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MATHEMATICAL LITERACY IN ALGEBRA REASONING

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Abstract

This study aims to describe prospective mathematics teacher's mathematical literacy in algebra reasoning and thinking process in solving mathematical literacy problems. This study used a qualitative case study approach by choosing two prospective mathematics teacher who solved problems with algebraic reasoning. The result has shown that prospective mathematics teacher has algebraic reasoning in type functional thinking and use generalization in solving mathematical literacy problems. Functional thinking reasoning type used table representation and number manipulation to find and compare the value of charge in justification and decision making, while use generalization reasoning type used supposition, algebra expression, conditioning, and number manipulation to find and compare the value of charge in justification and decision making. Furthermore, use generalization reasoning type interpreted thrice in conditioning before general interpreted.

Keywords: mathematical literacy, algebra reasoning, functional thinking, using generalization

PISA (Program for International Students Assessment) is one of the programs initiated by Organization for Economic Co-operation and Development (OECD) in the 1990s to provide information to government and other parties about education system effectiveness especially for preparing students future (Prenzel, Blum, & Klieme, 2015). Mathematics is one of the domains in the PISA study. The objects studied by PISA in mathematics are not limited to learning achievement, but studies in the field of mathematics include abilities termed *mathematical literacy*.

Mathematical literacy refers to the ability to formulate, employ, interpret, and evaluate mathematics in various contexts (OECD, 2016). Competencies were developed in mathematical literacy are reasoning, decision making, problem-solving, ability to manage resources, interpret information, ability to organize activities and to use and apply technology (Departement of Basic Education Republic of South Africa, 2011).

PISA conducted surveys since 2000, and it's held every 3 years. Indonesia has always been a participant in every survey conducted by PISA. Indonesian students have low mathematical literacy skills in each survey. The study conducted by Stacey, (2011), reported that mathematics literacy abilities of Indonesian students as a result of the PISA survey from 2003 to 2009 were unstable and were at level 2. Based on the PISA 2015 results, Indonesia is included in the 10 countries with low literacy abilities, with only 69th out of the 76 countries surveyed by PISA (OECD, 2016). The scoring average of Indonesian students for math literacy skills is 375 (level 1) while the average international score is 500 (level 3). Level 1 is the lowest level of the 6 levels of mathematical literacy abilities applied by PISA.

Many studies conducted to determine the difficulties of students in solving mathematical literacy problems. Research by Wijaya, Heuvel-panhuizen, Doorman, & Robitzch (2014) found that students' difficulties in completing PISA problems consisted of understanding difficulties (38%), transformation difficulties (42%), mathematical processing errors (17%) and coding errors (3%). Duong Huu Tong & Nguyen Phu Loc (2017), Vale, Murray, & Brown (2013) and White, (2010) found that students experiencing the most difficulties with the remaining misapplication solution roles were difficulties with subjectivity, carelessness, incorrect identification of problem role and wrong calculation. Edo, Ilma, & Hartono (2013) found that students experience difficulties in the process of formulating problems in everyday life into mathematical models, such as interpreting the context of real situations into mathematical models, understanding the structure of mathematics (including order, relationships, and patterns) in problems.

Study on mathematical literacy factors has been carried out. Uysal (2015) reported that mathematical literacy skills have 3 factors: interest, self-concept, and mathematical anxiety. Breen, Cleary, & Shea, (2009), in his research, found that leaving certificate (LC), self-confidence, and gender influenced mathematical literacy skills. Yılmazer & Masal (2014) found that arithmetical and mathematical literacy are related. Godek, Kaya, & Polat (2017) found mathematical literacy, mathematic content knowledge, and science literacy are positively correlated. Tariq, Qualter, Roberts, Appleby, & Barnes, (2013) found gender, emotionally intelligent, and emotional self-efficacy is a factor of mathematical literacy skill. Furthermore, the teacher's self-efficacy, attitude, and using technology factors (Letwinsky, 2017).

Some of the above studies examine more about the factors that influence mathematical literacy abilities and do not assess the competencies developed. One of the skills developed in mathematical literacy is reasoning ability (Departement of Basic Education Republic of South Africa, 2011). One of reasoning is related to mathematical literacy was algebraic reasoning. Algebraic reasoning is a process in which students generalize mathematical ideas from a set of particular instances, establish those generalizations through the discourse of argumentation and express them in increasingly formal and age-appropriate ways (Blanton & Kaput, 2005). Algebraic reasoning including (a) the use of arithmetic as domain for expressing and formalizing generalization (generalized arithmetic) (b) generalizing numerical patterns to describe functional relationships (functional thinking); (c) modeling as a domain for expressing and formalizing generalizations and (d) generalizing about mathematical systems abstracted from computations and relations. (Kaput, 1998). Algebraic reasoning, which was generalized from the particular situations, can help students “to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts” (Friel et al., 2001). Research on algebraic reasoning has been carried out, Blanton & Kaput (2005) found that teachers could integrate algebraic reasoning in spontaneous and planned learning, Hackenberg (2013) found that fractional thinking and algebraic reasoning are related. Lee, Capraro, Capraro, & Bicer (2018) found that metacognition training influenced students' algebraic reasoning. Glassmeyer & Edwards (2016) Explained that Teachers reported that three activities influenced a shift in their thinking about algebraic reasoning, specifically by requiring conceptual knowledge to solve problems using multiple solutions, solution strategies, or representations. From this description, this study examines students' mathematical literacy skills in algebraic reasoning.

METHOD

This study used a case study of a qualitative approach. Instruments were given to 40 second semester of prospective mathematics teacher of UIN Mataram, Indonesia. Selection of 40 prospective mathematics teacher is based on their knowledge of algebra in which they have taken subjects related to algebra. Of the 40 prospective mathematics teacher, 2 of them were selected who have excellent mathematical literacy skills (level 6), as they can conceptualize, generalize and utilize information based on their investigations and modeling of complex problem situations, and can use their knowledge in relatively non-standard contexts. They can link different information sources and representations and flexibly translate among them. They at this level are capable of advanced mathematical thinking and reasoning. These prospective mathematics teachers can apply this insight and understanding, along with a mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for attacking novel situations. Prospective mathematics teacher at this level can reflect on their actions and can formulate and precisely communicate their activities and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situation (OECD, 2016). An instrument in this study adopted form Dindyal (2009) in the Association of Mathematics Educators (2009) in Figure 1.

1. The "**A**" car rental agency charge Rp. 200.000 a day and Rp. 10.000 per kilometer. The "**B**" car rental agency charge Rp. 150.000 a day and Rp. 20.000 per kilometer. Which agency will you choose to rent a car for a day? Give a reason for your answer.
2. Printing A charge has 150 per sheet for grayscale (black and white) and 500 per sheet for color. Printing B charge has 200 per sheet documents for grayscale (black and white) and 450 per sheets for color. If you are going to print a document, which printing do you choose? Give reasons for your answer.

Figure 1. Research Instrument

Data collected by Think aloud by asking 2 subjects chosen to see the thinking process of the prospective mathematics teacher. Their answer was analyzed with the PISA framework (OECD, 2017) in Figure 2.

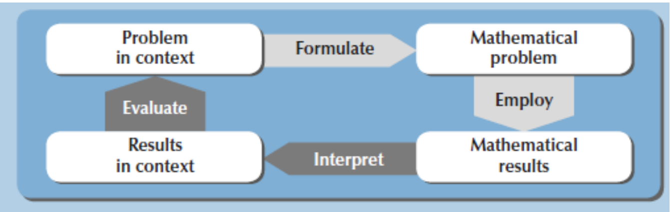

Figure 2. PISA Framework

RESULT AND DISCUSSION

Result

After the test instrument was given to 40 prospective mathematics teacher, 2 subjects were selected who had excellent mathematical literacy skills (level 6). Selection of 2 subjects is based on the results of their answers. Of the 2 subjects, one subject has functional thinking, and one subject uses generalization (Blanton & Kaput, 2005).

Subject A (*functional thinking*)

Formulating Stage

At the formulating stage of the problem, subject A simplifies the problem by writing the relationship (equation) between variables. In the first instrument subject A simplifies the problem by making the charge of the A car rental equation and the charge of B car rental per day with variable kilometers.

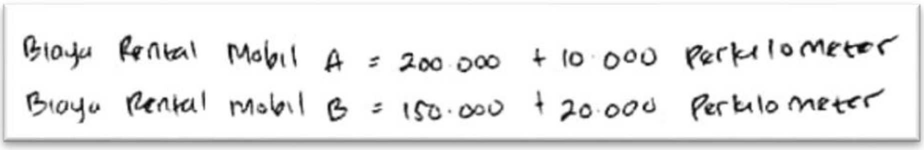

Figure 3. Subject A formulating stage to the first problems

In the second instrument subject A simplifies the problem by making a charge equation for printing A and printing B with a printed document variable in greyscale (black and white) and color.

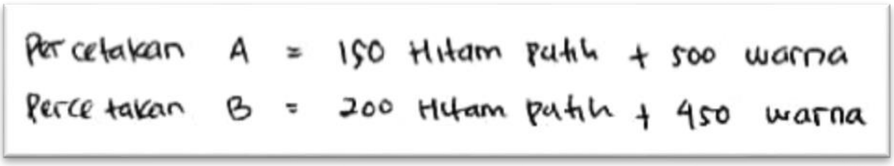

Figure 4.Subject A Formulating stage to the second problems

In simplifying the two problems subject A previously identified the mathematical aspects of the context of the problem then defined a significant variable. After identifying variables, subject A simplifies the representation of equations between variables (a charge, distance / printed documents).

Researcher: How do you understand the problem in these two questions?

Subjek A : in question number 1, I understand the problem by writing what is known in the problem, the car A and car B charge for each of the kilometers, while in the second problem I write the printing A and B charge for each greyscale (black and white) and color print document.

Employing Stage

At employing stage, in problem 1, subject A used the function concept by making a table with three rows, the first row for distance per kilometer, the second row for the car A charge and the third row for car B charge . in using the function concept, subject A also used a simple arithmetic concept of multiplication and addition for each distance.

Jarak tempuh	1 KM	2 KM	3 KM	4 KM	5 KM	6 KM	7 KM
Biaya Mobil A	210 000	220 000	230 000	240 000	250.000	260 000	270.000
Biaya Mobil B	170.000	190 000	210.000	230.000	250.000	270.000	290 000

Figure 5.Subject A Employing stage to the first problems

Dokumen Cetak	HP=1,W=0	HP=2 W=0	HP=0,W=1	HP=0,W=2	HP=1,W=1	HP=2,W=2
Percetakan A	150	300	500	1000	650	1300
Percetakan B	200	400	450	900	650	1300

Dokumen Cetak	HP=1,W=2	HP=1, W=3	HP=2,W=1	HP=3, W=1
Percetakan A	1.150	1.650	800	950
Percetakan B	1.100	1.550	850	1.050.

Figure 6.Students' Employing stage to the second problems

Researcher : What your strategy for solving the first problem?

Subject A : Firstly, I tried to determine the car A and car B charge with a distance of 1 Km, 2 Km, and so on. I wrote the trial results in a table. Results of the trial, I found that car A and car B charge can be the same at a distance of 5 Km. Furthermore, I tried at a distance of less than 5 Km, and the car B charge is cheaper, while at a distance of more than 5 Km, the car A charge is cheaper.

Peneliti : Then, how about the second problems?

Subjek A : I did the same thing, I tried to determine the printing A and B charge with only 1 to 5 black and white documents, and it turned out that A printing was cheaper, then I tried just 1 to 5 color documents, and it turned out that B printing was cheaper. Next, I try to print black and white, and color with the same number of 1 - 5 sheets and it turns out that the printing A and B charge are the same.

In the employing process subject A designs and applies strategies to find solutions uses facts, rules, algorithms, and structures, manipulates numbers in equation expressions, creates tables to extract information, and generalizes based on the results of applying mathematical procedures to find solutions.

Interpret and evaluate Stage

At interpret and evaluate stage, subject A interprets the mathematical results obtained in the real world context, for example in the first problem, subject A interprets the results of calculating the car A and car B charge relatively to distance, at a distance is less than 5 Km, the car B charge is cheaper, at the distance is more than 5 Km, the car A charge is cheaper. The car A and B charge was equal when distance 5 Km. as well as the second problem, subject A interprets the relevant results of printing A and B charge which depend on the number of black and white documents and color documents. Furthermore, subject A understands how the real world influences the results and procedures calculating.

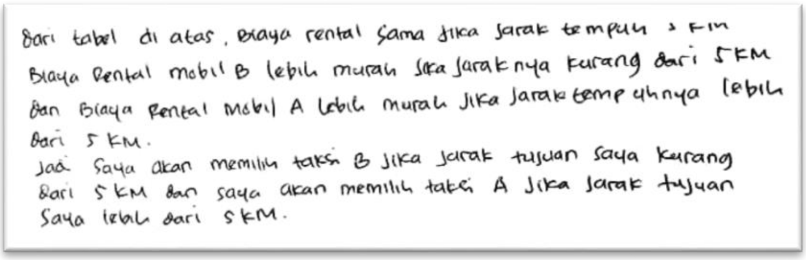
Dari tabel di atas, biaya rental sama jika jarak tempuh 5 KM
Biaya Rental mobil B lebih murah jika jaraknya kurang dari 5KM
dan Biaya Rental Mobil A lebih murah jika jarak tempuhnya lebih
dari 5 KM.
Jadi saya akan memilih taksi B jika jarak tujuan saya kurang
dari 5 KM dan saya akan memilih taksi A jika jarak tujuan
saya lebih dari 5 KM.

Figure 7. Subject A Interpret and Evaluate stage to the first problems

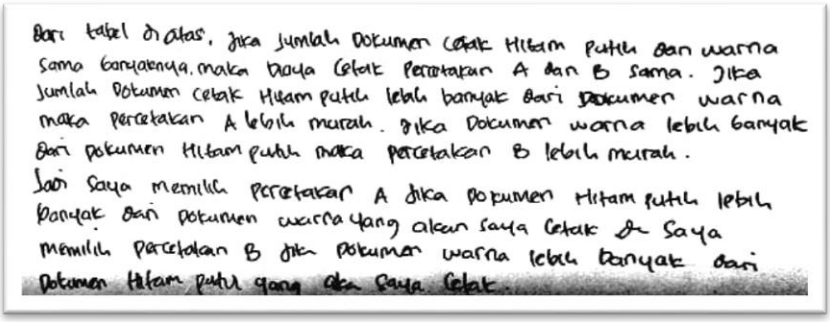
Dari tabel di atas, jika jumlah dokumen cetak hitam putih dan warna
sama banyaknya, maka biaya cetak percetakan A dan B sama. Jika
jumlah dokumen cetak hitam putih lebih banyak dari dokumen warna
maka percetakan A lebih murah. Jika dokumen warna lebih banyak
dari dokumen hitam putih maka percetakan B lebih murah.
Jadi saya memilih percetakan A jika dokumen hitam putih lebih
banyak dari dokumen warna yang akan saya cetak & saya
memilih percetakan B jika dokumen warna lebih banyak dari
dokumen hitam putih yang akan saya cetak.

Figure 8. Subject A Interpret and Evaluate stage to the second problems

Researcher: Do you often find the two questions in the real world?

Subject A : Yes, especially the second issue, I usually print assignment documents in several rentals (printing) and the charge sometimes varies. Sometimes the tasks that I print are black and white, sometimes black and white and color.

At interpret and evaluate stage, subject A also justifies which selection is better (A & B cars and A & B printing). The justification process is based on the results of the calculations in the table. Following is the process of thinking subject A:

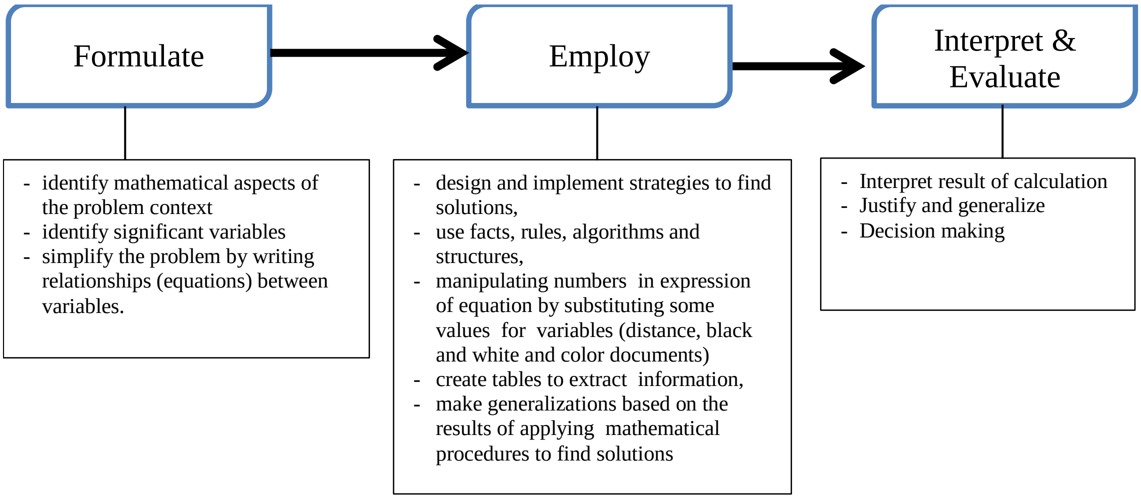

Figure 9.Subject A mathematical process in mathematical literacy

Subject B (*use generalization*)

Formulating stage

In the formulating stage, subject B simplifies the problem by making an example for each variable, then writing the relationship (equation) between variables. For the first problems subject B made an example using the variable x to represent the distance per kilometer, variable A for the car rental A charge and variable B for the car rental B charge then simplifies the problem by made equations A and B with variable x. In simplifying the first problem, subject B previously identified the mathematical aspects of the context problem then identified a significant variable. After defining a variable, subject B simplifies it in the representation of one variable linear equation

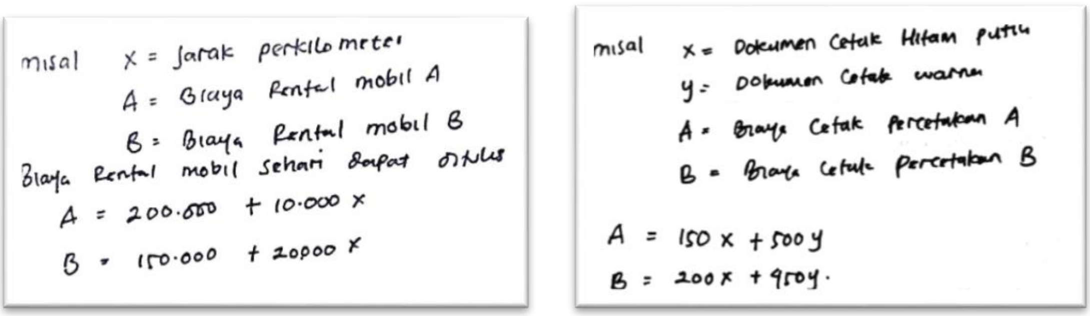

Figure 10.Subject B formulating stage to the first and second problems

In the second problem, subject B also given an example with variable x for black and white documents, y variable for color documents, variable A for printing A charge and variable B for printing B charge. In simplifying, the second problem subject B previously made identification of the mathematical aspects of the context problem then identifies significant variables. After defining the variable, subject B simplifies it in the representation of two-variable linear equations.

Researcher : How do you understand the problem in these two questions?

Subject A : in the first number, I understand the problem by made an example with the variable x for distance, variable A for the car rental A charge and variable B for the car rental B charge then writing the equation for each variable A and B for variable x. in the second number, I understand the problem by made an example with variable x for the number of black and white documents, y variable for the number of documents, variable A for printing A charge and variable B for printing B charge then write a two-variable linear equation for variable A and B.

Employing Stage

At employing stage, in first problems, subject B thinks there will be the possibility of the same charge between car A and car B that is by conditioning $A = B$. Furthermore, with simple algebraic operations the value of $x = 5$ is obtained. From the results of $x = 5$, subject B performs conditioning again for $x < 5$, makes an example for $x = 4$ and substitutes it for equations A and B then compares the value of A and value B obtained. Next, he does the conditioning again for $x > 5$, makes an example for $x = 6$ and substitutes it in equations A, and B then compares the values of A and B obtained

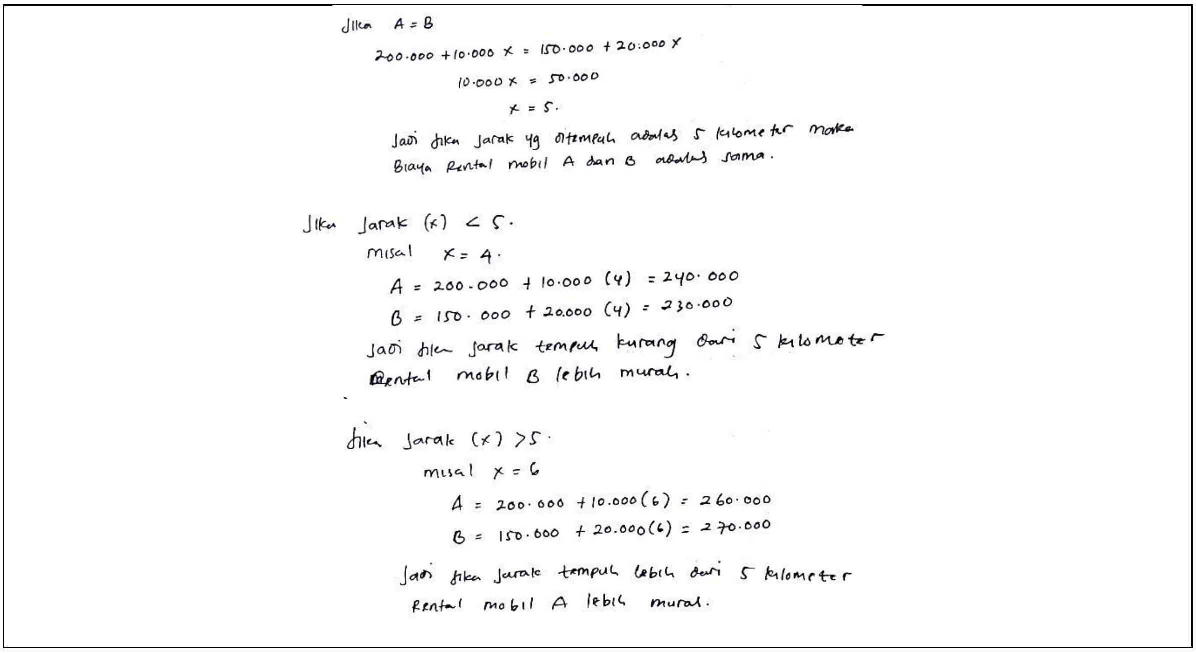

Figure 11.Subject B Employing stage to the first problems

For second problems, subject B performs conditioning for variables x and y with three possibilities, $x = y$, $x > y$ and $x < y$. for the first condition, subject B writes the example $x = y$, then substitutes to equation A and equation B then compares the values of equations A and B. For the second condition, subject B writes $x > y$, then makes the example $x = y + 1$, then substitutes it to equations A and B, then compare the values of equations A and B. For the third condition, subject B writes $x < y$, then makes an example $y = x + 1$, then substitutes it in equations A and B, then compares the values of equations A and B.

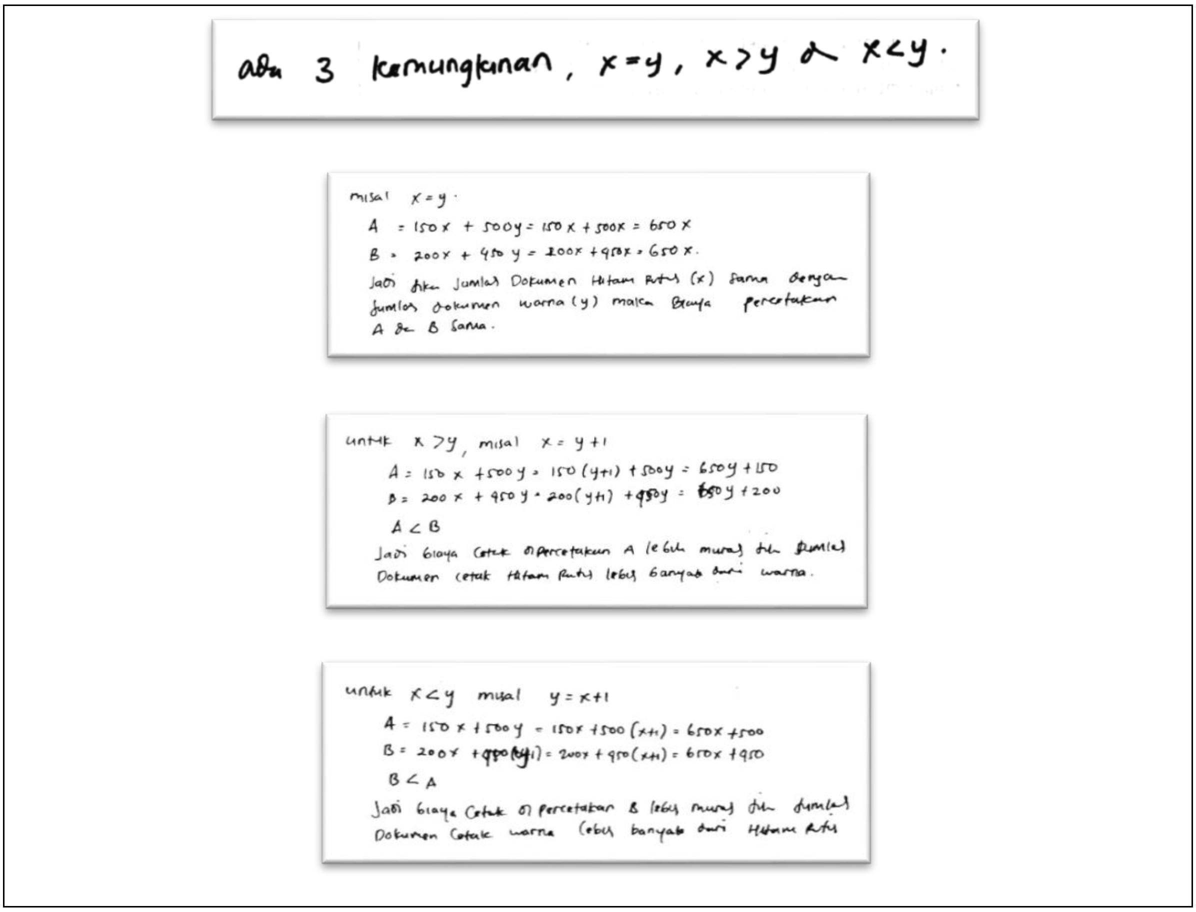

Figure 12.Subject B Employing stage to the second problems

Researcher :	What your strategy to solve first problems?
Subject A :	After observed equations A and B with the variable x, I think that is it possible that the car A charge (variable A) equals to the car B charge (variable B)? Then I tried to write $A = B$ and solved the equation then get the value $x = 5$. From this result, I made a tentative conclusion that for a distance of 5 KM, the two rental cars had the same charge. Then I made the example for a distance of less than 5 Km and more than 5 Km, and I got the results as in my answer.
Peneliti :	Then, How about second problems?
Subjek A :	Firstly I was confused by the second question because the equations A and B are in the form of a system of linear equations of two variables, but the constant value is unknown. Then I think because there are two variables x and y, then, of course, there are 3 possibilities $x = y$, $x > y$ and $x < y$. after that I substituted the three possibilities into equations A and B then I compared them.

In employing process subject B designs and applies strategies to find solutions, conducts conditioning, uses facts, rules, algorithms, and structures manipulate variables in equation expressions and generalize based on the results of applying mathematical procedures to find solutions.

Interpret and Evaluate Stage

At interpreting and evaluating stage, subject B interprets the problem with real life, for example in the first problem, subject B interprets the possibility of the car rental A and car B charge being the same and understanding that the car rental A and B charge is the same if it covered by 5 KM. these results lead subject B to interpret again for conditions of distances less than 5 Km and more than 5 Km. in the end subject B carries out justification and decision making that is relative. In the second problem, subject B also interpreted the possibility of the number of printed documents being black and white and color with three possibilities namely the number of both the same or the number of one of them more. This interpretation leads to subject B to interpret the results of calculations on the three interpretations. In the end, subject B carries out relative justification and decision making.

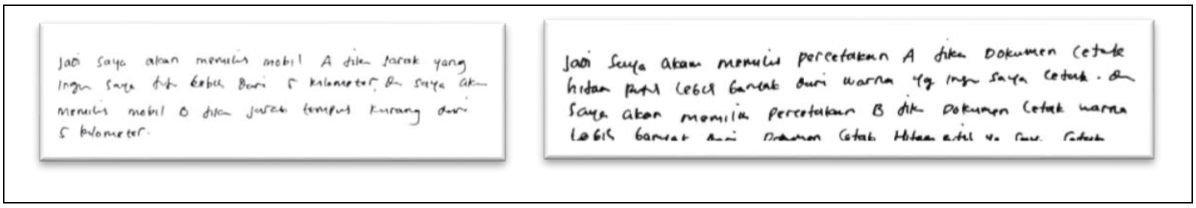

Figure 12. Subject B interpret and evaluate stage to the first and second problems

Subject B justifies each interpretation. In the first instrument, subject B carries out justification on three interpretations, namely interpretation for a distance of 5 Km, less than 5 Km and more than 5 Km. for the second instrument, subject B justifies three interpretations, $x = y, x > y\ dan\ x < y$. The B process of thinking as follows.

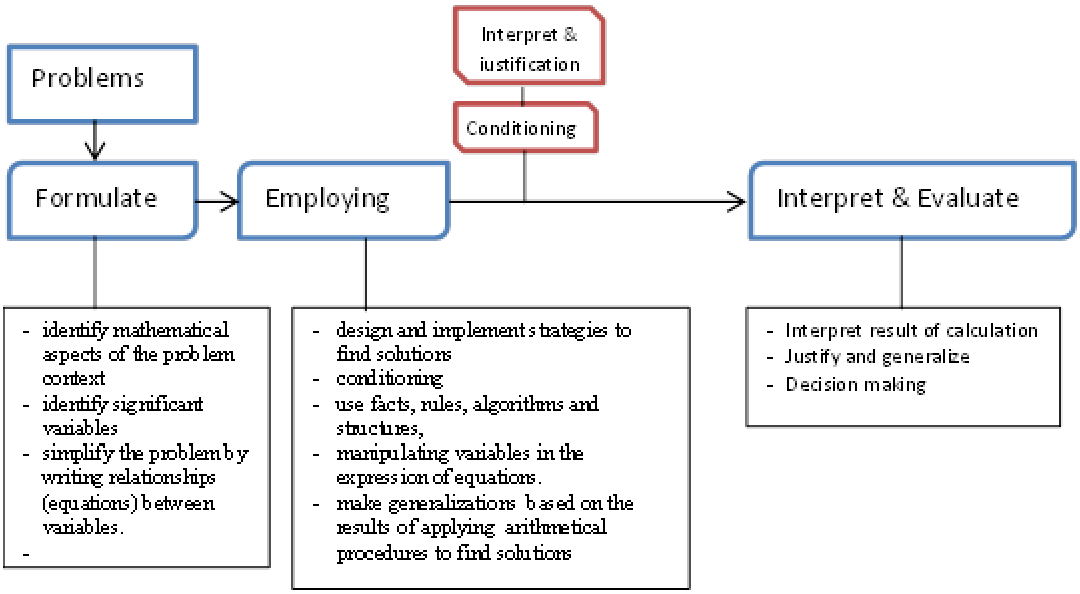

Figure 12.Subject B mathematical process in mathematical literacy

Discussions

This study analyzed the mathematical literacy process of prospective mathematics teachers for functional thinking and use generalization type of algebraic reasoning. The mathematical literacy process referred to in this study is a mathematical process developed by PISA 2015 consists of the formulating, employing, interpret, and evaluate. Mathematical literacy in this study refers to the PISA 2015, refers to the ability to formulate, employ, understand, and evaluate mathematics in various contexts (OECD, 2016). Functional thinking in this study referred to a generalization of number patterns to describe the relationships between functions in the form of quantization symbols and conducting operations with symbol expressions and graph/table/ diagram data representations. (Blanton & Kaput, 2005). While Use generalization in this study is to use generalizations to solve algebraic problems, justification, proof, and testing of conjectures and generalization of mathematical processes (Blanton & Kaput, 2005).

This study found that in solving real-world problems, prospective teacher complete with functional thinking and generalize by testing the equation (use generalization). Prospective mathematics teacher with useful thinking types formulates problems by simplifying problems by writing relationships between variables than using table representations and determining the value of the variable charge. In the table representation, functional thinking type used simple arithmetic concepts and rules by manipulating the value of the independent variable. Furthermore, prospective mathematics teachers with type use generalization formulated problem by making an example for each variable then writing the relationship equation between variables then doing conditioning and using simple mathematical rules and procedures to determine and compare the value of the charge variable. The ability to formulate problems is one of the factors in mathematical literacy abilities, such as in Research by Wijaya, Heuvel-panhuizen, Doorman, & Robitzch (2014), Duong Huu Tong & Nguyen Phu Loc (2017), Vale, Murray, & Brown (2013) dan White, (2010) dan Edo, Ilma, & Hartono (2013) revealed that the difficulty of students in solving maths literacy questions is to formulate problems.

In the employing stage, prospective of mathematics type functional thinking and use generalization use arithmetic rules to solve problems. This is in line with research by Yılmazer & Masal (2014) explained that arithmetic and mathematical literacy are related. In interpret and evaluate stage, functional thinking and use generalization type, interpret the results of calculations and carry out justification and decision making relatively. Relative decision making is part of relative thinking (Lamon, 2005). Comparative thinking involves the formation of a ratio by comparing two multiplicative quantities (Lobato, Ellis, Charles, & Zbiek, 2010). Both of type of Prospective teacher's ability to interpret and justify is supported by their interest in the problem of real-world problems. It's different from research (Rellensmann & Schukajlow, 2016) was found that students were more interested in solving math problems not related to real-world problems.

This study was found that mathematical literacy skill of a prospective teacher is supported by functional thinking. This supported by Beckmann (2009) was argued that functional thinking is part of mathematical literacy skills. At the employing stage, prospective mathematics teachers demonstrate concepts, knowledge, solution strategies, and different representations. This found supported by Glassmeyer & Edwards (2016) was argued that three activities affect algebraic reasoning, conceptual knowledge, solution strategy, and representation. In general, mathematical literacy skills of prospective mathematics teachers functional thinking and use generalization types are at level 6 as prospective mathematics teacher can conceptualize, generalize and utilize information based on their investigations and modeling of complex problem situations, and can use their knowledge in relatively non-standard contexts. They can link different information sources and representations and flexibly translate among them. Prospective mathematics teacher, at this level, is capable of advanced mathematical thinking and reasoning. This prospective mathematics teacher can apply this insight and understanding, along with a mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for attacking novel situations. Prospective mathematics teacher at this level can reflect on their actions and can formulate and precisely communicate their activities and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situation (OECD, 2016).

CONCLUSION

The study found that the prospective mathematics teacher has functional thinking and use generalization type of algebraic reasoning in the mathematical literacy process. Functional thinking algebraic reasoning type uses table representation and number manipulation to obtain and compare charge values in justification and decision making while use generalization reasoning type uses an example, algebraic expression, conditioning, and numerical manipulation to obtain and compare charge values in justification and decision making. Also, the type of reasoning use generalization interprets as many as three conditioning conditions before making a general interpretation.

With the results of these studies, researchers invited prospective mathematics teachers to develop algebraic reasoning abilities in supporting the development of mathematical literacy skills.

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