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Research Article

Effectiveness of using a bar model in solving story problems for elementary school students

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Abstract: One of difficulty student in study mathematics that is how to finish math narrative text. The purpose of research this that is for describe about effectiveness of the bar model for finish math narrative text for school base. Type of research used in study that is descriptive qualitative, with 22 of students in third grade as a research subject. Moreover, this research was conducted in State Elementary School 01 of Beji Junrejo Disctrict, Batu – East Java. Data collection techniques use observation, interviews and tests. Furthermore from the data obtained analyzed in a way qualitative with use stage: data reduction, data presentation, and withdrawal data conclusions. The research results show that the bar model is very effective help student in finish math narrative text this elementary school student capable draw a bar model for represent mark in mathematics. This is can help they in answer question with more easy and doable develop number sense ability.

Keywords: bar model; critical thinking; elementary teacher; mathematics narrative text

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1. Introduction

Problem solving in story cases is one of the important aspects of learning mathematics (Azizah et al., 2022; Liang et al., 2022). In its implementation, solving story problems requires good understanding and computational skills (Lei & Xin, 2023; Raiyan et al., 2023). Several researchers stated that the ability to think and reason which is honed through science learning, such as mathematics can improve the quality and intelligence of humans (Liang et al., 2022; Nur et al., 2022). From the learning perspective, mathematical analogical reasoning activities are important in helping students build relational thinking structures to solve a problem effectively (Emanuel et al., 2021; He-Yueya et al., 2023).

The use of problem-based story problems in mathematics learning has been widely proposed and is believed to improve students' analytical thinking skills (Golafshani, 2023; Novakowski, 2023; Yubali & Robert, 2023). In addition, this kind of innovative strategy improves mathematical problem-solving performance but also has a broader impact such as advancing artificial intelligence's ability to understand and solve complex mathematical tasks (Li et al., 2022; Nasrun et al., 2023; Witzel et al., 2022). Several previous studies have shown that using problems is quite reliable in teaching mathematical concepts that are often abstract into something that seems concrete when realized in everyday mathematical stories (Azizah et al., 2022; Juhairiah, 2020; Opedal et al., 2023). In addition, the story problem method can help determine the numeracy skills of early childhood students (Tabakova & Pelaheichenko, 2021). Through story problems, students can not only be motivated and involved in learning but also develop skills to apply mathematics effectively in daily activities, fostering a positive and open learning environment (Amita, 2023).

However, the real conditions in schools often show paradox. Based on the results of observations conducted in November 2022, information was obtained that 84.56% of students had difficulty working on mathematical story problems. Students spent 15 minutes without being able to write down the results to be answered. The further analysis showed that the difficulty was caused by several factors such as students' low understanding of the context of the problem questions, making it difficult to translate information into mathematical form. Both students had difficulty changing story problems into mathematical equations or models. This happens because students have difficulty determining relevant variables, numbers, or formulas from the context of the story problem. That situation has impacted students' difficulty in determining systematic problem-solving steps, hard to choose and apply appropriate mathematical concepts or formulas (Emanuel et al., 2021; Novak & Tassell, 2017). In addition, psychological conditions such as anxiety and fear of mathematics also have an impact on decreasing focus and the emergence of doubts in solving problems (Chaurasia, 2015; Hunt et al., 2021).

To solve those problems, teachers are used to using a bar model to help students solve story problems. The bar model is a representation of the use of diagrams that are intended to bridge students' understanding of the context of the problem in story problems. Several researchers have stated that diagrams can provide visual representations for students (Arneja & Tyagi, 2020). Bar charts act as visual representations that help in understanding problems and their solutions (Ashari et al., 2023; Matzin & Mundia, 2020; Zhou et al., 2021). By utilizing this strategy, students engage with textual, pictorial, and numeric expressions so that they can foster a deeper understanding of the relationship between numbers (Ceria, 2020) and become a stepping stone for students to transition to algebra learning (Lestiana & Wanita, 2019).

However, the effectiveness of the bar model in solving mathematics problems at the elementary school level has not been widely reported. Moreover, with the use of story problems that contain high order thinking skills (HOTS) and contextual (Ashari et al., 2023; Xin et al., 2023). This study aims to test the effectiveness of the bar model in helping students solve mathematical story problems. Furthermore, this study is expected to be an inspiration for teachers in elementary schools to be able to use the bar model in solving mathematics problems. In addition, it is also expected to be an inspiration for other researchers to follow up on research that is relevant to the use of the bar model.

2. Materials and Methods

This qualitative descriptive study collected and analyzed data on the effectiveness of using bar models in solving mathematical story problems. The subjects involved in this study were 22 third-grade students at Elementary School 01 of Beji - Junrejo District, Batu, East Java. The first data collection technique used was observing learning activities and interviews. To see the effectiveness of learning, the researcher also gave five test questions according to the objectives and indicators of learning. This test aims to see students' abilities in achieving learning objectives, especially in solving story problems. Data analysis in this study refers to the steps of (Miles et al., 2014) which consist of data collection, data reduction, data presentation, and concluding/verification (Figure 1).

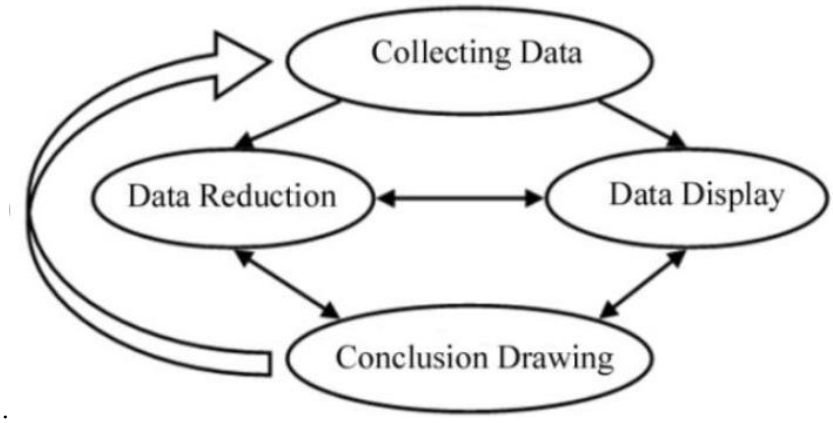

Figure 1. Interactive model of data analysis (Miles et al., 2014)

Data collection in qualitative research collects data by conducting observations, in-depth interviews, and documentation or a combination of all three (triangulation). Moreover, data reduction means summarizing, selecting and sorting things main, focusing on important things, looking for themes and the pattern. Thus, the reduced data will provide clear picture and makes research easier. Presenting data in qualitative research, presenting data is an activity when a set of information is arranged, to provide possibilities drawing conclusions and taking action. Stage am presentation of this data requires the data to be selected or specified focus of research problems. The data is adjusted according to problems in research. To sum up, conclusions are drawn while the three initial research processes this has been carried out. When the data has been presented with a focus on problems, then finally to draw conclusions regarding the results the analysis. Conclusions are not immediately explained in general, but it must be based on research.

The effectiveness of problem solving in this study uses Polya's theory. The criteria for solving problems based on Polya's theory are explained in four main stages as in Table 1. In contrast, the measurement instrument for the effectiveness of problem-solving is described in Table 2.

Table 1. Four stages of problem solving based on Polya's theory

No	Problem Solving Stage	Criteria
1	Understand the problem	a. Students are able to clearly identify what is known and what needs to be looked for (known and asked). b. Students understand the context and conditions given in the question c. Students can reformulate the questions in their own words to ensure understanding.
2	Devise a plan	a. Students are able to choose an appropriate strategy or solution method based on problem analysis (for example, substitution, elimination, diagram, or formula methods). b. Students are able to formulate specific steps to reach a solution. c. Students can relate this problem to similar problems they have solved before.
3	Carry out the plan	a. Students can follow the steps that have been planned systematically and thoroughly. b. Students check each step and ensure there are no errors in calculations or logic. c. Students are able to overcome difficulties that arise during the implementation of the plan.
4	Review and reflect	a. Students are able to review the solutions they have made, checking the accuracy and suitability of the results to the questions given. b. Students can reflect on the steps taken and consider whether there are other, more efficient ways to solve the problem. c. Students are able to generalize the results or methods that have been used to solve similar problems in the future.

Table 2. Measuring skills in problems solving according to Polya's theory

Aspects of Skill	Very Good (score 4)	Good (score 3)	Fair (score 2)	Poor (score 1)
Problems Solving	If students can solve the problem by fulfilling all the indicators in the 4 steps of Polya's theory in a coherent and systematic manner	If students can solve the problem by fulfilling all the indicators in the 3 steps of Polya's theory in a coherent and systematic manner	If students can solve questions by fulfilling all the indicators in the 2 steps of Polya's theory but they are not coherent and systematic	If students can solve questions by fulfilling all the indicators in the 2 steps of Polya's theory but they are not coherent and systematic

According to Sugiyono (2018), the score interpretation criteria based on respondents' answers can be determined based on the assessment range from 1 - 5, so that the distance between adjacent scores is 16 (Table 3).

Table 3. Interpretation of scores

Percentage (%)	Category
84 – 100	Very High
68 – 83.99	High
52 – 67.99	Moderate
36 – 51.99	Low
20 – 35.99	Very Low

Interpretation of this score is obtained by comparing the item scores obtained based on the respondent's answers with the highest score answer and then multiplying by 100%.

3. Results

In this study, we used three types of story problems. The results showed that by using the bar model, students were able to solve the problems relatively without any obstacles. The use of the model helped students understand story problems and develop their arithmetic skills. In solving the problems, students used Polya's steps.

Story Question 1

"Tim has four candies and Ben has two candies. How many Lots their candy have in a way whole?"

Solution:

a) *Understanding the problem*
Based on the question, there are two childrens named Tim who have four candies while Ben has two candies.

b) Planning strategy
How to implement the bar model in solving the problem in this question?

c) Implementing the strategy
First step: Students need to create an illustration essense of the story problem. Students can draw candy or other easy-to-make shapes such as circles. Here is an illustration that explains the first step (Figure 2).

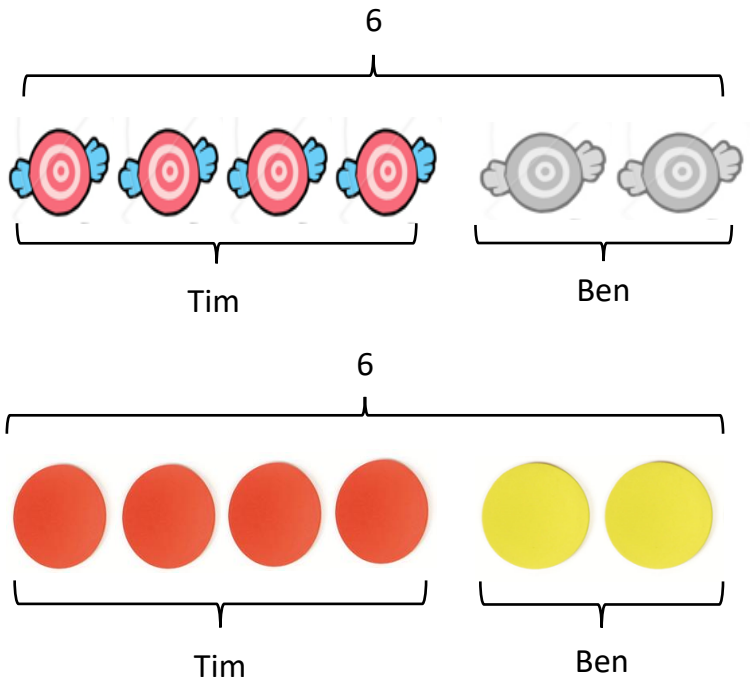

Figure 2. Illustration of candy and circle (Step 1)

Next step: Students draw bar charts to represent the respective quantities (Figure 3), namely four candies (represented by 4 bars) and two candies (represented by 2 bars). Here is a description of the explanation in the second step.

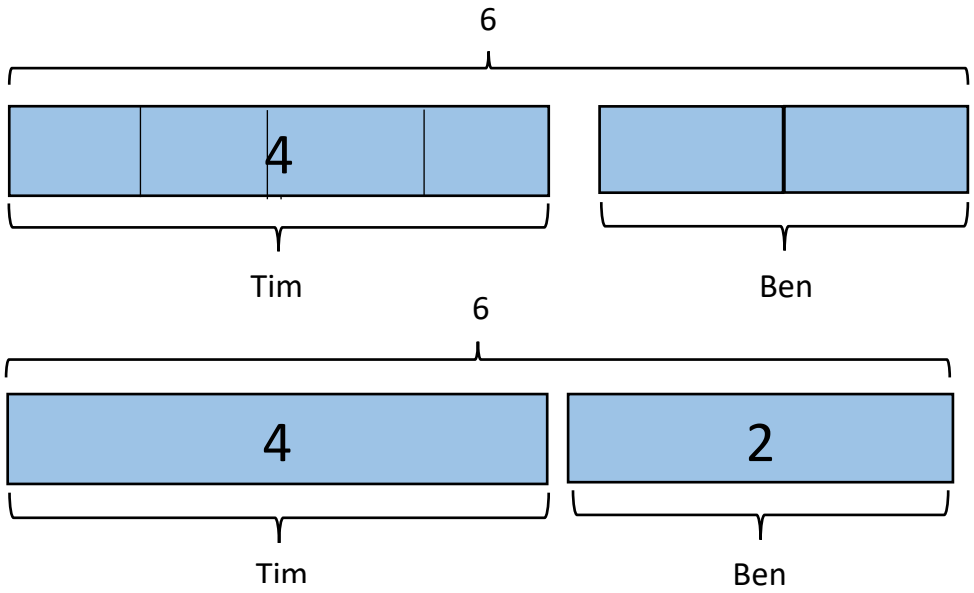

Figure 3. Illustrative a bar chart (Step 2)

d) Checking and interpreting results

4 + 2 = 6

Figure 3 shows that students can solve the problem smoothly. This is indicated by the student's ability to solve the problem in four stages systematically and the reflection in solving the problem so that students can solve the problem with a more structured and logical approach. In the first stage, students can write down what is known and

asked. Then, students start by drawing an illustration of the known problem, namely a picture of four candies belonging to Tim and two candies belonging to Ben. Furthermore, in the second stage, students can develop a strategy by drawing a Bar model based on what is known. Next, students start drawing another illustration showing candies in the form of circles (four belonging to Tim and 2 others for Ben) from a total of six candies. To sum up, students can re-examine the solutions obtained.

Story Problem 2

"Matthew has a 300g block of cheese. He consumed around 2/5 of the cheese and put the rest back in the fridge. How much cheese did Matthew put back in the fridge?"

Solution :

a) *Understand problem*
Based on the question, students can understand that Matthew has 300 g of cheese. As much as 2/5 of the cheese is eaten and the rest is stored in the refrigerator.

b) *Planning strategy*
How to implement the bar model in solving the problem in this question?

c) *Implementing the strategy*
First, create a bar chart by dividing 300 grams into five parts, each of which is 60 parts (Figure 4). Furthermore, each part is placed on each bar chart. After being drawn, it is then reduced by the two parts eaten by Matthew until only three parts remain. To sum up, it can be concluded that there are 180 grams of cheese placed in the refrigerator.

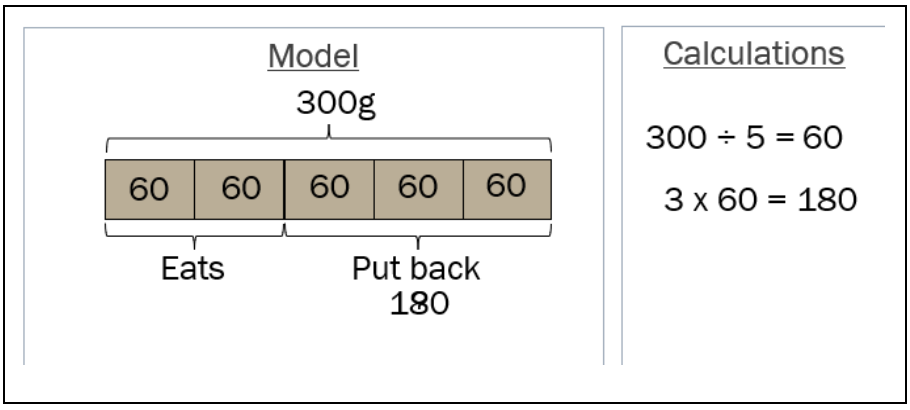

Figure 4. Illustrative image of the results of solving problem number 2 by students

d) *checking and interpreting results*
2 x 60 = 120
3 x 60 = 180
120 + 180 = 300
5 x 60 = 300

Question Number 3

"A drink factory makes 135,000 soda cans in three different colors. There are 16,900 more yellow cans than red cans. There are 46,500 red cans do they make?"

Figure 5. The illustrative of three different cans produced by the factory (source: https://depositphotos.com/)

Solution :

a) *Understand problem*

Based on the questions, students can understand that there are 135,000 cans of soda that will be made in three different colors i.e. yellow, red, and blue (Figure 5). Furthermore, yellow cans is 16,900 more lots from the red and the others else.

b) *Planning strategy*

How to implement the bar model in solving the problem in this question?

c) *Implementing the strategy*

First step. The students need to draw a bar model based on the information, include the total number of cans and the number of cans of a certain color that are known as described in Figure 6.

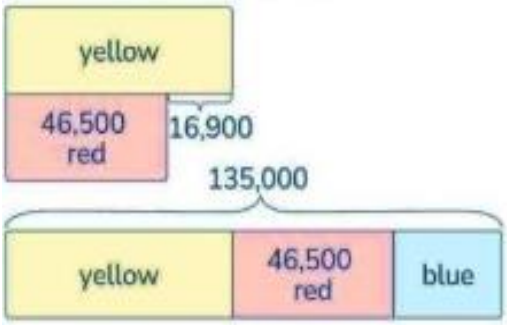

Figure 6. Illustrative image of the results of solving problem

Next step. Now, we can use the bar models to help us work out what calculations. We need to do it to solve the problem

1) Yellow cans

   46,500 + 16,900 = 63,400 (yellow)

2) Blue Cans

   135,000 – 63,400 – 46,500 = 25,100

d) *checking and interpreting results*

   46,500 + 63,400 + 25,100 = 135,000

Overall, students' ability to use bar models to solve story problems can be seen in Table 4.

Table 4. Percentage ability student in finish question story

Question Number	Amount Student			
	Correct	Percentage (%)	False	Percentage (%)
Story Problem 1	22	100	0	0
Story Problem 2	18	81.82	4	18.18
Story Problem 3	12	54.55	10	45.45
Story problem 4	17	86.36	5	13.64
Story Problem 5	15	68.18	7	31.82

Overall, students' ability to use bar models to solve story problems can be seen in Table 4. The analysis shows that the percentage of students' ability to solve first and fourth questions according to the criteria is very high. While second and fifth are high criteria. However, the third question is still in the medium criteria. As many as 10 students think that the third question is included in the most difficult category. This is because not all students understand the question well, many students misinterpret it and have an impact on how to make a bar model. As many as 10 students are not proportional in compiling the bar model, which causes calculation errors.

4. Discussion

The results of the analysis above indicate that the implementation of the bar model can be a problem-solving strategy, especially in solving mathematical story problems. Several studies have reported that the use of the bar model not only improves conceptual understanding but can also improve performance (Juhairiah, 2020; Opedal et al., 2023). By implementing the Bar Model technique, students showed a significant increase in their achievement in mathematical story problems, as evidenced by the comparison of pre-test and post-test (Madani et al., 2018; Osman et al., 2018). In addition, the Bar Model helps overcome common mistakes in story problems, which ultimately improves students' competence in solving story problems (Azizah et al., 2022). Overall, the bar model serves as a valuable tool in guiding students through complex mathematical story problems, improving their understanding, performance, and problem-solving skills.

Another finding in this study is that by using bar charts as a tool, students can develop a strong foundation in solving mathematical strategy and reasoning problems, leading to increased understanding and proficiency in handling story problems. This is supported by several studies stating that the bar diagram method, also known as the bar model technique, can be introduced before students learn algebraic solutions to story problems to improve their understanding (Putri et al., 2020). This visual representation helps simplify complex problems by providing a clear and intuitive way to understand mathematical concepts, especially in the algebra domain (Yubali & Robert, 2023). This shows that the use of the bar model technique significantly improves students' mathematical story problem-solving skills and literacy in algebraic material (Sani & Rosnawati, 2022).

The activity of making bar charts manually can be challenging for students (Ariza et al., 2024; Basu et al., 2016). Students need to analyze and interpret what the bar chart needs to be drawn. Although the diagrams made do not need to be very accurate, they still need to consider the proportionality of the diagrams made. This kind of ability is closely related to how the students understand and draw conclusions regarding the relationship between variables. This study has shown that some students often misinterpret the data presented in the bar chart, which causes significant deviations from the true values (Kashfi et al., 2023; Ramasamy & Puteh, 2019). This misinterpretation can result in errors such as uniformity errors, where students may not accurately understand the location of the mean, variability around the mean, and the distribution of the shape

(Lee et al., 2022; Radaikin et al., 2022). In addition, the bar-tip limit (BTL) error is a commonly observed error in interpreting average bar charts, where individuals incorrectly assume the data is limited by the edge of the bar rather than distributed across it (Kerns & Wilmer, 2021). This finding highlights the importance of considering the potential for misinterpretation when using bar charts, especially when drawn manually.

The results of this study and several other studies that show that this type of bar model is effectively applied in learning refer to the question of how this can happen. One answer that can be used as a reason is that the bar model helps students build knowledge through systematic steps. This activity can strengthen students' thinking skills in describing how the relationship between numbers when dealing with complex mathematical designs.

Despite several initial challenges, both teachers and students expressed increasing interest in utilizing the bar model approach because of its effectiveness in improving higher-order thinking skills and facilitating more understanding of mathematical problems (Baysal & Sevinc, 2022; Lestiana & Wanita, 2019). Therefore, the bar model method serves as a valuable instructional strategy for making abstract mathematical designs more real and realistic for students. This is in line with the realistic mathematics approach (RME) emphasizing the use of contextual bar models to support modeling in various scenarios, especially with low student achievement, facilitating bottom-up understanding that develops towards formal mathematics (Basuki & Wijaya, 2018; Hough et al., 2020; Supiarmo et al., 2022). In addition, research highlights the effectiveness of the bar model in improving students' understanding of draft percentages through systematic problem-solving steps and construction knowledge of connection numbers in calculating percentages (Baysal & Sevinc, 2022; Madani et al., 2018). Overall, the bar model emerges as a powerful tool for tackling multi-step and complex word problems in mathematics.

5. Conclusions

The results of the study concluded that the bar diagram model is one of the diagrammatic representations that can help students solve story problems. Using bar diagrams in solving story problems becomes a bridge for students to understand issues and create mathematical expressions. The bar diagram model has three different structures: part-whole, comparison, and situation (before-after).

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