Panicgogy International Journal

Publication details, including instructions for authors and subscription information:
https://nakiscience.com/index.php/pij

Analysis of student learning obstacles in exponential materials: exploratory case study

Aprianah Puspa Sari Dewi[a]*, Moh. Rizal[b], Muhammad Zaini[c], Widya Sani Safitri[d]

[a*]Universitas Nahdlatul Wathan Mataram, Indonesia, aprianahpuspa227@gmail.com
[b]Universitas Nahdlatul Wathan Mataram, Indonesia, muhammmadrizaltuga@gmail.com
[c]Universitas Nahdlatul Wathan Mataram, Indonesia, mz09zaini@gmail.com

To cite this article:
Aprianah Puspa Sari Dewi, A.P.S., Rizal, M., Muhammad Zaini, M & Safitri, W.S. (2023). Analysis of student learning obstacles in exponential materials: exploratory case study. *Panicgogy International Journal, 1*(2), 74-83.
To link to this article: nakiscience.com/index.php/pij

Panicgogy International Journal, *1*(2), 74-83, 2024
https://nakiscience.com/index.php/pij

Original Article

Analysis of student learning obstacles in exponential materials: exploratory case study

Aprianah Puspa Sari Dewi[a], Moh. Rizal[b], Muhammad Zaini[c], Widya Sani Safitri[d*]
[a]Universitas Nahdlatul Wathan Mataram, Indonesia, aprianahpuspa227@gmail.com
[b]Universitas Nahdlatul Wathan Mataram, Indonesia, muhammmadrizaltuga@gmail.com
[c]Universitas Nahdlatul Wathan Mataram, Indonesia, mz09zaini@gmail.com
[d*]Universitas Nahdlatul Wathan Mataram, Indonesia, wdysanisafitri01@gmail.com

*Correspondence: wdysanisafitri01@gmail.com

Abstract
Exponential learning that had been occurring so far did not pay attention to the learning obstacles that students experienced. In general, the teacher delivered material by referring to documents, textbooks, or reference books. Therefore, it was important to conduct a study that examined learning obstacles in exponential material. The purpose of this research was to analyze the learning barriers associated with exponential material. The method used in this study was descriptive qualitative, using data collection techniques in the form of observation, tests, interviews, and documentation. The research subjects were 30 students of Mts NW Aik Anyar class VIII D. Data retrieval in the research was based on the results of student answer tests using the exponential question instrument consisting of five items. The results showed that there were still many students who had difficulty working on exponential questions. It was concluded that student learning barriers were divided into two factors: ontogeny barriers (learning readiness) and epistemological barriers (knowledge of students with limited application contexts).

Keywords:
Learning Obstacle;
Case Study;
Ontogeny Obstacle;
Epistemology Obstacle

1. Introduction

Exponents are one of the most essential mathematical concepts with numerous applications in daily life, such as modeling population growth, radioactive decay, and compound interest calculations (Sokolowski & Sokolowski, 2018; Khanh & Loi, 2020; Loi & Khanh, 2020). This concept plays a crucial role in supporting students' understanding of more complex phenomena. However, several studies indicate that students' understanding of exponents is often limited. Russell an Potter (2022) revealed that many students tend to forget the properties of exponents after learning them and rarely explain the reasoning behind their usage. As a result, students frequently make errors in solving problems related to exponents, particularly those requiring the conceptual application of exponent properties (Top, 2022) .

Students' difficulties in understanding the concept of exponents do not occur without cause. Research by Gunadi & Aisah (2019) states that a weak mastery of basic concepts is one of the primary reasons students struggle with exponents. Gunawan & Fitra (2021) found that students often have difficulty connecting the concept of exponents with its application to non-routine problems. Furthermore, Satriani (2020) noted that teaching methods that lack relevant contextualization make it challenging for students to apply exponents in real-life situations.

Within the framework of learning theory, Brousseau (2002) proposed three categories of learning obstacles that may affect students' understanding: ontogenetic, didactic, and epistemological obstacles. Ontogenetic obstacles refer to students' developmental limitations, such as cognitive abilities that are not yet mature enough to grasp certain concepts. Didactic obstacles arise from inappropriate teaching approaches, such as using conventional methods without actively engaging students in the learning process. Meanwhile, epistemological obstacles relate to students' knowledge limitations, which are specific to a particular context. Valcarce & Vázquez (2008) further explained that epistemological obstacles often emerge when students struggle to understand new conceptual themes that differ from their prior learning experiences.

Another study by Cornu (1991) categorized learning obstacles into four types: cognitive, genetic and psychological, didactic, and epistemological obstacles. Cognitive obstacles are related to students' difficulties in understanding concepts taught during the learning process. Genetic and psychological obstacles refer to aspects of students' personal development, such as a lack of confidence in learning mathematics. Didactic obstacles occur due to teaching approaches that do not adequately address students' needs, while epistemological obstacles arise from the limitations of students' scientific knowledge, which is often confined to specific contexts (Sudirman et al., 2022).

Although various studies have examined students' difficulties in learning exponents, most have primarily focused on procedural errors or general conceptual understanding. Research specifically identifying epistemological, didactic, and ontogenetic obstacles in learning exponents, particularly in Indonesia, remains very limited. Additionally, the integration of Brousseau's (2002) and Cornu's (1991) theories as analytical frameworks for understanding students' learning obstacles in exponents has rarely been conducted.

Based on this background, this study aims to identify and analyze the learning obstacles experienced by Grade VIII students at MTs NW Aik Anyar in understanding the concept of exponents, particularly their properties. The study also seeks to uncover the factors contributing to epistemological, didactic, and ontogenetic obstacles affecting the learning process of exponents. Therefore, the findings of this study are expected to provide valuable insights for mathematics teachers in evaluating classroom teaching strategies and helping students overcome the obstacles they face.

2. Method

2.1 Research Design

This study uses an exploratory case study design aimed at gaining an in-depth understanding of the difficulties students face in understanding the concept of exponents. This approach was chosen because it allows the researcher to explore phenomena occurring in a natural context, specifically in the process of teaching and learning mathematics in the classroom. With this design, the researcher can gain a broader perspective on the factors influencing students' understanding of exponents and the obstacles they encounter while studying this material. The exploratory case study design is well-suited to identify contextual and in-depth problems that may not be uncovered in large-scale quantitative studies or surveys.

2.2 Research Subjects

The research was conducted on Thursday, July 27, 2023, at MTs NW Aik Anyar. The research subjects consisted of 30 students from class VIII, selected because they had been taught the concept of exponents but still encountered difficulties in understanding it. The selection of class VIII students aimed to more clearly identify the challenges students face in grasping the concept of exponents, especially concerning the properties of exponents, which were the main focus of this study. By selecting this specific group of students, the researcher hoped to obtain more relevant and contextual data regarding students' understanding of exponentiation concepts.

2.3 Data Collection Techniques

In this study, data were collected using tests, observations, interviews, and documentation. Each of these techniques served a specific role in gathering information about the difficulties students face in understanding the concept of exponents. First, a test was administered to assess students' understanding of the exponent material. This test consisted of five questions designed to examine how well students could apply the properties of exponents to solve related problems. Observations were made during the learning process to note how students interacted with the exponent material and the challenges they faced. By observing student activities in the classroom, the researcher could gain insight into the thought processes of the students and the strategies they employed when encountering difficulties. Interviews were conducted after the students completed the test, aiming to explore more deeply their understanding of the questions and to identify where they experienced difficulties. The interviews were unstructured, allowing the researcher to explore various aspects of students' understanding in a more open and flexible manner. Lastly, documentation was used to collect notes, teaching materials, and relevant observation results, which could serve as additional evidence in data analysis.

2.4 Research Instruments

The primary instrument used in this research was a written test consisting of five exponentiation questions. These questions were designed to explore various aspects of students' understanding of exponentiation, particularly the properties of exponents. Each question was created with varying levels of difficulty to assess students' ability to apply the concept of exponents in different contexts. These questions aimed to measure how well students could apply the concept of exponents to solve more complex mathematical problems. In addition to the written test, unstructured interviews were also used as an instrument to identify students' difficulties in understanding exponents and to gain clarification on the results obtained from the test.

2.5 Data Analysis

The data collected from the tests, observations, interviews, and documentation were analyzed using the data analysis technique developed by Miles and Huberman (1992). The analysis process began with *data reduction*, which involves filtering and sorting the data relevant to the research objectives. Data that were irrelevant or did not support further analysis were discarded. Next, the relevant data were presented in a structured format, such as tables, diagrams, or narratives, to make them easier to understand and analyze. This data presentation process allowed the researcher to identify patterns or themes emerging from the data. The final step in the data analysis was *drawing conclusions*, which is the process of summarizing the main findings from the research. Drawing conclusions is crucial as it provides a clear understanding of the difficulties students face in solving exponentiation problems and the factors influencing their learning process.

2.6 Research Objectives

The main objective of this research is to identify and analyze the learning barriers that students encounter when understanding the concept of exponents, particularly the properties of exponents. This study also aims to uncover the epistemological, didactic, and ontogenetic factors that influence the learning process of exponents. It is expected that the findings from this research will significantly contribute to the development of effective teaching strategies for mathematics, particularly in teaching exponents, and assist teachers in designing instructional approaches that better meet students' needs. By understanding the barriers students face, teachers can adapt their teaching methods to better address students' challenges and provide appropriate support in overcoming the difficulties they encounter.

3. Results and Discussion

3.1 Results

In the results and discussion section, the learning obstacles faced by students are categorized into several types, namely:

3.1.1 Ontogenic Obstacles

Ontogenic obstacles refer to the developmental or growth challenges that individuals face in understanding certain concepts (Pauji et al., 2023; Lutfi et al.,2021). In the context of exponentiation material, ontogenic obstacles may involve cognitive aspects, experiences, and individual developmental stages. Cognitive limitations, such as difficulties in abstract thinking or problem-solving, can hinder students' ability to understand the properties of exponents and apply them in various contexts. Additionally, a lack of experience or exposure to similar mathematical concepts can also contribute to students' struggles with exponentiation. The individual's developmental stage is also a key factor, as students at different cognitive developmental levels may encounter different challenges in understanding abstract mathematical ideas like exponents. Therefore, these ontogenic factors—whether cognitive, experiential, or related to developmental maturity—play a significant role in determining how well students can comprehend and apply the concept of exponents in their learning process. Based on the analysis, the information is presented in Figure 1.

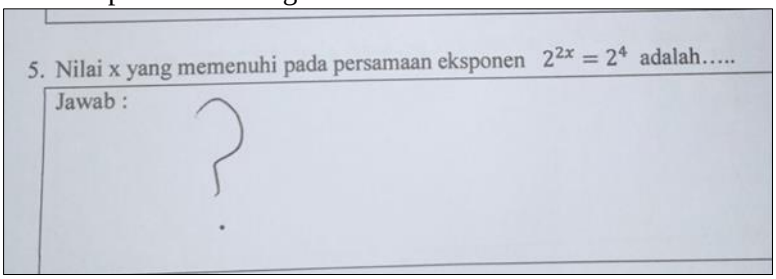

Figure 1. Student D's question and answer for number 5

Original Article

The respondents show difficulty in understanding basic exponentiation concepts, such as how exponents work or the relationship between the base and the exponent. This indicates that the students' understanding of exponents is still limited to fundamental aspects. Some respondents even struggle to relate the exponent to the base, which can affect how they solve more complex exponentiation problems. In some cases, the individual's developmental stage also plays a role. Students who have not yet reached a certain cognitive developmental stage may struggle with abstract mathematical concepts like exponents, which require the ability to think in a more complex and abstract manner. As a result, most respondents left the answer blank for question number 5. This suggests that exponentiation material is sometimes taught in an abstract manner without connecting it to real-life situations, making it harder for students to relate the concepts to everyday life.

When an interview was conducted with one of the subjects who left question number 5 unanswered, the subject revealed that the material on exponential equations made them confused and struggled to choose which properties or formulas to use to solve the problem. This shows that although students are familiar with the properties of exponents, they still struggle to choose the right strategy to solve more complicated problems. Their confusion is further exacerbated by the lack of connection between exponentiation material and real-life situations that could clarify the application of the concept. As a result, students not only find it difficult to understand the concept but also struggle to apply their knowledge in broader contexts.

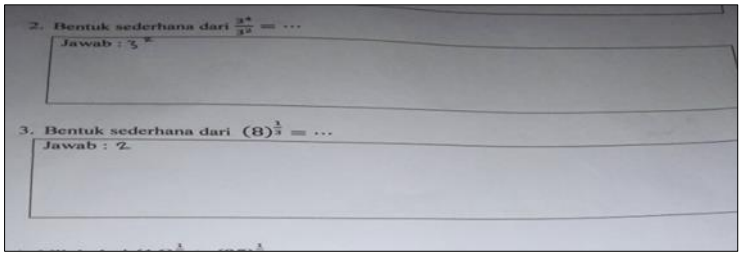

Figure 2. Student A's questions and answers for numbers 2 and 3

Most of the tested subjects seem not to pay attention to the formulas and properties of exponents being tested. The majority of students only wrote the final answer without showing the steps or formulas used to arrive at the answer. This reflects a habit of not prioritizing the process of solving math problems. Even though the students managed to get the correct answer, they often neglect the methods or steps used to reach that result. This phenomenon suggests that their understanding of the fundamental concepts of exponents has not fully developed. However, in mathematics learning, understanding formulas and properties of exponents is crucial, as it helps students solve more complex and varied problems. Ignoring the formulas or steps also hinders students' ability to identify mistakes if errors occur during the problem-solving process.

An interview with one of the students, Student A, provided further clarification about this habit. Student A argued that writing down the exponent formula was not that important as long as they got the correct answer. This reflects a view focused more on the final result than the process required to achieve that result. According to Student A, the most important thing is the correct answer, without thinking too much about the steps or formulas used. This view shows that the student does not fully understand the importance of the process in mathematics learning, especially in the exponentiation material. Meanwhile, in a deeper approach, writing formulas and steps is very important because it helps students understand the relationships between the involved concepts and strengthens their understanding of exponents themselves. Neglecting to write formulas and properties of exponents may also cause students difficulties when facing more complicated problems, where a deeper understanding and the ability to connect basic concepts are essential.

Original Article

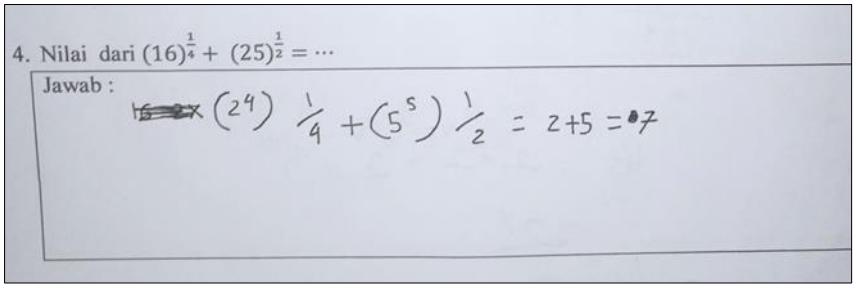

Figure 3. Student's question and answer for number 4

The students' understanding of basic mathematical concepts, such as subtraction, multiplication, and division, shows a very low level, which directly affects their ability to solve exponentiation problems. Many students struggle to apply these basic operations in the context of exponentiation problems. This can be seen from the number of errors made by students in performing basic calculations, which ultimately affects the results of solving exponentiation problems. For instance, when performing calculations with numbers, they often make mistakes in multiplication or division, which should be the foundation for understanding exponentiation concepts. Without a strong understanding of these basic operations, students will face significant challenges when asked to work on more complex problems, including those involving exponents. This difficulty becomes more apparent when they encounter problems requiring a deeper understanding of the relationship between the base and the exponent, which should be grounded in mastery of basic mathematical operations.

Interviews with several students revealed that some of them have not fully memorized basic multiplication tables, which is a major obstacle when they are asked to solve exponentiation problems. In the interview, some students admitted that they felt confused when asked about exponentiation because they could not quickly recall basic multiplication results. This was clearly evident in one student's response when solving an exponentiation problem, where they wrote the exponentiation result of 25 as 5^2, which is a significant error in applying the concept. Responses like this indicate that students not only struggle to calculate the results of exponentiation but also have trouble understanding how the numbers interact in more complex mathematical operations. The difficulty in recalling and understanding basic multiplication becomes a barrier to further understanding of exponentiation, which requires mastery of these fundamentals to apply the concept correctly.

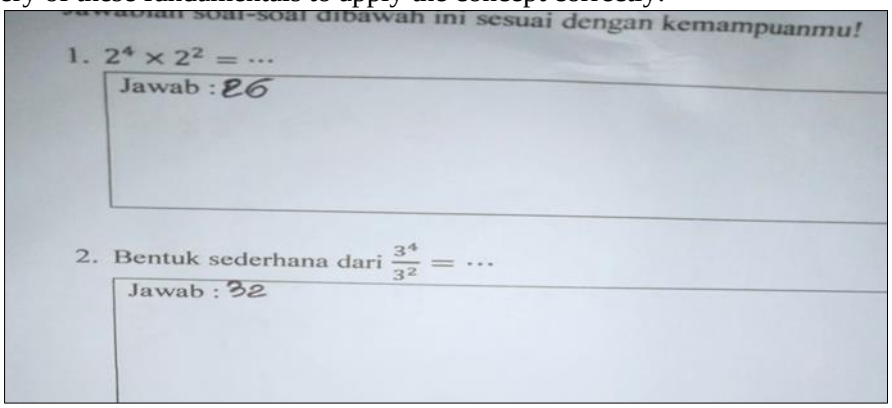

Figure 4. Student F's question and answers for numbers 1 and 2

Student F showed significant errors in writing the base and exponent for exponentiation problems. In solving the problems, this student wrote the exponent in line with the base, which clearly led to confusion in understanding the correct notation. For example, in a problem requiring the student to write the result of two raised to the power of six (2^6), Student F wrote the number as "26," which does not represent the correct relationship between the base and the exponent. This indicates that the student has not fully understood how to write exponent expressions correctly and has not grasped the basic difference between writing regular numbers and writing exponents. This error is important to address

because writing exponent expressions incorrectly can further deepen the confusion when dealing with more complex exponentiation problems in the future.

Errors in writing exponents like the ones made by Student F can also be linked to a general lack of understanding of mathematical concepts. Incorrect writing of expressions indicates that the student may not be familiar with the mathematical symbols used in these operations. This could be caused by a lack of practice in writing mathematical expressions correctly or insufficient emphasis on notation in teaching exponentiation material. Additionally, this writing error shows difficulty in distinguishing between regular numbers and exponential forms, which involve two elements: the base and the exponent. Therefore, this not only indicates a problem with the technical aspect of writing but also with the basic understanding of the exponent concept itself. Student F may need more practice and explanations regarding correct exponent notation to correct this error and better understand more complicated exponentiation concepts.

3.1.2 Epistemological Obstacle

Epistemological obstacle refer to difficulties that arise when individuals try to connect and integrate new information with previously acquired knowledge (Modestou& Gagatsis, 2007; Maknun et al., 2022). In the context of learning exponents, this barrier occurs when students attempt to understand the concept of exponents by linking it to a framework of understanding they already possess, which may be irrelevant or inaccurate. For example, students accustomed to basic mathematical operations like addition and subtraction may struggle when faced with more complex operations such as exponentiation and division of exponents. This is due to their inability to separate these new concepts from their more basic understanding or from prior experiences that do not fully align with the exponentiation concepts they are learning. As a result, students have difficulty grasping the basic principles of exponents and fail to internalize the concept deeply.

Based on data collection results, some students appear to encounter significant epistemological barriers in understanding exponent material. For example, several frequent errors were observed in students' work, indicating a difference between how they understand exponent operations and the correct method as taught by the curriculum. One example of this is the inability of some students to distinguish between basic exponent rules, such as the law of multiplication or division of exponents, leading to errors in solving problems. Additionally, there are students who incorrectly apply the properties of exponents because they try to relate the concept to prior experiences or knowledge that are not relevant, such as struggling to understand how the base and exponent interact in certain operations. This demonstrates that epistemological barriers play a crucial role in hindering students' understanding of exponent material, which ultimately affects their ability to correctly solve exponent-related problems.

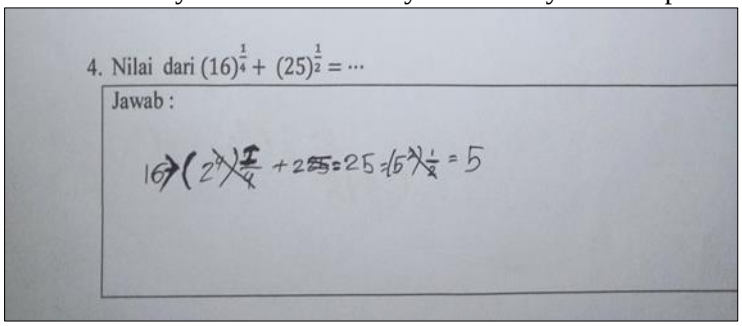

Figure 5. Problem and Answer by Student A, Question 4

In the figure above, it can be seen that Student A answered the exponent question without following the correct steps in solving the problem. The student should have first simplified the exponent expression and then performed the addition of the exponents. However, Student A did not perform the correct addition of the exponents, such as in Question 4, which should have resulted in 2+5 equaling 7. As a result, Student A provided an incorrect answer. This shows that the student has not fully understood how exponent rules work, especially in performing basic operations such as adding exponents, leading to inaccuracies in solving the problem. In this case, Student A's approach to solving the problem appears unsystematic and unclear, making it difficult to understand the material further.

Original Article

The errors in solving the problem made by Student A align with findings in a study by Hanaf & Wulandari (2019), which showed that students often make mistakes in calculations, especially in problems involving specific mathematical rules like exponents. The study revealed that ignorance or misunderstanding of solution steps often causes students to provide incorrect answers. In this context, Student A seems unable to manage the exponent concept correctly, as evidenced by their failure to solve the problem in its simplest form. This emphasizes that there are fundamental difficulties students face in understanding exponent operations, and they need deeper understanding and more directed practice to overcome such errors.

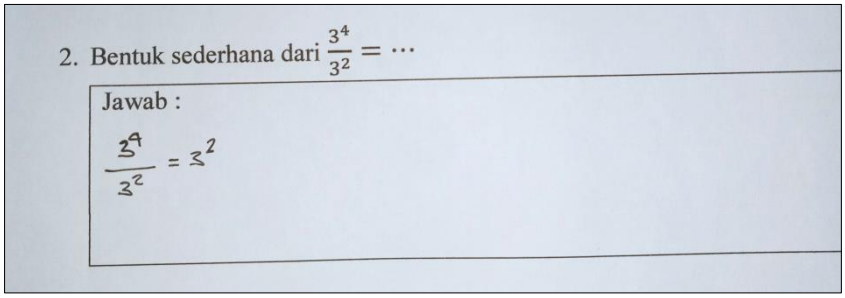

Figure 6. Problem and Answer by Student C, Question 2

In Figure 6, it can be seen that Student C only rewrote the problem and immediately gave the final answer without demonstrating the correct steps. To solve a problem like $\frac{3^4}{3^2}$, students should follow the exponent rule that requires them to subtract the exponents of the same base, i.e., 3^{4-2}, which results in 3^2. However, Student C did not follow this step and simply listed the final answer without explaining the process used to reach that answer. This indicates that Student C might not fully understand how to apply the exponent rules in solving division problems between exponents with the same base.

After an interview with Student C, they revealed that they forgot to write down the calculation steps. Student C seems to understand the concept, but struggles with presenting the steps correctly on paper. Disorganization in writing down the calculation steps may reflect a lack of attention to the systematic process required in solving mathematical problems, which is essential for justifying the results logically. This also suggests that while Student C has a basic understanding of exponent concepts, there is a need to train their skills in organizing solution steps more clearly and systematically.

3.2 Discussion

Ontogenetic and epistemological learning barriers are two highly relevant concepts in understanding how individuals overcome difficulties in learning, especially in the context of mathematics. Ontogenetic barriers refer to the differences in individuals' cognitive and psychological development, which directly affect how they understand and learn a subject. In this study, it was found that ontogenetic barriers emerge when students lack the basic mathematical skills needed to fully understand exponent concepts, such as multiplication, division, and understanding numbers themselves. This aligns with findings from previous research by Rabillas et al (2023), which states that cognitive development, as age and experience increase, can affect students' ability to understand more complex mathematical concepts. Students who lack sufficient understanding of basic mathematical operations will struggle when confronted with more advanced material, such as exponents. Therefore, a learning approach tailored to the cognitive developmental stage of students is needed to help them understand mathematical concepts more effectively. This study supports the importance of learning strategies that consider students' cognitive development stages in overcoming ontogenetic barriers, enabling them to develop a stronger understanding of mathematical concepts.

In addition to ontogenetic barriers, epistemological barriers were also found in this study. Epistemological barriers focus on how students perceive mathematical knowledge and how they relate new information to existing knowledge. This relates to how individuals build their understanding of a concept and their beliefs about the validity and sources of that knowledge. In the case of exponents, epistemological barriers arise when students have a misconception about exponent rules or do not recognize the importance of the relationship between the base and exponent. Some students experience difficulty solving problems because they do not have a correct understanding of exponent rules or even

assume that those rules do not apply in certain cases. This is in line with findings from NCTM (2000), which states that epistemological understanding of mathematics is crucial in helping students overcome difficulties in understanding mathematical concepts. Students who have a limited view of mathematical operations or exponent rules will face challenges in solving more complex problems because they lack a strong foundation to understand the relationships between mathematical concepts. Therefore, to overcome epistemological barriers, a learning approach is needed that not only explains mathematical rules but also helps students understand how knowledge develops and connects.

This study found that many students struggled to write exponent formulas or failed to write calculation steps systematically. This indicates that epistemological barriers can also arise when students lack a clear understanding of how mathematical knowledge is structured and applied. For example, students often only write the final answer without considering the steps they should take to reach that result. Research by Maarif et al. (2021) also shows that epistemological barriers can occur when students have a mistaken view of how mathematical knowledge develops or is applied. For example, students who do not write formulas or steps in solving exponent problems may not understand the importance of the process or sequence of steps in solving mathematical problems. Therefore, it is important to develop a more explicit approach in teaching students how to organize the steps in solving math problems and how formulas and mathematical properties are applied in broader contexts. A more systematic and structured approach to learning can help students understand the importance of each step in problem-solving and overcome the epistemological barriers they face.

Based on these findings, it can be concluded that overcoming ontogenetic and epistemological learning barriers in mathematics education, particularly in the material of exponents, requires an approach that takes into account both students' cognitive development and epistemological understanding. This study supports the view presented by Kaiser & Schwarz (2010), which states that mathematics education should involve an approach that includes clear explanations, the use of appropriate illustrations, and exercises that allow students to connect concepts they have learned to real-life situations. This will help students develop a deeper understanding of exponents and enable them to apply that knowledge in solving various mathematical problems. Therefore, it is important for mathematics teaching to adapt to students' cognitive development stages and provide them with a comprehensive understanding of how mathematical knowledge develops and is applied in various contexts. This approach will not only address the ontogenetic and epistemological barriers students face but also strengthen their understanding of more complex mathematical concepts.

4. Conclusion

Based on the results and discussion of this study, it is concluded that there are two main learning barriers faced by students in the exponent material, namely ontogenetic and epistemological barriers. Ontogenetic barriers are related to students' lack of understanding of basic mathematical operation concepts such as multiplication, division, and subtraction, which form the foundation for their understanding of exponents. In addition, most students also struggle with following the correct solution steps and using exponent properties correctly. This is evident in errors in writing the base and exponent, which indicates a lack of understanding of how these operations should be applied in the context of exponents. These barriers suggest that students have not yet sufficiently mastered the basic mathematical skills needed to understand exponent material well.

Meanwhile, epistemological barriers focus more on students' lack of understanding of the concept of exponents itself, as reflected in errors in the solution procedures and the calculation of exponentiation results. These errors indicate a misunderstanding of the exponent concept and how to apply its mathematical rules. Therefore, to address these barriers, it is crucial for educators to understand the ontogenetic and epistemological barriers students experience. Educators need to design learning strategies tailored to the cognitive development stages and epistemological views of students, so they can help students understand exponent concepts more deeply and effectively. With the right approach, it is hoped that students can overcome the learning barriers they face and improve their understanding of exponent material more effectively.

Limitations

This study, while offering valuable insights into the ontogenetic and epistemological barriers faced by students in learning exponents, has several limitations. First, the study is limited by its sample size and scope, which focused primarily on a specific group of students in one educational setting. This may not fully represent the diversity of learning experiences and challenges that students face across different regions or educational systems. Second, the study primarily relied on students' written responses and tests to assess their understanding of exponents, which may not capture the full complexity of students' cognitive and epistemological processes. Observations of students' learning behaviors in real-time classroom settings could provide a more comprehensive view of their difficulties. Additionally, the study did not explore the impact of other external factors such as teacher experience, teaching methods, or technological tools on students' learning barriers, which could have influenced the results. Finally, while the focus was on exponents, the findings may not be directly transferable to other areas of mathematics, as each mathematical concept may present its own unique challenges in terms of cognitive and epistemological barriers. Future research could expand the sample size, include more diverse settings, and explore a broader range of mathematical topics to further validate and refine the conclusions of this study.

Acknowledgments

The researchers would like to extend their heartfelt gratitude to all participants in this study for their valuable time, insights, and cooperation, which made this research possible.

Author Contribution

Author 1: Conceptualization, Writing - Original Draft, Editing, and Visualization;
Author 2: Writing - Review & Editing, Formal Analysis, and Methodology;
Author 3: Validation and Supervision.

Conflict of Interest

The authors declare no conflict of interest.

5. References

Brousseau, G. U. Y. (2002). Epistemological obstacles, problems, and didactical engineering. *Theory of Didactical Situations in Mathematics: Didactique des Mathématiques, 1970–1990*, 79-117.

Cornu, B. (1991). Limits. In *Advanced mathematical thinking* (pp. 153-166). Dordrecht: Springer Netherlands.

Gunadi, F., & Aisah, L. S. (2019). Comic's Mathematics Learning (CML): Pembelajaran Matematika Untuk Mengembangkan Kemampuan Literasi Matematis Siswa. *Mathline: Jurnal Matematika Dan Pendidikan Matematika*, *4*(2), 128-138. https://doi.org/10.31943/mathline.v4i2.113

Gunawan, M. S., & Fitra, D. (2021). Kesulitan siswa dalam mengerjakan soal-soal eksponen dan logaritma. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(2), 257-268. https://doi.org/10.31980/mosharafa.v10i2.659

Hanafi, M., & Wulandari, K. N. (2019). Analisis kemampuan siswa dalam menyelesaikan soal high order thinking ditinjau dari kemampuan awal matematis siswa. In *Seminar & Conference Proceedings of UMT*.

Kaiser, G., & Schwarz, B. (2010). Authentic modelling problems in mathematics education—examples and experiences. *Journal für Mathematik-Didaktik*, *31*(1), 51-76.

Khanh, T. L. C., & Loi, N. H. (2020). An analysis of the concept of exponential functions in history and textbooks in vietnam. *The International Journal of Engineering and Science*, *9*(11), 23-28. https://doi.org/10.9790/1813-0911022328

Loi, N. H., & Khanh, T. L. C. (2020). Connecting mathematics and practice: a case study of teaching exponential functions. *European Journal of Education Studies*, *7*(12), 612-624. http://dx.doi.org/10.46827/ejes.v7i12.3473

Lutfi, M. K., Juandi, D., & Jupri, A. (2021). Students' ontogenic obstacle on the topic of triangle and quadrilateral. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012108). IOP Publishing.

Maknun, C.L., Rosjanuardi, R., & Jupri, A. (2022). Epistemological Obstacle in Learning Trigonometry. *Mathematics Teaching Research Journal*, *14*(2), 5-25. https://files.eric.ed.gov/fulltext/EJ1350528.pdf

Maarif, S., Perbowo, K. S., & Kusharyadi, R. (2021). Depicting epistemological obstacles in understanding the concept of sequence and series. *IndoMath: Indonesia Mathematics Education*, *4*(1), 66-80. https://doi.org/10.30738/indomath.v4i1.9339

Modestou, M., & Gagatsis, A. (2007). Students' improper proportional reasoning: A result of the epistemological obstacle of "linearity". *Educational Psychology*, *27*(1), 75-92. https://doi.org/10.1080/01443410601061462

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author. No Child Left Behind Act, 20 U.S.C. §6301 (2001).

Pauji, I., Hadi, H., & Juandi, D. (2023). Systematic literature review: Analysis of learning obstacle in didactical design research on geometry material. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *7*(3), 2895-2906.

Rabillas, A., Kilag, O. K., Cañete, N., Trazona, M., Calope, M. L., & Kilag, J. (2023). Elementary Math Learning Through Piaget's Cognitive Development Stages. *Excellencia: International Multi-disciplinary Journal of Education (2994-9521)*, *1*(4), 128-142.

Russell, B., & Potter, M. (2022). *Introduction to mathematical philosophy*. Routledge.

Satriani, S. (2020). Analisis Kemampuan Pemecahan Masalah dan Kemampuan Penalaran Matematis Siswa Materi Eksponen dan Logaritma. *Delta: Jurnal Ilmiah Pendidikan Matematika*, *8*(2), 193-200. https://doi.org/10.31941/delta.v8i2.1006

Sokolowski, A., & Sokolowski, A. (2018). Modeling with exponential decay function. *Scientific Inquiry in Mathematics-Theory and Practice: A STEM Perspective*, 65-82. https://doi.org/10.1007/978-3-319-89524-6_7

Sudirman, S., Kusumah, Y. S., Martadiputra, B. A. P., & Runisah, R. (2023). Epistemological Obstacle in 3D Geometry Thinking: Representation, Spatial Structuring, and Measurement. *Pegem Journal of Education and Instruction*, *13*(4), 292-301. https://doi.org/10.47750/pegegog.13.04.34

Valcarce, M. C., & Vázquez, M. S. (2008). Análisis y clasificación de errores cometidos por estudiantes universitarios en el aprendizaje del concepto de convergencia de serie numérica. In *Investigación en educación matemática XII* (p. 22). Sociedad Española de Investigación en Educación Matemática, SEIEM.