Koordinat **Jurnal Pembelajaran Matematika dan Sains**
Volume 6, Number 1, January-June 2025, Pages 13-24

https://doi.org/10.24239/koordinat.v6i1.147 **e-ISSN : 2745-4215**

LEARNING OBSTACLE OF PROSPECTIVE MATHEMATICS TEACHERS ON REAL ANALYSIS

Rafiq Badjeber[1*], I Wayan Sukayasa[2], Windia Hadi[3], Margareta Madha Melissa[4]

[1] Doctoral School of Science Education, Tadulako University, Central of Sulawesi, Indonesia
[2] Department of Mathematics Education, Tadulako University, Central of Sulawesi, Indonesia
[3] Doctoral School of Education, University of Szeged, Szeged, Hungary
[4] International Education Development Program, Hiroshima University, Hiroshima, Japan

ARTICLE INFO

Article History
Received: 25 Mar 2025
Revised: 02 Apr 2025
Accepted: 03 Apr 2025
Published: 06 May 2025

Keywords:
Learning Obstacle
Prospective Mathematics Teachers
Real Analysis

ABSTRACT

This study aims to identify the learning obstacles experienced by prospective mathematics teachers when constructing proofs in real analysis. This study uses a qualitative method with a case study design. The research subjects comprised 20 third-year prospective mathematics teachers at a university in Palu. Five prospective mathematics teachers were selected for interviews based on the types of obstacles they experienced. The research instruments included a respondent ability test and interview guidelines. Data analysis was conducted by reducing data, presenting data, and drawing conclusions. The results of the study indicate that prospective mathematics teachers experience ontogenic obstacles, namely difficulty in thinking deductively and axiomatically; epistemological obstacles when difficulty in understanding definitions, difficulty in starting proofs, and difficulty in constructing complete proofs; and didactical obstacles that occur due to a procedural learning approach. These findings can be used by lecturers in designing relevant learning designs based on prospective mathematics teachers' learning trajectories to anticipate potential learning obstacles.

Corresponding Author:
Rafiq Badjeber, Doctoral School of Science Education, Tadulako University, Central of Sulawesi, Indonesia
Email: rafiqbadjeber@gmail.com

How to cite:
Badjeber, R., Sukayasa, I. W., Hadi, W., & Melissa, M. M. (2025). Learning Obstacle of Prospective Mathematics Teacher on Real Analysis. *Koordinat Jurnal Pembelajaran Matematika dan Sains*, *6*(1), 13-24. https://doi.org/10.24239/koordinat.v6i1.147.

INTRODUCTION

Proving is a core activity of mathematics, and it has gradually been accepted that justification and proof should be central to mathematics learning at all levels of schooling (Komatsu, 2016). Prospective mathematics teachers must translate informal language into formal expressions, reason from definitions, understand and apply theorems, and establish relationships between mathematical objects (Di Martino & Gregorio, 2019; Siswono et al., 2020). In proof construction, prospective mathematics teachers must formulate conjectures, mathematical models, and generalizations to produce valid arguments (Nurafni et al., 2019).

Real analysis is one of the higher education courses that emphasizes proof (Roh & Lee, 2017). This course covers several fundamental concepts regarding the properties of real numbers, the Archimedean properties, set theory in real numbers, sequences of real numbers, the limit theorem, Cauchy series, convergence of sequences, and special convergence tests (Ashari & Salwah, 2021). The competencies prospective mathematics teachers must achieve include proving simple mathematical statements using familiar concepts and developing critical, creative, structured, and systematic thinking (Helma & Murni, 2021). In real analysis classes, prospective mathematics teachers are trained to verify the truth of statements, explain the reasoning behind them, and present proofs in logical and systematic language (Septiati, 2021).

Several studies have shown that prospective mathematics teachers face significant challenges in learning real analysis (Caglayan, 2018; Isnani et al., 2020). These challenges include difficulties initiating proof construction, expressing ideas formally, and understanding the abstract concepts underlying proofs (Widiati & Sthephani, 2018). They also struggle to select and integrate appropriate definitions or theorems, choose suitable proof methods (Mutaqin et al., 2022), and overcome misconceptions about the material (Faisal et al., 2024; Mardianto et al., 2024). Additional difficulties include abstract thinking, foundational knowledge gaps, and mathematical language complexity (Isran et al., 2025). Furthermore, they often face problems identifying how to begin a proof, generating ideas, applying mathematical concepts, and logical reasoning to determine the correct proof steps (Sucipto & Mauliddin, 2017). The same situation is observed among prospective mathematics teachers at UIN Datokarama Palu, who struggle relatively with constructing proofs.

These learning difficulties are influenced by various factors, including insufficient preparation by both lecturers and students during the learning process (Koparan & Rodríguez-Alveal, 2022). When prospective teachers encounter such difficulties, it often leads to errors in problem-solving (Mahmud et al., 2023), which creates learning obstacles. These obstacles can be categorized into three types: ontogenic obstacles stemming from cognitive limitations, epistemological obstacles due to limited conceptual understanding, and didactical obstacles arising from instructional methods (Brouseau, 2002). Obstacles are conditions experienced by students that make them unable or difficult to solve problems (Sari et al., 2023). Fauzi dan Suryadi (2020) state that learning obstacles are one of the problems in mathematics learning that are important to study.

According to Suryadi (2019) learning obstacles in mathematics arise from a mismatch between students' prior knowledge and the new concepts they are expected to know. Addressing these obstacles is crucial, as failure to do so can impede students' progress (Rohimah et al., 2024). Therefore, learning tasks should help students build on their current understanding while facilitating the gradual acquisition of new knowledge (Hendriyanto et al., 2024). This highlights the importance of designing content that supports students' learning trajectories and anticipates potential difficulties (Rohimah et al., 2024).

Previous studies have investigated learning obstacles in real analysis but in limited contexts focusing on epistemological obstacles, such as difficulties in applying concepts, understanding principles, interpreting problems, and constructing proofs (Isnani et al., 2022). Other studies have examined general student difficulties (Perbowo & Pradipta, 2017) without using the Brosseau framework. Studies about learning obstacles have also extended to different courses, such as geometric transformations (Kandaga et al., 2022; Noto et al., 2019), and introductory proof courses (Norton et al., 2025). Some studies have addressed obstacles in specific types of proofs, including mathematical induction (Sholihah, 2024), and proof by contradiction (Hamdani et al., 2023).

Based on previous studies, there are still gaps in exploring prospective mathematics teachers' learning obstacles in constructing proofs in real analysis. Therefore, this study aims to explore prospective mathematics teachers' learning obstacles, including ontogenic, epistemological, and didactical obstacles in real-analysis learning. The findings of this study are expected to serve as a reference in developing teaching materials and learning strategies that can minimize obstacles and support the development of prospective mathematics teachers' mathematical abilities. By understanding the various obstacles, lecturers can more effectively design adaptive and responsive learning strategies to meet prospective mathematics teachers' needs, particularly developing essential proof construction in real analysis.

METHOD

This study used a qualitative approach with a case study design. The subjects were 20 third-year prospective mathematics teachers at a university in Palu City who were selected using purposive sampling because they had taken real analysis courses. Data collection techniques included a Respondent Ability Test (RAT) and interviews. The test consisted of two questions that had been tested for validity and reliability through expert judgment.

The data collected from the test results were categorized based on Brousseau's framework (2002). Ontogenic obstacles result from students' cognitive levels (Rohimah et al., 2024). Epistemological obstacles arise from students' inadequate understanding and mastery of a concept, problem, or other subject matter that is only relevant in certain situations (Hendriyanto et al., 2024). Meanwhile, didactic obstacles arise due to inappropriate didactic interventions (Sari et al., 2023).

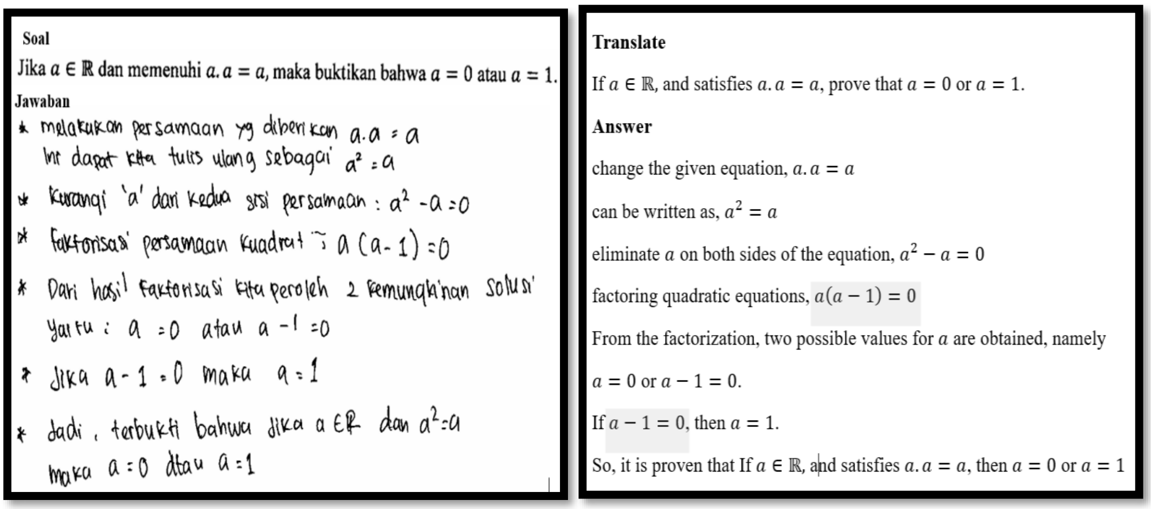
Next, unstructured interviews were conducted with five selected students based on the type of obstacle they experienced to confirm the test results. The data analysis techniques used included reduction, presentation, and conclusion drawing. Triangulation techniques were used to check the test results and interviews to ensure the credibility and validity of the data

RESULT AND DISCUSSION

The results of the study revealed that prospective mathematics teachers experienced ontogenic, epistemological, and didactical obstacles, as evidenced by the strategies they employed when solving problems related to real analysis

1. Ontogenic Obstacles

Researchers found that prospective teachers experienced ontogenic obstacles in real analysis. These obstacles indicate a gap in students' thinking as they struggle to solve proof problems. Students have difficulty thinking deductively and axiomatically, which shows that they do not fully understand the basic concepts in real analysis, as illustrated in Figure 1.



Soal

Jika $a \in \mathbb{R}$ dan memenuhi $a.a = a$, maka buktikan bahwa $a = 0$ atau $a = 1$.

Jawaban

* melakukan persamaan yg diberikan $a.a = a$ ini dapat kita tulis ulang sebagai $a^2 = a$
* Kurangi 'a' dari kedua sisi persamaan : $a^2 - a = 0$
* Faktorisasi persamaan kuadrat ; $a(a-1) = 0$
* Dari hasil faktorisasi kita peroleh 2 kemungkinan solusi yaitu : $a = 0$ atau $a - 1 = 0$
* Jika $a - 1 = 0$ maka $a = 1$
* dadi, terbukti bahwa jika $a \in R$ dan $a^2 = a$ maka $a = 0$ atau $a = 1$

Translate

If $a \in \mathbb{R}$, and satisfies $a.a = a$, prove that $a = 0$ or $a = 1$.

Answer

change the given equation, $a.a = a$

can be written as, $a^2 = a$

eliminate a on both sides of the equation, $a^2 - a = 0$

factoring quadratic equations, $a(a-1) = 0$

From the factorization, two possible values for a are obtained, namely

$a = 0$ or $a - 1 = 0$.

If $a - 1 = 0$, then $a = 1$.

So, it is proven that If $a \in \mathbb{R}$, and satisfies $a.a = a$, then $a = 0$ or $a = 1$

Figure 1. Answer PMTs03

Figure 1 shows that prospective mathematics teachers (PMTs03) could not solve the problem correctly. PMTs03 only used the concept of quadratic equations rather than definitions, properties, or theorems in real analysis to solve the problem. The results of the researcher's (R) interview with PMTs03 who experienced obstacles are as follows:

R : Can you explain how you solved the problem??

PMTs03 : I converted the equation into a quadratic form and factored it to obtain the value of a.

R : Do you think that this is a proof?

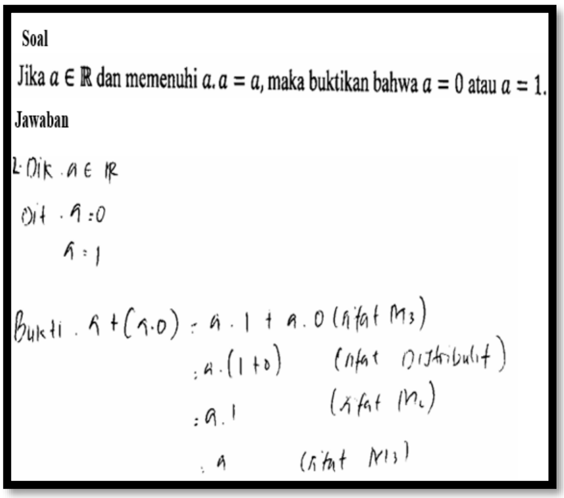
PMTs03 : Yes, because I found the value, which is 0 or 1, and obtained it through factorization.

The interview results indicate PMTs03 cannot think formally and deductively. PMTs03 still stuck in a procedural rather than an axiomatic framework of thinking. This reflects a lack of critical and analytical thinking skills, which hinders their ability to engage in the logical reasoning required for mathematical problem-solving (Isran et al., 2025).

PMTs03 solve proof problems procedurally because she believe that obtaining the result (0 or 1) through factorization is sufficient as proof. PMTs03 equate procedural solutions (quadratic factorization) with formal proofs. She do not yet understand that proofs require deductive reasoning based on properties/axioms and logical justification in each step of the solution. This aligns with Kandaga et. al (2022) that students use informal arguments, examples, and generalizations and draw conclusions from pictures more often..

2. Epistemological Obstacles

This obstacle refers to the limitations of the context prospective mathematics teachers understand, making it difficult to understand or internalize the abstract and formal concepts that form the basis for constructing proofs. The identified obstacle is prospective mathematics teachers' difficulty starting the proof construction. They show confusion when faced with proof problems in real analysis. They do not know the first steps to take, either in recognizing the logical form of a statement or in relating it to relevant definitions or theorems. The difficulties experienced by students can be seen in Figure 2.


Soal

Jika $a \in \mathbb{R}$ dan memenuhi $a.a = a$, maka buktikan bahwa $a = 0$ atau $a = 1$.

Jawaban

1. Dik . $a \in \mathbb{R}$

Dit . $a : 0$

$a : 1$

Bukti . $a + (a.0) = a.1 + a.0$ (sifat M3)

$= a.(1+0)$ (sifat distributif)

$= a.1$ (sifat M2)

$= a$ (sifat M3)

Translate

If $a \in \mathbb{R}$, and satisfies $a.a = a$, prove that $a = 0$ or $a = 1$.

Answer

Given $a \in \mathbb{R}$

Find $a = 0$ or $a = 1$

Prove

$a + (a.0) = a.1 + a.0$ (Property M3)

$= a(1 + 0)$ (Property Distributive)

$= a.1$ (Property M2)

$= a$ (Property M3)

Figure 2. Answer PMTs09

These difficulties arise because prospective mathematics teachers (PMTs09) cannot organize their knowledge appropriately to begin the deductive reasoning process. When constructing proofs, students find it difficult to logically connect different mathematical statements (axioms, definitions, and theorems) and apply definitions/theorems to choose the correct proof path (Chand, 2021). The limitations of the context studied by prospective mathematics teachers are caused by the fact that they only receive a complete understanding of concepts, so when faced with different contexts, they experience difficulties applying them (Suryadi, 2019). The results of the researcher's (R) interview with PMTs09 who experienced obstacles are as follows:

R : Can you explain how you solved the problem?
PMTs09 : I looked at the problem and thought it might be related to the algebraic properties of real numbers..
R : Then what did you do?
PMTs09 : I started with the distributive property and then used the addition and multiplication identities
R : So you tried to use a specific theorem or property?
PMTs09 : I tried using algebraic properties, but I'm unsure if they're appropriate.
R : What did you do next?
PMT09 : I got stuck in solving the problem because the result I got was different.

PMTs09 appeared hesitant in determining the right first step and did not understand the logical approach to prove the statement. When asked to explain the strategy, she mentioned that they tried to recall concepts in real number algebra, such as distributive properties and identity elements, assuming that the proof could be solved through these properties. Therefore, in solving proof problems, strong analytical skills are essential to identify the initial idea that needs to be proven (Widiati & Sthephani, 2018).

Another obstacle was the difficulty of prospective mathematics teachers in compiling a complete proof structure using relevant definitions, properties, or theorems. They only wrote down some of the steps of the proof, as shown in Figure 3.

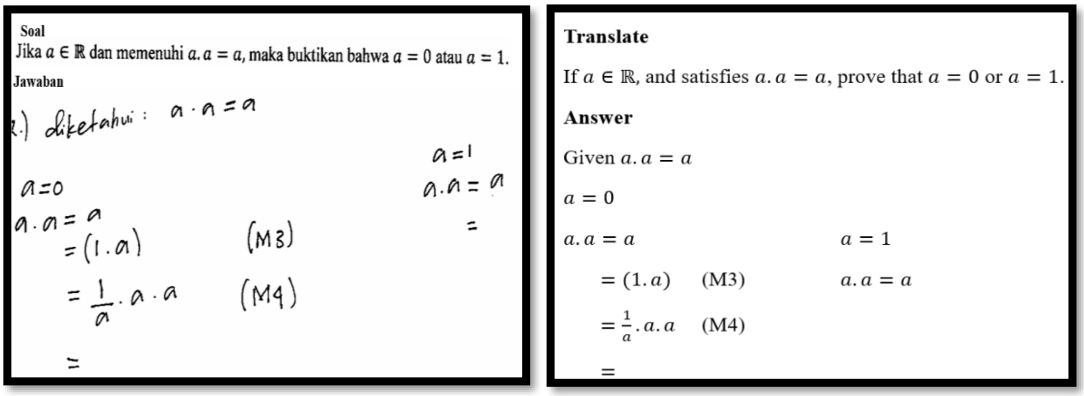


Figure 3. Answer PMTs11

Prospective mathematics teachers (PMTs11) have used relevant properties to start the proof process. However, the process was not completed. Although they were able to start the proof well, they faced challenges in understanding and applying basic concepts, leading to unstructured and incomplete proofs (Isran et al., 2025). The results of the researcher's interviews with PMTs11 who experienced obstacles are as follows.

R : Can you explain how you solved the problem?

PMTs11 : I started using the identity property and $a = 1.a$, rearranging the equation $1 = \frac{1}{a}.a$

R : Why did you choose to write it that way?

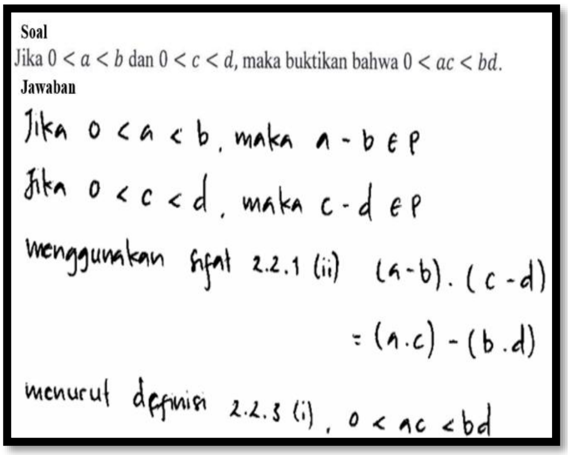
PMTs11 : Based on the problem, the property I used was the most appropriate to prove the statement.

R : Do you think your answer proves tha ta $= 0$ or $a = 1$?

PMTs11 : Not yet, but I'm unsure how to continue my answer.

PMTs11struggle to select relevant concepts in continuing the proof process. She fail to identify that other algebraic properties of real numbers can be the primary foundation for constructing a complete proof. This condition indicates that students do not yet have a good conceptual structure, where mathematical knowledge is mastered separately and organized for use in the context of proof. This suggests that prospective mathematics teachers have a limited understanding of how to apply mathematical concepts that are interrelated with the material being studied (Sunariah & Mulyana, 2020). Prospective mathematics teachers ' proof skills are weak because they are not familiar with the theorems given and experience difficulties and confusion if the conditions in the theorems are incomplete (Widiati & Sthephani, 2018).

Prospective mathematics teachers also encountered obstacles in understanding concepts in real analysis. In the proof process, they did not accurately describe a mathematical statement. This is shown in Figure 4.


Soal

Jika $0 < a < b$ dan $0 < c < d$, maka buktikan bahwa $0 < ac < bd$.

Jawaban

Jika $0 < a < b$, maka $a - b \in P$

Jika $0 < c < d$, maka $c - d \in P$

Menggunakan sifat 2.2.1 (ii) $(a-b).(c-d)$

$= (a.c) - (b.d)$

menurut definisi 2.2.3 (i), $0 < ac < bd$

Translate

If $0 < a < b$ and $0 < c < d$, prove that $0 < ac < bd$

Answer

If $0 < a < b$, then $a - b \in P$.

If $0 < c < d$, then $c - d \in P$.

Using property 2.2.1 (ii), $(a - b).(c - d)$

$= (a.c) - (b.d)$

According to the definition 2.2.3 (i), $0 < ac < bd$

Figure 4. Answer PMTs14

Prospective mathematics teachers (PMTs14) find it challenging to understand and apply formal definitions in the context of mathematical proofs. Epistemological obstacles can result from errors in understanding mathematical concepts, definitions, or procedures, which are often caused by superficial or limited understanding (Elfiah et al., 2020). In this case, PMTs14 wrote that because $a < b$ then $a - b \in P$. The results of the researcher's interviews with PMTs14 who experienced obstacles are as follows.

R : Can you explain how you solved the problem?

PMTs14 : I started by using the definition of positive numbers

R : Y ou stated that why$0 < a < b$, maka $a - b \in P$. Can you explain?

PMTs14 : Because I see that $a > 0$ dan $a < b$, then $a - b$ is a positive number

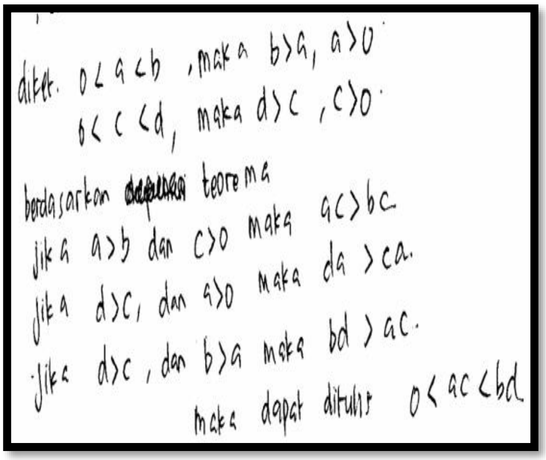
R : Is the result a positive number?

PMTs14 : No, it should be negative. So, I was wrong.

The interview results indicate PMTs14 still think intuitively when solving problems. She find it difficult to relate their knowledge to new contexts, especially when understanding more abstract mathematical concepts (Chand, 2021). Variations in conceptual understanding based on thinking styles can lead to inconsistent knowledge (Armah & Kissi, 2019). The lower the mathematical understanding, the more complex the learning obstacles experienced by an individual (Nurhayati et al., 2023)

3. Didactical Obstacle

A didactical obstacle will occur if the learning process does not match the students' learning trajectoires (Mahmud et al., 2023). Therefore, lecturers are essential in facilitating students' understanding of concepts. A didactical obstacle occurs when the instructions given by the teacher are only procedural (Rohimah et al., 2024). Figure 5 presents the findings related to the didactical obstacles that occurred.



Translate

If $0 < a < b$ and $0 < c < d$, prove that $0 < ac < bd$

Answer

Given $0 < a < b$, then $b > a, a > 0$

$0 < c < d$, then $d > c, c > 0.$

According to the theorem

If $a > b$ and $c > 0$, then $ac > bc$

If $d > c$ and $a > 0$, then $da > ca$

If $d > c$ and $b > a$, then $bd > ac$

therefore, it can be written that $0 < ac < bd$

Figure 5. Answer PMTs20

In Figure 5, PMTs20 only work procedurally without understanding the proven concepts' interrelationships. This error occurs because PMTs20 only memorize facts and procedures but do not understand the concepts. The results of the interview with the PMTs20 are as follow

R : Can you explain how you solved the problem?

PMTs20 : I started by using the multiplication theorem with positive numbers.

R : What was your purpose in breaking down the parts separately ($a > b, d > c$)?

PMTs20 : I used the parts in the problem to solve the problem

The interview results indicate PMTs20 only think procedurally when solving problems. PMTs20 lack the appropriate connections in learning definitions due to irrelevant learning practices, which prevents them from understanding them meaningfully and applying them in unfamiliar situations (Chand, 2021). If the material is presented inappropriately using unsuitable methods and approaches, it will result in learning obstacles (Firdaus et al., 2022).

CONCLUSION

This study identified three types of learning obstacles encountered by prospective mathematics teachers when constructing proofs in real analysis namely ontogenic, epistemological, and didactical obstacles. Ontogenic obstacles arise when there is a gap in the thinking process of prospective mathematics teachers. They have difficulty thinking deductively and axiomatically. Epistemological obstacles occur because of the limited contextual understanding of prospective mathematics teachers, resulting in difficulties in understanding definitions, difficulties in starting proofs, and difficulties in constructing complete proofs. Didactical obstacles occur because of a procedural approach to learning.

This study provides significant insights into the characteristics of learning obstacles experienced by prospective mathematics teachers in the context of proof in real analysis. This information can be used to design learning that anticipates learning obstacles. This learning design can also facilitate students' learning trajectories, making learning more meaningful. However, this study has several limitations. The sample size was relatively small, which may affect the generalizability of the findings. Additionally, the scope of the study was limited to real numbers within real analysis, suggesting a need for further research that explores learning obstacles across a broader range of mathematical topics.

ACKNOWLEDGMENT

The researchers would like to thank the head of the mathematics education study program, lecturers, and all participants involved in this study.

AUTHOR CONTRIBUTIONS
Author One : Conceptualization, writing - original draft, and Investigation
Author Two : Validation and Supervision
Author Three : Writing - Review & editing,
Author Four : Writing - Review & editing
Author Five: Formal analysis
Author Six : Data Curation

REFERENCES

Armah, R. B., & Kissi, P. S. (2019). Use of the van Hiele Theory in Investigating Teaching Strategies used by College of Education Geometry Tutors. *EURASIA Journal of Mathematics, Science and Technology Education*, *15*(4). https://doi.org/10.29333/ejmste/103562

Ashari, N. W. & Salwah. (2021). Bringing Real Analysis Subject Into Real Life: An Experimental Research for Prospective Teacher of Mathematics Study Program Using Realistic Mathematics Education. *Journal of Physics: Conference Series*, *1752*(1), 012010. https://doi.org/10.1088/1742-6596/1752/1/012010

Brouseau, G. (2002). *Theory of Didactical Situation in Mathematics*. Kluwer Academic Publishers.

Caglayan, G. (2018). Real analysis students' understanding of pointwise convergence of function sequences in a DGS assisted learning environment. *The Journal of Mathematical Behavior*, *49*, 61–81. https://doi.org/10.1016/j.jmathb.2017.09.001

Chand, H. B. (2021). Difficulties Experienced by Undergraduate Students in Proving Theorems of Real Analysis. *Scholars' Journal*, 149–163. https://doi.org/10.3126/scholars.v4i1.42475

Di Martino, P., & Gregorio, F. (2019). The Mathematical Crisis in Secondary–Tertiary Transition. *International Journal of Science and Mathematics Education*, *17*(4), 825–843. https://doi.org/10.1007/s10763-018-9894-y

Elfiah, N. S., Maharani, H. R., & Aminudin, M. (2020). Hambatan Epistemologi Siswa Dalam Menyelesaikan Masalah Bangun Ruang Sisi Datar. *Delta: Jurnal Ilmiah Pendidikan Matematika*, *8*(1), 11. https://doi.org/10.31941/delta.v8i1.887

Faisal, T. A., Hasanah, R. U., & Fatmawati, R. (2024). Systematic Literatur Review (SLR): Analisis Problematika Mahasiswa Pendidikan Matematika Pada Mata Kuliah Analisis Real. *Student Scientific Creativity Journal*, *2*(3), 42–51. https://doi.org/10.55606/sscj-amik.v2i3.3129

Fauzi, I., & Suryadi, D. (2020). The Analysis of Students' Learning Obstacles on the Fraction Addition Material for Five Graders of Elementary Schools. *Al Ibtida: Jurnal Pendidikan Guru MI*, *7*(1), 33. https://doi.org/10.24235/al.ibtida.snj.v7i1.6020

Firdaus, R., Sa'ud, U. S., & Arisetyawan, A. (2022). Desain Didaktis Untuk Mengatasi Hambatan Belajar Pada Keliling Dan Luas Persegi Serta Persegi Panjang. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(4), 3632. https://doi.org/10.24127/ajpm.v11i4.5592

Hamdani, D., Purwanto, Sukoriyanto, & Anwar, L. (2023). Causes of proof construction failure in proof by contradiction. *Journal on Mathematics Education*, *14*(3), 415–448. https://doi.org/10.22342/jme.v14i3.pp415-448

Helma, H., & Murni, D. (2021). Study of factors affecting student learning outcomes in Real Analysis lectures during the Covid-19 pandemic.

Journal of Physics: Conference Series, *1742*(1), 012039. https://doi.org/10.1088/1742-6596/1742/1/012039

Hendriyanto, A., Suryadi, D., Juandi, D., Dahlan, J. A., Hidayat, R., Wardat, Y., Sahara, S., & Muhaimin, L. H. (2024). The didactic phenomenon: Deciphering students' learning obstacles in set theory. *Journal on Mathematics Education*, *15*(2), 517–544. https://doi.org/10.22342/jme.v15i2.pp517-544

Isnani, I., Waluya, S. B., Dwijanto, D., & Asih, T. S. N. (2022). Analysis Of Students' Difficulties In Mathematical Proof Ability Viewed From An Epistemological Aspect. *ISET: International Conference on Science, Education and Technology*, 735–739.

Isnani, I., Waluya, S. B., Rochmad, R., Sukestiyarno, S., Suyitno, A., & Aminah, N. (2020). How is Reasoning Ability in Learning Real Analysis? *Proceedings of the International Conference on Agriculture, Social Sciences, Education, Technology and Health (ICASSETH 2019)*. International Conference on Agriculture, Social Sciences, Education, Technology and Health (ICASSETH 2019), Cirebon, Indonesia. https://doi.org/10.2991/assehr.k.200402.059

Isran, D., Susanta, A., Rahimah, D., & Syafri, F. S. (2025). Exploring Mathematical Proofs and Solutions in Higher Education: A Case Study on Real Analysis. *Jurnal Pendidikan Matematika*, *19*(1), 163–180. https://doi.org/10.22342/jpm.v19i1.pp163-180

Kandaga, T., Rosjanuardi, R., & Juandi, D. (2022). Epistemological Obstacle in Transformation Geometry Based on van Hiele's Level. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(4), em2096. https://doi.org/10.29333/ejmste/11914

Komatsu, K. (2016). A framework for proofs and refutations in school mathematics: Increasing content by deductive guessing. *Educational Studies in Mathematics*, *92*(2), 147–162. https://doi.org/10.1007/s10649-015-9677-0

Koparan, T., & Rodríguez-Alveal, F. (2022). Probabilistic thinking in prospective teachers from the use of TinkerPlots for simulation: Hat problem. *Journal of Pedagogical Research*, 5. https://doi.org/10.33902/JPR.202217461

Mahmud, M. R., Turmudi, T., Sopandi, W., Rohimah, S. M., & Pratiwi, I. M. (2023). Learning obstacles analysis of lowest common multiple and greatest common factor in primary school. *Jurnal Elemen*, *9*(2), 440–449. https://doi.org/10.29408/jel.v9i2.12359

Mardianto, N. F. D., Hasanah, R. U., Nasution, S. F. Y., & Sazatul Asmal. (2024). Analisi Kesulitan Mahasiswa dalam Perkuliahan Analisis Real. *Jurnal Arjuna : Publikasi Ilmu Pendidikan, Bahasa Dan Matematika*, *2*(3), 28–36. https://doi.org/10.61132/arjuna.v2i3.778

Mutaqin, A., Syamsuri, S., & Hendrayana, A. (2022). Analisis kesulitan mahasiswa dalam pembuktian matematis pada mata kuliah analisis real. *Tirtamath: Jurnal Penelitian Dan Pengajaran Matematika*, *4*(1), 1–11. https://dx.doi.org/10.48181/tirtamath.v4i1.15907

Norton, A., Antonides, J., Arnold, R., & Kokushkin, V. (2025). Logical implications as mathematical objects: Characterizing epistemological obstacles experienced in introductory proofs courses. *The Journal of Mathematical Behavior*, *79*, 101253.

https://doi.org/10.1016/j.jmathb.2025.101253
Noto, M. S., Priatna, N., & Dahlan, J. A. (2019). Analysis of learning obstacles on transformation geometry. *Journal of Physics: Conference Series*, *1157*, 042100. https://doi.org/10.1088/1742-6596/1157/4/042100
Nurafni, N., Miatun, A., Khusna, H., & Jusra, H. (2019). Pengembangan Bahan Ajar Materi Induksi Matematika Dan Teori Binomial Berbasis Pembuktian. *KALAMATIKA Jurnal Pendidikan Matematika*, *4*(1), 89–108. https://doi.org/10.22236/KALAMATIKA.vol4no1.2019pp89-108
Nurhayati, L., Suryadi, D., Dasari, D., & Herman, T. (2023). Integral (antiderivative) learning with APOS perspective: A case study. *Journal on Mathematics Education*, *14*(1), 129–148. https://doi.org/10.22342/jme.v14i1.pp129-148
Perbowo, K. S., & Pradipta, T. R. (2017). Pemetaan Kemampuan Pembuktian Matematis Sebagai Prasyarat Mata Kuliah Analisis Real Mahasiswa Pendidikan Matematika. *KALAMATIKA Jurnal Pendidikan Matematika*, *2*(1), 81. https://doi.org/10.22236/KALAMATIKA.vol2no1.2017pp81-90
Roh, K. H., & Lee, Y. H. (2017). Designing Tasks of Introductory Real Analysis to Bridge a Gap Between Students' Intuition and Mathematical Rigor: The Case of the Convergence of a Sequence. *International Journal of Research in Undergraduate Mathematics Education*, *3*(1), 34–68. https://doi.org/10.1007/s40753-016-0039-9
Rohimah, S. M., Anaya, S. N., Putri, S. A., & Nurdiansah, Y. (2024). Challenges In Learning Multiplication: A Study On Elementary School Students. *Kalamatika: Jurnal Pendidikan Matematika*, *9*(2), 213–224. https://doi.org/10.22236/KALAMATIKA.vol9no2.2024pp213-224
Sari, A. D., Suryadi, D., & Dasari, D. (2023). Learning obstacle of probability learning based on the probabilistic thinking level. *Journal on Mathematics Education*, *15*(1), 207–226. https://doi.org/10.22342/jme.v15i1.pp207-226
Septiati, E. (2021). Kemampuan Mahasiswa Dalam Mengkonstruksi Bukti Matematis Pada Mata Kuliah Analisis Real. *Indiktika : Jurnal Inovasi Pendidikan Matematika*, *4*(1), 64–72. https://doi.org/10.31851/indiktika.v4i1.6761
Sholihah, W. (2024). Analisis Hambatan Belajar Pada Pembuktian Induksi Matematika Dalam Kemampuan Pemahaman Matematis Mahasiswa. *Jurnal Derivat: Jurnal Matematika Dan Pendidikan Matematika*, *11*(2), 157–167. https://doi.org/10.31316/jderivat.v10i2.6225
Siswono, T. Y. E., Hartono, S., & Kohar, A. W. (2020). Deductive Or Inductive? Prospective Teachers' Preference Of Proof Method On An Intermediate Proof Task. *Journal on Mathematics Education*, *11*(3), 417–438. https://doi.org/10.22342/jme.11.3.11846.417-438
Sucipto, L., & Mauliddin, M. (2017). Analisis Kesulitan Belajar Mahasiswa Dalam Memahami Konsep Bilangan Real. *Beta Jurnal Tadris Matematika*, *9*(2), 197. https://doi.org/10.20414/betajtm.v9i2.37
Sunariah, L., & Mulyana, E. (2020). The didactical and epistemological obstacles on the topic of geometry transformation. *Journal of Physics: Conference Series*, *1521*(3), 032089. https://doi.org/10.1088/1742-6596/1521/3/032089

Suryadi, D. (2019). *Penelitian desain didaktis (DDR) dan implementasinya*. Gapura Press.

Widiati, I., & Sthephani, A. (2018). Difficulties analysis of mathematics education students on the real analysis subject. *Journal of Physics: Conference Series*, *1088*, 012037. https://doi.org/10.1088/1742-6596/1088/1/012037