as a goal, process, and basic skill. In S. Krulik & R. E. Reys (Eds.), *Problem solving in school mathematics* (pp. 3-8). National Council of Teachers of Mathematics.

Brookhart, S. M. (2010). *How to assess higher-order thinking skills in your classroom*. Alexandria VA: ASCD.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Harisman, Y., Noto, M. S., Bakar, M. T., & Amam, A. (2017). The different patterns of gesture between genders in mathematical problem solving of geometry. *Journal of Physics: Conference Series*, *812*, 012039. https://doi.org/10.1088/1742-6596/812/1/012039

Harisman, Y., Noto, M. S., & Hidayat, W. (2021). Investigation of students' behavior in mathematical problem solving [Behavior; Naïve; Problem solving; Routine; Semi-Sophisticated; Sophisticated]. *Infinity Journal*, *10*(2), 235-258. https://doi.org/10.22460/infinity.v10i2.p235-258

Hino, K. (2007). Toward the problem-centered classroom: trends in mathematical problem solving in Japan. *Zdm*, *39*(5), 503-514. https://doi.org/10.1007/s11858-007-0052-1

Hutajulu, M., Perbowo, K. S., Alghadari, F., Minarti, E. D., & Hidayat, W. (2022). The process of conceptualization in solving geometric-function problems [Bloom Taxonomy; Cognitive Process; Conceptualization; Geometric-Function; Knowledge Dimension]. *Infinity Journal*, *11*(1), 145-162. https://doi.org/10.22460/infinity.v11i1.p145-162

Hwang, G.-J., Hung, C.-M., & Chen, N.-S. (2014). Improving learning achievements, motivations and problem-solving skills through a peer assessment-based game development approach. *Educational Technology Research and Development*, *62*(2), 129-145. https://doi.org/10.1007/s11423-013-9320-7

Kariadinata, R. (2021). Students' reflective abstraction ability on linear algebra problem solving and relationship with prerequisite knowledge [Prerequisite Knowledge; Problem Solving; Reflective Abstraction]. *Infinity Journal*, *10*(1), 1-16. https://doi.org/10.22460/infinity.v10i1.p1-16

Karlimah, K., Hamdu, G., Pratiwi, V., Herdiansah, H., & Kurniawan, D. (2021). The development of motion comic storyboard based on digital literacy and elementary school mathematics ability in the new normal era during covid-19 pandemic. *Journal of Physics: Conference Series*, *1987*(1), 012026. https://doi.org/10.1088/1742-6596/1987/1/012026

Kosyvas, G. (2016). Levels of arithmetic reasoning in solving an open-ended problem. *International Journal of Mathematical Education in Science and Technology*, *47*(3), 356-372. https://doi.org/10.1080/0020739X.2015.1072880

Mann, E. L. (2006). Creativity: The essence of mathematics. *Journal for the Education of the Gifted*, *30*(2), 236-260. https://doi.org/10.4219/jeg-2006-264

Muir, T., & Beswick, K. (2005). Where did I go wrong? Students' success at various stages of the problem-solving process. In The 28th Annual Conference of the Mathematics Education Research Group of Australasia, Melbourne, Australia.

Muir, T., Beswick, K., & Williamson, J. (2008). "I'm not very good at solving problems": An exploration of students' problem solving behaviours. *The Journal of Mathematical Behavior*, *27*(3), 228-241. https://doi.org/10.1016/j.jmathb.2008.04.003

Pehkonen, E. (1997). The state-of-art in mathematical creativity. *Zdm*, *29*(3), 63-67. https://doi.org/10.1007/s11858-997-0001-z

Pertiwi, C. M., Rohaeti, E. E., & Hidayat, W. (2021). The students' mathematical problem-solving abilities, self-regulated learning, and VBA Microsoft word in new normal: A development of teaching materials. *Infinity Journal*, *10*(1), 17-30. https://doi.org/10.22460/infinity.v10i1.p17-30

Pramuditya, S. A., Noto, M. S., & Purwono, H. (2018). Desain game edukasi berbasis android pada materi logika matematika [Android-based educational game design on mathematical logic material]. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *2*(2), 165-179. https://doi.org/10.33603/jnpm.v2i2.919

Pramuditya, S. A., Noto, M. S., & Syaefullah, D. (2017). Game edukasi RPG matematika [Math RPG educational game]. *Eduma: Mathematics Education Learning and Teaching*, *6*(1), 77-84. https://doi.org/10.24235/eduma.v6i1.1701

Pramuditya, S. A., Noto, M. S., & Syaefullah, D. (2018). The educational game design on relation and functionmaterials. *Journal of Physics: Conference Series*, *1013*, 012138. https://doi.org/10.1088/1742-6596/1013/1/012138

Prihandika, Y. A., & Saputro, D. R. S. (2021). How are student's spatial intelligence for geometry problem-solving? In International Conference of Mathematics and Mathematics Education (I-CMME 2021).

Sahulata, R. A., Wahyudi, A., Wuwungan, B. G., & Nayoan, M. A. (2016). Aplikasi virtual reality pengenalan kerangka tubuh manusia berbasis android [Android-based virtual reality application for human skeleton recognition]. *CogITo Smart Journal*, *2*(2), 204-215. https://doi.org/10.31154/cogito.v2i2.30.204-215

Setiawan, R. H., & Harta, I. (2014). Pengaruh pendekatan open-ended dan pendekatan kontekstual terhadap kemampuan pemecahan masalah dan sikap siswa terhadap matematika [The effect of an open-ended and contextual approach on problem solving abilities and students' attitudes towards mathematics]. *Jurnal Riset Pendidikan Matematika*, *1*(2), 241-257. https://doi.org/10.21831/jrpm.v1i2.2679

Suwanroj, T., Leekitchwatana, P., & Pimdee, P. (2019). Confirmatory factor analysis of the essential digital competencies for undergraduate students in Thai higher education institutions [confirmatory factor analysis, CFA, digital competency, undergraduate students, Thai higher education institutions]. *Journal of Technology and Science Education*, *9*(3), 340-356. https://doi.org/10.3926/jotse.645

Valdez, J., & Bungihan, M. (2019). Problem-based learning approach enhances the problem solving skills in Chemistry of high school students [problem-based learning, problem solving skill, pedagogy, chemistry education]. *Journal of Technology and Science Education*, *9*(3), 282-294. https://doi.org/10.3926/jotse.631

Wahyuni, R., Efuansyah, E., & Sukasno, S. (2020). Developing student worksheet based on missouri mathematics project model by using think-talk-write strategy of class VIII [Missouri Mathematics Project; Student Worksheet; Think Talk Write Strategy; 4-D]. *Infinity Journal*, *9*(1), 81-92. https://doi.org/10.22460/infinity.v9i1.p81-92

Widodo, S. A., Ibrahim, I., Hidayat, W., Maarif, S., & Sulistyowati, F. (2021). Development of mathematical problem solving tests on geometry for junior high school students. *Jurnal Elemen, 7*(1), 221-231. https://doi.org/10.29408/jel.v7i1.2973