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The urgency of Polya model problem-solving on students mathematical ability in facing the Industrial Revolution 5.0

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***Abstract*:**
In the millennial era, most students consider mathematics a difficult subject, so mathematics can be a scary threat to them when this subject takes place. Conditions like this occur for two reasons: problem-solving is difficult, or they get an educator who is usually called a *killer*. This research aims to teach students that difficult mathematics problems can be solved using the Polya model. The research method used is qualitative, with technical data collection in interviews, questionnaires, tests, and observations. The data analysis was done using the Miles and Huberman models. There were 16 High School students, Ibrahimy Sukorejo, who were the subjects of this research to provide research results on the urgency of using the Polya model. The research results show that (1) The test results of students using the Polya model were obtained for the categories of very critical (12.5%), critical (12.5%), quite critical (37.5%), less critical (18.75%), and not critical (18.75%); (2) the results of the analysis using Shapiro-Wilk on SPSS software showed that the research had a normal distribution because the final significance results were 0.823 and 0.998 > 0.05; and (3) the results of the analysis also show the advantages felt by Polya model users over non-Polya models. There is great hope for students, especially in mathematics, who can apply the Polya model to every mathematical problem they face to find answers to these problems and a systematic way of thinking to solve them.

Keywords: Industrial Revolution 5.0; Mathematical Ability; Polya Models; Problem-Solving; Student Mathematics.

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Introduction

Mathematics is one of the materials that is urgent for every human being to know because they face it daily. One example is when someone makes a buying and selling transaction. Mathematics is considered a branch of science that is very important and much needed because, in everyday life, we encounter many things related to mathematics

(Phonapichat et al., 2014). In mathematics, super-genius people are needed to face the era of society 5.0. Apart from that, humans must be able to create new values through technological developments that can minimize future human inequality and economic problems. However, those who study mathematics, specifically students, often encounter problems in solving them. Problems are logical consequences that humans will experience when they face something but cannot find a solution. According to Yuwono, problems cannot be separated from human life (Yuwono, 2019). This problem must be solved so that it does not continue and disrupt the lives of the people concerned. Problem-solving combines previously known knowledge with new knowledge to resolve problems quickly (Alifah & Aripin, 2018). Problem-solving is also an urgent matter and is the main focus in mathematics (Farrokhizadeh et al., 2022; Goli et al., 2023; Karatas & Baki, 2013). Mathematical models should be applied in elementary school because, with this modeling, students can find answers to problems systematically. Apart from that, students can also know the procedures for solving their problems, especially in mathematics.

According to Auning and Auning, a mathematical model is a simple representation of a phenomenon or natural event that occurs to be presented in a mathematical concept (Auning & Auning, 2023). Most researchers currently use mathematical models as the basis for research to facilitate the completion process. The field of mathematics with the application of mathematical models is grouped as the field of applied mathematics. Mathematical modeling is also considered one of the objectives of the important process of mathematics education in terms of maintaining relevant mathematics education so that it leads to better outcomes (Abassian et al., 2020; Alsina & Salgado, 2022; Paolucci & Wessels, 2017; Riyanto & Putri, 2019; Schukajlow et al., 2018). One model that may need to be applied in mathematics, especially for students, is the Polya model. In this model, four steps must be carried out: *Understanding the Problem, Devising a Plan, Carrying out the Plan, and Looking Back* (Tohir et al., 2022). The advantage of the Polya model is that students can research and analyze the problems they will solve [14], and it is also easy to solve problems with a high level of difficulty (Pardimin & Widodo, 2016). The hope of using the Polya model is that students not only know the results or answers to a problem they are solving but also the process of finding the answer. Students are required to be able to think critically and creatively.

The research results by Lasak show that the Polya model can improve mathematics problem-solving skills in prospective mathematics teachers by 78.77% and increase mathematics learning achievement by 75% (Lasak, 2017). The results of research by Brijlall showed that the learning process in the Polya model makes students actively participate in discussions to solve the mathematical problems presented (Brijlall, 2015). The research results by Vilianti et al. showed that students who can pass or apply the steps in the Polya model are categorized as high-ability students. Meanwhile, students who cannot pass all stages of the Polya model because they do not understand what is known and what is asked in the questions are categorized as low-ability students. Next, the phases of the Polya model train students to work systematically in solving problems (Vilianti et al., 2018). The results of research conducted by Anugraheni showed significant differences between users of the Polya problem-solving model and users of the conventional model (Anugraheni, 2019).

Meanwhile, the results of research by Astuti show that students' ability to work on problem-solving questions is still at a low level; as many as 68.97% and 90.32% of students are still below the minimum completeness criteria for science subjects. Students achieved the two indicators of Polya model problem solving: understanding the problem and making a plan. Students could not achieve the next two indicators: implementing the Plan and checking again. Students find it difficult to interpret problem-solving-type questions. Students do not

understand the meaning of the questions, so errors occur in formulating strategies, which results in students experiencing confusion in writing each answer. Thus, it is necessary to carry out training in working on problem-solving questions (Astuti et al., 2020).

Based on the results of observations made by researchers on several students, it was found that some students still had difficulty solving Polya model mathematical problems because they did not understand what the problem was asking for. However, several other students who succeeded in solving problems using the Polya model would be able to solve the problems very easily. Thus, this research aims to provide an understanding that the Polya model is very efficient to use and its application is not complicated, so this can encourage students in the future to use the Polya model in every mathematical problem they face. On the other hand, a description or classification of the Polya stages will also be explained. Moreover, in the era of Society 5.0, creative and critical students are needed. And through the Polya model, this can be realized to create quality cadres.

Research Methods

The method used in this research is qualitative. The qualitative method examines a natural object, where the researcher acts as a key instrument. In this instance, humans play the role of instruments. Descriptive data that focus more on the process under study are the foundation of inductive data analysis and theory creation, both of which are necessary for qualitative approaches. This study is constrained by its scope, specified requirements for data validity, and temporary design. Additionally, qualitative data is created through shared decisions (Tohir et al., 2024). According to Pfarrwaller et al. (2024), a qualitative research design is employed for a thorough examination of the current condition in real-life circumstances. The data research technique uses triangulation, and the research results prioritize meaning over generation (Abdussamad & Sik, 2021). This research aims to educate students about the importance of using the Polya model in every mathematical problem they face. The study's subjects were 16 students from Ibrahimy Sukorejo High School, who provided a thorough picture of the importance of applying the Polya model to solve mathematics issues.

Data collection techniques: (1) Observation. This technique is carried out to determine the problem-solving process directly by students using the Polya model and the advantages they will experience; (2) Questionnaire. This technique is carried out by asking students questions to determine their ability; (3) Test Questions. This question is given to determine students' abilities in solving mathematical problems; and (4) Interviews are conducted by asking students to find out what competencies the students have mastered. This interview was conducted face-to-face with the student concerned. Three expert lecturers with good results have validated this research questionnaire and interview guide.

Data analysis was obtained from the test results given to students to measure the urgency of solving the Polya model problem and its effect on students' mathematical abilities. Descriptive statistical analysis as a data analysis approach used to explain the findings of research data from test results and questionnaires. Triangulation was carried out to check the suitability of the data obtained between observation results, test results, and interview results. The last stage is drawing conclusions based on data groups, in this case, the urgency of using the Polya model in solving mathematical problems in facing the industrial revolution 5.0. This study also discusses the group of student categories based on the problem-solving ability of the Polya model. Thus, markers of problem-solving skills are required to conveniently categorize pupils into extremely crucial, critical, fairly critical, less critical, and non-critical categories. Table 1 below is the indicator of Polya's problem-solving model.

Table 1. Problem-Solving Indicators for the Polya Model

Category	Polya Model Problem-Solving Indicators
Very Critical	He could use the Polya model properly and correctly and add necessary information.
Critical	He could use all existing Polya stages without adding information to the problem.
Quite Critical	He could use the three stages of the Polya model but still answer correctly.
Less Critical	He could use only two or one of the existing Polya stages, and he could answer the question at hand, but the answer he completed was wrong.
Not Critical	He cannot apply the Polya model that has been mentioned, so he cannot answer the problems he faces.

Results and Discussion

The research results are important data the researcher will explain in this section. The data is in the form of grades or scores produced after testing eight students who used the Polya model and eight who used the conventional model. The results of this data will create a classification of student types in terms of the Polya model. Research subjects were divided into five student categories: very critical, critical, quite critical, less critical, and non-critical. The comparison of test results between Polya and non-Polya user groups can be described in Table 2 below.

Table 2. Results of the Polya Model Problem-Solving Test

			Statistic	**Std. Error**
Polya Group	Mean		85.6250	1.61397
	95% Confidence Interval for Mean	Lower Bound	81.8086	
		Upper Bound	89.4414	
	5% Trimmed Mean		85.6389	
	Median		86.0000	
	Variance		20.839	
	Std. Deviation		4.56501	
	Minimum		79.00	
	Maximum		92.00	
	Range		13.00	
	Interquartile Range		8.50	
	Skewness		-0.229	0.752
	Kurtosis		-0.962	1.481
Non-Polya Group	Mean		72.8750	1.60843
	95% Confidence Interval for Mean	Lower Bound	69.0717	
		Upper Bound	76.6783	
	5% Trimmed Mean		72.8611	
	Median		73.0000	
	Variance		20.696	
	Std. Deviation		4.54933	

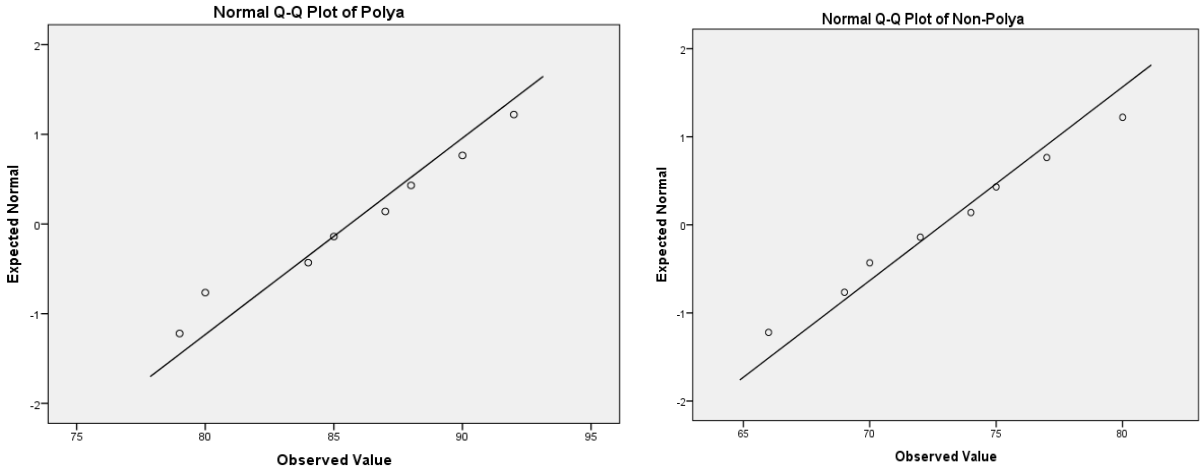
	Statistic	Std. Error
Minimum	66.00	
Maximum	80.00	
Range	14.00	
Interquartile Range	7.25	
Skewness	0.072	0.752
Kurtosis	-0.564	1.481

Based on the presentation in Table 2 above it shows that students who use the Polya model are more efficient and get maximum scores or marks than students who use conventional models. This condition is proven by research conducted on eight students using Polya and eight students using the traditional model above. The minimum score for Polya model users is 79, while non-Polya users are 66. And the maximum value for Polya users is 92, while non-Polya users are 82. The average score for Polya users is 85.6, while for non-Polya users is 72.8. The data above is presented through the SPSS program. SPSS is a software that can read data and turn the data into statistics. It is very suitable for use with research data. According to Hinton, SPSS is an extraordinary statistical analysis package (Hinton, 2014). The data above also presents frequency, standard deviation, average, etc.

Table 3. Polya Model Problem-Solving Test Results Using Shapiro-Wilk

Shapiro-Wilk		
Statistic	**df**	**Sig.**
0.961	8	0.823
0.992	8	0.998

Table 3 shows the results of the final data normality test using the Shapiro-Wilk test. From the data above, it can be stated that it is normally distributed because the final significance value obtained is more than 0.05. Based on Faradiba's opinion, if the significance value is more than 0.05, it can be said to be normally distributed. He also added that small sample sizes (<50) cannot use the Kolmogrov-Smirnov test but instead use the Shapiro-Wilk test (Faradiba, 2020). If expressed using the Q-Q plot test, results will be produced, as shown in Picture 1 below.



Picture 1. Polya Model Problem Solving Test Results Using Q-Q Plot.

Based on Picture 1 above shows that the distribution between Polya and Non-Polya users is normal because the points are not far from the line (spread around the line). Nasrum said that if the data distribution is close to the line, then the data distribution is normal (Nasrum, 2018). On the other hand, if the data distribution is too far down the line, it is not typical. Then, it emphasized that the distance between the two points is relative. As a reference, in addition to the primary line, two extra lines (confidence interval bar lines) are added, and other tests, such as Kolmogrov-Smrinov, Shapiro-Wilk, and others, can be performed.

Table 4. Percentage of Problem-Solving Test Results

No.	Category	Percentage of Test Results (%)
1	Very Critical	12.5
2	Critical	12.5
3	Quite Critical	37.5
4	Less Critical	18.75
5	Not Critical	18.75

Table 4 above shows that the least categories occur at the critical and critical levels with the same percentage (12.5%). This situation shows a lack of students in the critical and critical categories for solving Polya model problems. It is hoped that teachers can design more interesting lessons for students by frequently giving them questions so that they can develop their problem-solving skills very well. Things like this are relevant to what Yunin said, namely that learning design is one of the things that triggers critical thinking abilities. He added the urgency of implementing the Problem-Based Learning (PBL) learning model to improve students' critical thinking skills (Nafiah & Suyanto, 2014)**.**

Understanding the Problem Stage

At this stage, students are required to understand the problem in question well. Some students immediately understand their problem, and some must read it repeatedly. This stage is the first thing that must be paid attention to because if the subject in question does not understand the problem, then it is likely that he will be confused about continuing to the next step.

Devising a Plan Stage

At this stage, students must make a plan to make their problems simpler and easier to solve. Even at this stage, students usually simplify the object of the problem in question with certain variables. The better students design the solution, the easier it will be and look systematic.

Carrying out the Plan Stage

At this stage, students are required to realize what they have planned. Students are also required to use mathematical models properly and correctly and carry out calculations correctly to get solutions to their problems. If the student in question finds it difficult to solve the problem he is facing, then there are still things that he must fix at the stage of understanding the problem and designing a solution.

Looking Back Stage

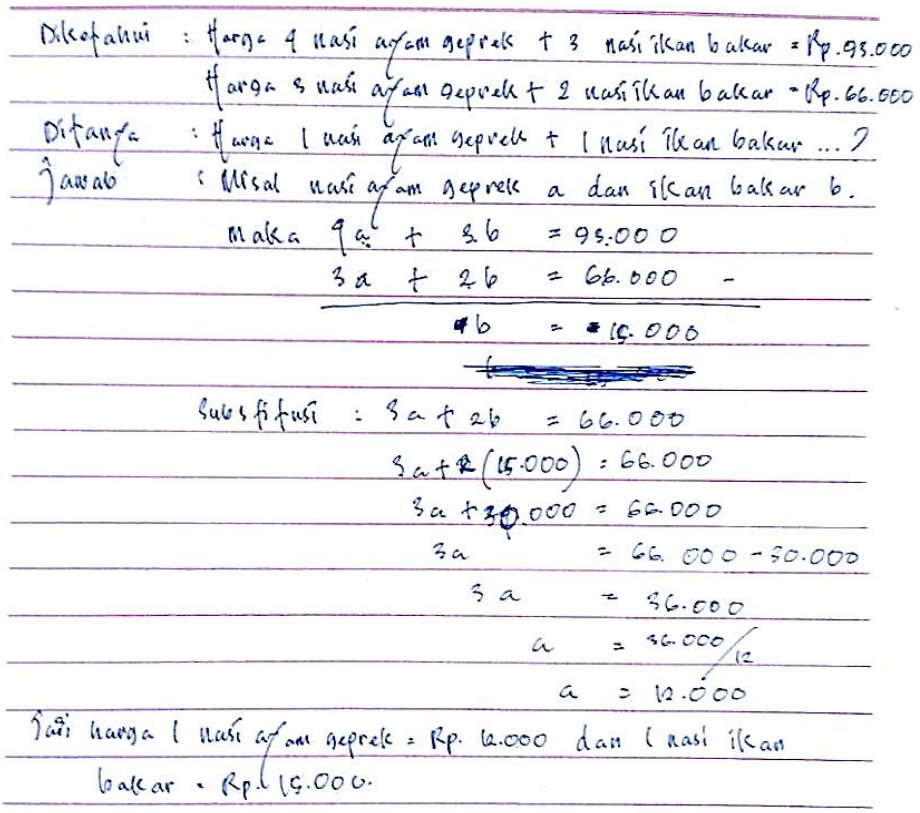
At this stage, students must check the problems they have solved again. This check is carried out as proof so that other people can have more confidence in the problem that has just been solved by the subject in question. Students are also required to add explanations that they may need to add so that there are no misunderstandings from other people about the problem, and also, other people will not ask because the problem being solved is very clear and understandable. However, students using the Polya model are categorized into five sections.

Students in the Very Critical Category

Students in this category are students who can apply all stages of the Polya model well and correctly. According to Tohir et al., students in this category can "generalize" perfectly at the "understanding the problem" stage, where the subject can choose the right depiction to create an appropriate illustration based on the information and purpose of the problem (Tohir et al., 2020). Then, if he feels something needs to be added, he will add his information regarding the problem in question. For example, the question in question is as follows.

> "*It is known that the price of 4 fried chicken rice and three grilled fish rice is Rp. 93,000; the price for three fried chicken and two grilled fish and rice is Rp. 66,000. How much do one grilled fish rice and one fried chicken rice cost?*"

Students in the critical and creative categories will be able to grasp the difficulties above and come up with procedural answers by looking at the challenges above. Figure 3 below shows a student's answer in the critical category.



Picture 2. Results by students in the critical category

Students in this category will add information that the price applies if both are purchased at the same food stall/rice depot. However, if this is not the case, then this price cannot be used as a benchmark for determining the price of fried chicken rice and grilled fish in the above problem. This research aligns with Rizza's research; the results show that students in the critical category obtain high critical thinking skills because they go through and carry out all the stages in the Polya model (Rizza, 2020).

Students in the Critical Category

Students in this category can only use the Polya model according to the procedures stated in the Polya model provisions without being able to criticize the shortcomings in the problem being faced. For example, as mentioned by students in the very critical category, it's just that he didn't analyze further whether the two types of rice were bought at the same stall or different stalls. Thus, if an assessment is carried out, the students in the moderate category are below those in the critical category. According to the research results by Rizza, students in this category obtained moderate critical thinking skills because there were stages they did not fulfill (Rizza, 2020).

Students in the critical category are expected at this time or era because, with the change from the era of Society 4.0 to the Industrial Revolution 5.0, critical and creative cadres are needed to deal with problems. According to research results by Syafruddin and Pujiastuti, students in the critical category, in this case, also include the critical category of classification, assessment, inference, and strategy and tactics (Syafruddin & Pujiastuti, 2020). In the sense that students can know what the question is intended to mean, they can understand the answer, can explain the answer they have obtained well, and can answer the question according to their tactics and strategies.

Students in the Quite Critical Category

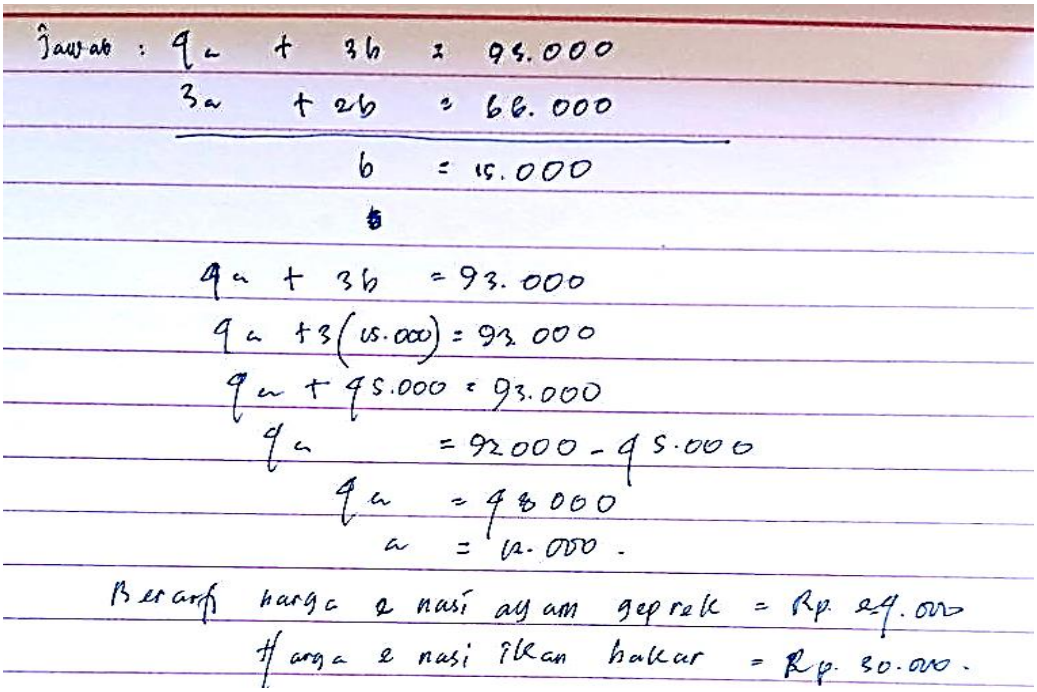
Students who fall into this category can only use the three stages of the Polya model. However, despite this, he could answer his problems well and correctly. He still can't be categorized as critical because there is one step he hasn't faced yet.

Students in the Less Critical Category

Students in this category can still not use the Polya model properly and correctly. Maybe he can only use two stages or only one stage so he can answer, but the resulting answer is not right or wrong. According to Nugroho and Sutarni's research results, there are two reasons why something like this occurs (Nugroho & Sutarni, 2017).

a. Students do not write down what they know and what they ask

The mistake that often occurs from students is not writing down what they know and what is asked or asked about the problem they face. For example, for the problem above, students in this category will write the answer as follows.



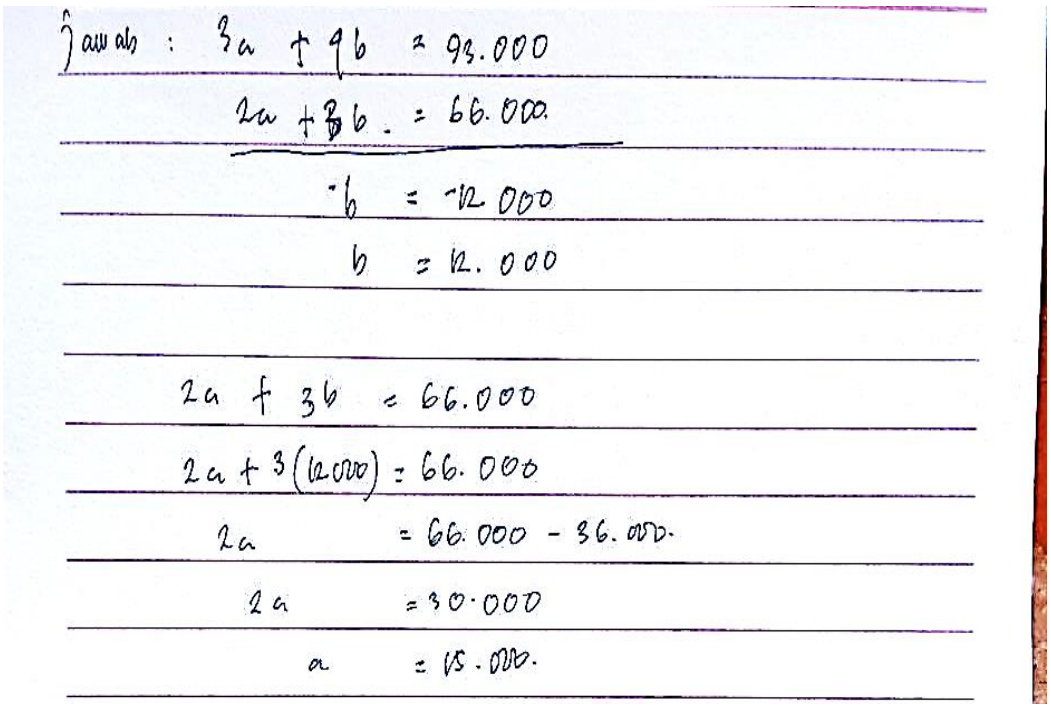
Picture 3. Results by Students A in the Less Critical Category

Because students do not write down what they know and what they ask on the worksheet, they could be wrong in determining the prices of the two types of rice. The following are the results of an interview with one of the students.

Researcher : What is the answer to this problem?
Student A : The answer is the price of 2 fried chicken rice is IDR 24,000 and 1 grilled fish rice is IDR 15,000.
Researcher : How can that be the answer? Even though the price asked is one fried chicken rice and one grilled fish rice. Maybe you don't write down what you know and what you ask.
Student A : Yes, sir.
Researcher : Next time, write what you know and what you ask!
Student A : Yes, sir. Maybe I'm too lazy to write it. But next time, I will write what is known and what is asked.

b. Students Misunderstand the Problems Faced

Another thing that often becomes a problem for students when solving mathematical problems is misunderstandings in understanding the problem. If this happens to some students for a long time, then it is likely that they will be wrong in determining each solution or answer that they solve. As in the example above, what is known is that the price of 4 fried chicken rice and three grilled fish rice is IDR 93,000, and the price of 3 fried chicken rice and two grilled fish rice is IDR 66,000. Students who do not understand the problem will make mistakes in determining the number of variables for the equation. For example, a should be a variable for fried chicken rice and b for grilled fish rice. Students who do not understand the problem may make solutions as follows.



Picture 4. Results by Students B in the Less Critical Category

Researcher : What is the answer to this question?
Student B : The answer is that the price of one fried chicken rice is IDR 15,000, and one grilled fish rice is IDR 12,000.
Researcher : The answer is wrong because you don't understand the problem. Please note that what is known is that the price of 4 fried chicken rice and three grilled fish rice is IDR 93,000, and the price of 3 fried chicken rice and two grilled fish rice is IDR 66,000. Most younger siblings include the equation: 3 fried chicken rice, four grilled fish rice, two fried chicken rice, and three grilled fish rice.
Student B : Hehehe, yes, sir.
Researcher : Next time, understand the problem you want to solve properly and correctly.
Student B : Yes, Sir, Ready.

Students in the Non-Critical Category

Students in this category cannot apply the Polya model step by step, so they cannot find solutions to their problems. The results of Rizza's research show that there are students who can't do it at all at the level of critical thinking in understanding a problem, so there are still students who have a low level of critical thinking ability because they cannot solve the problems they face following the stages mentioned in Polya (Rizza, 2020). Meanwhile, based on the research results produced by Darmawan, there are at least seven errors that occur to students when facing problems, namely: (1) students have not mastered the formula and do not know how to do it or plan the solution; (2) students do not mention what is asked and known; (3) students do not solve questions well; (4) students make mistakes in arithmetic operations so they get unexpected answers; (5) students have difficulty following the flow or procedure for solving questions; (6) not using appropriate units; and (7) students make mistakes in making conclusions (Darmawan et al., 2018).

Advantages of the Polya Model

The Polya model has made a major contribution to improving students' mathematical abilities in the problems they face. Thus, many elementary and middle school students are helped by using the Polya model to solve the mathematical problems they face. According to Handayani and Ramlah, several advantages of the Polya model are (1) Students can develop their thinking skills to solve the problems they face appropriately; (2) it provides a systematic framework for solving complex problems that can help students to organize their efforts in solving a problem; and (3) Make students careful in recognizing the appropriate stages in the problem-solving process (Handayani & Ramlah, 2017).

Thus, it shows that apart from finding answers to their problems, they can also know the steps to solve a problem properly and correctly because, in the Polya model, the framework is neatly arranged. The Polya model also aims to obtain students' cognitive skills in problem-solving rationally, straightforwardly, and thoroughly (Asman & Ariani, 2020). Through the Polya model, students are expected to gain meaningful learning experiences involving students' attitudes, experiences, knowledge, and abilities (Ayustina & Ahmad, 2020). On another occasion, Putri said that the Polya model is appropriate for mathematical problems, especially story problems, because it can help students with high levels of reasoning solve problems and explain them logically and systematically (Putri et al., 2018). In this way, students will obtain a high paradigm. However, this is not an absolute provision because previous research determines this success.

Conclusion

Based on the analysis and research conducted on several students, a common thread can be drawn that the Polya model can greatly influence students to solve their problems, especially in learning mathematics. Conditions like this are because, in the Polya model, there are steps that give students a higher frame of mind. From understanding the problem to solving the problem and looking at some of the advantages of the Polya model, the Polya model must be applied to students, even in elementary school.

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