Pseudo Thinking Process in Understanding the Concept of Exponential Equations

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Abstract. The thought process is a very interesting thing to examine in mathematics learning. Sometimes in solving questions, students' answers are wrong not because of the wrong thinking process, as well as correct answers, it is not certain that students understand why the process was carried out. Such conditions occur because the students' thought processes are pseudo, meaning that the thought process that occurs is not a reflection of the real thought process. The focus in this study is students who experience pseudo thinking in understanding the concept of exponential equations. The pseudo thinking categories are grouped according to the Vinner and Subanji frameworks. Based on the research results, the students' pseudo thinking process in understanding the concept of exponential equations was shown that most students in understanding the concept of exponential equations still memorized the formula without understanding the formula. Students only think of looking for answers quickly using formulas that have been learned. If learning only emphasizes procedures and memorization, what happens learning mathematics has no meaning. In addition to memorizing procedures, it is very risky for students to forget, students are not able to use mathematics according to the actual concept.

1. Introduction

Learning mathematics is learning abstract objects. Therefore mathematics is very important to be taught in school to organize students' reasoning. From learning mathematics, students are taught to get used to thinking scientifically using logic and being able to think systematically [1]. Discussing mathematics learning is certainly an interesting thing to discuss, namely the thinking process of students. When faced with mathematical activities, students need work from their memory resources [2]. Problem solving is one of the mathematical activities carried out by students. Solving a problem requires a thought process to find a solution to the problem. When thinking, students will call the thinking structure that already exists in their brain to be associated with the stimulus provided, namely in the form of mathematical problems [3]. The thinking structure of students in learning mathematics is certainly related to mathematical concepts. The construction of students' thinking structures occurs continuously during the learning process of mathematics by linking one concept to another and this construction will become the student's mathematical knowledge [4]. The thinking structure of students will affect the thinking process of students because the thinking process of students will follow the structure of thinking they have. Well-connected conceptual knowledge becomes an important attribute in making effective decisions and plans to solve problems [5].

Learning mathematics is closely related to concepts, therefore mathematics learning will run well if students are able to understand concepts from the basic level to concepts related to the material being
studied. Mathematical understanding is a network of connections from one concept to another as a result of integrating the formation of a continuous connection during the learning process of students [6]. Students are expected to be able to think about concepts correctly, be able to interpret and be able to relate relationships between concepts. Students are said to understand concepts when they are able to comprehend mathematical ideas as a whole and their functions [7]. Meanwhile [8] defines conceptual understanding as an understanding of mathematics which includes understanding concepts, operations and their relationships. [9] describes the indicators of understanding mathematical concepts including: being able to restate a concept with their own language, being able to group objects according to properties that are in accordance with the concept, being able to provide examples and not examples related to concepts, able to present concepts with various forms of mathematical representation, able to understand the necessary and sufficient conditions of the concept, able to utilize certain procedures for solving and certain operations, able to apply the concept into problem solving.

Syafiqoh [10] revealed that in understanding the concept of exponential equations students have basic exponential abilities, are able to express exponential properties into mathematical symbols, however, students are unable to provide logical arguments to prove exponential properties. Students' understanding is limited to imitating and memorizing without understanding the meaning of exponential properties. Understanding the concept of exponential equations means that students are able to explain exponential concepts in their own language, are able to provide examples and not examples related to the concept of exponential equations, are able to properly utilize exponential operations and are able to apply exponential concepts to problem solving. If one of the indicators of understanding the concept is not owned by students, it is very possible for students to experience a missconcept in understanding the concept of exponential equations. Missconception will certainly result in student errors in solving math problems related to exponential equations.

Difficulty learning mathematics is often reflected in the difficulties of students in solving math problems or problems [11]. To improve the quality of learning, of course, it is necessary to evaluate the mistakes of these students. One way that can be used to evaluate is by analyzing the mistakes made by students to be able to find out the cause and find solutions to fix these errors [12]. When the mistakes made by students are related to the thought process, then what educators need to do is to understand how the students' thinking processes are. Often in solving problems, students try to link existing problems with problems they think are the same. When in fact these students do not understand the real concept. Such a thinking process is certainly not the result of an actual thought process but rather a pseudo-thought process [13]. The way of thinking of students who only think about the correct results by only memorizing formulas or procedures that are often given by the teacher so that students experience a thinking process pseudo. The pseudo thinking process of students in understanding the concept of exponential equations can be seen from the results of the researchers' observations, there are still many students when faced with exponential equations and find the same base the student crosses the base. The answers of students who crossed the bases because they equated analogies with linear equations are of course conceptually wrong. In a linear equation, when the two sides are the same, it is crossed out in the sense that it is divided to produce the value of one. Meanwhile, when looking for exponential equations, if the bases are the same, the equation will have the same value if the value of the exponents is the same, then what needs to be done is equalizing the exponents.

According to [13] pseudo thinking there are two points of view, namely pseudo based on the final results of students' answers and pseudo thinking based on the process being carried out. From the results of the final answer, students think pseudo is divided into two, when students are able to answer correctly but the reasoning is wrong is called pseudo true, otherwise pseudo false occurs when students are wrong in giving answers, but in fact these students are able to reason correctly so that when given a reflection the participants the student is able to answer correctly [3] Whereas [14] divides two thinking, pseudo namely pseudo conceptual where students appear to think conceptually, but is actually produced by mental processes that do not characterize conceptual thinking. The second is pseudo-analytic where students are not able to provide a variety of solutions, which is in the minds of students to solve problems correctly following the instructions that are usually taught by the teacher.
Several researchers have studied pseudo thinking processes such as [3], [14] which were used as references in this study. In addition, several studies related to pseudo-thinking processes in solving math problems such as [15] pseudo-true tend to be carried out by subjects with moderate mathematical ability and pseudo error tends to be carried out by subjects with low mathematical abilities. Anggraini [16] say that the characteristics of subjects who experience a thinking process pseudo are: the subject's thinking process is spontaneous, fast, unconscious and uncontrolled , experiences misconceptions, tends to imitate procedures and memorize formulas and experiencing fuzzy memory when faced with problem solving. Research from [17] examines the thinking process of students in solving HOTS questions.

The pseudo thinking process in understanding the concept of exponential equations needs serious attention from educators. Pseudo thinking often occurs because students memorize more often, respond spontaneously, do not control what they think or do, and remember procedures that occur vaguely [4]. Students who experience pseudo-thinking in understanding the concept of exponential equations when faced with non-routine problem solving students will experience difficulty even not knowing if the problem can be solved using the concept of exponential equations. If left unchecked, it will have an impact on the construction of the thinking structure of students. Because the characteristics of mathematics learning where one concept is related to another. The construction of a pseudo structure will certainly be very hindering when students are faced with non-routine problems. The habit of students who only follow the procedures taught by the teacher without understanding the concept actually makes students unable to connect their knowledge with the problems at hand. The focus of the problem in this study is to analyze the pseudo thinking process of students in learning exponential equations based on the Vinner and Subanji framework.

2. Methods
This research is a qualitative research. This research will describe the pseudo thinking process in constructing the concept of exponential equations. This study involved three students who had received exponential equation material. The instrument used in this study was a task-based interview. The data collection technique in this study was carried out by the method think out loud, where students were asked to complete the questions given by expressing aloud what they were thinking. After students answered with the method, think out load participants were given tracer questions related to the concepts of exponential equations and conducted interviews to find out the actual thinking structure of students and as data triangulation to ensure the validity of the data. Data triangulation was carried out by comparing the correctness of information obtained from different data sources and methods [18].

Due to the Covid-19 pandemic so that all schools conduct online learning so that researchers have limitations in choosing objects freely, subject selection is carried out in coordination with the subject teacher to pinpoint the names of students who are deemed able to communicate well and have various mathematical abilities. Then contact students to ask permission from students and parents. If students are willing and their parents allow it, then the researcher comes to the students to be given a task and is asked to complete the task using the think aloud method. Students who are selected as research subjects are students who experience a thinking process pseudo based on the Vinner and Subanji framework.

3. Results and Discussion
Based on the results of the subject answers (think aloud) and the results of the interviews, the thinking process is grouped pseudo based on the Vinner and Subanji frameworks. [14] divides pseudo thinking based on the process carried out when working on problems into pseudo conceptual and pseudo analytic. Furthermore, [3] distinguished thinking pseudo based on the final results of students' answers, namely pseudo true and pseudo false.

3.1 Conceptual Pseudo thinking in understanding the concept of exponential equations
Subjects experience pseudo conceptual understanding of exponential concepts if the subject is unable to think about the meaning of the concept of exponential equations and their relationships (conceptual thinking), but in the process of doing so, students only seem to be able to think conceptually [14]. Pseudo
The subject is actually able to answer correctly and appears in the process as if he had thought conceptually as shown in Figure 1 and Figure 2 below:

**Figure 1.** Answer to subject 1 number 1

**Figure 2.** Answer to subject 2 number 1

However, when explaining these steps there are subject expressions that do not match the real concept. The expression is seen when the subject has equalized the bases on the two sides. The subject expression 1 " because the base is the same, the base can be removed, and the rank is equalized". Then a second mockery in the same step said, "this is the same base, so it can be crossed out. Keep looking for value by equalizing the ranks". After the subject has finished answering and expressing his thought process, the researcher tries to clarify the subject's expression by conducting the following interview:

| Researcher | if the basis is the same does that mean it can be removed? |
|------------|----------------------------------------------------------|
| Subject 1  | yes sir ..                                               |
| Researcher | Do you understand what question number 1 means? What do you mean? |
| Subject 1  | find the value for x so that both sides are equal in value. |
| Researcher | means that you are looking for only x?                   |
| Subject 1  | eh ... yes sir, but usually when the bases are the same, you can remove them, sir, just calculate the rank. There is only x, sir, so the rank counts. |
| Researcher | try to understand the problem first, is the equation in the problem only the exponential equation or the whole thing? |
| Subject 1  | that's an exponential equation sir, meaning everything sir. |
| Researcher | As a whole, it means including base and power? Think again then explain why at the same time the base you removed the base? When the bases are the same then the equation will be the same if what? |
| Subject 1  | oh ... yes sir I know, that means that it is not eliminated sir, but because the bases are the same so that the equations are the same in power also the same. |
| Researcher | Why did you eliminate the answer?                         |
| Subject 1  | hehe .... usually like that sir, if the basis is the same, just calculate the power. |

**Figure 3.** Excerpt of interview with subject 1

From the results of the interview, it can be seen that the subject only follows the procedure that can be done, the subject thinks when the basis is the same then it is removed. In the process of doing it, it has followed the concept correctly and produced the correct answer for subject 1, but understanding the concept of the subject is still lacking. The subject is unable to explain the concepts used correctly. The
base should not be removed, logically when the bases are the same then the equation will be the same if the exponents are the same. Such an understanding that the subject does not yet have. In this case the subject experiences deviations in the logic of thinking (miss logical thinking) [19]. The same thing is seen in subject 2. The subject makes an analogy as in linear equations when there are the same numbers, they can be crossed out. Then the researcher tries to deepen the thought process of the subject by conducting interviews as in the following:

| Researcher | : oh so if the same basis is crossed out? Does it mean crossed out divided or what? |
|------------|-----------------------------------------------------------------------------|
| Subject 2  | : yes sir ..                                                                |
| Researcher | : then it means that if it is crossed out the result is 1 power, right?     |
| Subject 2  | : mmmm ........ (thinking subject)                                           |
| Researcher | : if the basis is 1, it should not be necessary to equalize even the powers of both sides are equal? 1 to the power regardless of the result is 1? |
| Subject 2  | : ummm ... but usually crossed out sir, just count the rank. Later, we will find the value $x$ and continue to be substituted, check the results are the same, sir. |
| Researcher | : try this, for example $3^x = 3^3$ means what value $x$ satisfies the equation? |
| Subject 2  | : it is based on the same, sir, it means that you just have to equalize the root $x = x$ then $x - x = 0$ but how come this is $0 = 0$ sir. That means $x = 0$ maybe sir? |
| Researcher | : Is it only 0? For example, if the $x$ is replaced by 1,2,3 etc, the value is still the same. |
| Subject 2  | : Yes sir ... mmmm oh this means that if the base is the same, it means that you just have to find the value of $x$ so that the rank is the same, sir. Later, if the base and rank are the same, the value is the same, sir. |

**Figure 4.** Excerpt of interview with subject 2

Conceptually, the steps for working are correct, but the subject is wrong in analogizing the equation. When finding the same base, the subject makes an analogy like an ordinary linear equation by crossing out the same number which can be interpreted as dividing the two equal numbers. If the base is crossed out, the base is 1. When asked, "if the basis is 1, then it is not necessary to equalize the rank even the two segments are equal?" the subject experienced cognitive conflict. The steps taken by subject 1 and subject 2 did look like the subject had behaved conceptually. However, when investigated further, the two subjects actually did not think that the idea of the concept was involved. The assumption that if the basis is the same then it is removed or crossed out is a wrong understanding of the concept. The behavior pseudo subject's conceptual occurs when the subject is unable to provide the meaning of words, symbols, and mathematical meanings to the concepts it uses [14].

### 3.2 Pseudo-analytical thinking

Pseudo-analytic occurs when learners do not exercise control over the selection procedure used, the students just thought spontaneously. In addition, students are not able to provide a variety of solutions, which are in the minds of students to solve problems correctly following the instructions that are usually taught by the teacher. Pseudo-analytic can be seen from the final answer of subject 2 in question number 1 as shown in Figure 2. The subject spontaneously answers $-x = -14$ even though the value $x$ should be sought. From the subject's final answer, the value $x = 14$. If so, the students' answers are wrong.
Figure 5. Excerpt of interview with subject 2

Subjects do not control the answers given. The subject feels it is correct by answering spontaneously without double checking the correctness of the answer. In addition, thinking can be pseudo-analytic subject 2 seen from the interview process conducted during the previous interview.

Figure 6. Excerpt of interview with subject 2

From the interview excerpt, it can be seen that the subject only followed the usual procedure. The subject only thinks when the bases are the same, then it remains only to equalize the ranks without seeing that the exponents already have the same variable, so that any variable value will produce the same answer for both sides. The thinking process pseudo subject's analytic occurs when the subject is asked \( 3^x = 3^x \) questions. It is as if to work on an exponential equation if the bases are the same then you have to calculate the exponents. What the subject does is not based on prior analysis but answers spontaneously like the steps that have been done before. The subject's arguments are based solely on experiences or habits taught in the school which are also in line with the view [20] which is categorized as plausible reasoning (PR) errors. Even though they are able to answer correctly, the thought process of the subject is still pseudo so that it is categorized as having pseudo-analytic. Examples of pseudo-analytics that produce wrong answers are like in research [13], when given the equation \( x^2 - 5x + 6 = 2 \) students immediately look for the factors of the equation. Students assume that the solution of the equation is the same as the solution of the equation \( x^2 - 5x + 6 = 0 \). Pseudo analytic occurs because students only look for similar solutions that are often faced. Superficial identification of students without the ability to analyze and control the problem given and immediately provide solutions. Subjects experiencing pseudo-analytics often just imitate. Due to imitation, it is likely that the pseudo-analytic subject has memories of the actual concept. Such conditions [14] call it a fuzzy memory event.
3.3 Pseudo-true thinking

Figure 7. Answer to subject 1 number 2

True pseudo thinking occurs when students are able to answer correctly, but cannot explain the answer [3]. From the answer to subject 1 in Figure 3, the following subject is able to answer correctly.

The researcher then conducted an interview with subject 1 to ascertain whether subject 1 could explain the steps used or just follow the procedures given by the teacher.

| Researcher | : try to explain the steps you took to find the set of solutions to the problem? |
|------------|-----------------------------------------------------------------------------------|
| Subject 1  | : question number 2 is in the form $f(x)^{h(x)} = g(x)^{h(x)}$ so to answer there are 2 conditions 1) $h(x) = 0$ after finding $(x)$ is checked into the equation in order $f(x), g(x) \neq 0$. 2) $f(x) = g(x)$ |
| Researcher | : in your opinion that both segments are valued there must be two conditions, right? If one of the conditions is not met, that means there is no set of solutions, right? |
| Subject 1  | : no sir, if it does not meet it means that the HP of the exponential equation is not taken, so only those that fill the pack will be taken. |
| Researcher | : then what do you think is the requirement 1) why should it be checked? |
| Subject 1  | : for condition 1 must be checked sir, $f(x), g(x) \neq 0$ |

Figure 8. Excerpt of interview with subject 1

The subject working on the problem assumes that the set of solutions in question no. 2 is a requirement, not a possibility by checking 2 possibilities so that the equation has the same value. The assumption of subject 1 that this possibility is a requirement is certainly conceptually wrong. If the requirements are supposed to be, when one of the requirements is not met, the solution set does not exist, or problem number two is not an exponential equation. In this case the subject is pseudo-true, because it produces a correct answer. However, the subject was unable to explain the steps used. The subject misunderstands the possibility of the same equation as a requirement for determining the set of solutions.

3.4 Pseudo-false thinking

Students are said to experience pseudo-false if in producing answers students answer incorrectly, but after reflection the students are able to justify their answers [3]. The pseudo-false can be seen from the
The answer to subject 3 is wrong but based on the expression of subject 3 in answering the question, the subject actually understands the steps that must be taken in solving the problem. This can be seen when the subject explains the steps taken when trying to solve the problem. When working on the problem, the subject has thought about changing the form of the root to the power form like the following expression of the subject: "This equation is the left side of the root form must be changed first to the fraction power so that it is obtained \(3^{\frac{2x+1}{2}}\), then the right side of the base is equalized so that the base of the left and right segments is so \((3^3)^{x+5}\).” To ensure that the subject experienced a pseudo thought process, the researcher conducted an interview with subject 3. The interview was conducted to find out how subject 3 thought about solving question number 3, how subject 3’s understanding of the concept of changing roots into fractions. Excerpt from the researcher interview with subject 3 as in figure 10.

| Researcher | : check it out. You found the value \(-9^4\) right? Try to plug it into the equation. The result is not the same for both sides. |
| Subject 3 | : (trying to substitute the x obtained into the question and find different results in both sides.) ... the results are different, huh .. (subject thinks again) |
| Researcher | : try to check the steps you took from above. Explain the first step first. How do you change the roots? |
| Subject 3 | : This changes from the root to the fractional power, sir, so the root of nine is 3, then there is a sum, the formula for the power of nine is divided by the power of the root so the result is \(3^{\frac{2x+1}{2}}\) |
| Researcher | : oh do you think the concept is like that? Suppose this \(\sqrt{4^2} = 2^2\) Do you think the statement is true or false? |
| Subject 3 | : wrong sir, it should be \(2^2\) that the root means pangkat 2 so the power of 4 divided by the rank of the root? |
| Researcher | : so = \(2^2\) or 2 right? Try to count \(4^2\) how much? You root later whether the value is equal to 2? |
| Subject 3 | : (trying to do) wrong sir .., the answer should be 4 packs, note 2.
Researcher: it means the concept is wrong, right? Try to explain the concept you use in converting roots to fractional powers?

Subject 3: but it must be true sir, right? What was taught there was a formula \( \sqrt[\frac{m}{n}]{a^m} = a^{\frac{m}{n}} \) (writing down the formula used)

Researcher: well now pay attention to this (pointing to \( \sqrt[\frac{2}{2}]{4^2} \)) where is the "a"?

Subject 3: oh this "a" is 4 packs, so the result is correct so the result \( 4^{\frac{2}{2}} \) is equal to 4. (then the subject looks again at the answer to the first question) oh this means wrong, correct sir \( 9^{\frac{2x+1}{2}} \)

Researcher: : okay right. Then you check again on the right side of the meaning of this (refers to the answer \((3^3)^{x+5}\) is 3 only multiplied by \(x\)?)

Subject 3: : oh yes this is also wrong sir, it should be multiplied by 5 too sir. (Subject corrects the previous answer)

Figure 10. Excerpt of interview with subject 3

The final answer given by subject 3 is wrong. After tracing, subject 3 is actually able to think of solutions or can think correctly. After going through reflection, the subject is able to explain the concepts that should be used in solving the problem. Subject 3 looks in a hurry because he is sure that the answer given is correct. Lack of control is seen in solving the subject's problems incorrectly in implementing the root concept used [20]. In the process, the mistakes made by the subject can also be categorized as pseudo-analytic. The subject is actually able to remember the real concept, but because the subject only thinks of looking for equations without doing analysis first, the subject experiences a fuzzy memory event [14]. Fuzzy memory event is seen when the subject remembers vaguely the concept used, the subject is actually able to remember the concept of changing the root form into a fraction \( \sqrt[\frac{m}{n}]{a^m} = a^{\frac{m}{n}} \), but due to hasty decision making without controlling or analyzing what happens the subject is wrong to make decisions. From the results of the \( \sqrt[\frac{2x+1}{2}]{9^{2x+1}} \) answer, the subject thinks that because 9 can be rooted, then the root operation is carried out first, what happens is that the subject is wrong in using the concept, therefore the final answer produced by the subject is wrong. Unlike the pseudo right, students who experience pseudo wrong will certainly harm these students because their work will always be judged wrong by the teacher. Therefore, the teacher also needs to explore the causes of student errors, by knowing the causes of student errors, the teacher can find solutions so that students are able to think correctly and produce correct answers in every job.

4. Conclusion

From the research results, the following conclusions are obtained: 1) Subjects who experience pseudo conceptual are able to provide the correct steps because they follow the examples they have studied. The subject assumes that if the base is the same then it can be crossed out or removed, but the subject understands that the value of is part of the overall exponential equation. The thinking process of students is still pseudo, even though they are able to answer correctly, the subject is unable to explain the concepts used correctly. The subject does not think about the meaning of the concept used and its relation to other concepts. 2) Subjects who experience pseudo-analytic are seen when the subject only answers spontaneously regarding the problems it faces. Subjects do not control or check the problems given and quickly respond by equating the problems they often face. What is in the mind of the subject when there is the same problem, it is done in the same way. The subject did not try to understand the question again. Like when asked a question, the subject immediately sees that the bases are the same and immediately looks for the equations of exponents without first ensuring that the power variable is the same, so any
answer should be possible without having to equalize the rank. 3) the subject experienced a pseudo-true when the subject experienced a pseudo conceptual experience. The subject just followed the procedure and coincidentally came up with the correct answer. When the subject works on the problem assumes that the set of solutions in question no. 2 is a non-probability condition that is possible by checking 2 possibilities that the equation will have the same value. 4) the subject is pseudo-false. The subject is in a hurry because he is sure that the answer given is correct without checking the answer given. The subject thinks that when he meets him that is the answer.

The pseudo thinking process in understanding exponential equations can be seen from the results of this study, most students still memorize formulas without understanding the formula. Students only think of looking for answers quickly using formulas that have been learned. Of course memorization is not the goal of learning mathematics, on the contrary mathematics is taught to be unable to train students' reasoning and creativity. If learning only emphasizes procedures and memorization, what happens when learning mathematics has no meaning. In addition to memorization procedures, it is very risky for students to forget, students are not able to use mathematics according to the actual concepts. the theoretical framework of thought are pseudo- Vinner's and Subanji's actually interrelated. When in the process of working on students experiencing pseudo conceptual there is a possibility that students are able to answer right or wrong. Likewise, when students experience pseudo analytics, students also have the possibility to answer correctly or answer wrongly. However, to trace the pseudo thinking that occurs during the process of working on and tracing the final results of the students' answers, of course, have different techniques. Tracing the pseudo thinking while working on the teacher may be able to ask students to make a concept map first and then work on. So that the teacher can see how the thinking structure of their students is in working on the problem. Teachers may also be able to find out thinking pseudo when they have corrected students' answers. In learning the teacher gives questions then the teacher corrects. Steps to explore thinking pseudo students 'can be done by trying to ask questions related to students' understanding of the material when the teacher concludes learning at the end of the learning hour. Possible efforts to explore thinking processes pseudo that can be carried out in line with the learning process certainly need further research to find the right solution so that the teacher is able to understand the thinking process pseudo of students.

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