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A PRELIMINARY STUDY OF STUDENTS' NUMERACY SKILLS IN COMPARING MODES OF TRANSPORTATION BASED ON HEALTH AND CARBON EMISSIONS

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ABSTRACT

Numeracy skills encompass not only the ability to perform calculations but also the ability to understand, interpret, and use numerical information to make decisions in real-life contexts. However, research on students' numeracy skills in comparing modes of transportation based on health and carbon emissions remains limited. This study aims to examine students' numeracy skills in comparing modes of transportation based on these two aspects. The study employed a qualitative descriptive approach involving 12 eighth-grade middle school students. Data were collected through a transportation-context-based numeracy test and semi-structured interviews with six students representing high, moderate, and low ability categories. Data were analyzed using the Miles and Huberman model through data reduction, data presentation, and drawing conclusions. Data validity was verified through triangulation of test results and interviews. The results showed that students in the high-ability category were able to understand information, perform calculations, and use the results to make decisions consistently. Students in the moderate category were able to perform calculations correctly but did not yet fully base their decisions on the results of those calculations. Meanwhile, students in the low category still struggled to perform calculations and connect the results to their decisions. These findings indicate that numeracy skills depend not only on calculation skills but also on the ability to interpret numerical information and use it as a basis for decision-making in contextual problems.

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INTRODUCTION

Numeracy is one of the essential competencies students need to tackle various problems in everyday life. Numeracy is not only related to the ability to perform mathematical calculations, but also to the ability to understand, use, and interpret quantitative information presented in various forms to support sound decision-making

(Bolstad, 2023; Heyd-Metzuyanim et al., 2021; Kappassova et al., 2025; Pickering et al., 2025). Within the framework of the 2022 Programme for International Student Assessment (PISA), numeracy or mathematical literacy is defined as an individual's ability to formulate, employ, and interpret mathematics in various real-life contexts (OECD, 2023). Thus, numeracy is one of the key competencies in mathematics education because it helps students use mathematical concepts to understand problems and make decisions based on available information.

Nevertheless, the 2022 PISA results show that Indonesian students' numeracy skills remain below the average of OECD member countries. The OECD (2023) reports that most students still struggle to apply mathematical concepts to solve contextual problems, particularly when they must connect calculation results to real-world situations. These findings are reinforced by Nirfayanti et al. (2025), who state that Indonesian students still face challenges in integrating various pieces of numerical information and interpreting calculation results to draw conclusions appropriate to the context of the problem. Similar difficulties in solving contextual mathematics problems have also been reported in previous studies (Jailani et al., 2020; Khaesarani & Ananda, 2022; Kolar & Hodnik, 2021; Sa'diyah et al., 2024; Saputri et al., 2018). This situation indicates that numeracy skills should not be measured solely by the accuracy of performing arithmetic operations, but also by the ability to understand information, interpret results, and use numerical information as a basis for decision-making.

One approach that can be used to assess numeracy skills is through the presentation of contextual problems that are relevant to students' lives. Task design that is grounded in realistic contexts is considered important for helping students apply mathematics and numerical information in real-life situations (Geiger et al., 2022). Contexts that are relevant to students' experiences help them connect mathematical concepts to everyday life, making the process of mathematical thinking more meaningful. In line with this, the OECD (2023) recommends the use of personal, social, scientific, and work-related contexts in the development of numeracy questions because they effectively illustrate the application of mathematics in real life.

One relevant context is mode of transportation. In daily life, students are faced with various transportation options that have different characteristics, both in terms of health and carbon emissions. Creutzig et al. (2022) explain that each mode of transportation produces different levels of carbon emissions, thereby having different impacts on the environment. In addition, daily active travel such as cycling can contribute to reducing

carbon emissions in cities (Brand et al., 2021). Meanwhile, active transportation, such as cycling, provides greater health benefits than the use of motor vehicles (Götschi et al., 2016; Mueller et al., 2015; Stankov et al., 2020). These differences in characteristics provide comparable numerical data, enabling students not only to perform mathematical calculations but also to use the results of those calculations as a basis for decision-making.

Several studies have examined students' numeracy skills through various everyday contexts (Efriani et al., 2019; Oktiningrum et al., 2016; Susanta et al., 2023). Sari et al. (2023) demonstrated that the context of transportation can be used to develop valid and practical numeracy questions for middle school students. However, that study focused primarily on instrument development and therefore did not provide insight into students' numeracy skills when using numerical information to compare modes of transportation based on more than one aspect. To date, studies that specifically describe students' numeracy skills in comparing modes of transportation based on health and carbon emissions remain limited. In fact, using these two aspects allows students not only to perform calculations but also to compare various numerical information, interpret the results obtained, and provide data-supported reasoning in the decision-making process.

Based on the above description, this study is novel in its use of a comparative context involving modes of transportation that integrates two aspects simultaneously namely, health and carbon emissions to assess students' numeracy skills. This study not only describes students' ability to perform mathematical calculations but also analyzes how students understand information, compare data, interpret results, and use calculation results as a basis for making decisions regarding contextual problems.

Therefore, this study aims to examine students' numeracy skills in comparing modes of transportation based on health and carbon emissions. The results of this study are expected to provide an overview of the characteristics of students' numeracy skills across each proficiency category and to serve as input for teachers in designing authentic, context-based mathematics instruction that can develop students' numeracy and decision-making skills in a more meaningful way.

RESEARCH METHODS

This study employed a descriptive qualitative approach to examine students' numeracy skills in comparing modes of transportation based on health and carbon emissions. The study involved 12 eighth-grade students from a junior high school in Banda Aceh. All participants completed a numeracy test, and six students were purposively

selected for semi-structured interviews, representing high, medium, and low numeracy ability, with two students from each category.

The research instruments consisted of a numeracy test and a semi-structured interview guide. The test was developed based on the 2022 Programme for International Student Assessment (PISA) framework, which includes three mathematical processes: formulating, employing, and interpreting (OECD, 2023; Suciati et al., 2020). The development of the test items also referred to transportation-context-based numeracy tasks developed by Sari et al. (2023), while the numeracy indicators were aligned with the characteristics of numeracy tasks described by Nirfayanti et al. (2025). The interview guide was used to explore students' thought processes when solving the test items.

The numeracy test was designed to assess students' abilities to work with numerical information presented in a transportation context. The tasks required students to identify relevant information from the provided table, calculate total carbon emissions, determine differences in carbon emissions, complete a comparison table, calculate differences in physical activity, explain the differences between transportation modes, and make decisions based on the available data. These tasks were intended to examine students' abilities across the three mathematical processes of formulating, employing, and interpreting. Thus, the assessment focused not only on the accuracy of students' calculations but also on their ability to understand and use numerical information in a contextual problem.

The numeracy test was assessed using an analytical scoring rubric, with a score of 3 for correct and complete answers, 2 for partially correct answers, and 1 for incorrect or inappropriate answers. The maximum total score was 21. The scoring rubric is presented in Table 1.

Table 1. Scoring Rubric

Item	Assessment Indicators	Score 3	Score 2	Score 3
1a	Identifying information in the table	All information is correct	Some information is correct	Most information is incorrect or no answer
1b	Calculating total carbon emissions	Correct procedure and result	Correct procedure but incorrect result	Incorrect procedure and result

Item	Assessment Indicators	Score 3	Score 2	Score 3
1c	Calculating the difference in carbon emissions	Correct and complete	Partially correct	Incorrect
2 (tabel)	Completing the comparison table	All data are correct	Some data are correct	Most data are incorrect or incomplete
2a	Calculating the difference in physical activity	Correct result with calculation	Correct result without steps or with minor errors	Incorrect
2b	Explaining differences based on the data	Appropriate explanation using data	Inaccurate explanation or incomplete use of data	Inappropriate explanation
2c	Making a data-based decision	Appropriate decision supported by data	Decision insufficiently supported by data	Inappropriate decision without supporting data

The maximum total score is 21.

Each student's numeracy score was calculated using the following formula:

$$N = \frac{S}{S_{maks}} \times 100$$

Description:

N = numeracy scores

S = score obtained

S_{maks} = maximum score (21)

Next, the students' scores were categorized into three levels of numeracy ability: high, moderate, and low, as shown in Table 2.

Table 2. Classification of Students' Numeracy Skills

Value	Category
$85 \leq N \leq 100$	High
$70 \leq N \leq 85$	Medium
$N \leq 70$	Low

Based on these classifications, six students were selected for interviews, with two students representing each ability category. The interviews were conducted after the students completed the numeracy test. The questions focused on the difficulties students encountered while solving the tasks, the procedures they used to obtain their calculation results, and the reasons behind their transportation choices. Through these questions, the researcher explored how students understood the numerical information, applied mathematical procedures, and interpreted the results in relation to the given context. The interview responses were subsequently used to clarify and support the findings obtained from students' written work. Data were collected through the numeracy test administered to all participants, followed by semi-structured interviews conducted after the test to explore their reasoning and responses in greater depth.

Data were analyzed qualitatively using the Miles et al. (2014) model, which consists of data reduction, data display, and conclusion drawing. During data reduction, students' test results were assessed using the scoring rubric, converted into numerical scores, and classified into ability categories. Interview transcripts were then examined, and relevant information was selected based on the numeracy indicators. In the data display stage, students' written responses, interview excerpts, and the researcher's interpretations were presented descriptively to illustrate their abilities in identifying information, performing calculations, comparing data, and interpreting results. Finally, conclusions were drawn by examining the relationship between test results and interview findings. Data validity was established through methodological triangulation by comparing the two sources of data to examine the consistency of students' responses.

The analysis also considered the relationship between students' written responses and their explanations during the interviews. Particular attention was given to whether students could explain the information they identified, describe the procedures used in their calculations, and relate the results to their transportation decisions. This comparison enabled the researcher to examine not only whether students obtained correct answers but also how they approached the tasks and interpreted the numerical information. The results

were then described according to the three numeracy ability categories to provide a comprehensive account of students' performance.

RESULTS AND DISCUSSION

The numeracy test was administered to 12 eighth-grade students to examine their abilities in identifying information, performing calculations, comparing data, and interpreting results in the context of transportation. Based on the assessment results, students were classified into three categories: high, medium, and low numeracy ability. The distribution of students' scores and their respective categories is presented in Table 3.

Table 3. Results of the students' numeracy tests

Student ID	Score	Skill Categories
S1	75,00	Medium
S2	33,00	Low
S3	88,00	High
S4	83,33	Medium
S5	100,00	High
S6	98,00	High
S7	97,00	High
S8	25,00	Low
S9	34,00	Low
S10	41,00	Low
S11	83,00	Medium
S12	97,00	High

Based on the results of the numeracy test in Table 3, five students fell into the high numeracy category: S3, S5, S6, S7, and S12. Additionally, three students were in the moderate category: S1, S4, and S11. The remaining four students fall into the low category: S2, S8, S9, and S10. Based on these results, six students were selected as interview subjects two from each of the high, moderate, and low categories to gain deeper insight into the students' thought processes when solving numeracy problems.

Numeracy Skills of Students in the High Category

Students in the high category demonstrated strong abilities in identifying information, performing calculations, comparing data, and interpreting results to support decision-making. In this study, S5 and S7 represented this category.

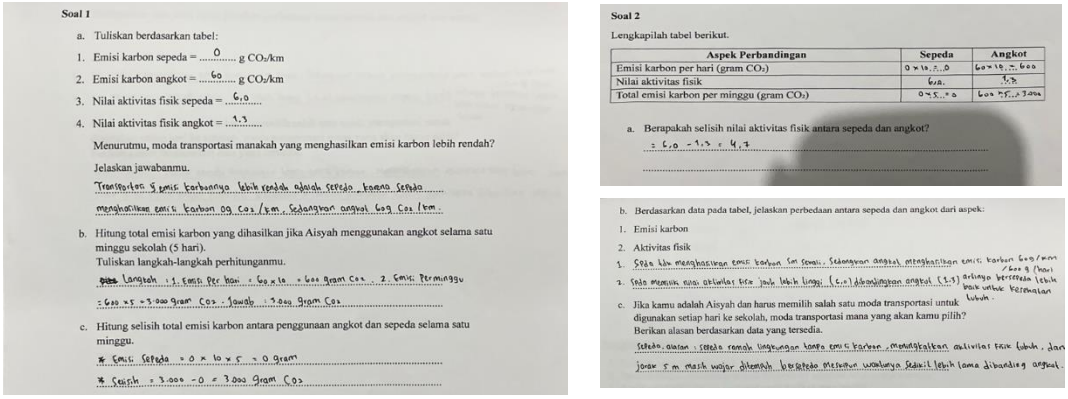


Figure 1. S5 students' answers to the numeracy questions

As shown in Figure 1, S5 successfully identified the relevant information regarding carbon emissions and physical activity associated with bicycles and public minibuses. The student accurately calculated the total weekly carbon emissions of public minibuses (3,000 g CO_2), the difference in carbon emissions (3,000 g CO_2), and the difference in physical activity (4.7). Furthermore, S5 selected bicycles as the preferred transportation mode because they produce no carbon emissions and involve higher physical activity.

The student's written work was further supported by the following interview.

P: Which part of the questions did you find the most difficult?

S: Question number two, especially completing the table, because I had to examine the carbon emission and physical activity data for bicycles and public minibuses.

P: How did you obtain the result of 3,000 grams of CO_2?

S: The carbon emissions from the public minibus were calculated by multiplying 60 by the distance of 10 kilometers, resulting in 600 grams per day. Then, I multiplied it by five days, which gave me 3,000 grams of CO_2.

P: Why did you choose the bicycle?

S: Because bicycles do not produce carbon emissions, and cycling involves more physical activity, making it healthier.

The interview findings supported these results. S5 explained the calculation process

by multiplying daily carbon emissions by the travel distance and five school days. The student also justified the choice of bicycle based on the numerical information provided in the problem. Similarly, S7 demonstrated the ability to identify information, perform calculations accurately, and make decisions supported by the available data.

Overall, students in the high category demonstrated the ability to integrate numerical information, mathematical calculations, and contextual interpretation when comparing transportation alternatives.

Numeracy Skills of Students in the Medium Category

Students in the medium category were able to identify information and perform calculations accurately. However, they did not consistently use the calculation results as a basis for decision-making. S1 and S11 represented this category.

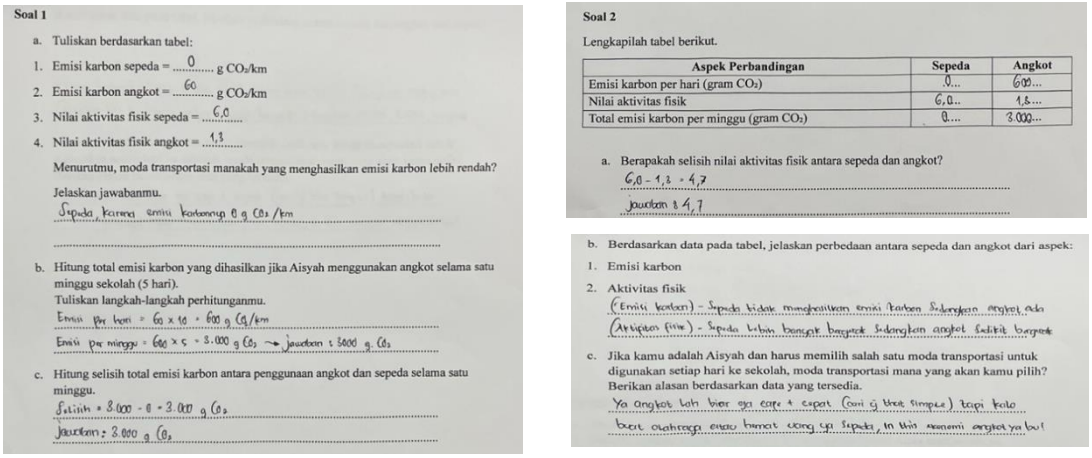


Figure 2. Undergraduate students' answers to numeracy questions

As shown in Figure 2, S1 successfully identified information regarding carbon emissions and physical activity and calculated the total weekly carbon emissions of public minibuses (3,000 g CO_2), the difference in carbon emissions, and the difference in physical activity (4.7). However, the student chose the public minibus because it was considered faster and less tiring, despite the calculation results indicating that bicycles had lower carbon emissions and involved higher physical activity.

The student's written work was further supported by the following interview.

P: Which part of the questions did you find the most difficult?

S: Question 1a, because I had to pay attention to the carbon emission and physical activity figures in the table.

P: How did you obtain the result of 3,000 grams of CO_2?

S: The daily carbon emissions were obtained from the data in the table. Then, I multiplied the result by 10 kilometers and by five school days, which gave me 3,000 grams of CO_2.

P: Why did you choose the public minibus as your mode of transportation?

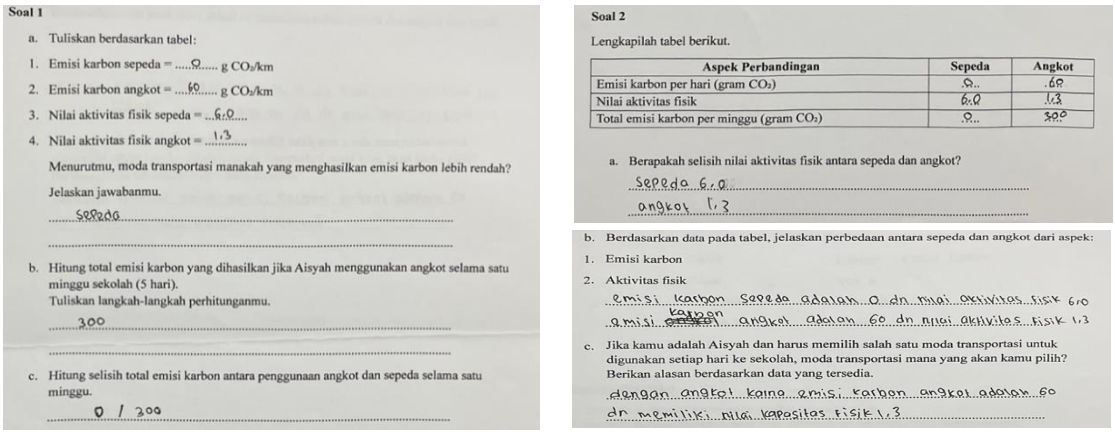
S: Because it gets me to school faster and is less tiring.

During the interview, S1 explained the calculation process correctly but justified the transportation choice based on practical considerations rather than the numerical results. S11 demonstrated similar characteristics, showing accurate calculations but making decisions influenced by convenience and personal considerations.

These findings indicate that students in the medium category had developed procedural calculation skills but had not consistently integrated numerical results into their decision-making process.

Numeracy Skills of Students in the Low Category

Students in the low category demonstrated difficulties in performing calculations and interpreting numerical information to support decision-making, although they could identify some information presented in the problem. S8 and S9 represented this category.


Soal 1

a. Tuliskan berdasarkan tabel:

1. Emisi karbon sepeda = ...0..... g CO_2/km
2. Emisi karbon angkot = ...60..... g CO_2/km
3. Nilai aktivitas fisik sepeda = ...6,0....
4. Nilai aktivitas fisik angkot = ...1,3....

Menurutmu, moda transportasi manakah yang menghasilkan emisi karbon lebih rendah? Jelaskan jawabanmu.

sepeda

b. Hitung total emisi karbon yang dihasilkan jika Aisyah menggunakan angkot selama satu minggu sekolah (5 hari). Tuliskan langkah-langkah perhitunganmu.

300

c. Hitung selisih total emisi karbon antara penggunaan angkot dan sepeda selama satu minggu.

0 / 300

Soal 2

Lengkapilah tabel berikut.

Aspek Perbandingan	Sepeda	Angkot
Emisi karbon per hari (gram CO_2)	0	60
Nilai aktivitas fisik	6,0	1,3
Total emisi karbon per minggu (gram CO_2)	0	300

a. Berapakah selisih nilai aktivitas fisik antara sepeda dan angkot?

sepeda 6,0

angkot 1,3

b. Berdasarkan data pada tabel, jelaskan perbedaan antara sepeda dan angkot dari aspek:

1. Emisi karbon
2. Aktivitas fisik

emisi karbon sepeda adalah 0 dan nilai aktivitas fisik 6,0

emisi karbon angkot adalah 60 dan nilai aktivitas fisik 1,3

c. Jika kamu adalah Aisyah dan harus memilih salah satu moda transportasi untuk digunakan setiap hari ke sekolah, moda transportasi mana yang akan kamu pilih? Berikan alasan berdasarkan data yang tersedia.

dengan angkot kaina emisi karbon angkot adalah 60 dn memiliki nilai kapasitas fisik 1,3

Figure 3. S5 Student S8's answer to the numeracy question

As shown in Figure 3, S8 successfully identified several numerical values related to carbon emissions and physical activity for bicycles and public minibuses. However, the student incorrectly calculated the total weekly carbon emissions of public minibuses as 300 g CO_2 instead of 3,000 g CO_2 and did not calculate the difference in physical activity. The student also selected the public minibus without adequately considering the numerical

information provided.

The student's written work was further supported by the following interview.

P: Which part of the questions did you find the most difficult?

S: The table containing the carbon emission and physical activity figures for bicycles and public minibuses.

P: How did you calculate the total carbon emissions of the public minibus?

S: I looked at the numbers in the table and multiplied them until I got 300.

P: What did you learn after completing the questions?

S: I learned about the differences in physical activity between riding a bicycle and taking a public minibus.

The interview findings confirmed these difficulties. S8 was able to recognize information in the table but could not clearly explain the calculation process. Similarly, S9 identified some relevant information but made errors in calculations and did not consistently use numerical evidence to support the transportation choice.

Overall, students in the low category could recognize some numerical information but experienced difficulties in processing it accurately and interpreting the results to make data-based decisions.

Discussion

The findings indicate that students' numeracy skills in comparing modes of transportation based on health and carbon emissions vary across ability categories. These differences are reflected not only in students' calculation accuracy but also in their ability to interpret numerical information and use it as a basis for decision-making. This finding is consistent with the mathematical literacy framework proposed by the OECD (2023), which emphasizes three interconnected processes: formulating, employing, and interpreting mathematics in real-world contexts. Therefore, numeracy involves more than performing mathematical calculations; it also requires students to connect mathematical results with the context of a problem and use them to make informed decisions.

The differences in students' performance can also be understood through the relationship among the three mathematical processes. The formulating process involves identifying relevant information and understanding what is required in a problem. The employing process involves applying mathematical concepts and procedures to obtain

solutions, while the interpreting process requires students to relate the results to the original context. These processes are interconnected rather than independent stages. In this study, students' responses showed that being able to perform calculations did not always mean that they could interpret the results appropriately. This indicates that students' numeracy abilities need to be examined through the entire process of working with mathematical information, rather than through calculation accuracy alone.

Students in the high category demonstrated consistent performance across the numeracy indicators examined. They were able to identify relevant information, perform calculations accurately, compare data, and use the results to justify their transportation choices. Their decisions were supported by numerical information regarding carbon emissions and physical activity rather than personal preferences alone. This finding is in line with Nirfayanti et al. (2025), who emphasize the importance of connecting mathematical information with real-world situations. The students' ability to interpret calculation results and use them to support decisions reflects the integration of mathematical procedures and contextual reasoning.

Students in the moderate category were able to understand the information and perform calculations correctly; however, they did not consistently use the results as a basis for decision-making. Although their calculations indicated that bicycles produced lower carbon emissions and involved higher physical activity, some students still preferred public minibuses because they considered them faster and less tiring. This finding illustrates that the ability to employ mathematical procedures does not necessarily indicate the ability to interpret and apply mathematical results in a real-world context. In relation to the OECD (2023a) framework, these students demonstrated proficiency in the employing process, but their interpreting process was not yet consistently reflected in their decisions. Difficulties in relating calculation results to the context of a problem have also been reported in earlier studies (Kolar & Hodnik, 2021; Saputri et al., 2018).

Meanwhile, students in the low category could identify some numerical information but experienced difficulties in performing calculations accurately and connecting the results to their decisions. Their responses indicate that recognizing information does not automatically enable students to process and interpret it appropriately. Difficulties in the formulating and interpreting processes among students with moderate and low mathematical literacy have also been reported by Jailani et al. (2020) and Sa'diyah et al. (2024). This finding highlights the importance of developing the interconnected processes of formulating, employing, and interpreting mathematics. Students need opportunities to

practice not only identifying numerical information but also processing it, comparing alternatives, and explaining decisions based on mathematical evidence.

The findings also demonstrate the value of using transportation contexts involving health and carbon emissions to examine students' numeracy skills. While Sari et al. (2023) focused on developing transportation-based numeracy problems, the present study examines how students use numerical information to compare transportation alternatives based on two aspects simultaneously. This provides insight into students' abilities to connect mathematical calculations with contextual considerations when making decisions. Therefore, mathematics instruction should provide opportunities for students to engage with real-life problems that require them to understand information, perform calculations, interpret results, and justify decisions using numerical evidence.

Overall, the findings highlight the importance of developing students' abilities to connect mathematical procedures with real-life situations. In the context of transportation, students are expected not only to calculate carbon emissions and compare physical activity levels but also to interpret the results before making decisions. The differences observed among the three ability categories suggest that students need more opportunities to engage with contextual numeracy tasks. Such activities can encourage them to examine numerical information, evaluate alternatives, and provide logical reasons for their choices. Therefore, integrating everyday contexts into mathematics learning may help students develop more meaningful numeracy skills.

CONCLUSIONS AND SUGGESTIONS

Conclusions

This study shows that students' numeracy skills in comparing modes of transportation based on health and carbon emissions vary across ability categories. These differences are evident not only in the accuracy of calculations but also in students' abilities to understand information, compare data, interpret results, and use numerical information as a basis for decision-making. Students in the high-ability category demonstrated comprehensive numeracy skills. Students in the moderate-ability category were able to perform calculations correctly but did not consistently use the results as a basis for decision-making. Meanwhile, students in the low-ability category struggled to process numerical information accurately and connect calculation results to their decisions.

These findings indicate that numeracy skills involve more than computational abilities. They also require students to understand information, interpret results, and use

numerical data to solve contextual problems. Therefore, the ability to connect mathematical calculations with real-life situations is an important aspect of students' numeracy skills.

Suggestions

Based on the findings, mathematics teachers are encouraged to incorporate contextual problems related to students' everyday lives into mathematics instruction. Such problems should provide opportunities for students to identify information, perform calculations, compare data, interpret results, and make decisions based on numerical evidence. Teachers should also provide guidance and learning activities that strengthen students' ability to connect calculation results with the context of the problems so that their numeracy skills can develop more meaningfully.

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