Commognitive analysis of the solving problem of logarithm on mathematics prospective teachers

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Abstract. This study aims to describe the commognitive analysis of the solving problem of logarithm on college students of Mathematics. This type of research is a qualitative description. The research subjects were three college students of Mathematics Education from Universitas Madura. The instruments used in this study were mathematical problem sheets and semi-structured interviews. The results of this study show that college students have many differences in working or mistake in mathematics problem-solving. In the word use or use precise words to inform the comprehension, the students have differences in writing base, degree of the numeral, or other symbols. In the visual mediator or use of precise object or media, the students have differences in the premise of working logarithm. In the narratives, students have differences in solving the problem systematically based on comprehension of logarithm form. In the routines, students have differences in understanding the basic concept of logarithmic characteristics.

1. Introduction

The teacher has an essential role in education. The teacher is one of the human resources that are expected to be able to make reforms in the field of education [1]. One of the future education is determined by the successful formation of the quality of prospective teachers. It applies to prospective teachers in all fields of science, including in mathematics. Therefore, Prospective teachers majoring in mathematics need to prepare themselves as professional teacher candidates early [2]. The teacher’s role is to help the students to learn mathematics so that the mathematics teacher needs to know how the math process is to be understood or mastered by students. In this case, the teacher must have good pedagogical knowledge [3].

Problems occur if the teacher does not master the field of study. Less mastery of the field begins from the teacher are not understanding of learning material. It can be caused misconception on mathematics material because mathematics is a learning material that is interrelated with each other, for example, logarithms relating to exponents [4]. Concept errors that have occurred since elementary school, and it was not immediately addressed might well have an impact at a higher level [5]. Concept errors often occur in students’ elementary school until students in the university, especially when processing the information obtained. It is in line with the opinion that ongoing misconceptions, if not appropriately handled and overcome as early as possible, will cause problems in further learning [6].

Understanding someone in a mathematical concept can be seen from the solution in solving mathematical problems. Errors experienced in solving mathematical problems tend to be caused by a lack of mastery of concepts and procedures. So, low concept mastery leads to procedural errors [7][8]. The inability of students to understand the language in the questions is one of the causes of the wrong
answer [9]. Also, inaccuracy causes procedural errors [10]. According to Malau [11], the causes of mistakes that are often made in solving math problems can be seen from several things. One of which is due to a lack of understanding of the prerequisite material and the subject matter being studied, lack of mastery of the language of mathematics, misinterpreting or applying formulas, miscalculated, inaccurate, and forget the concept.

The problem-solving process can be used as a measure of how deep the prospective teacher-student understanding of a concept. The process of solving problems is one of the thought processes carried out by someone. One of the solutions to problem-solving is by doing a process of thinking and reasoning in solving problems [12]. Thinking is a form of communication, and as an individualization of communication [13]. Conversations can occur when someone is given a problem and tries to solve it. It happens because, in the process of solving mathematical problems, one’s speaking ability changes to a new form of communication [14].

Communication and thinking are combined to become commognitive. Commognitive methodology analyzes how students solve mathematical problems [15]. The commognitive component consists of word uses, visual mediators, narratives, and routines. Word use is a word used in mathematics learning [3]. Visual mediators are objects that look like symbols, graphs, and diagrams that are used by participants in mathematical discourse to identify objects into focus [16][17]. The narratives are the sequence of text, oral or written, which is used as a description of objects labeled true or false. In mathematical discourse, the approved narratives are known as mathematical theory [14]. Routines are repetitive patterns in the discourse, such as defining, estimating, proving, predicting, predicting, and abstracting [16].

Error analysis can be used to look deeper into the mistakes made when prospective teachers answer the questions and assignments that have been given [18]. Analysis of the problem-solving process of prospective teachers with commognitive is an essential thing because in seeing the abilities of prospective teachers not only with the results obtained but also on word uses, visual mediators, narrative, and routines used. In this study, word use is terms or mathematical symbols that were written and spoken. A visual mediator is an object or a comprehensive picture created in solving mathematical problems. The narrative is a mathematical theory used in solving mathematical problems such as formulas, theorems, postulates, and definitions. Routines are processes carried out by students in completing the chosen strategy. By knowing the abilities of prospective teachers, it can also be known to the limits of skills and difficulties experienced by prospective teachers. Therefore, this research is about the analysis of logarithm material problem-solving in mathematics teacher prospective students.

2. Method
This type of research is a qualitative descriptive study. Descriptive research aims to gather information about the status of an existing phenomenon, which is the state according to what it was at the time the study was conducted. The purpose of descriptive research is to describe a phenomenon and its characteristics [19]. The approach used in this study is qualitative. This research was carried out online (via Whatsapp) with research subjects as three prospective semesters 4 Prospective teachers in the Madura University Mathematics Education study program. The research instruments used were 1) written tests, in the form of math problem sheets, 2) Semi-structured interview guidelines. Mathematical problem sheets and interview guidelines were developed by researchers so that they could bring up all the students’ commognitive frameworks, namely: word uses, visual mediators, narrative, and routines. The questions are:

1. If \(2 \log_a \frac{1}{2} = \frac{3}{2}\) and \(2 \log_a \frac{1}{a} = \frac{3}{2}\) and \(16 \log b = 5\), then the value of \(\frac{a}{b^3}\) is... 
   \(16 \log b = 5\), then the value of \(\frac{a}{b^3}\) is ....

2. If that is known \(2 \log_a x = \log \left(6 - 2 \log_a x\right) + 1\), the value of \(x\) is ....
Data collection techniques are the most strategic step in research because the primary purpose of the study is to get data [20]. Data collection techniques used in this study are 1) Collection of library data, which is looking for references related to commognitive; 2) field data collection, namely answers to questions belonging to the subject and the results of semi-structured interviews.

Data analysis is done by organizing data, sorting it into manageable units, synthesizing it, searching and finding patterns, finding what is essential and what is learned, and deciding what can be told to others [21]. Ellis [22] stated that there were five steps in the analysis work, namely: 1) sample collection, 2) error identification, 3) error explanation, 4) error classification, and 5) error evaluation. Data analysis used refers to data analysis [23], namely data reduction, data presentation, and conclusion drawing. The validity of the data in this study used the criteria of the degree of trust (credibility), namely: 1) perseverance of observation, 2) triangulation, and 3) peer checking [20].

3. Result and discussion

Commognitive description of each subject in solving logarithmic material problems that are adjusted to the four commognitive frameworks, namely: word use, visual mediators, narratives, and routines are as follows:

3.1 Question 1

3.1.1. Subject 1 (S1). The result of S1 in answering question number 1, clearly in figure 1 and figure 2. It can be seen that S1 uses word use very well. S1 rewrites what is known from the problem and describes it. On visual mediator, S1 completes the logarithmic equation by describing one of the sides so that \( x \) can be found. S1 uses the method "each side added/subtracted/multiplied/divided/and so on". The work process is nicely arranged down. From figure 2, on narrative, in solving the problem, S1 uses one of the exponential properties in changing the numerous form \( \frac{1}{a^n} = a^{-n} \), the logarithmic properties \( a^m \log b = \frac{m}{n} a \log b \), and logarithmic properties \( a \log b = \frac{m}{n} \log a \). On routine, to find the value \( a \log \frac{1}{b^2} \), S1 changed the form of the known logarithm. Using the appropriate logarithmic properties, S1 finds \( 2 \log a = -\frac{3}{2} \) and \( 2 \log b = 20 \). After that, S1 changes \( a \log \frac{1}{b^3} \) becomes \( -\frac{3}{2} \frac{2}{2} \log a \) so the value of \( 2 \log a \) and \( 2 \log b \) are substituted in this form. When substituting, S1 changes the division operation into multiplication and then strikes out numbers that can be omitted.
Subject 2 (S2). The result of S2 on answering question number 1 can be seen in figure 3 and figure 4. It can see in figure 3 that S2 uses word use very well. S2 rewrites what is known from the problem and describes it, and write what was asked with using a question mark. On visual mediators, S2 completes the logarithmic equation by describing one of the sides so that \( x \) can be found. S2 uses the method "each side is added/subtracted/multiplied/divided/and so on". The work process is nicely arranged down. From figure 4, on narrative, in solving the problem, S2 uses one of the exponential properties in changing the numerous form \( \frac{1}{a^n} = a^{-n} \), the logarithmic property \( a^n \log b^m = \frac{m}{n} a \log b \), logarithmic properties \( a \log b = \frac{m}{m} \log b \), and form \( a \log c = b \) become \( a^b = c \). On routines, to find the value \( \log \frac{1}{b} \), S2 changed the form of the known logarithm. Using the appropriate logarithmic properties, S2 finds \( 2 \log a = -\frac{3}{2} \) and \( 2 \log b = 20 \). S2 continues and changes the form \( a = 2^{\frac{3}{2}} \) and \( b = 2^{20} \) although, in the end, it is not used. After that, S2 starts to change the form \( a \log \frac{1}{b} \). During the process, S2 writing \( a \log \frac{1}{b} \) is like an equation with right-hand dots and question marks. After getting the \( -3 \log a \), value of \( 2 \log a \) and \( 2 \log b \), S2 substituted in this form. When replacing, S2 changes the division operation into multiplication and then strikes out numbers that can be omitted.
3.1.3. Subject 3 (S3). The result of S3 in answering question number 1 can be seen in figure 5 and figure 6. It can be seen in figure 5 that S3 uses word use very well. S3 rewrites what is known and asked the problem and then write the general form of logarithm namely $a \log b = c$ and below the written given $a^c = b$ after that, S3 explain it one by one, and S3 give a sign every different step. On visual mediator, S3 resolves the logarithmic equation by changing the shape of the problem and describing it until the substitution process can be carried out. It can be seen in figure 6, on narrative, in solving the problem, S3 uses the form $a \log c = b$ becomes $a^b = c$, $a \log a = 1$, and the logarithmic property $a^m \log b = \frac{m \log b}{\log a}$. On Routine, S3 changes the known logarithm into an exponential form so that $2^{\frac{3}{2}} = \frac{1}{a}$ and $16^5 = b$. And S3 write unnecessary operation and unknown purpose namely

$$\left(2^\frac{3}{2} \cdot a^{-1}\right) \times 1^{-1}$$

and in the bellow is S3’s statement after the interview.

P: “For number 1, after all, you write $2 \log \frac{1}{a} = \frac{2}{3}$ so that $2^{\frac{3}{2}} = \frac{1}{a}$ . And then in the below your writing this, there is $\left(2^\frac{3}{2} = a^{-1}\right) \times 1^{-1}$ and I want to ask $\left(2^\frac{3}{2} = a^{-1}\right) \times 1^{-1}$, what does that mean?”

S3: “All right, $\left(2^\frac{3}{2} = a^{-1}\right) \times 1^{-1}$, I think the exponent $a^{-1} \times 1^{-1}$ can be $(a \times 1)^{-1x-1}$, and then When I look again it turns out that the exponent becomes $a^{-1+(-1)}$. ”
To find the value $\frac{3}{2} \log \frac{1}{b^x}$, S3 substitutes the found exponent to the problem. $a$ is replaced by $2^{\frac{3}{2}}$ and $b$ is replaced by $16^5$. After using the properties $a^n \log b^m = \frac{m}{n} \log a \log b$, S3 gets

$$\left(-15 \cdot \left(-\frac{3}{2}\right)^{-1}\right) 2 \log 2^4.$$ After that $2 \log 2^4$ is changed to 4 without being explained in more detail.

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3.2. Question 2

3.2.1. Subject 1 (S1). The result of S1 in answering question number 2 can be seen in figure 7 and figure 8. Based on figure 7, it appears that S1 has made word use well, namely writing bases and degree of the numerous correctly and clearly. S1 understands that basic writing use small numbers above the log symbol and the degree of a numerous can be placed in front of the logarithmic in regular size letters, like when S1 writes $3^2 \log x = 12$. On visual mediator, S1 completes the logarithmic equation by describing one of the sides so that $x$ can be found. S1 uses the method "each side added/subtracted/multiplied/divided/and so on". The process is neatly arranged down. Based on figure 8, In solving a problem, on narratives, S1 uses logarithmic properties properly, among which is S1 starts by changing 1 to $2 \log 2$, logarithmic properties $a \log a = 1$, and using properties $a \log b + a \log c = a \log (b \times c)$. S1 also uses the logarithmic equation form, if $a \log f(x) = a \log g(x)$ then $f(x) = g(x)$. S1 uses routines by implementing the strategy that has been chosen in the previous step. After becoming $2 \log 2 \log x = 2 \log 2 (6 - 2 \log x)$, S1 equally removes $2 \log$ which means $2 \log x$ as a numerous of $2 \log$ on the left side $= 2 \log 2 (6 - 2 \log x)$ on the right side. Then S1 adds $2 \log x$ to each side of the equation. After S1 gets $3^2 \log x = 12$, S1...
divides each side by 3, S1 only writes \( \frac{12}{3} \) on the right side, S1 does not write about \( \frac{3}{3} \) on the left side but directly write the results from the division, namely one which does not need to be written so that it found \( 2 \log x = 4 \), then \( x \) is looked for by changing its shape according to its properties.

![Visual Mediator](image1)

**Figure 7.** Word use and visual mediators of S1 in answering question 2.

![Routine](image2)

**Figure 8.** Narratives and routines of S1 in answering question 2.

3.2.2. Subject 2 (S2). The result of S2 in answering question number 2 can be seen in figure 9 and figure 10. Based on figure 9, it appears that S2 has used word use to describe the comprehension and strategy quite well. S2 uses the word ‘for example’ to state the value that is replaced by a simple symbol to simplify the process. However, when S2 assumes \( 2 \log x \) with \( x \), this is wrong because there will be confusion. The first confusion is that \( x \) as a number will not be the same value as \( x \) which is the degree of 2; the second confusion is when going to assume \( 2 \log 2 \log x \), S2 changes it to \( 2 \log x \) because \( 2 \log x \) is assumed to be \( x \). However, S2 stops, it does not assume \( 2 \log x \) with \( x \) even if it is seen from the example created by S2, \( 2 \log x \) can be assumed to \( x \) again. On visual mediator, S2 uses the assumption in the problem-solving process. After the assumed value was found, S2 continues by searching for the actual \( x \) value. But, S2 has made an error in the assumption. S2 did not realize her mistake as in the following interview:

P: “I want to ask, you use assumption in number 2, why are you thinking about \( 2 \log x = x \)?”

S2: “So here goes, why did I assume \( 2 \log x = x \), here in the rights side, there was \( 2 \log x \), on the left side, there was also \( 2 \log x \) and there are the same \( 2 \log x \) like that, so I guess if I assume. It will make it easier. The problem is here in \( 2 \log \), it still contains \( 2 \log x \) again.

Based on figure 10, on narrative, S2 is not very understood with logarithmic properties. When the shapes of two sides are not the same, S2 immediately equalizes so that the next step becomes wrong. S2 should change 1 to \( 2 \log 2 \) first, then change the right side to \( 2 \log (6 - x) \) so that the shapes of the two sides be the same and can be continued using the form of logarithmic equations if \( \log f(x) = \log g(x) \) then \( f(x) = g(x) \). S2 changes the form \( a \log c = b \) become \( a^b = c \) correctly. S2’s at the interview is below:

P: “Then for the process \( 2 \log x = 2 \log (6 - x) + 1 \), why does the next step become \( x = (6 - x) + 1 \), why is the \( 2 \log \) removed? What is the reason?”

S2: “okay for \( 2 \log x = 2 \log (6 - x) + 1 \), why the next step \( 2 \log \) is removed because in the right and left side both contain \( 2 \log \). Well, in the property of the equation, if the abscissa is same and both
contains the same log then we can direct to the equation, directly $2 \log$ is equally eliminated, we just go to the function.”

On routine, S2 makes unnecessary reductions when eliminating 6. In the process of finding $x$, initially, S2 reduces both sides by 6 so that the number 6 on the right side disappears. After that, S2 makes additions to the two sides with 6 so that number 6 reappears in the right side, then S2 adds 6 + 1. According to the interview results, S2 is a little confused because there are parentheses in operation.

When S2 has found $x = 2^2$, S2 incorrectly calculates the value of $x$. S2 finds $x = 32$ while $532 = 32$.

P: “well, in your work, $x = (6-x) + 1$. You have $6 + x + x = 1$, so $-6 + 2x = 1$, so I understand that you reduce both sides by $6 - x$, then after that, you add two sides with 6. My question is, why don’t you add the two sides directly with $x$, don’t you need to include 6?”

S2: “It’s okay to just add the $x$, because it makes sense if we add the $x$ right away. Well, why did I bother because I was confused when I was working on it. I was still confused the $6 - x$ because it still had parentheses, I was afraid it could not connect to the plus 1, so I moved it first like that.. after the sides is moved, the side can be moved back in the next step so that it becomes $2x = 1 + 6$, now it can. The one you said to just add the $x$ on both sides, in my opinion that is right too. The thing is I’m a little confused. I’m afraid of being wrong.”

Figure 9. Word use and visual mediators of S2 in answering question 2.

Figure 10. Narratives and routines of S2 in answering question 2.

3.2.3. Subject 3 (S3). The result of S3 in answering question number 2 can be seen in figure 11 and figure 12. Based on figure 11, in the use of word use, S3 uses the word ‘for example’ to convey the strategy she chooses and uses the symbol $a$ to assume. But, when S3 elaborates $2 \log 6$ become $2 \log 2 \times 3$. There is an error. On visual mediator, S3 uses examples in the problem-solving process. After the speculated value is found, S3 continues by searching for the actual $x$ value. Based on figure 12, in the use of narratives, S3 was wrong in choosing the right property because there is a mistake in the translation. The property that can be used in this problem are $2 \log (b \times c) = a \log b + a \log c$. But, S3 uses $a \log a = 1$ so that $2 \log 2$ becomes 1. This is caused by an error in word use. This shows that S3 lacks an understanding of the logarithm concept. S3 also uses $a \log b - a \log c = 2 \log \left(\frac{b}{c}\right)$. Using that property is correct, but because of S3 made a mistake in the first step, it has an impact on the next step. S3 also changes the form $a \log c = b$ to $a^b = c$. Here are the reasons for S3 when conducting an interview:
P: “well, in number 2 in step $2 \log a = 2 \log 2 \times 3 - 2 \log a + 1$, why $2 \log 2 \times 3$ it becomes $2 \log 3$?”

S3: “I think of it this way, if $2 \log 2 \times 3$ is translated into $2 \log 2 \times 2 \log 3$, $2 \log 2$ becomes 1, the rest of it is $2 \log 3$."

In the use of routines, S3 changes the form $\frac{3}{a}$ to $3a^{-1}$. After getting the form $2 \log a - 2 \log 3a^{-1}$, S3 changes it to $2 \log \frac{a}{3}$. So, changing the form $\frac{3}{a}$ is not necessary. When $a^2 = 6$, S3 takes root, the result obtained is $a = \sqrt{6}$. When S3 is asked about the reason, here is S3’s answer.

P: “in number 2, you already find $a^2$ is 6, then $a = \sqrt{6}$. My question is why $a$ is it not $\pm \sqrt{6}$?"

S3: “For the $a^2 = 6$, $a = \sqrt{6}$, I don’t remember that there are pluses and minuses.”

Based on interviews, S3 does not write ± because of forgetting. In fact, the base must be more than 0 and may not be equal to 1.

The results of this study describe the way and location of the difficulties of prospective teachers in solving logarithmic material problems. The following will be discussed based on the commognitive frameworks, namely: word use, visual mediators, narratives, and routines:

3.3. Word use

Prospective teachers can generally use word use well. The difference between prospective teachers candidates in using word use is that there are teacher candidates who write the general form of a formula...
or words such as to clarify the problem-solving process. The difficulty experienced by prospective teachers is that there is an incorrect use of mathematical symbols, causing errors and confusion in the process of completion. As stated that the ability of students to solve problems depends on how students translate phrases into mathematical symbols [24]. The primary source of difficulty in problem-solving is in converting written words into mathematical symbols [25]. According to the opinion of Ningtyas, prospective teachers cannot link question sentences to mathematical forms, including problem transformation errors [26]. The inability of prospective teachers to understand the language in the questions is one of the obstacles experienced by prospective teachers, which causes them to fail to get the correct answers [9]. Jana states that errors in using data are due to a discrepancy between what is known with the used formula. So, it does not match. It also occurs because of misunderstanding what is known [27].

3.4. Visual mediator

The description of the settlement that was designed by prospective teachers is quite good and can be easily understood. There is a similarity between the visual mediators used by prospective teachers. The difference found is there are some prospective teachers use more complex visual mediators, such as assumption. The difficulties are some students make a mistake on the assumption. This happens because prospective teachers cannot use word use correctly. In mathematical processing errors, this includes problem transformation errors where prospective teachers cannot identify the operations or methods needed to solve the problem [26].

3.5. Narrative

In an organized strategy, prospective students can choose the right formula for solving problems. However, there are Prospective teacher who are mistaken in determining the exact logarithmic properties in solving the problem. Students often forget formulas when solving problems is one of the many mistakes that students make in solving math problems [28]. The steps used in the problem-solving process are as a narrative [15] as well as choosing a formula. Some are correct in determining the nature of the logarithm but cannot apply these properties correctly because they do not understand the concept.

3.6. Routine

Implementing the chosen strategy shows the routine conducted by prospective teachers. For the basic concept, the majority of prospective teachers have mastered it. However, some prospective teachers do unnecessary operations due to concept errors. Tambychik and Meerah state that the inability of students to use the correct concepts when solving problems causes wrong answers [29]. Other than that, there are errors in calculating due to a lack of accuracy. The general mistake is that students cannot understand the problem well, students understand the concepts used in the problem, and are wrong in calculating answers [30]. Following the opinion of Rohmah and Sutiarso [10], which states that errors are caused by weaknesses in the prerequisite concepts possessed by students, and students are not careful in the work process. This inaccuracy has resulted in procedural errors. Based on Malau [28], which states that students often made errors in solving mathematical problems. Several things cause it. One of it which is due to lack of understanding of the prerequisites and subject matter studied, lack of mathematical mastery language, misinterpreting or applying formulas, miscalculating, inaccurate, and forgetting concepts. Low concept mastery leads to procedural errors [7][8].

4. Conclusion

Based on the results of analysis and discussion, there are differences in processing methods or errors of prospective teachers in solving logarithmic material problems based on a commognitive framework. In the word use or use precise words to inform the comprehension, the students have differences in writing base, degree of the numeral, or other symbols. In the visual mediators or use of precise object or media, the students have differences in the premise of working logarithm. In the narratives, students have differences in solving the problem systematically based on comprehension of logarithm form. In the
routes, students have differences in understanding the basic concept of logarithmic characteristics. Prospective teachers should familiarize themselves with understanding the material well and often practice for the goodness of students in the future.

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