PAEDAGOGIA
Journal of Educational Research
http://jurnal.uns.ac.id/paedagogia

DOI: 10.20961/Paedagogia.v28i3.103035
Vol. 28, No. 3, 2025, pp. 492-502
p-ISSN 0126-4109
e-ISSN 2549-6670

Elementary School Students' Problem-Solving Strategies in Adding and Subtracting Whole Numbers through Open-Ended Problems

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Keywords: *Math, Addition, Subtraction, Whole Number, Counting Operations, Open Ended, Elementary School*

Riwayat article
Receive: 7 June 2025
Revised: 23 October 2025
Accepted: 24 October 2025
Published: 31 October 2025

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Doi: 10.20961/paedagogia.v28i3.103035

Abstract: Problem-solving skills are an important aspect of mathematics learning that needs to be developed from elementary school. One way to stimulate this ability is through *open-ended problems* that allow students to express a variety of solution strategies. This study aims to analyze problem-solving strategies and difficulties experienced by grade IV elementary school students in solving story problems of addition and subtraction of whole numbers with an open approach. The research method used is qualitative with a case study design. The research subjects were grade IV students who were given validated open-ended story questions. Data were collected through learning observation and analyzed descriptively. The results showed that students employed various strategies, including gradually summing, reducing the remaining capacity, and combining the total number with the bus capacity. However, errors in place values, procedural errors, and a lack of thoroughness were also found. These findings confirmed that open-ended questions are effective in promoting problem-solving skills and exposing students' misconceptions.

How to cite: Umayrah, A., Herman, T., Jupri, A., Salsabila, S. (2025). Elementary School Students' Problem-Solving Strategies in Addition and Subtraction of Whole Numbers through Open-Ended Problems. *PAEDAGOGIA*, *28*(3), 492-502. Doi: 10.20961/paedagogia.v28i3.103035

INTRODUCTION

Mathematics is one of the educational tools that is highly beneficial in the development of high-quality human resources. In fact, mathematics has been considered a fundamental subject because it contains arithmetic and logical reasoning as the basis of science and technology (Freudenthal, 1968). The development of the increasingly sophisticated world in terms of technology, communication, and information, of course, requires humans to have the ability to acquire, select, manage, and follow up on information to be used in a dynamic life. All of these abilities can be developed through learning mathematics (Herman, 2010). Thus, mathematical skills are one of the important aspects that students must have in learning mathematics. Students can improve their math skills through curiosity, attention, and a keen interest in math, as well as a tenacious and confident attitude in solving math problems (Liu et al., 2022).

This educational authority emphasizes students' proficiency in computing and problem-solving skills (Yeh et al., 2019). Problem-solving is one of the important competencies that students must master in learning mathematics. Through problem-solving competencies, students can develop other mathematical competencies such as concept understanding, critical thinking, creativity, and the ability to apply mathematics in various real-life contexts. Problem solving not only emphasizes the final result, but also the thinking process that students go through to understand the problem, plan strategies, carry out calculations, and re-examine the answers. Thus, problem-solving becomes an important means to train high-level thinking skills and support students' mathematics learning achievement.

At the elementary school level, the operation of counting numbers such as addition and subtraction is the main foundation that students must master. These operations became the basis for more complex computational skills in the future, such as multiplication, division, fractions, and algebra, and were very useful in everyday life(Rahmatin & Marzuki, 2022). Mastery of counting numbers is not only important for students' academic success, but also contributes to supporting their ability to solve various practical problems.

Based on the results of a literature review and direct field observations, researchers found that students often relied on standard procedures without investigating the conceptual meaning or relationships between number concepts. Research conducted by (Rosanti et al., 2022), found that most students erred in distinguishing place values and often made procedural errors in calculation operations. Research (Karlimah et al., 2019). It also emphasized that the weak mastery of the concept of borrowing in reduction is one of the main causes of students' difficulties. The results of the researchers' observations in grade IV of elementary school also showed similar symptoms; it was found that students were incorrect when faced with addition and subtraction problems, particularly when given more complex questions.

This difficulty cannot be separated from the learning pattern that is still oriented towards correct or wrong answers. Teachers often assess students' understanding only based on the truth of the results, without examining the way of thinking or the strategies used (Reys et al., 2017). As a result, students are not accustomed to exploring different ways of solving problems, and teachers have difficulty identifying the conceptual and procedural errors that students make. In fact, understanding students' ways of thinking through the problem-solving strategies they use is very important so that teachers can provide more appropriate interventions. This results in limited flexibility and dependence on procedures, which when students are faced with unstructured story problems or situations, can show weaknesses in their understanding.

The unstructured situation referred to in this study is one where students are presented with non-routine problems that have an open nature, also known as open-ended problems. Open-ended problems are those that allow for multiple answers or various solution strategies. Unlike closed questions that only demand one correct answer, open-ended questions open up space for creativity, flexibility, and metacognitive reflection of students. In Realistic Education, open-ended questions even encourage students to approach everyday problems and find mathematical strategies naturally. Through open-ended questions, students are allowed to show their own way of thinking, develop various strategies, as well as practice reasoning skills and numeracy skills, Shimada in (Faridah & Aeni, 2016). Open learning can provide opportunities for students to gain knowledge or experience finding, discovering, and solving problems with a variety of techniques (Febriani et al., 2021).

Although there is a number of international and national studies that address open problem solving, most of the focus is still limited to the general cognitive level or to more abstract mathematical material. Explicit focus on open-ended problems for integer operations, especially in the context of elementary school students in Indonesia, is still relatively rarely studied. In fact, the high potential to uncover diverse strategies as well as conceptual weaknesses underscores the importance of research specifically designed for this domain. This research intended to fill this gap by presenting an analysis of how open-ended problems can present variations in students' problem-solving strategies, including aspects such as creativity, verbal ability, thinking flexibility, and solution representation. As well as revealing the weak points in mastering number operations, especially in understanding concepts, planning strategies, implementing operations, and reflecting on the solutions produced.

Through the application of the Open-Ended approach, researchers wanted to find out more about the level of openness or way of thinking of students in solving problems related to addition and subtraction of integers. In addition, the researcher also wants to gain an overview of the suitability of pre-prepared answer predictions in comparison to students' answers. This research is important to do both theoretically and practically. Theoretically, this study enriches the literature on constructivist mathematics teaching with an open-ended approach in the context of number operations. Practically, the results of the research can be a reference for teachers in designing questions that facilitate diverse solution strategies and encourage reflection. In addition, the disclosure of student weaknesses can serve as a basis for instructional design improvements and more concrete, evidence-based pedagogic interventions.

Therefore, the researcher raised the problem with the title " Elementary School Students' Problem Solving Strategies in Adding and Subtracting Whole Numbers Through Open-Ended Problems ". With the hope of providing insights that can help teachers and schools implement more varied and up-to-date learning approaches, utilizing various methods to motivate students in learning mathematics. This, in turn, aims to improve the quality of human resources in Indonesia and contribute to achieving national development goals.

METHOD

This study used a qualitative approach with a case study design. This design was chosen because the research aims to analyze students' strategies in solving open problems of number operations in depth. Case studies allowed researchers to describe in detail the variations of problem-solving strategies that students use in a given classroom context. The subject of the study was a grade IV student in one of the elementary schools with a total of 19 students. The class selection was carried out purposively because students had studied the material on adding and subtracting numbers. All students in the class are involved to get a complete picture of their problem-solving strategies.

The research instruments included observation sheets, teaching materials, worksheets, and open-ended story questions related to the operation of addition and subtraction of the number of counts. This question has been validated by a lecturer in mathematics education as a guarantor of the validity of the content. The reliability of the instrument is obtained through expert analysis, so that the questions are believed to be in accordance with the purpose of the research. Data collection is carried out through the provision of written tests to all students in the class. In addition, the researcher conducts direct observation while students complete the questions, recording activities, visible ways of thinking, and student interactions as they work on the questions. The data were analyzed using the Miles & Huberman model qualitative analysis technique, which includes:

1. Data reduction: grouping students' answers based on problem-solving strategies and errors that arise.
2. Data presentation: compile results in the form of narrative descriptions and sample tables of student answers.
3. Drawing conclusions: identify the variety of problem-solving strategies used by students as well as the difficulties they face in addition and subtraction operations.

RESULTS

The data of this study illustrated the mathematical problem-solving ability of grade IV elementary school students in performing addition and subtraction operations through story problems with an open-ended approach. The main purpose of using open-ended questions is to uncover the variety of problem-solving strategies used by students as well as to identify their weaknesses in mastering numerical operations. This is in line with the view of Becker & Shimada (2005) that the open-ended approach is not solely to form an understanding of concepts, but to encourage the development of high-level thinking skills through the process of problem solving. In this study, the type of open-ended question used is the *finding relationships type*. This type of question is designed to allow students to discover for themselves a wide range of possible mathematical relationships in the operations of adding and subtracting integers.

The learning activity began with the teacher inviting students to imagine the situation of riding the school bus. Students were asked to calculate the maximum capacity of the bus shown in the picture, then determine the remaining capacity that can still be filled by other passengers. From the calculation results, it was obtained that the remaining load that could still be transported by the bus was 200 kg. This open situation encourages students to strategize, choose steps, perform calculations, and conclude solutions so as not to exceed the capacity of the bus.

Question: *"See! The school bus that will take students home has a maximum load of 1000 kg. The bus has been filled by 50 students with a total weight of 800 kg. Who are the other students who can take the bus without exceeding the bus load?"*

Figure 1. Open-ended questions

This learning concept offers students to move forward and write directly on the board, and invites students to think about who other children can ride the bus up to no more than 200 kg. From these activities, it is evident that students are highly active and enthusiastic in the learning process. The researcher identified three types of thinking strategies in problem-solving relationships that students themselves discovered through the activity of finding friends who could ride the school bus together to avoid exceeding the maximum capacity. The following figure (Figure 2) explains some of the answers obtained by students, which subsequently led to mathematical conclusions. The following is a description of the research results that can be presented by researchers:

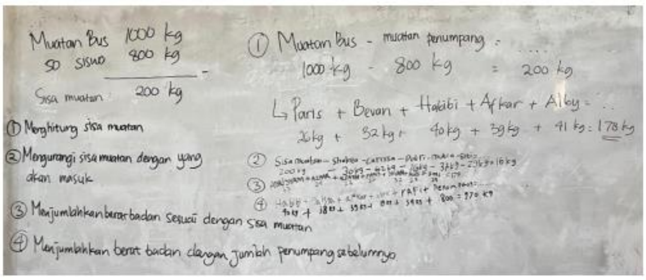


Figure 2. Student Findings.

The first problem-solving strategies were achieved by Paris, Bevan, Habibi, Afkar, and Alby. The first student to advance was Paris. He wrote that his weight was 26 kg. Paris then invited Bevan to come to the front of the class and added his weight plus Bevan's weight (26kg + 32kg = 58kg). Feeling that they had not reached 200kg, Paris and Bevan then invited Habibi, Afkar, and Alby and added up all their weights to get a total weight of 178kg. They then concluded that school buses can carry less than 200 kg for no more than as buses will be overloaded. So, the teacher helps them make a mathematical conclusion or rule for the problem, which is to add up the weights so that they do not exceed the weight of the rest of the bus.

Figure 3. The first group of open-ended relationship discoverers

The second problem-solving strategy was obtained by Shakilla, Charissa, Putri, Mutia, and Siti. They used a different method than that obtained by Paris et al. They already know that the remaining weight that can still fit in the bus is 200kg. The rest of the load is then reduced by the weight of each. Their assumptions are important for no less than 0. The calculation is 200kg minus Shakilla's weight, and then Charissa's weight decreases again, Putri's weight decreases, Mutia's weight decreases, and Siti's weight decreases, or 200kg – 30kg – 62kg – 26kg – 37kg – 29kg = 16kg. Although there are still 16 kilograms left, they argue that the bus can still run because the load is no longer a problem, so even less is not a concern. Based on the problem-solving methods obtained by the students, the teacher was then directed to get a mathematical rule to solve the problem, namely, reducing the residual load by the weight of each student so that it did not exceed the weight of the remaining load.

Figure 4. The second group of open-minded founders

The third problem-solving strategy was found by Habibi, Gaisya, Afkar, Virly, and Rafi (Figure 4.8). They summed up their weight first, including: 40kg + 38kg + 39kg + 19kg + 34kg = 170kg. Then, they added the total weight to the weight of the passengers who had entered the school bus, which was 800kg. Since they already know that the maximum capacity of the bus is 1000kg, then they add 800kg to their total weight as long as it does not exceed 1000kg. So the calculation result they got was 970kg. Through this solving method, students and teachers write down the conclusion of the mathematical rules for the problem, namely, adding up the entire weight plus the weight of the load that has been entered, so that it does not exceed 1000kg.

Figure 5. The third group of open-minded founders

The emergence of these three distinct strategies reflects what (Bahar & June Maker, 2015) described as the "cognitive background of open-ended problem solving," where multiple mental representations coexist, and students actively construct their own solution structures. This diversity of strategies also aligns with Piaget's stage theory of cognitive development, particularly the concrete operational stage, where children aged 8–11 (as in grade IV elementary). The "bus capacity" context provided a familiar and concrete environment that allowed students to manipulate numbers meaningfully, supporting Van de Walle et al.'s (2016) argument that mathematical understanding grows when children can connect symbols with real-world referents. The open-ended nature of the problem activated not only procedural computation but also *relational reasoning*, which is an essential component of mathematical understanding (Herzog & Fritz, 2022).

DISCUSSION

The open-ended approach successfully encouraged flexibility; it also revealed specific areas of computational difficulty. The data showed that many students struggled with place value understanding, procedural accuracy, and consistent calculation when performing addition or subtraction involving larger numbers. Errors such as misalignment of digits, omission of carried values, and confusion between tens and hundreds indicate that the conceptual foundation of place value has not been fully consolidated. This difficulty has been widely reported in prior studies. For example, Lambert & Moeller (2019) found that students with weak place value understanding tend to rely on rote procedural execution, which leads to error accumulation in multi-digit arithmetic. Similarly, Nelson & Powell (2018) highlighted that even students with average performance often demonstrate superficial procedural fluency without a corresponding conceptual grasp of the decimal system, making them prone to mistakes when numbers exceed single digits.

These findings suggest that students' computational challenges are not merely procedural lapses but symptoms of a deeper conceptual gap. According to Van de Walle et al. (2016), place value understanding is foundational for arithmetic development, and without it, children cannot effectively perform regrouping or borrowing operations. The errors observed in this study, particularly misplacement in the tens and hundreds columns, indicate that students may not fully comprehend the hierarchical structure of the base-ten system. This aligns with findings by Jensen et al., (2024), who emphasized that true number sense develops when learners internalize the idea that each digit's position signifies a quantitative relationship within a whole. When such understanding is missing, procedural drills alone do not lead to meaningful learning.

Moreover, the persistence of these computational difficulties may also be linked to instructional practices that overemphasize correct answers rather than reasoning processes. Previous studies, Putra & Milenia (2021); Umayrah et al. (2024), have noted that Indonesian elementary classrooms often rely heavily on closed-form exercises and teacher-centered demonstrations, leaving little room for exploratory reasoning. Consequently, students tend to perceive mathematics as a set of fixed procedures rather than as a system of logical relationships. The open-ended approach used in this study helps counteract this tendency by shifting focus from product to process, encouraging students to verbalize, visualize, and justify their solutions.

An interesting pattern also emerged regarding how students dealt with computational uncertainty. Instead of showing frustration when their answers differed, many expressed curiosity about why alternative strategies led to similar or slightly different results. By collaboratively verifying whether the total weight exceeded 1,000 kg, students engaged in reasoning that resembled hypothesis testing, a form of metacognitive monitoring that is rarely achieved in routine exercises. The teacher's facilitation during these interactions was crucial, as it allowed the classroom discourse to remain mathematically focused while still valuing multiple perspectives.

Another dimension worth discussing is the relationship between conceptual understanding and procedural fluency in the students' work. The first and second groups' strategies exemplified intuitive conceptualization: they seemed to understand the constraint (the bus's capacity) as a real-world boundary, guiding their computation. The third group, however, showed stronger procedural fluency, performing accurate addition but sometimes lacking complete interpretation of the problem context. The open-ended approach seems particularly effective in fostering this reciprocal relationship, as it requires students to apply procedures in meaningful contexts and adjust their conceptual models when confronted with new information.

Cultural and contextual factors may also influence students' performance in such problem-solving tasks. As noted by Rizos & Gkrekas, (2023), students' familiarity with contextual cues can affect how they interpret problem situations and choose strategies. In this study, the "school bus" scenario provided a relatable context, yet some students still focused solely on numeric manipulation, suggesting that contextual comprehension varies even among peers sharing the same classroom environment. In the present study, for instance, identifying that some students neglected to carry over digits during addition provided the teacher with immediate feedback to adjust instruction. This diagnostic potential makes open-ended questioning an efficient bridge between assessment and pedagogy, supporting what Black & Wiliam, (2018) describe as *assessment for learning*.

The evidence from this study also highlights a recurring pattern in the nature of students' mathematical difficulties: many errors originated not from carelessness but from partial understanding of numerical structures. Students who could correctly describe the situation verbally sometimes failed to translate it into appropriate symbolic representations. This observation supports the claims by Li et al. (2018) and Bonny & Lourenco that young learners often develop an approximate sense of quantity before mastering exact symbolic representation. This transition phase can lead to inconsistencies between what they conceptually understand and what they write numerically. The open-ended problem format used in this study clearly exposed this gap. When solving closed-form problems, such errors might go unnoticed because only the final numeric answer is evaluated. However, in open-ended tasks, students' reasoning processes become visible, allowing teachers to diagnose where misunderstanding begins, whether in conceptualization, translation, or execution.

Understanding the Concept of Place Value

The concept of place value is a basic concept that must be mastered by students in elementary school. Not understanding the concept of place values can lead to suboptimal abilities in addition and subtraction, as well as more complex arithmetic problems. In fact, understanding the concept of place value is considered an important requirement in developing mathematical computing skills (Yusri & Sari, 2017). Understanding the concept of place value starts by first introducing numbers to children. From the beginning, families can even help a 2- or 3-year-old count fingers, toys, people on a table, ladders, or other small objects.

Asking everyday questions like "Who has more?" This evidence suggests that when children have real-life experiences like this, they will develop an understanding of the concepts of numbers and counting. Then, the child should be able to connect rows of numbers in one-to-one correspondence on each object in the calculated set. Each object must get one and only one count. As part of this skill, children should be aware that each counting number identifies a quantity that one is greater than the previous one and that a new quantity is attached to the previous one (see Figure 6).

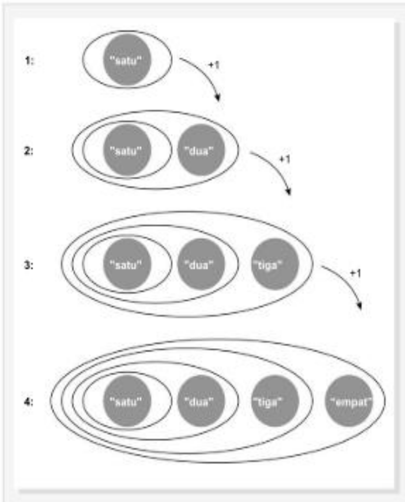


Figure 6. In the calculation, each number is increased by one from the previous number (Source: National Research Council in the book Teaching Mathematics in Primary and Secondary Schools in Development by (Van de Walle et al., 2016))

This knowledge will later be useful in breaking down numbers. Experience and guidance are the main factors in the development of children's numeracy skills (Van de Walle et al., 2016). Therefore, it is very important to include a variety of activities to support the various experiences that children need to gain a full understanding of the concept of numbers.

An alternative strategy that teachers can use in the early stages of introducing the concept of place value to students is to use concrete objects around them, such as gravel. Gravel is a familiar object used as garden decoration and is familiar to students. Ask students to classify the pebbles based on their different colors (black, white, and green). Then, wrap the pebbles in medium-sized wraps of 100 grains or small wrappers of 10 pebbles each. The teacher asks students to record their work in the following Table 1. Based on the activity, students are asked to determine the amount for each type of gravel. Teachers can test students' understanding of place values by asking them to explain the meaning of the numbers shown in the "number of pebbles" column for each type of pebble. For example, can students distinguish between a value of two in a hundred and a value of two in one unit in a white pebble that totals 242? Or ask students to explain what the number 0 means in terms of the number of green pebbles, which is 10^6. Problems related to the calculation of real objects for students are problems that can be solved relatively by students, with the characteristics of problems that can be imagined and created by students. As a problem solver, it is hoped that it can inspire students to overcome these problems (Putrawangsa, 2017).

Table 1. Introduction to the Concept of Place Value Activities

Pebbles	Medium-sized wrappers of 100 pebbles	Small wrappers of 10 pebbles	Remaining pebbles	Total
Black	2	3	5	
White	2	4	2	
Green	1	0	6	

Addition and Subtraction of Computational Numbers

Basic mathematics is taught at the beginning of elementary school, including addition and subtraction of decimal numbers. A number is made up of a set of non-negative integers, such as 0, 1, 2, 3, and so on (Aras, 2020). At this level, students learn to perform addition and subtraction operations, which helps them understand more complex mathematical concepts later in life. In fact, children since preschool age have made efforts to increase and decrease the number of numbers in their daily lives. Summing, for example, is shown by collecting pebbles that children carry while playing (joining). Reduction, for example, is shown by comparing the lengths of two straws when buying a drink (comparing) and arranging two towers of the same height when playing (finished) (Syarifah & Prabawanto, 2023).

Conceptual and procedural processes are used to develop algorithms to add and subtract numbers. Combining, taking, comparing, and complementing are examples of his conceptual activities that demonstrate the meaning of addition and subtraction, and his procedural activities involve the application of calculation methods to complete addition and subtraction operations. Both activities were carried out simultaneously. Conceptual activities teach procedures, and procedural activities apply concepts (Van de Walle et al., 2016). Below are the procedural errors made by students in performing the calculation of addition and subtraction of numbers. This happens because conceptual understanding is not fully understood by students.

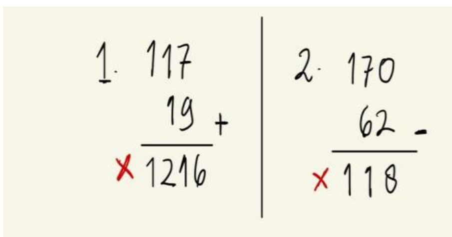


Figure 7. Error in the calculation procedure of counting numbers

To introduce the addition and subtraction calculation operating system to students, it can be assisted with props such as "place value bags" by utilizing 3 color markers, namely black, red, and blue, each of which is agreed that for black markers means unit values, red markers mean tens, and blue markers mean hundreds of values. Example question: 135 + 88=...

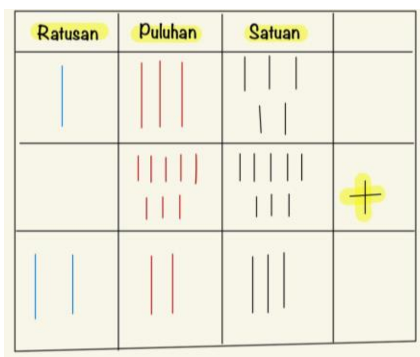
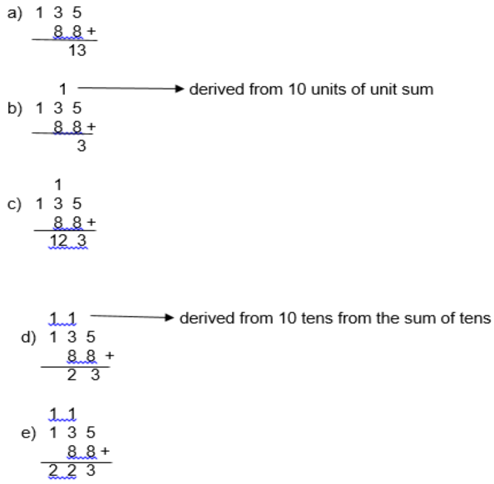


Figure 8. Pocket space value

Through hands-on activities like this, ensure that students can understand the meaning of each value pocket. Starting from three lines with black markers, what does it mean in terms of the value of the bag, as well as the other colored line segments? After students have mastered the concept, the teacher can provide an understanding of a more procedural system by involving numbers.



The following procedural system needs to be explained to students as follows:

In the unit column, if the number of unit numbers is less than 10, then the result is written immediately. However, if the result is 10 or more, then only the unit number is written, while the tens are written above the top row, above the top column, and above the tens column, and are referred to as "deposits".

In the tens of numbers column, dozens of numbers and deposit results are then summed up, If the result is less than 10, then the number is written immediately, but if the result is ten or more, then what is written is the unit only and the number of tens is written in the top row (parallel to the deposit result of the number of units) above the hundred column. Until finally all the numbers in this hundred column are added (including the storage of the number of tens), and the result is expressed as the number of hundreds.

Students need to be given exercises with a variety of questions, both in terms of the number of numbers in the operation (for example, three numbers with two numbers, or two numbers with one number), and in terms of the location of the place value that requires the process of saving or borrowing, either in units, tens, or a combination of both. This kind of exercise aims to give students a deeper understanding of the system of summing and subtracting numbers. The findings of this study showed that *open-ended problems* have a dual function, namely:

1. Provide space for students to use diverse problem-solving strategies according to their respective understandings and ways of thinking.
2. Reveal students' fundamental weaknesses in mastering number operations, which are often not visible when the teacher only assesses correct or incorrect answers.

The implication is that teachers should use open-ended questions more frequently in mathematics instruction. In addition to developing problem-solving skills, this approach also enables teachers to identify students' misconceptions early on, allowing for more targeted and effective follow-up learning.

Limitation

Although this study provides valuable insights into students' mathematical problem-solving processes through the use of open-ended questions, several limitations should be acknowledged. First, the study involved a relatively small and homogeneous sample, which may restrict the generalizability of the findings to broader populations. The participants were drawn from a single elementary school with similar academic and socio-economic backgrounds, potentially limiting the diversity of observed problem-solving behaviors. Second, the scope of the mathematical material was confined to integer operations, particularly addition and subtraction, which constrains the extent to which conclusions can be applied to other mathematical domains such as multiplication, division, or fractions. Third, the qualitative design relied primarily on written responses and teacher observations, without incorporating longitudinal or experimental data, which might have provided a deeper understanding of cognitive development over time. Furthermore, contextual factors such as students' motivation, learning environment, and prior mathematical exposure were not systematically controlled. These methodological constraints should be considered when interpreting the results. Future studies are encouraged to address these limitations by employing larger and more diverse samples, expanding the mathematical scope, and integrating mixed-method or longitudinal approaches to achieve a more comprehensive understanding of students' mathematical thinking and strategy development.

CONCLUSION

The results of this study demonstrated that the use of open-ended questions in mathematics learning effectively reveals two crucial aspects of students' thinking processes. First, it provides students with opportunities to apply diverse problem-solving strategies based on their individual understanding and reasoning styles. Second, it reveals fundamental weaknesses in mastering integer operations, particularly in understanding place values, performing addition and subtraction procedures, and maintaining calculation accuracy. These findings are illustrated in students' varied strategies, such as adding or reducing weight to balance the total load without exceeding limits and summing all components to remain within a set capacity. The implications of these results highlight the importance of integrating open-ended questions not only as a tool to foster problem-solving skills but also as a diagnostic means for teachers to identify students' misconceptions at an early stage. Consequently, teachers can design more targeted interventions to promote balanced development between conceptual understanding and computational proficiency. This study contributes practically by guiding elementary school teachers in selecting varied and reflective instructional strategies and theoretically by reinforcing the role of open-ended approaches in enhancing mathematics learning quality.

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