HIGH SCHOOL STUDENTS' CRITICAL THINKING ABILITY: ANALYSIS IN TVLS WORD PROBLEM

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Abstract

Problem solving is an important skill, and making decisions about the basis of critical thinking skills. This study is a descriptive qualitative study to describe the critical thinking of 8th grade public junior high school students in the suburbs of Surabaya, East Java in solving TVLS problems. Fifteen junior high school students contributed to the study and were given questionnaires to get three subjects with different critical thinking abilities. Furthermore, each subject was requested to solve TVLS word problems and then interviewed. The instruments used in this study were a critical thinking questionnaire (CTAT), TVLS word problems, semi-structured interview guidelines. The data was analyzed based on indicators that combined the stages of Polya's problem solving and critical thinking. The data were analyzed using critical thinking indicators that have been determined by the authors and the results obtained showed that (1) uncritical and low critical subjects were unable to complete the critical thinking indicators at each stage of problem solving; (2) medium critical, critical, and highly critical subjects were able to complete the critical thinking indicators at each stage of problem solving. For this reason, it is advised that teachers teach their students to think critically in solving problems in every learning process.

Keywords: critical thinking, problem-solving, word problem

1. Introduction

Mathematics is a universal science that is useful for human life and plays a role in advancing the power of human thought. Mathematics is taught at every level of education and is known as learning mathematics in the learning process. Mathematics learning contributes to students' academic potential (Nazariah & Abidin, 2017), provides experience, and teaches critical thinking through problem-solving. Through problem-solving, students are taught to think clearly and directed to get a solution (Inayah, 2018; Rahman, 2019).

Students who think critically in solving problems indeed involve the process of analyzing, criticizing, and reaching conclusions based on the inference process. In this case, problem-solving is seen as a means to grow critical thinking skills, while critical thinking was seen as a condition for problem-solving abilities (Cahyono, 2004; Hidayat & Sariningsih, 2018). Both are closely related and require critical thinking skills in finding various alternative solutions.

The problem-solving process involves reasoning abilities, the ability to connect problems into ideas so that they can solve the given mathematical problems. Problem-solving underlies the essential ability to solve problems and make decisions as to the basis for critical thinking skills (Hedges, 1996). The ability to think critically in solving mathematical problems has become an exciting discussion on previous studies (Basri et al., 2019; Benyamin et al., 2021; Binti, 2020; Fatmawati et al., 2014; Rahimah, 2019; Riskiyah et al., 2018; Salahuddin & Syahrir, 2020).

From observations and interviews with senior mathematics teachers at SMPN 28 Surabaya show that students' proficiency in analyzing problems, evaluating information, and taking reasonable decisions needs attention. This affects students' ability to solve complex and unstructured math problems. In addition, during the learning process, teachers use less approaches that promote students to ask questions, analyze, and try to solve problems independently, thus constraining the development of critical thinking skills.

The study discusses critical thinking on different topics, such as math problems (Basri et al., 2019; Binti, 2020), TVLS' problems (Rahimah, 2019), functions (Riskiyah et al., 2018; Salahuddin & Syahrir, 2020), quadratic equations (Fatmawati et al., 2014), and System of Three Variable Linear Equations (Benyamin et al.,

2021). Then, to analyze the data is based on the point of view that uses the critical thinking stages of Facionne (Basri et al., 2019; Benyamin et al., 2021; Riskiyah et al., 2018), the stages of Polya's problem solving (Binti, 2020; Fatmawati et al., 2014; Rahimah, 2019), and the critical thinking stages of Ennis (Salahuddin & Syahrir, 2020). Based on previous studies, the point of view of analyzing the data, it shows that the study of Basri et al. (2019) provides an understanding of the application of Facionne's critical thinking stages in mathematical problem solving. Binti's (2020) study can highlight the use of Polya's problem solving stages in TVLS problems. This shows that there is a research gap regarding TVLS word problems analyzed by combining the stages of critical thinking and Polya's problem solving stages.it is necessary to carry out further research on the TVLS word problem which the analyzed that combines the stages of critical thinking and Polya's stages problem solving.

Word problems were placed in the context of daily life situations. So that students are required to be able to read, understand and use their mathematical understanding (Fatmanissa & Kusnandi, 2020). Belecina & Ocampo (2018) explained that the situation of the word problem presented could significantly improve students' critical thinking to solve it. The stage of problem-solving that is familiar among researchers is Polya. (Wulandari et al., 2016) explain that Polya uses four phases of problem-solving, understanding the problem, planning, implementing the plan, and re-examining the results of the answers obtained.

The researcher chose the Two-Variable Linear Equation System (TVLS) because it is closely related to the daily life situation (Wulandari et al., 2016). TVLS is very because it fits into the context of everyday life that students are familiar with. Thus, this study to analyze the critical thinking skills of students in solving TVLS word problems. The importance of this study is that critical thinking skills played a key role in complex problem solving and innovation. Promoting critical thinking skills will assist individuals to understand and use technology effectively and face the challenges that emerged in the industrial transformation.

2. Method

This is a descriptive study with a qualitative approach carried out at 8th grade SMPN 28 Surabaya. Fifteen students in 8th grade voluntarily participated in this study. Data were collected

through a critical thinking ability test (CTAT), word problem TVLS, and semi-structured interviews. The critical thinking ability test used was adapted from the existing questions. They then grouped students into categories not critical, low critical, medium critical, critical, and very critical.

One student was taken from medium, critical, and very critical group as the research subject. The authors chooses a single subject, the study has a more precise and clear focus. This allows researchers to concentrate their efforts on an in-depth understanding of the subject and

analyze relevant variables in detail. A clear focus helps avoid confusion and confounding in the interpretation of the study results. The basis for selecting research subjects was that the researchers discussed with the 8th grade mathematics teacher to determine subjects with good communication skills in keeping with advice from the math teacher. From the results of the questionnaire, three subjects with different critical thinking abilities were analyzed. The test used is in the form of a TVLS word problem, and the questions used in this study were translated as follows.
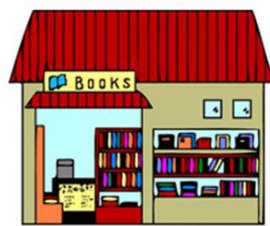
Mother gave Sam one hundred thousand rupiahs to buy books and pencils at Adi Buana Bookstore. Previously, Sam asked his friends Indro and Susan, who had bought books and pencils at the shop. Indro bought four notebooks and two pencils for Rp. 17,400.00, while Susan bought three notebooks and five pencils for Rp. 19.000,00. On the way to Adi Buana's bookstore, Sam filled up with Pertamax fuel for Rp. 9,000 for his 2-liter vehicle. What do you think

a. How many books and pencils can buy after fuel and how much rest the money?
b. Have you another answers? Which situation pleasure mother? Explain your answer !

Figure 1. TVLS word problem

In the word problem in Figure 1 above, the sentence that stimulates students' literacy to think critically is "which situation pleases mother?". In this situation, students are also required to be creative in determining the number of books and pencils that can be purchased but with provisions that please the mother. Students can assume that they please the mother through the amount of change that the mother receives, it can also be according to the needs required by Sam, or there are other considerations. Students can write down the reasons on the answer sheet given to explain what they mean.

Before being employed, the instruments used had gone through an expert validation process for questionnaires, word problems, and interview guidelines. Experts were engaged in validating the instruments with feedback that the researchers used as a basis for revision. The revisions were used by researchers to conduct research. After the WP-TVLS was given to the students, the researcher carefully corrected the students' answers according to the critical thinking indicators associated with the Polya stage. Critical thinking indicators based on the Polya stages used in this study are describes in Table 1 as follows.

Table 1. Critical thinking indicator and problem solving

Step	Aspect	Indicator
Understanding the problem	Interpretation	1. Reveal problem situations in their own language (MMI_1). 2. Reveal information from the problem (MMI_2)
	Analysis	Determine important information to solve the problem (MMA).
Planning	Interpretation	Create mathematical models of problem situations (MRI).
	Analysis	1. Choose the correct example (MRA_1). 2. Choose the method to solve it (MRA_2)
Executting the plan	Analysis	Perform calculations accurately and correctly (DPA).
	Evaluation	1. Write down the answer to the problem correctly (DPE_1). 2. Write down alternative solutions (DPE_2).
Crosschecking	Inference	Conclude the answer from the problem situation (MKI).
	Explanation	Write down the final results and give reasons (MKP).
	Self Regulation	Re-check the results of the problem solving correctly (MKRD).

Furthermore, semi-structured interviews were conducted to explore students' critical thinking skills in solving the WP-TVLS. The questions asked are what information is obtained

from the problem, how and what must be done to solve the problem, and what conclusions can be obtained from the problem. The data were analyzed through the stages of data reduction, data

presentation, and conclusions (Sugiyono, 2013). Researchers carried out data triangulation by comparing the results of interviews and student answers. The data is valid if the students' answers and the interview results are the same. So in this

study, the triangulation used is technical triangulation by comparing the two answers.

The flowchart of this study can be described as follows.

Figure 2. TVLS word problem

3. Results and Discussion

3.1 Results

The 15 students who participated in this study showed one student in the very critical, five students in the critical, two in the medium critical, one in the low critical, and six in the uncritical. The results can be seen in Figure 3 below.
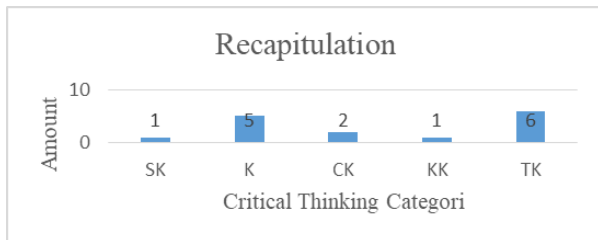

Figure 3. Graph of students critical thingking

Note:
TK   : not critical
KK   : low critical
CK   : medium critical
K   : critical, and
SK   : very critical

The subjects were selected with the consideration of the mathematics teacher in order to obtain HB (Medium Critical), ARA (Critical), and ADS (Very Critical). The following describes the students' critical thinking skills in solving word problems based on the Polya stages.

Understanding the problem

a. Subject HB (Medium Critical)

The results of HB's work understanding the problem are presented in Figure 4 below.

Known : Mom give Sam money 100.000 rupiahs to buy books and pencil. Sam's friend called Indro and Susan bought at Adi Buana's store. Indro buy 4 books and 2 pencils amount 17.400 and Susan buy 3 books and 5 pencils amount 19.000. Sam refuel pertamax 2 litres at price 9.000/litre.
a. How many books and pencils can buy with rest the money after fuel Pertamax?
b. From anwer (a), how much money returned Sam to their mom?
c. Have you another answer?
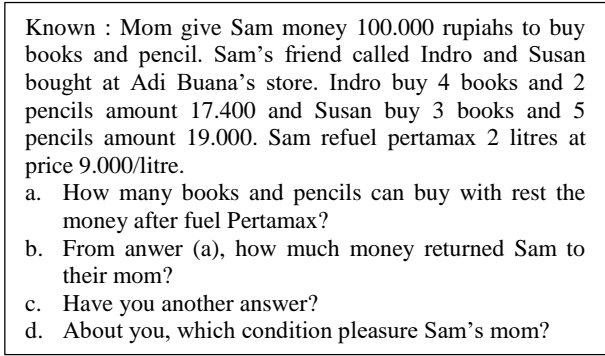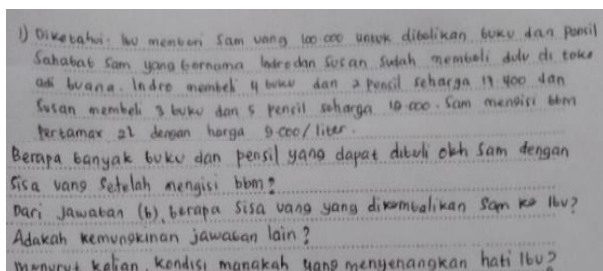d. About you, which condition pleasure Sam's mom?

Figure 4. Understanding problem situation by HB

Figure 4 showed that HB expressing the problem situation with his language and then analyzing it (MMI1, MMA). The result is that HB writes down the known information and asks from the word problem situation (MMI2).

b. Subject ARA (Critical)

The results of ARA's work understanding the problem are presented in Figure 5 below.

Known :
(1) Money given Sam's mom in the amount IDR 100.000
(2) Sam buy books and pencil at Adi Buana's store
(3) Indro buy 5 books and 2 pencils amount IDR 17.400
(4) Susan buy 3 books and 5 pencils amount IDR 19.000
(5) Sam fuel their motor cycle as much as 2 litres amount IDR 9.000
Asked:
a. How many books and pencils pencils can buy by Sam?
b. From answer above, how much mom's money returned?
c. Another answer?
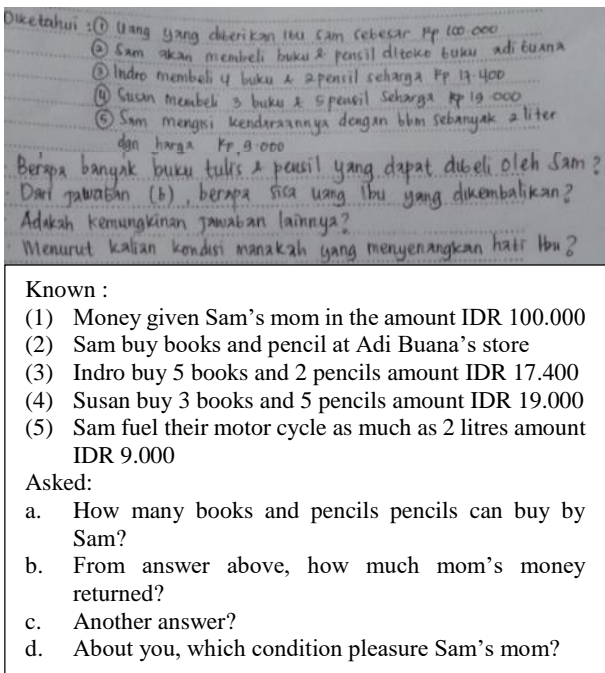d. About you, which condition pleasure Sam's mom?

Figure 5. Understanding problem situation by ARA

Figure 5 obtained that ARA information reads the problem then analyzes the problem situation (MMA). Then, RA continued to reveal the problem situation by writing down information that

is known and asked from the word problem situation (MMI1, MMI2).

c. Subject ADS (Very Critical)

The results of ADS's work understanding the problem are presented in Figure below.
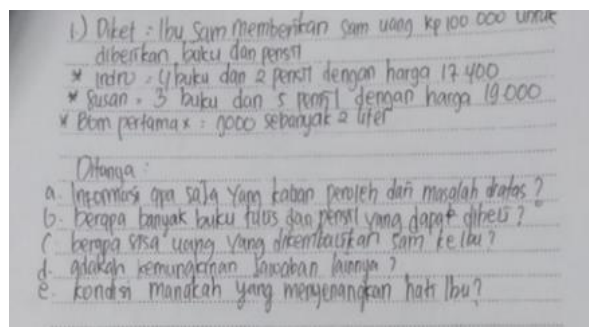
Known:
Sam's mom given Sam money IDR 100.000 to buy books and pencils
Indro = 4 books and 2 pencils amount 17.400
Susan = 3 books and 5 pencils amount 19.000
Pertamax oil = 9.000 many 2 litres
Asked
-    How many books and pencils can buy?
-    How much money change?
-    Have an another anwers?
-    Which conditions pleasure mom?

Figure 6. Understanding problem situation by ADS

Figure 6 showed that information is obtained starting by reading the problem and analyzing the problem situation (MMA). Then, ADS continues to reveal the problem situation by writing down information known and asked from the word problem situation (MMI1, MMI2).

Planning

a. Subject HB (Medium Critical)

The results of HB's work in planning are presented in Figure 7 below.
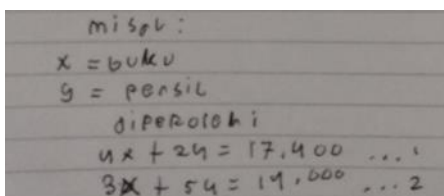
Suppose
　　　x = book
　　　y = pencil
obtained　4x + 2y = 17.400　　　　　(1)
　　　　　3x + 5y = 14.000　　　　　(2)

Figure 7. Planning subject HB

HB began to develop a plan by supposing a book and pencil (MRA1), then converting it into a mathematical model (MRI). Next, HB determines the method used to solve the word problem. This is reinforced by interview quotes below.

R　　: What are you doing now?

HB　　: Suppose x are books and y are pencil
*　　　　So, we get equation 4x + 2y = 17.400 and*
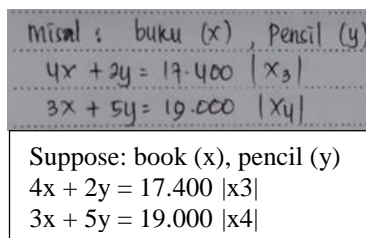*　　　　3x + 5y = 19.000*
R　　: Then?
HB　　: I used elimination method, sis

The interview above shows HB as a suppose of the given word problem situation and then converting it into a mathematical model. From the mathematical model, HB determines the method used to generate the solution. In this case, HB used the elimination method and immediately applied it to solve the word problem.

b. Subject ARA (Critical)

The results of ARA's work in planning are presented in Figure 8 below.

Suppose: book (x), pencil (y)
4x + 2y = 17.400 |x3|
3x + 5y = 19.000 |x4|

Figure 8. Planning subject ARA

In the planning, ARA performs an analysis by making a supposing (MRA1) and then converting it into a mathematical model (MRI). Next, ARA plans to find a solution using the elimination method. This is shown in figure 9 by multiplying each equation by a certain number and proved by the following interview.

R　　: What's your plan to find solution?
*ARA　: Suppose x are books and y are pencil*
R　　: Why you multiple every equation with
*　　　　different number?*
ARA　: Yes, because I want to used eliminination
*　　　　method to find the solution*

In the interview above, ARA assumes the given word problem and continues to convert it into a mathematical model. ARA multiplies by a certain number from the mathematical model because it plans to use the elimination method to produce the right solution.

c. Subject ADS (Very Critical)

The results of ADS's work in planning are presented in Figure 9 below.
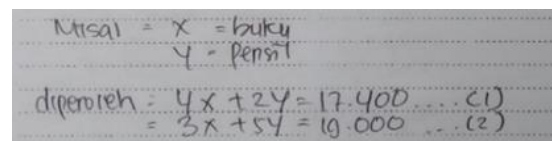
Suppose : x = book
　　　　　y = pencil
Get　　4x + 2y = 17.400　　　... (1)
　　　　3x + 5y = 19.000　　　... (2)

Figure 9. Planning subject ADS

ADS performs an analysis of making a suppose (MRA1) and converting it into a mathematical model (MRI). ADS continued by determining the method used in solving the problem, the mixed method (MRA2). The following interview reinforces this.

R   : *What are you doing with this situation?*
ADS   : *Hhmm.. I'm suppose x are book then y are pencil. So, we get equation 4x + 2y = 17.400 and 3x + 5y = 19.000*
R   : *With this equation, what you're planning to solve it?*
ADS   : *I'm used two method sis, elimination and subtitution*

ADS plan by starting the suppose according to the word problem situation (MRA1) and obtaining two equations, the mathematical model (MRI). Next, ADS plans a solution to get a solution using the combination elimination and substitution method (MRA2).

Execute the plan

a. Subject HB (Medium Critical)

The results of HB's work in executting the plan are presented in Figure 10 below.
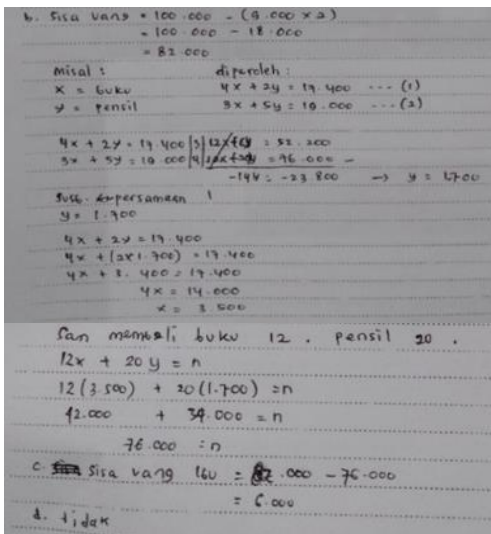
The rest of money $= 100.000 - (9.000 \times 2)$
$= 100.000 - 18.000$
$= 82.000$
Planning then carry out the plan
$4x + 2y = 17.400$ |3| $12x + 6y = 52.200$
$3x + 5y = 19.000$ |4| $\underline{12x + 20y = 46.000 -}$
$-14y = -23.800$
$y = 1.700$
Subtitution to equation (1) for $y = 1.700$
$4x + 2y = 17.400$
$4x + (2 \times 1.700) = 17.400$
$4x + 3.400 = 17.400$
$4x = 14.000 \rightarrow x = 3.500$

Sam buy 12 books and 20 pencils
$12x + 20y = n$ → $12(2.500) + 20(1.700) = n$
$42.000 + 34.000 = n$
$76.000 = n$
Mom's rest money $= 82.000 - 76.000 = 6.000$
No

Figure 10. Executing the plan by HB

HB can perform calculations according to numbers in word problem situations (DPA) and provide the right solution (DPE1). Figure 9, HB cannot determine other alternative answers (DPE2) because it shows only one single answer. Interview quotes reinforce below

R   : *Have you another answers?*
HB   : *Sorry, I don't have miss*

The interview above shows that HB did not devise an alternative solution to the situation. So in concluding the problem situation only the answer "No" is given by HB. This is because only the single answer from HB, so HB cannot provide the best solution to please the mother.

b. Subject ARA (Critical)

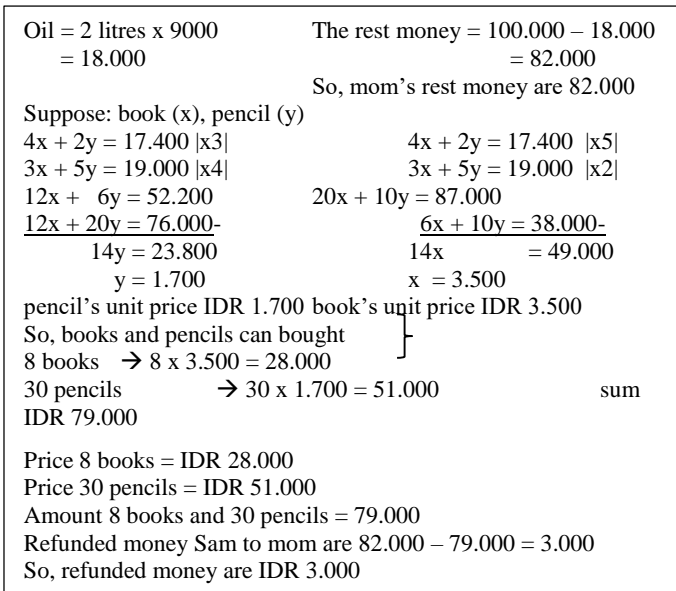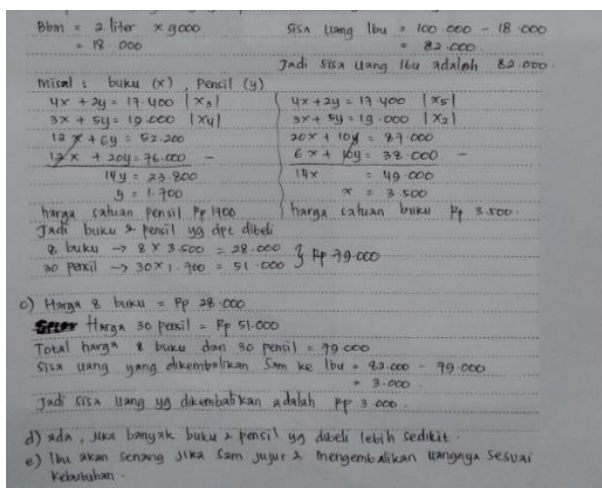The results of ARA's work in executting the plan are presented in Figure 11 below.

Figure 11. Executting the plan by ARA

ARA performs the calculation process correctly (DPA) and provides the right solution according to the word problem (DPE1) situation. In addition, ARA can also determine other alternative answers (DPE2) that are different from the initial answer. From Figure 14, ARA states that the remaining money will be a lot if the number of books and pencils purchased is only a little. Meanwhile, mom would be happy if Sam honestly returned the remaining money according to the number of books and pencils he bought.

c. Subject ADS (Very Critical)

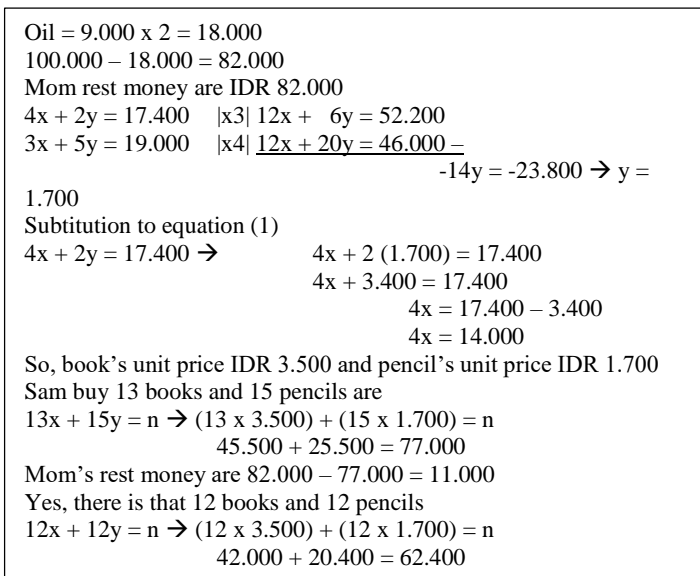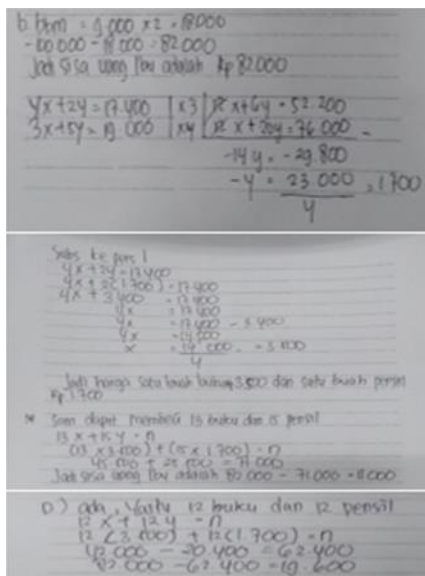The results of ADS's work in executting the plan are presented in Figure 12 below.

Figure 12. Executting the plan by ADS

ADS performs the calculation correctly (DPA) and writes the settlement correctly (DPE1). ADS can determine other alternative answers to support it in conclusion (DPE2). The answer is correct but ADS is wrong in writing down the operation and does not conclude which situation pleases the mother.

Crosschecking

a. Subject HB (Medium Critical)

The results of the HB crosschecking are presented in Figure 13 below.
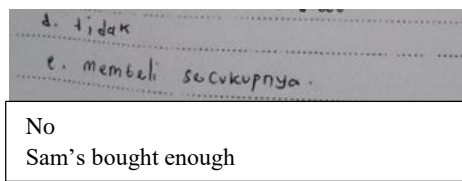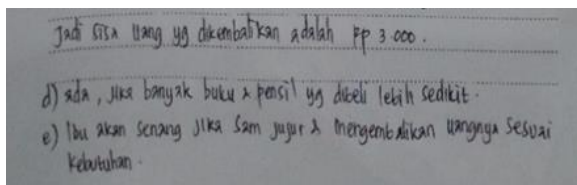

Figure 13. Crosscheck by HB

HB does not initiate concluding the final result of the problem and explaining the result

with confidence but can check again. The interview results with HB crosscheck the answers given (MKRD), such as the following quote.

> R   : *Have you crosscheck your answer?*
> HB : *Yes sis, I did it*

b. Subject ARA (Critical)

The results of the ARA crosschecking are presented in Figure 14 below.

So the money returned are IDR 3.000
Yes, there is. If the number of books and pencils purchased is less
Mom will be happy if Sam is honest and returns the money as needed

Figure 14. Crosschek by ARA

ARA provides the final answer by the solving process carried out (MKI) and explains the reason for the answer given (MKP). The interview results with ARA crosscheck the answers given (MKRD), such as the following quote.

> R   : *Have you crosscheck your answer?*
> ARA: *Yes sis*.

c. Subject ADS (Very Critical)

The results of the ADS crosschecking are presented in Figure 15 below.

Yes, 12 books and 12 pencils
$12x + 12y = n$ → $12 (3.500) + 12 (1.700) = n$
$42.000 – 20.400 = 62.400$
$82.000 – 62.400 = 19.600$
more money left
The condition that makes mother's heart happy is the remaining money as much as IDR 19.600

Figure 15. Crosscheck by ADS

ADS concludes the final result of the problem, explains the final result confidently, and rechecks. The interview results with ADS crosscheck the answers given (MKRD), such as the following quote.

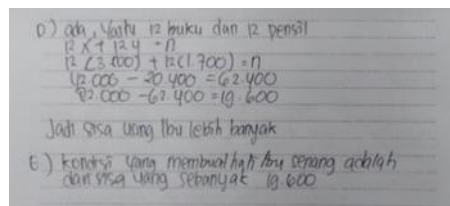> R   : *You crosscheck your answer?*
> ADS : *Yes sis*

3.2   Discussion

Based on the work of three subject above, we can presented in Table 2 below.

Table 2. Recapitulation subject work based on Polya

Step	Aspects	HB	ARA	ADS
Understanding the problem	Interpretation	All of the subjects reads and reveals the problem situation in his language		
	Analysis	All of the subjects write down important information from the problem		
Planning	Interpretation	The subjects make mathematical models.		
	Analysis	The subjects determines the method of solving the problem		
Executting the plan	Analysis	The subjects can do the calculations well		
	Evaluation	The subjects can make the solution precisely		
Crosschecking	Inference	The subject does not conclude the answer correctly	The subjects can deduce the answer correctly	
	Explanation	The subject is not sure in explaining the reason	The subjects confidently explains the reason	
	Self Regulation	The subjects does self-regulation well		

At the stage of understanding the problem, each subject with a different level of critical study that in solving the WP-TVLS, understanding the problem situation and identifying relevant information and concepts is the key to success in problem-solving (Mawaddah & Anisah, 2015; Yuwono et al., 2018). The interpretation of the problem situation describes the understanding of the subject, writes down the objectives, and identifies the keywords clearly and precisely. In line with previous study (Prayitno, et al., 2020) identifying problem situations by mentioning keywords and goals is essential in problem-solving. While working on the WP-TVLS, the researcher observed that most subjects reread the presented problem situations. (Sa'adah et al., 2020) explained that this activity is a student process that aims to understand the word problem situation and determine keywords.

All of the subjects can make mathematical models and choose the method used to solve problems. Determination of strategies and methods is critical in solving problems (Mawaddah & Anisah, 2015). In planning the strategy, the subject must make connections between existing

information so that there is no misinterpretation (Doko et al., 2020; Prayitno, et al., 2020; Sa'adah et al., 2020).

When carrying out the plan, all subjects can perform calculations until they get the right solution. Subjects who cannot formulate problem situations well (KFR and AZR) do not solve problems correctly (Fatmawati et al., 2014). This does not apply to HB, ARA, and ADS subjects who can understand the problem situation to solve it appropriately. The correct calculation process so that obtaining the right solution is the key to the success of the subject in solving word problems (Abdiyani et al., 2019).

At the rechecking stage, the subject is not critical, low critical, and critical enough not to conclude the answer correctly. Meanwhile, subjects with critical and highly critical categories can conclude answers appropriately. When viewed from the ability to explain, the five subjects did not have the confidence to give a reason for the answer given. Self-regulation, the subject is not critical of not self-regulation while the other four subjects do self-regulation well. The subject's ability to write the final answer, explain the reason, and self-regulate has an essential role in problem-solving (Pravesti et al., 2020; Yuwono et al., 2018).

From the results above, it shows the combination of Polya's stages and critical thinking related to the stages of effective thinking and problem solving known as IDEAL (Facione, 2011). In addition, problem solving can also involve the use of ill-structured problems for assessing student thinking. Students have to collect relevant information, analyze the situation, and formulate effective strategies to reach a solution. This assists students in developing in-depth problem-solving skills and thinking critically (Prayitno et al., 2022).

However, in this study found an obstacle in familiarizing students in critical thinking in problem solving, namely the limited time in the learning process in the classroom. This is where the role of determining learning that integrates with project-based learning is carried out in schools as an alternative to teaching critical thinking (Peter, 2012).

4. Conclusion

Based on the results and discussions above, it can be concluded that students' critical thinking ability in solving word problems, among others (1) The stage of understanding problems, all of the subjects can interpret and analyze word problem situations, (2) planning, the uncritical and low subject can not interpret and analyze, but another subject can interpret and analyze well, (3) The executing stage, the uncritical and low subject can not analyze and evaluate, but another subject can analyze and evaluate well, and (4) The subjects can infer, explain and self-regulate. Exploring effective teaching strategies to develop critical thinking and open-ended mathematical problem solving is needed in future studies. Future researchers should identify teaching strategies which are effective in facilitating the development of critical thinking and problem solving skills in an open-ended mathematics context.

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