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Students' Ability to Solve Mathematical Problems in The Context of Environmental Issues

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Abstract: The environment is a global issue that must be addressed in a variety of ways, including education. Environmental topics will be included into mathematics, which is allowed to boost students' awareness of environmental concerns. This is a qualitative study conducted in a qualitative technique. The objectives of this study were to (1) describe students' mathematical abilities in solving problems related to environmental issues and (2) determine students' knowledge and responses to the environment. The research was performed on 26 students in class VIII at Villanova Catholic Middle School in Manokwari, West Papua, during the even semester of the 2020/2021 academic year. The results indicated that students were classified into four categories based on their ability to solve mathematical problems relating to environmental issues. Students who are capable of solving mathematical problems while also being environmentally conscious. Students that are capable of solving mathematical problems but have no interest in environmental issues. Students who are unable to answer mathematical tasks but are concerned about environmental issues, and students who are not able to solve mathematics problems at the same time don't care about environmental problems.

INTRODUCTION

Education plays a critical role in developing humans with positive attitudes, specifically concern for and understanding of the environment (Velempini 2016; Susanti, et al, 2018; Mumu, et al. 2020; Tanujaya, et al. 2021). Education contributes to the development of students' favorable attitudes toward the environment. This is confirmed by Samani and Hariyanto (2012) and Suparno (2015), who argue that the educational community at all levels of education is the appropriate focus for fostering a positive attitude toward the environment.

Integrating environmental education into classroom mathematics instruction can help students develop environmental sustainability characteristics. This is understandable because mathematics is a required topic at every stage of education, from elementary to university, for it to develop into

a "habitat" that can continually cultivate an environmental stewardship character (Jianguo, 2004). However, in Mathematics disciplines, the thematic - integrative approach that includes components of environmental education to build environmental stewardship traits is almost non-existent (Sutriani, et al. 2020). Additionally, Panjaitan (2020) noted that teachers' difficulty incorporating environmental factors into mathematics learning was owing to a dearth of mathematics teaching materials that may serve as a resource for mathematics teachers. This investigation confirms the findings of Spiropoulou et al. (2005) and Litner (2016) that there is a dearth of literature on environmental integration in mathematics.

Connecting mathematics with the environment is not novel or difficult. Mumu et al. (2020) argued that mathematics is a tool that the environment uses to describe a variety of environmental events, including problem solving. Several experts have been documented that global and national environmental problems can be brought into the mathematics classroom to be solved and solutions discovered (Byrne, 2009; Schwartz, 2010; Gutstein & Peterson, 2013; Barwell, 2013; Widodo, et al. 2019). These include problems with pollution, water, deforestation, natural disasters, garbage, oil and energy, and other local environmental problems. Students must be aware of and sensitive to national and global environmental concerns, possess the information necessary to understand them, and be familiar with a variety of viable solutions (Schwartz, 2010). Thus, integrating the environment into mathematics can contribute to the achievement of the Sustainable Development Goals (SDGs).

The context of the environment and environmental problems can be utilized to explain and guide students' comprehension of abstract mathematical objects. The realistic context of the learning environment enhances the understanding of mathematics instruction, which is one of the characteristics of Realistic Mathematics Education (Hadi, 2017; Hendriana, et al. 2019). Some other characteristics of Realistic Mathematics Education (RME) are the use of model, students' creation, and contribution, interactive of teaching process, and intertwining of various learning strands (de Lange, 1987; Gravemeijer, 1994).

RME is a Netherlands theory of mathematics instruction, developed by Freudenthal Institute (Van den Heuvel-Panhuizen & Drijvers, 2020). This theory views mathematics as a human activity (Freudenthal, 1973; Gravemeijer, 1994), so learning mathematics should be connected to reality. Consequently, in RME, studying mathematics entails doing mathematics, which includes addressing real-world problems (contextual problems) (Freudenthal, 1991). Students should be encouraged to develop mathematical concepts, and the teaching-learning process should be much more interactive (Fauzan, et al. 2002).

Therefore, RME is a possible instruction approach for increasing students' knowledge of mathematics (PMRI Team, 2010). This is due to the fact that mathematics is an abstract discipline that is difficult to understand. The abstract of mathematics should be adjusted to make it more tangible so that students could visualize it through a contextual situation (Swanson & Williams, 2014). Additionally, Gravemeijer (1994) believe that students should be allowed to rediscover Mathematics in their own way, guided by adults, and that the process should begin with the exploration of diverse issues and real-world situations. Mathematics may be used to investigate

waste, population expansion, global warming, flooding, pollution, and the destruction of biodiversity. Students will feel better because of experiencing what they are learning and realizing the importance of mathematics in their lives when they learn from everyday happenings.

Students' behaviors and responses when confronted with an issue and seeking answers vary depending on a variety of circumstances, including their necessary abilities and the level of their cognitive thinking. Similarly, students' perceptions on the environment and its problems vary. Panjaitan (2020) discovered that students were unable to address environmental essay task throughout her investigation. The student reasoned that the question did not correspond to the provided example. This confirms Daryanto and Karim (2017) assertion that students can solve difficulties only if the problem is identical to the one has been provided by the teacher and that students will fail if the problem's context is different from the example problem. According to Clement (2009), such impediments are classed as "epistemological" barriers, i.e., impediments that develop because of one's knowledge being contextualized. On the other hand, one of the hurdles that students face when attempting to solve story problems is a lack of problem-solving abilities.

In terms of the curriculum, problem solving is one of the objectives of the learning process. Problem solving is critical because it helps make Mathematics more relevant and sustainable (Guzman, 2018; Stacey 2005). Problem solving is one of the components of 21st century learning that must be mastered (Szabo, et al. 2020). Students with high problem-solving abilities will be able to navigate the intricacies of global concerns in the future. Problem solving ability is a necessary skill for students to possess to address mathematical problems, problems in other fields, and challenges encountered in daily life (Risdiyanti & Prahmana 2020). Students with a high-level problem-solving ability will be able to resolve issues. Numerous issues that will always arise throughout life.

The National Council of Teachers of Mathematics (NCTM) has stressed the importance of problem solving in learning. According to NCTM (2000), mathematics learning involves five primary standard competencies: problem solving ability, reasoning capacity, connection ability, communication ability, and representation ability. This inability will result in low-quality human resources, as shown by the inability to solve problems. This is because so far, education has not provided opportunity for students to build their abilities to solve problems, and students are therefore less acclimated to problem solving (Hesti & Setiawati, 2016; Widodo, et al. 2019; Muhammad & Pujiastuti, 2020). Additionally, problem solving questions are frequently assigned towards the conclusion of class hours, ensuring that they are not discussed in class by the teacher (Alison, 2017). This method of instruction does not facilitate students in developing their problem-solving abilities.

Based on the statements above, the researchers are interested in the students' competence to solve mathematical problems when challenged with essay questions about environmental issues. This study is the initial research a series of research that will culminate in the development of an environment-based mathematics teaching material. As a result, the findings of this study are intended to guide academics in developing mathematical learning materials that are integrated with

environmental concerns. As such, this study will investigate students' mathematical problem-solving abilities and their awareness of environmental issues.

METHOD

This is a qualitative study using a descriptive technique. The objectives of this study were to describe students' mathematical abilities in solving problems related to environmental issues and determine students' knowledge and responses to the environment. The research was conducted on 26 students in class VIII at Villanova Catholic Middle School in Manokwari, West Papua, during the even semester of the 2020/2021 academic year. They are students who have studied environmental topics in the elementary school and the grade VII junior high school. They have studied the environment issue in elementary school through thematic subjects, and in junior high school through natural sciences. This is in accordance with the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 24 of 2016 concerning the basic competencies of mathematics lessons in the 2013 curriculum.

Data collecting procedures included observation, essay tests, and unstructured interviewing. An essay test consists of three numbers was used as the research instrument. Environmental issues such as clean water, flooding, and garbage is employed as realistic contexts. Mathematical concepts related to environmental issues include decimal numbers, distances, exponent, unit conversions, fractions, and sets. Details of the context of environmental issues and mathematical concepts for each item are presented in Table 1.

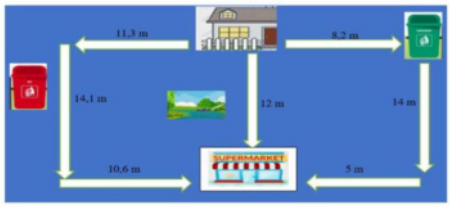
Task Number	Environmental Issues	Mathematical concepts
1	Toxic Waste	Addition of decimal number and distance
2	Clean Water	Exponent and Unit Conversion
3	Flooding	Fraction and Sets

Table 1: Context of environmental issues and mathematical concepts

The first problem is developed using two mathematical concepts, distances, and addition of decimal number using the context of hazardous waste. In other words, this assignment is designed to measure their ability to solve mathematical problems as well as their awareness of hazardous waste (see Figure 1). The second question is based on the concept of exponent numbers and converting units in the context of clean water, to evaluate students' awareness of the environment, particularly about clean water. Meanwhile, the third item was established in consideration of the waste that contributes to flooding. This item contains a mathematical concept involving the set and addition of fractions. It is predicted that students who possess knowledge of organic and inorganic waste will be able to correctly solve this question.

Task Number 1

Perhatikan denah di bawah ini. Pada denah ini terdapat beberapa tempat penting yaitu rumah, supermarket, sungai, bak sampah merah dan bak sampah hijau. Anak panah menunjukkan arah jalan yang dilengkapi panjang jalan dalam meter.



Pada suatu hari yang terik, Abner meminta ijin kepada ibunya untuk pergi ke Supermarket membeli buah. Ibu Abner mengijinkan dan meminta Abner untuk terlebih dulu membuang satu kantung sampah yang berisi masker-masker bekas, botol bekas disinfektan, kaleng baygon bekas dan beberapa buah baterei. Bantulah Abner untuk memilih :

a. Rute paling tepat ke supermarket sekaligus membuang sampah. Berikan alasan jawabanmu

b. Rute paling tepat untuk kembali ke rumah. Berikan alasan jawabanmu

Translation

Consider the floor plan below. There are various significant locations on this floor plan, including homes, stores, rivers, red trash cans, and green trash bins. The arrows indicate the road's direction and the road's length in meters.

Abner requested permission from his mother one scorching day to go to the supermarket and get fruit. Abner's mother permitted and requested that Abner discard a rubbish bag containing used masks, disinfectant bottles, baygon cans, and many batteries. Assist Abner in making a decision:

a. The most efficient path to the store, as well as rubbish disposal. Justify your response.

b. The most direct path home. Justify your response.

Figure 1: Task Number 1 and Its Translation

The three questions consist of four indicators of the problem solving, namely understanding the problem, planning a strategy, solving the problem, and re-examining. The four indicators are used to classify students' problem-solving abilities and their environment awareness into four types of abilities, as stated in Table 2.

Type	Criteria
I	Students are able to solve mathematics problems correctly and have a positive response to the environment
II	Students are able to solve mathematics problems correctly but have a negative response to the environment
III	Students are able to solve mathematics problems correctly but have a negative response to the environment
IV	Students cannot solve mathematics problems correctly and have a negative response to the environment

Table 2: Type of Students Problem-Solving Ability and Environment Awareness

Furthermore, the research subjects were grouped based on the four types of problem-solving abilities and environment awareness on each item. From these groupings, one of students' answer was selected that represents each type of students' ability for further analysis.

RESULTS

Students are grouped into four problem-solving abilities and environmental awareness categories based on the outcomes of the essay test, except for type II for the second item. Table 3 summarizes the percentages of students' ability for each category.

Item Number	Type of Students' Performance			
	I	II	III	IV
1	26,92	7,69	7,69	57,69
2	23,07	0,00	15,38	61,54
3	15,38	23,07	7,69	53,84

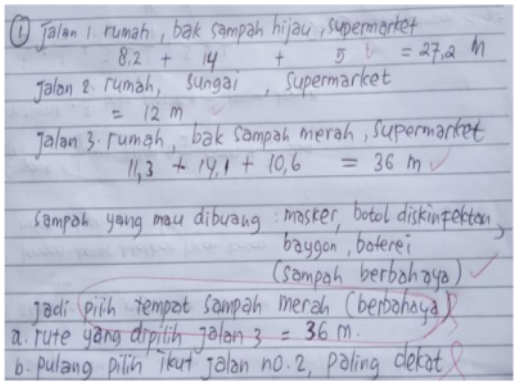
Table 3: Distribution of Students' Problem-Solving Ability and Environment Awareness

Based on Table 3, most students assessed are classified as belonging to group fourth. This category of students is comprised of those that are unable to solve problems correctly and have a bad attitude toward environmental issues. This shows that generally students have low ability to solve mathematical problems as well as their lack of care for environmental issues. However, there is a second percentage that is extremely significant for pupils who are environmentally conscious and possess strong problem-solving abilities. This group consists of students classified as the first type.

Furthermore, an analysis of students' abilities based on each item's type of problem-solving ability. The student answers to task number one and number three are vary and can be grouped into 4 types of students. Students' answers to the second question can only group them into three types of students, without students having characteristics that can be categorized into the second group. The following are some instances of student responses as presented on figure 1 to figure 4.

Based on the student' statements in Figure 2, it appears that students comprehended the issue of choosing the "most appropriate" pathway to the grocery while also taking out the rubbish. Garbage that needs to be disposed of is classified as hazardous waste and deposited in a red garbage container. The student then determines the shortest route home. Additionally, the student demonstrates her understanding of the concept of decimal number addition.

A sample of student answer



Translation

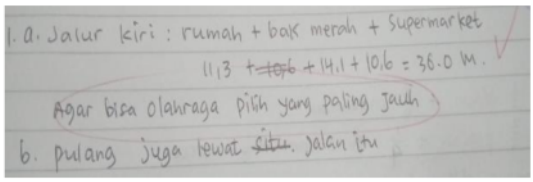
Route 1 : Home → Green Can → Grocery
8,2 + 14 + 5 = 27,2 m
Route 2 : Home → River → Grocery
14 m
Route 1 : Home → Red Can → Grocery
11,3 + 14,1 + 10,6 = 36 m
Garbage that needs to be discarded (used masks, unused disinfectant bottles, used baygon bottles, and batteries) is classified as hazardous waste, which is why I chose the red trash can.

a. The route chosen is route number three, which is 36 meters long.
b. Return home using route number 2, as it is the shortest.

Figure 2: Type I students' answers to the first task

The following is student answer as an example for those who are capable of accurately solving mathematical problems but has a negative attitude about the environment, as presented on Figure 3.

A sample of student answer



Translation

a. Left path: house + red box + supermarket
11,3 + 14,1 + 10,6 = 36,0 m
To exercise, take the far more distant path.
b. Return home along that road.

Figure 3: Type II students' answers to the first task

The responses of student in Figure 3, provided information that the student appear to understand how to correctly do decimal number addition operations as well as the concept of distance. Student, on the other hand, is unaware of the issue of hazardous waste and its relationship to the red trash can. This is reflected from student' stated reasons for choosing the route, notably "to be able to exercise." Student make the connection between distance and health. Student' environmental sensitivity is not evident in their responses.

Based on the two answers, students' ability to solve mathematical problems appears to be unrelated to their care about environmental issues. Students with a high-level mathematics problem-solving ability could have completely opposite perspectives on environmental issues. Mathematics instruction do not influence pupils' attitudes on environmental issues. This is consistent with the findings of interviews with students, who reported that teachers hardly ever discuss environmental issues while teaching mathematics or other lessons. Another student mentioned that he gathered

knowledge of environmental issues outside of the classroom from television, social media, and the internet. On the other hand, according to Jianguo (2004), incorporating environmental topics into mathematics classroom can help students develop characteristics associated with environmental awareness.

The absence of a relationship between students' ability to solve mathematical problems and their concern for environmental issues is also noticeable in the results of students' answers as presented in Figure 4, Figure 5, Figure 6, and Figure 7.

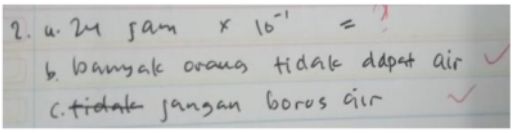
A sample of student answer	Translation
	a. 24 hours x 10^{-1} = b. Numerous people lack access to water. c. don't waste water

Figure 4: Type III students' answers to the second task

Figure 4 presented information that the student doesn't understand the problem of the task. The student is unable to recognize any information of the provided questions. Despite his failure to overcome the problems posed, the student is concerned about the issue of clean water, which is required by a large number of people. Other student demonstrated the same results, as presented in Figure 5.

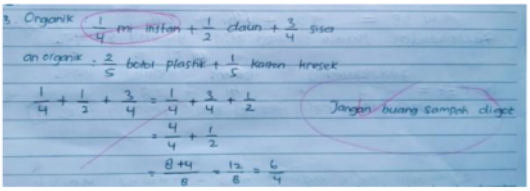
A sample of student answer	Translation
	a. Organic: ¼ instant noodle + ½ leaves + ¾ leftover b. An organic: 2/5 plastic bottles + 1/5 bag section ¼ + ½ + ¾ = ¼ + ¾ + ½ = 4/4 + ½ $= \frac{8+4}{8} = \frac{12}{8} = \frac{6}{4}$ c. don't throw trash in the ditch

Figure 5: Type III students' answers to the third task

Based on the student' responses in Figure 5, it appears as though students has already comprehension the problem. Students understand that garbage can be classified as organic or inorganic. The grouping is an approach for simplifying the calculation of the result of fraction addition. However, due to the error of included the instant noodle packet in the organic waste group, the fractions addition was not completed correctly. However, pupils have an awareness of the garbage that contributes to flooding. Don't throw the trash in the ditch.

The following are samples of students' answers that are unable of solving mathematics problems but are unconcerned about environmental issues.

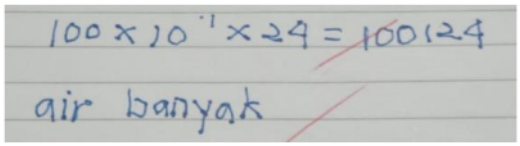
A sample of student answer	Translation
	$100 \times 10^{-1} \times 24 = 100124$ Plenty/over water

Figure 6: Type IV students' answers to the second task

In the sheet answer as presented in Figure 6, student could not identify the problem and incorrectly planned the problem-solving strategy. The student is unable to perform multiplication procedures accurately. Additionally, student doesn't believe that the issue of clean water is a major one. This is assumed to be influenced by the pupils' daily lives. The student lives in an area with bountiful mountain water, ensuring that he is never without water.

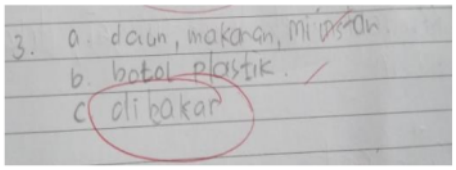
A sample of student answer	translation
	a. leaves, food, instant noodles b. plastic bottles c. burnt

Figure 7: Type IV students' answers to the third task

Figure 7 presented information about students who do not understand the problem in the task. Students attempted to classify organic and inorganic garbage, but did so incorrectly due to a lack of information about the many types of waste. This error prevented pupils from progressing to the next step of problem solving. Furthermore, students realize that rubbish might cause flooding, but the solutions proposed are unsatisfactory. It is advised that the garbage be burned.

DISCUSSION

Based on the data collected and the analysis results, it appears that students' problem-solving capacity is still somewhat limited. In general, students do not comprehend problems involving mathematical concepts and environmental situations. They are unable to devise effective solutions for resolving mathematical issues that are constructed in terms of their environmental setting. As a result of this condition, they will have a low level of care about environmental issues. This is consistent with Henderina's (2018) assertion that students' ignorance of the environment is a determinant of environmental consciousness. Additionally, Szabo et al. (2020) state that the primary requirement for solving a problem is to understand the problem, what is known, what is

being asked, whether there is a requirement to answer what is being asked, and whether the requirement is sufficient or additional conditions are required.

Students must have a basic understanding of the environment in order to solve environmental problems. Similarly, students must be able to comprehend mathematical concepts in order to solve mathematical problems. In other words, students must possess environmental knowledge and a proper understanding of mathematical concepts in order to answer environmental-related mathematics issues. Mathematics problems involving environmental issues can be handled only if students possess adequate and accurate understanding of the environment and the challenges that surround it. As a result, they will have a favourable reaction to the environment, as well as a knowledge of and concern for the environment. According to Zheng et al. (2018), adequate environmental knowledge is required to influence students' environmental behaviour. Their research demonstrates a positive correlation between environmental knowledge, environmental behaviour, and environmental attitudes. Furthermore, education is crucial in fostering positive attitudes in humans, particularly a concern for and awareness of the environment (Yumusak et al., 2016; Leksono, 2017).

One aspect contributing to students' lack of understanding about environmental issues is the scarcity of mathematics textbooks that incorporate environmental issues. According to Spiropoulou (2005), including environmental elements in mathematics textbooks can help students have a better understanding of ecological, social, technological, and historical environmental challenges. Additionally, He was said that when considering society's changing needs and beliefs, education must take this into account and provide opportunity for students to learn more about environmental issues. Furthermore, Matilde et al. (2020) noted that mathematics plays a critical part in reaching the Sustainable Development Goals (SDGs) while also allowing students to interact with real-world scenarios in mathematics topics, which promotes active learning.

CONCLUSION

Environmental-based mathematics learning and the availability of environment-based mathematics textbooks must be supported by professional mathematics teachers. This is because the teacher plays a critical part in the instruction process. The teacher serves as the lesson's planner, implementer, and evaluator. These three responsibilities position the teacher as the primary determinant of the success of environmental-based mathematics instruction. They should be able to integrate environmental issues into their mathematics instruction. According to Rosenshine (2012), the effective teachers ensured that pupils were acquired, practiced, and connected to other knowledge in an efficient manner.

Finally, environmentally oriented mathematics instruction can assist students in developing their capacity to address mathematical problems involving the environment. The teacher is the agent of

this learning's accomplishment. Mathematics teachers must be able to incorporate environmental education into their classes in order to teach mathematics successfully. Mathematical teachers should incorporate more examples of mathematics issues that are related to the environment into their classroom instruction. Environmental issues can be used as a realistic context in an effort to improve students' understanding of mathematical concepts. In order to realize this, it is necessary to develop environment-based mathematics textbooks

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