Students' Ability to Formulate Situation Mathematically from Context-Based Mathematics Problems

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Abstract **– Mathematical literacy has become one of the new standards for students' understanding. To be able to develop suitable problem-solving strategies, especially context-based problems, students need to have the ability to formulate situations mathematically well. This research was conducted to observe students' abilities in formulating situations mathematically. The research subjects were students aged 14-16 years in Malang City in February 2023. This research was qualitative research. The data collected was students' answers on context-based mathematical problems from the Program for International Student Assessment (PISA) whose questions are related to activities of formulating situations mathematically. Result showed that the majority of students did not have sufficient ability and experience in formulating situations mathematically, both in terms of understanding the context of the problem, determining variables, and developing problem-solving strategies. This means that many students still have difficulty determining procedures for solving PISA problems, especially context-based ones. Teachers need to provide more learning and familiarization regarding the process of formulating situations mathematically to make it easier for students to solve context-based mathematical problems.**

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1. Introduction

In learning, teachers need to pay attention to the basic competencies that students need to develop in the learning carried out in class. To enable each student to develop their abilities, the provided learning must be balanced between one student and another [1]. One form of basic competency that needs to be developed, according to the Organization for Economic Co-operation and Development (OECD) [2], is mathematical literacy which is generally needed along with the use of mathematics to solve problems related to everyday life (context-based problems).

Mathematical problems related to everyday life (context-based problems) give quite a lot of difficulties to students, especially students in Indonesia. This fact is proven by the results of student ability tests held by PISA in 2018. The results released by PISA show that Indonesian students' literacy skills in 2018 were ranked 73rd out of 79 countries [2]. To be able to increase Indonesia's ranking in PISA, students need to improve their mathematical literacy skills [3]. The difficulties experienced by students in solving everyday context-based problems are generally caused by their difficulties in sorting and processing information [4]. The weak ability of students to solve context-based problems shows that students' mathematical literacy skills still need to be improved, especially in understanding the context of mathematical problems.

Several studies have used the PISA problem as an instrument to analyze or improve students' mathematical literacy abilities [5], [6], [7], [8]. Ambarita [6] discussed the ability of mathematical modeling in solving PISA problems. Wasis [7] discussed cognitive process analysis of the problems presented in PISA.

Meanwhile, Wijaya [8] discussed the difficulties in solving context-based PISA problems. However, these studies still focus on PISA problems as material for assessing students' problem-solving abilities, not students' processes in formulating situations, including understanding problems, determining variables, and designing strategies.

Several studies showed that students have less ability in the process of formulating situations mathematically. Susandi [9] said that most students were unable to determine steps to solve the problem because of a lack of understanding regarding the question or situation in the problem given. The lack of focus in the activity of formulating situations mathematically can also be seen from research conducted by Ahyan and Juandi [10]. This research showed that some students experience difficulty in processing information into mathematical form due to a lack of understanding of mathematical concepts which are crucial in the process of formulating situations mathematically. Not only in Indonesia, students in other countries also experienced the same difficulties in understanding and processing information in problem contexts [11], [12], [13], [14] whereas this ability is very necessary for students to make it easier for them to determine appropriate problem-solving strategies, especially context-based problems [15]. Al-Mutawah [16] also said that students' conceptual and procedural understanding abilities are very important to be trained and taught to make it easier for students to develop problem-solving strategies. Based on this problem, research needs to be carried out to observe more deeply regarding students' mathematical literacy abilities in formulating situations mathematically.

This research aims to study students' mathematical literacy skills in formulating situations mathematically, including recognizing students' difficulties in the process of formulating situations mathematically. It is hoped that this research can become a reference for learning focus that needs to be considered in efforts to improve students' mathematical literacy skills.

1.1. Mathematical Literacy and PISA Problems

Mathematical Literacy is a person's ability to formulate, use and interpret mathematics in various contexts. This understanding was conveyed by OECD [2] which compiled an assessment that included mathematical literacy skills. This ability includes reasoning mathematically and using concepts, procedures, mathematical facts to describe, explain and predict phenomena.

In general, the main focus of research related to mathematical literacy is solving problems.

In fact, mathematical literacy does not only focus on problem-solving abilities but also broad and in-depth mathematical knowledge from several parts, namely spatial literacy, numeracy and quantitative literacy [17]. Mathematical literacy refers to a person's ability to analyze and communicate mathematical ideas. Therefore, students' ability to organize situations mathematically is also something that needs to be considered.

One of the international assessments that includes mathematical literacy skills is the PISA problem prepared by the OECD [2]. This assessment then becomes a reference for ranking the mathematical literacy abilities of students from various countries. This made many countries start to study PISA problems and carry out a lot of research to develop the abilities of students in their countries. Several studies discussing the PISA problem [18], [19], [20], [21].

1.2. Formulating Situations Mathematically

There are three main steps in the activity of mathematical literacy according to OECD [2], namely formulating, using and interpreting mathematics. The focus of this research is to develop students' conceptual understanding in this process to make it easier for students to process the information needed in the problem-solving process. Studies related to mathematical literacy that were mentioned before were not focused on the ability to organize situations. Therefore, students become less familiar with this process even though the process of formulating situations mathematically also plays an important role in improving students' mathematical literacy skills. Research conducted by Purnomo [22] also shows that there are still many students who do not have sufficient abilities in terms of formulating situations mathematically. In fact, this process is the basis for students to develop problem-solving strategies, especially PISA problems [16]. Students need to master the necessary mathematical concepts and have skills in processing information to be able to determine the direction of the desired solution based on the information obtained and the mathematical concepts that students have studied previously.

2. Methodology

This research is qualitative-descriptive research [23]. Data collection was carried out on 24 students from two schools in Malang City in February 2023. The research subjects were students on average 16 years old.

Determining the age of the research subjects was accompanied by the consideration that students aged 16 would more easily understand the material they had previously studied. The problems given have also been studied by students. Students were assumed to have no difficulties regarding the material/concepts needed to solve the problem. So, students could focus on processing information and formulating situations mathematically which could help them simplify the problem-solving process.

Students were given several problems related to students' literacy skills in formulating situations mathematically. Students will be asked to answer the questions given and at the same time asked to provide feedback regarding the solution process and the difficulties faced when working on the problem. The work results would be observed and its process would be analyzed based on aspects of students' mathematical literacy abilities [2]. Student questionnaire answers became a reference for the level of difficulty of the questions according to students.

There are 3 sub-activities in the activity of formulating situations mathematically that can be observed, namely: understanding the problem, determining variables, and developing problem-solving strategies. For each sub-activity, there are several aspects to observe for mathematical literacy abilities. For the sub-activity of understanding problems, there are aspects of communication, using tools, and mathematizing, for the sub-activity of determining variables, there are aspects of using language and symbolic and representing operations. Meanwhile, the aspects of reasoning-and-arguing and formulating strategies are included in the indicators for formulating strategies. For the aspect of communication, students were asked to first read the problem given then provide examples of conditions based on the information obtained from the problem. Students' written answers became a reference for assessing students' abilities in understanding the problem.

After understanding the problem given, students needed to know important information from the given context to answer the question. Students' mathematizing aspect was observed by asking students to determine the truth of statements based on the information provided. From the results of students' answers in the task of determining the truth, students were asked to provide reasons for the answers they chose. The results of the answers were then used as a reference for observing students' reasoning and opinion abilities.

For representation, students were given a form of mathematical representation that suited the problem.

Students were asked to determine the meaning of each variable that was associated with the information in the problem. For the aspect of formulating strategy, students were given a condition and were asked to determine the value of one of the variables based on some mathematical information. The results of this work are then analyzed regarding how they utilized the information provided and developed a resolution strategy.

Students' ability to understand symbols was observed by how they answered questions related to information from graphs. Meanwhile, for the aspect of using mathematical tool, there were several diagrams that represented information on the problem. Students were supposed to use these diagrams to obtain the necessary information by making estimates or observing diagrams.

In making the research instrument, the OECD explanation regarding the ability to organize situations mathematically was used as a reference. From this explanation, it was found that there were 7 indicators used based on the 7 aspects of mathematical processing mentioned by the OECD. Questions that have been adjusted to mathematical processing associated with literacy ability aspects for formulating situations mathematically compiled by the OECD can be seen in Table 1.

Table 1. Aspect of mathematical literacy in formulating situations mathematically and the questions

Mathematical Literacy Aspect	Questions / Instruction
Communicating	Make an example based on given information
Using mathematical Tools	Collect information using mathematical tools
Mathematizing	Sort out statements related to given information
Representation	Make or arrange formal representation from given situation
Reasoning and Arguing	Verify some statements and give reasons from their choice
Devising strategies for solving problems	Arrange solving strategies based on information given from context
Using symbolic, formal and technical language and operations	Choose suitable diagram related to given information

3. Results

There were 34 students who participated as subjects. Collection was held in February 2023 at two different schools in Malang. School selection is based on the curriculum and learning references used by students. Students are asked to answer some questions related to their ability in formulating situations mathematically.

From the results of the students' work, the average student got a score of 7.58 out of 17 total correct answers. The percentage of students' correct answers is only around 44.6%. This result is considered low and shows that students' mathematical literacy skills especially in formulating situations mathematically still need to be improved. Table 2 shows the total correct answers from each student per indicator.

Table 2. The number of right answers from students

Name	Score	Name	Score
IMS	14	AAA	5
YH	17	FF	5
KFZ	12	DA	6
ZN	9	AF	3
YAD	9	SS	0
SAT	13	DFRZ	6
ZFN	11	FFA	6
MLN	13	ASA	6
AYN	5	AV	10
AEM	2	ADA	10
AZHNI	5	FLP	5
ADS	4	ABVA	6
Total	182		
Average	7,583		
Percentage	44,6%		

For the first stage, namely determining important information, there are three aspects that are the focus of observation, namely the communicating aspect, using tools, and the mathematizing aspect.

In general, at this stage students need to understand the content of the story. Based on the results of the questionnaire, most students admitted that they needed to read the questions repeatedly to understand the problem. However, even though they have read it repeatedly, some students still had difficulty answering related questions. The common problem that most students often face is that students tend to take this process for granted. As a result, they indirectly realized the importance of this aspect in learning mathematics. The first question that arose from most students is "how do you do it?" This question shows that students were still focused on the final result of the solution without studying the process of understanding the problem.

These results indicated that students still lack focus during the sub-activities of understanding problems which consist of aspects of communicating, using tools, and mathematizing.

Specifically, in communicating activities, students' lack of recognition of important information in the problem caused them to make mistakes in providing examples that match the information provided. In fact, students admitted that they had read the material repeatedly and had no difficulty in understanding the problem. This showed that observing activities which were almost always carried out at the beginning of learning need to be further developed and accustomed to. It is not enough for students to just read the problem and understand it in depth, or answer questions according to the information provided. There needed to be development of communication activities so that their ability to understand information can develop. This can really help them when they are faced with complex problems that require deeper analysis of the information on the problem [24]. Students' lack of communication skills was clearly visible when they were asked to provide other examples of similar situations based on the information obtained. Most students just rewrote the situation in the example with few modifications. They didn’t write any other situation that used the same rule. Some students only changed the number written on the example. One of the students' work results are shown in Figure 1.

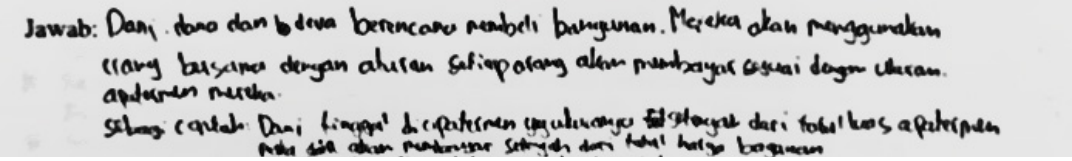
Soal 1. Sekelompok orang yang tinggal di apartemen berencana untuk membeli bangunan. Mereka akan mengumpulkan uang bersama dengan aturan setiap orang akan membayar sesuai dengan ukuran apartemen mereka.

Sebagai contoh, Seorang pria tinggal di apartemen yang ukurannya adalah seperlima dari total luas apartemen. Dia akan membayar seperlima dari total harga dari bangunan tersebut.

(a)

Problem 1. A group of people living in an apartment plan to buy a building. They would pool the money together with the rule that each person would pay according to the size of their apartment. For example, a man lives in an apartment whose size is one-fifth of the total area of the apartment. He will pay one fifth of the total price of the building.

(b)



(c)

Answer: Dani, Dana, and Deva plan to buy a building. They will use shared money with the rule that each person will pay according to the size of their apartment. For example: Dani lives in an apartment that is half the size of the total apartment area. Then he will pay half of the total price of the building.

(d)

Figure 1. (a) given situation, (b)given situation in English, (c) example of similar situation made by student, (d) example of similar situation made by student in English

Next, for the process of using mathematical tools, students were expected to be able to use the number line to make estimates. From the results of the students' work, it can be seen that they have quite mastered it because it has often been used as supporting material for learning in class.

For the aspect of mathematizing, students' abilities were observed from the student's process of determining the truth of a statement based on information on the problem. Most students gave inappropriate answers. This means that they can understand the context of the problem, but do not understand the meaning and important information of the problem. Apart from that, the students' answers prove that it is not enough for students to just read and understand the problem, but they also need to pay attention to the important information contained in it.

The next stage is determining variables. This stage consisted of two aspects: representation and using symbolic, formal, and technical language and operations. In answering questions about representation, most students gave simple answers. They only state that the comparisons given are related to money, without more detailed information regarding the variables that appear. Some students provided brief explanations regarding the variables used. In this process, most students only demonstrated concepts based on the formal statements given.

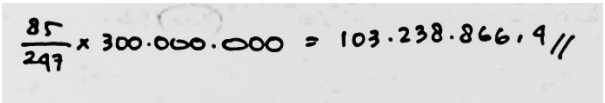
Students were unable to identify each variable that represents information in the situation. There were several students who tried to state the information represented by variables, but the answers given were still wrong. Students admitted that they were confused by the given questions even though the instructions given were clear. This indicates that the questions asked are less familiar to students. Students tend to miss this representation process in the process of student work. Based on the questionnaire filled out by students, students still have to ask other people to answer this question. However, the questions asked by students were not questions to help them answer questions. Some students asked the answer without asking about the process of finding the answer.

Aspect of using symbolic, formal, and technical language and operations was observed from students' ability in reading graph. They did not have any problem in reading graph since they have already known and trained much about graphs. They can answer the question related to that without asking others. The questionnaire also showed that students do not have any difficulties in reading graph and relate that to the question.

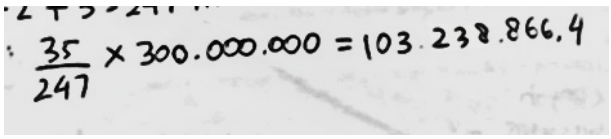
When students were asked about analysis based on the answers given when determining the truth, only a few students were able to provide answers that were rational and in accordance with the information provided.

Most students experienced misunderstandings that caused inaccuracy in their answers. These students experienced confusion regarding the information on the problem to answer questions and the use of the information is less appropriate in preparing problem-solving strategies.

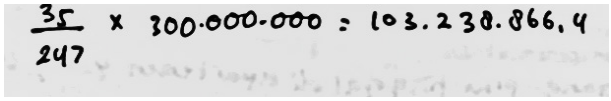
In preparing strategies, students did not experience much difficulty in reading diagrams as a means of mathematical representation. However, students had difficulty in choosing and using important information for problem-solving. This results in students having difficulty determining the right strategy based on the information provided. In addition, some students were able to give the right answer. The solution strategy written is in accordance with the information available in the problem. It is just that, some students made several mistakes in writing down the solution process. However, the answers they wrote were still correct. This raises question "Do students really understand each solution process written in their answers?". After observing it, turned out that several students had procedures that were similar to each other. From the two students who made errors in writing information in the solving process, it can be concluded that the students have not mastered how to formulate situations mathematically, especially their understanding of the information provided in the problem. Students only relied on help from students without a full understanding of the variables needed and the problem-solving process that they could develop based on the information they had collected. The similarity of students' answers and writing errors in some students' answers can be observed in Figure 2. The correct answer is 85/247. But some students misread the student's writing and write 35/247. But the result is the same. This means those students only copy their friend's work without calculating or checking.



(a)



(b)



(c)

Figure 2. Students' answer (a) correct answer, (b) and (c) wrong procedures, but the answers are correct

4. Discussion

The interesting thing in this research is the extent of their understanding regarding the problem given. This relates to students' abilities in terms of communicating, mathematizing, reasoning, and representing. Bartell [1] stated that several things that need attention are rationalizing problems, analyzing, looking for relationships, and developing problem-solving strategies. Although several studies have utilized these aspects as assessments, there are still few studies that specifically teach these aspects of ability. This can be seen from the fact that there are still many students who are unable to work independently to answer questions related to rationalizing problems, analyzing and looking for relationships. Especially because this aspect is not explicitly carried out in the problem-solving process. Basically, the process of formulating situations mathematically aims to help students better understand the information in problem situations so that students can develop appropriate and most effective problem-solving strategies.

For the aspect of representation there are some differences in understanding the representation forms. In fact, the process of representing students can differ between students [25]. The study stated that students carry out the representation process using different methods. Some students need a symbolic representation explanation and some students need an arithmetic explanation. If it is related to the results of students' work, it can be seen that some students still have difficulty understanding the solution process carried out by other students because the solutions are written in symbolic form. This makes it impossible for other students to learn directly based on pictures. There needs to be a more complete explanation of arithmetic to help students understand the representation process. The same problem was also experienced by students in research conducted by Ambarita [6] where students had difficulty understanding the results of the representation. So learning is needed that specifically trains their abilities in terms of mathematical representation.

For the aspect of using symbolic, formal, and technical language and operations, students did not have any problem. Learning mathematics using graphs and number lines has been done by many teachers so this is more familiar to students. This shows that there is a need for regular habituation and introduction to maintain students' memories so that knowledge about using mathematical tools is not buried. This helps students build their confidence when they are asked to solve problems related to mathematical symbols.

This statement is in line with Borgonovi and Pokropek [26] statement which states that problem specification can increase students' self-confidence.

Another interesting thing can also be seen in the mathematizing and reasoning activities. Positive student perceptions should show that they have confidence in their mathematical and reasoning abilities [27]. However, the wrong answers given are proof that students are not optimal in carrying out the process of mathematizing and reasoning when they are faced with a condition. Their understanding of the information in the problem is still not deep so the answers given are still based on students' general understanding. Apart from that, in reasoning activities, students also do not utilize the mathematical concepts taught. This makes them still respond based on their general understanding without being based on strong evidence built from understanding the problem. This deficiency was also found in research conducted by Marsitin [28]. Apart from that, mistakes made by students are also caused by students' lack of conceptual and procedural understanding. This opinion is also supported by research conducted by Indrawatiningsih [29] which states that in the proof process, most students experience difficulties due to conceptual and procedural errors.

Research conducted by Tanudjaya and Doorman [30] also shows the same thing, where students have many problems in determining the correct proof of the assumptions they make. The proof they make still does not utilize students' mathematical knowledge. This makes the evidence they provide less strong and less supportive of their answers.

In the process of formulating strategy, similarities on students' answers give rise to suspicions that students are still asking other students for completion procedures. The answers given are not based on their understanding of information and information processing, but rather from imitating friends' answers. In fact, in the learning process that refers to the independent curriculum, students are free to choose the problem-solving process based on the knowledge they have learned. Like research conducted by Sa'dijah [31] on how teachers teach higher-order thinking skills (HOTS) in class. Teachers give students the freedom to choose the strategies they can use. This freedom is also limited by students' conceptual knowledge. These results are supported by by Supandi's [32] research which stated that students tend to lack the ability to choose the right strategy based on the concepts they have learned.

This deficiency causes students to tend to ask other students about the problem-solving process.

These results indicate that students' focus is on the problem-solving process, or commonly known as procedural knowledge. Students do not learn much conceptual knowledge. Education so far has focused a lot on procedural knowledge and less involved conceptual knowledge, which has resulted in a lack of conceptual understanding among students [16].

5. Conclusion

Several aspects of mathematical literacy in the activity of formulating situations mathematically have been taught implicitly by including these aspects periodically in learning, or by habituation, such as aspects of strategizing, using symbols and mathematical tools. However, some aspects require specific learning activities to help students develop their mathematical literacy skills. Such as activities to communicate problems, mathematize, reason, and represent. Observation results show that students still lack the ability to understand and process information which is very necessary in the process of formulating situations mathematically. Further research is needed regarding student deficiencies in this process. Some of them are assessments to assess students' abilities to understand, select and process the information needed to develop problem-solving strategies. It is hoped that the results of this research can become a reference for developing the learning that students need to increase their mathematical literacy skills, especially in the activity of formulating situations mathematically.

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