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Learning Obstacle of Integral Course Learning Based on APOS Theory Perspective

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Abstrak

Penelitian ini bertujuan untuk mengetahui learning obstacle mahasiswa calon guru dalam pembelajaran integral tentu. Pentingnya integral dalam meningkatkan mutu pendidikan menuntut pemahaman yang lebih mendalam dari para guru agar materi ini dapat diajarkan secara efektif. Penelitian ini merupakan penelitian kualitatif dengan studi kasus yang difokuskan pada 10 mahasiswa calon guru Matematika di Universitas swasta di bandung, Indonesia, yang dipilih secara purposive sampling. Mahasiswa diberikan soal TKR (tes kemampuan responden) sebagai tes kemampuan awal dalam pemahaman konsep integral tentu. Selanjutnya, menggunakan analisis APOS (Aksi, proses, objek dan skema) melalui wawancara In-depth interview diperoleh indikasi learning obstacle dari mahasiswa. Hasil yang diperoleh, siswa mengalami hambatan belajar didaktis, hambatan belajar ontogenik konseptual khususnya materi aljabar sebagai prasyarat pembelajaran integral yang belum dipahami dengan baik dan psikologi dimana siswa mengalami hambatan belajar karena kurangnya rasa percaya diri dalam menyelesaikan masalah perhitungan integral tentu. Learning obstacle yang ditemukan dapat dijadikan dasar dalam membuat desain pembelajaran yang epistemic.
Kata Kunci: Hambatan Belajar; Hambatan Belajar Ontogenic; Integral Tentu; Teori APOS.

Abstract

This research aims to determine the learning obstacles of prospective teacher students in integral learning of course. The importance of integrals in improving educational quality requires teachers to have a deeper understanding of this topic to teach it effectively. This research is a qualitative research with a case study focused on 10 prospective Mathematics teacher students at a private university in Bandung, Indonesia, who were selected using purposive sampling. Students are given TKR (respondent ability test) questions as an initial ability test in understanding integral concepts of course. Furthermore, using APOS analysis (Action, process, object and scheme) through in-depth interviews, indications of learning obstacles were obtained from students. The results obtained showed that students experienced didactic learning obstacles, conceptual ontogenic learning obstacles, especially algebraic material as a prerequisite for integral learning that has not been well understood, and psychology where students experienced learning obstacles due to a lack of self-confidence in solving definite integral calculation problems. The learning obstacles found can be used as a basis for creating epistemic learning designs
Keywords: Learning obstacle; Ontogenic learning obstacles; Definite Integral; APOS Theory.

I. INTRODUCTION

Integral has an important role in various scientific disciplines and develops human thinking (Nurhayati, Suryadi, et al., 2023). According to Permendikbud Number 7 of 2022 on Content Standards, high school students must understand integrals to compute surface area and volume in mathematics. Teachers, therefore, need a deeper understanding of integrals to effectively teach this material, as they are pivotal in enhancing educational quality (Nugraheni & Jailani, 2020; Nuraeni & Siregar, 2024). Many students, however, struggle to grasp the idea of integral.

A strong grasp of integral concepts among prospective teachers is fundamental for effective knowledge transposition (Salam, 2023). These future educators play a crucial role in teaching integral concepts to their students. According to Gunawan et al (2019) indicators of conceptual understanding include: interpreting a concept from multiple perspectives, translating between verbal statements and mathematical symbols, predicting trends from data, applying algorithms and procedures skillfully, and connecting related concepts. Mastery of these concepts is essential for enhancing mathematical reasoning, especially in integral learning

Based on the results of preliminary research, many prospective mathematics teachers at Langlang Buana University have experienced obstacles in understanding the concept of integrals including definite integrals. One of the factors that has caused students' lack of understanding in integral learning is the existence of learning obstacle problems (Kurniawan et al., 2019; Nurhayati, Priatna, et al., 2023; Nurhayati, Suryadi, et al., 2023; Yulianti et al., 2021). Learning obstacles are those that arise from outside the student. Ontogenic, epistemological, and didactic learning obstacles are the three categories of learning obstacles. Ontogenic obstacles to learning are classified into three types: psychological, instrumental, and conceptual (Suryadi, 2019). The objective of this study is to identify the sorts of learning obstacles encountered by prospective mathematics teacher students when studying the concept of integral. What kinds of learning challenges do prospective mathematics teachers have when learning integral? This is the research's central question. It is possible to increase the quality of integrated learning by anticipating learning obstacles by understanding the types of obstacles to learning encountered by students.

The importance of knowing the types of learning obstacles experienced by students is in line with the many relevant studies related to learning obstacles. Among these, Fadillah et al. (2019) examined obstacles to learning in integrated learning in general for high school students. Furthermore, learning obstacles in integral (antiderivative) material with a didactic situation theory approach for civil engineering students (Nurhayati, Priatna, et al., 2023). A similar study was undertaken by (Nurhayati, Suryadi, et al., 2023) on the analysis of learning obstacles in antiderivative learning using the APOS theory technique. Another study was conducted to eliminate learning obstacles in indefinite integral material of algebraic functions (Sufitri et al., 2023). The novelty

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of this research is to analyze the learning obstacle of understanding the concept of definite integral of prospective teacher students by using the APOS (Action, Process, Object-Scheme) theory approach (Dubinsky et al., 2014; Winarsih & Mampouw, 2019; Novianti & Pratama, 2022) as in Figure 1 below (Nurhayati et al., 2023).

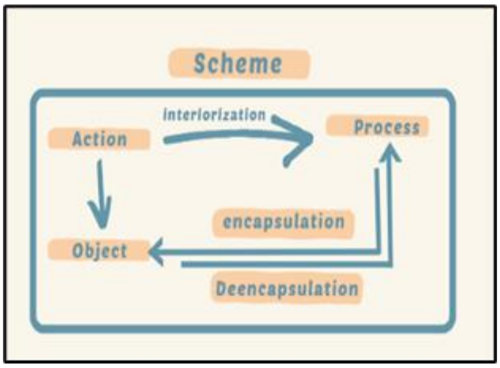

Figure 1. APOS Theory Flow

II. METHOD

This research is case study qualitative research (Creswell, 2018). A case study is a heuristic that functions continuously to focus one's attention on a phenomenon by collecting evidence by involving a careful depiction of the phenomenon that occurs based on facts. A case study of a phenomenon cannot understand all phenomena thoroughly without giving meaning to the experiences of the research subject. Case study became the paradigm of this research in finding learning obstacles of prospective teachers through the learning experience of prospective teachers in learning the concept of definite integral with the APOS (Action, Process, Object-Schema) theory perspective approach.

This research was conducted in the mathematics education study program at a private university in Bandung, Indonesia in October 2023. The research sample was selected using purposive sampling technique (Etikan, 2016). The sample was selected with certain objectives and considerations. The research samples were 10 students of the prospective mathematics teachers who had attended calculus lectures, especially about the definite integral. The prospective math teacher students were given a test about understanding the concept of definite integral (Utari & Utami, 2020). This research went through several stages, as shown in Figure 2 below.

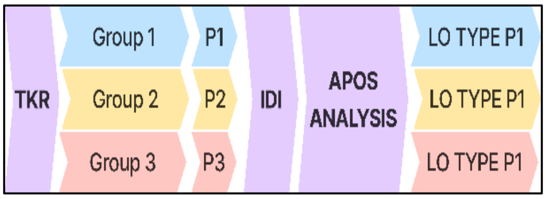

Figure 2. Research Flow

The Respondent Ability Test (TKR) was given to all research participants in the first stage. In this study, the test instrument was a test question on understanding the idea of definite integral, which consisted of five questions based on the concept understanding. The TKR question instrument was validated by expert judgment. Essentially, the readability of the questions was validated by the respondents themselves by looking at the answers and explanations given by the respondents (Nurhayati, Suryadi, et al., 2023). This written test question is intended to assess the participants' comprehension abilities. Following the written test, the participants' test results were checked in the second stage.

The work of the participants was divided into three categories. Using the Holistic Scoring Rubrics, three categories were defined for the integral concept comprehension test results, as shown in Table 2 below. The Holistic Scoring Rubrics were used to grade the participants' responses. Moskal (2000), defines the Holisctic scoring Rubric as a comprehensive assessment with no separate components. The rubric was modified to reflect the indicators of comprehension of the integral concept.

Table 1.
Test Result Criteria

Score	Criteria
Score ≥ 75	High comprehension ability
60 ≤ Score <75	Moderate comprehension ability
Score < 60	Low comprehension ability

In the third stage, one person from each of the three groups was chosen by purposive sampling (Campbell et al., 2020) to represent the group. After taking a TKR problem test, students were asked to confirm their answers with an in-depth individual interview (IDI) in the fourth stage (Carter et al., 2014). The fifth stage involves researchers using APOS theory to identify learning obstacles experienced by students through individual in-depth interviews. Furthermore, the data triangulation method was used for data analysis. All TKR test question results, as well as detailed individual and observation results, were reduced, presented, and concluded using triangulation techniques (Alfansyur & Mariyani, 2020).

III. Result and Discussion

The participants' TKR results were categorized using Holistic Scoring Rubrics, with P1 representing the high comprehension group. P1 correctly solved the first problem but demonstrated only procedural understanding, relying on perceptual knowledge and previously learned integral rules. Through APOS analysis, it was revealed that P1 did not fully grasp the underlying concept, particularly the idea of calculating the area. P1's understanding was limited to replicating classroom examples, likely due to the constraints of online learning during the pandemic. This aligns with Purnomo et al., (2018), who noted that such reliance on examples and external resources can hinder deep conceptual understanding, leading to didactical learning obstacles.

The TKR results of questions number 2, 3 and 5, respectively, P1 had the right answer as number 1. However, after an interview related to the completion of numbers 2, 3 and 5, P1 could explain it correctly. This is because the researcher conducted scaffolding related to the first problem solving, so that P1 did not find it difficult to solve problems number 2 and 3. Based on APOS analysis, using his memory knowledge, P1 took action by doing the problem well. P1 did interiorization related to how the calculation of $\int_1^3 (2x+1)\,dx = [x^2+2]_1^3$ so that it can produce a value of 10. Based on the results of IDI and scaffolding number 1, P1 understood that 10 here means that the area under the function $f(x) = 2x + 1$ bounded by the $x = 1$ axis, $x = 3$ axis and $y = 0$ axis has an area of 10 units. This led P1 to be able to express the function $f(x) = x + 2$ bounded by $x = 2$ axis, $x = 4$ axis and $y = 0$ axis into the form $\int_2^4 (x+2)\,dx$ easily. Thus, P1 has encapsulated and deencapsulated well in producing the object of understanding the integral concept, so that a scheme is formed in understanding the concept. P1 is able to choose the right strategy in problem solving.

Students will understand the purpose or object of the problem well if they have been able to determine what are the similarities and differences between problems with each other, thus solving each problem well. P1 has been able to translate problem number 5 into mathematical symbols and understand the meaning of the problem. P1's experience of working on similar problems several times, resulted in P1 having no difficulty in calling on his memorial knowledge in solving these problems. However, in the TKR results P1 wrote that "because there is no minus in the displacement distance, the distance = 20, not -20". It can be seen from this that P1 deencapsulates the object that the definite integral, which is the distance, is always positive. P1 can achieve a well-defined integral learning scheme related to solving problems that use the definite integral that is not only limited to the area but also calculates the distance displacement as problem number 5 by doing some scaffolding.

P1 experienced a tendency to make mistakes in solving problem number 4. P2's TKR results for answer number 4 are shown in Figure 3. According to the interview results, P1 can perform action, followed by interiorization of algebraic material as apriori knowledge. Therefore, P1 made the decision to describe the form of $\int_1^3 2x^2(3x^3+4)^4 dx$. P1 did this because the memorization was stronger in describing the form of polynomial functions of rank 4 compared to the memorization related to integration techniques. P1 interiorizes the polynomial function so that the process of translation and multiplication with each term is formed because what P1 thinks must be in the form of a basic integral formula, namely $\int x^n dx = \frac{1}{n+1} x^{n+1}$.

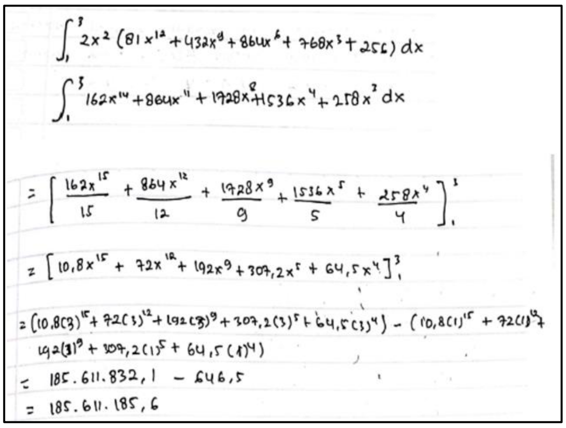

Figure 3. P1's Answer

Despite P1's efforts, the object of the substitution integration technique was not successfully formed, as P1 neither encapsulated nor deencapsulated the technique. Lacking recall of substitution or partial integration methods, P1 resorted to decomposing the polynomial function into repeated multiplications and using distribution to solve the problem. Although proficient in algebraic methods, P1's approach did not align with the intended learning objective, preventing the formation of the integration technique scheme. This limitation became evident when P1 struggled with polynomial functions of higher degrees. These findings align with Marhayati & Farida (2018), who noted that errors in applying the substitution technique often stem from a lack of conceptual understanding, leading students to rely on remembered strategies rather than grasping the integral concept fully.

Furthermore, the second group with moderate understanding ability is represented by P2. Based on the results of the interview, P2 did not understand the concept of definite Integral. In the results of P2's confirmation of the completion of problem number 1, the difficulty P2 faced was that P2 did not understand $\int_1^3 2x + 1\, dx$ meaning, even though P2 knew that it was a definite integral. P2 did not understand what the results of the work meant. The results of the analysis with APOS showed that P2 performed mental actions by using perceptual by being able to read and do the problem well as in Figure 3a below. P2 can work well according to what was read from the source book. P2 performed interiorization so that a process was formed in the memory and could recall what was in thought with encapsulation and deencapsulation to be able to work on problem number 1, resulting in an object. However, P2 did not correctly believe in the answer, but believed that the steps taken were correct.

The below indicates that the learning obstacle found from P2 is ontogenical learning obstacle psychology. P2 experienced psychological problems with lack of confidence in working on the problem. In addition, this also shows that the schema was not formed to understand the integral material. P2 experienced didactical learning obstacles. This can be seen from the results of interviews related to the understanding. P2 only followed what was written in the book procedurally. P2 could not explain what was meant by 10 from the results of the answer. This is in accordance with what Utari & Utami (2019) stated that the majority of students tend to have advantages in the ability to understand concepts procedurally, but they do not conduct in-depth analysis and only have a limited understanding of the integration process.

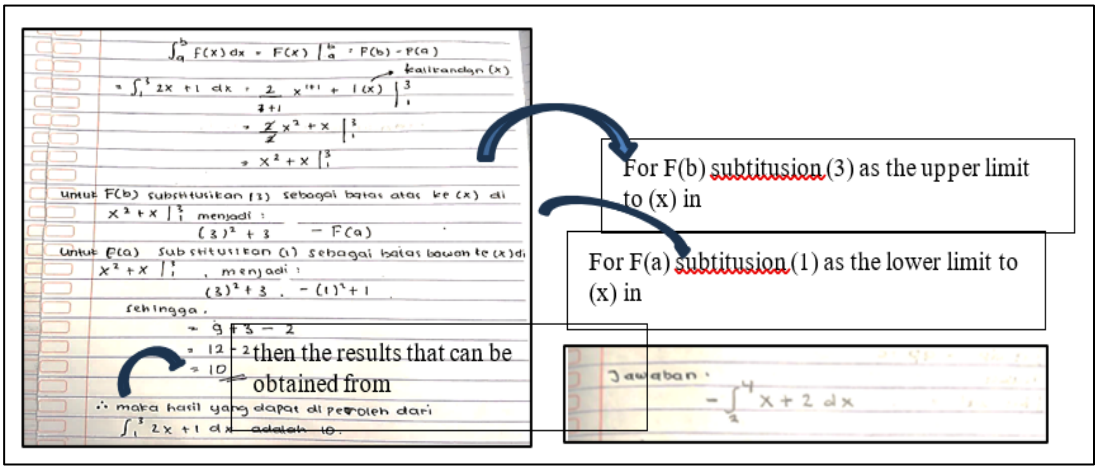

Figure 4. P2's Answer

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As shown in Figure 4, TKR P2's answer to question number 2 appears to be incorrect. Why is it negative, will be answered by the results of the IDI interview. P2 stated that it was because the area was under the curve, but P2 did not understand what the area under the curve was or whether it was below or above the x-axis. P2 was perplexed by the concept of area represented in integral form. P2 only performed mental actions while working on this problem, unable to retrieve previously learned knowledge. In this case, P2 encapsulated the previously learned material, resulting in the formation of an integral thought process related to area. However, no deencapsulation occurred, so P2 was unable to form an object of the area material under the curve with predetermined limits.

Because P2 had difficulty describing the area curve, P2 had difficulty determining the correct integral model for the area problem. This result is consistent with (Dharshinni, 2021)'s claim that understanding of integral material is strongly influenced by students' ability to describe the area of curve which indirectly is an apriori algorithm for understanding the concept of integral area under the curve. Similarly, Wagner's (2018) study argues that many students try to explain what integrals do by using their understanding of algebra to interpret the symbolic operations involved. However, it is the understanding of the Riemann integral that is the basis for understanding what the integral is.

P2 provided an accurate response to question number 3's TKR results, following to the same pattern as shown in Figure 4. It does not, however, display the correct integration results. P2 used perceptual and memory knowledge to perform mental actions by answering and thinking about the problem even though it was incorrect. P2 interiorized the existing pattern, resulting in the calculation process of $\frac{c}{d+a}$ and $\frac{c}{d+a}$. However, P2 was unable to encapsulate and deencapsulate the process from previous patterns, so the value of b in the problem appeared to have no effect. This was reinforced during the IDI interview, when P2 was given some guidance or scaffolding in the form of changing the boundaries of the integral, despite the fact that P2 was unable to make the next pattern. Septiyana et al., (2023) stated that algebraic communication skills are important skills needed to solve mathematical problems including algebraic patterns. Algebra must be mastered by students because it is related to other materials, including integral calculations. However, after being directed in detail and procedurally, only then P2 could mention the general form. This shows that P2 still has difficulty in carrying out the mental process of algebra as apriori knowledge in the memory so that P2 has difficulty encapsulating and deencapsulating into the intended integral object. From this, it can be identified that P2 also experienced conceptual ontogenical learning obstacles. Where, algebraic material as a prerequisite material for integral learning has not been understood properly which becomes an obstacle in the calculation of the definite integral.

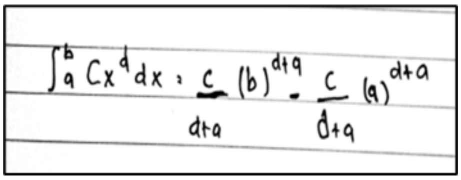

Figure 5. P2's Answer of Number 3

As with the results of TKR number 3, P2 made a mistake in solving question number 4. From the IDI results to confirm the answer number 4, P2 only reached the metal action stage with interiorization related to prior knowledge. Additionally, P2 encountered numerous challenges, particularly those relating to algebraic problems. P2 wrote that $\int_1^3 2x^2(3x^3+4)^4dx = 2x^2\int_1^3(3x^3+4)^4dx$. This demonstrates that P2 cannot tell the difference between the variable and the constant in integration. After the interview, P2 admitted that he/she did not understand the constants and variables in integration. In addition, P2 made mistakes in the integral calculation process. P2 wrote $2x^2\int_1^3(3x^3+4)^4dx = 2x^2\left(\frac{3}{3+1}x^{3+1}+4(x)\right)^4 |_1^3$. P2's conceptual understanding is only limited to the use of the basic formula that he/she has remembered in working on problem number 3. P2 immediately integrates $3x^3$ and 4 against x regardless of the power of 4 outside the () sign. P2 tends not to understand the concept of substitution integration technique. According to the findings of the APOS analysis from the interview process, P2 engages in mental action and interiorization until the process of remembering the algebraic material is completed. P2 was unable to encapsulate or deencapsulate the previously required materials in the substitution integration technique process. Similarly, when P2 was given scaffolding and similar problems with different forms, P2 realised that P2 had made an error while working on the problem. Despite knowing the error, P2 was unable to solve the problem properly. P2 is incapable of achieving mental objects relating to substitution and partial methods on the definite integral.

Likewise, the results of TKR P2's answer to question number 5 had errors. P2 wrote the answer $\int_1^5 3t^2-24t+3t$, the first error did not include dt as an indicator of the integration variable, then wrote +3 as $3t$. However, after being confirmed through an interview P2 stated that he did not understand the problem and was confused in translating the problem into an integral symbol. In addition, P2 did not understand the meaning of the number "20" obtained from the calculation results. Based on APOS analysis, P2 has a didactic learning obstacle tendency from the book that has been studied in understanding the concept of the problem with the formula obtained. P2 only followed the instructions of the source book as written in the textbook, but when given a problem that differed from the example in the book, P2 was unable to complete the problem properly. P2 did not form a definite integral scheme in this case. These findings are consistent with the findings Musyrifah et al., (2022) research, which show that students can work on problems procedurally but struggle when given different problems. Similarly, Nurrahmah et al., (2022) believe that the habit of doing problems procedurally leads to a lack of understanding of mathematical concepts, making it difficult to form the desired object of knowledge.

P3 represents the next group for the criteria of low understanding ability. The TKR results for problem number 1, P3 made errors while solving problem number 1 even though the final answer was correct, which was 10. According to the interview results for solution number one, P3 did not understand the concept of integral well, did not know that the procedure chosen was incorrect, and did not know whether the answer was correct or incorrect. Similarly, with the results of TKR number 2 in Figure 6, P3 made mistakes from the start, despite the fact that the final answer was correct. P2 struggled to understand the problem, let alone solve it. According to the findings of the APOS analysis, P3 only performed mental actions by reading the problem and was unable to interiorize related to previous memory knowledge as a supporter of this integral material. Following further investigation through the IDI interview, it was discovered that P3 disliked her high school teacher because the teacher was a Field Experience Practice teacher. Even though P3 is a math education major, this made P3 dislike math. Based on this, it was determined that P3 had ontogenetic learning obstacle psychology. P3 mentally rejects what the lecturer will teach because P3 recalls the previous teacher, making it difficult for P3 to understand the definite integral material.

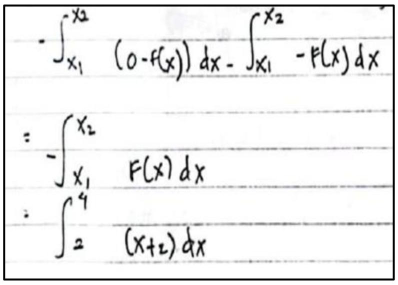
Figure 6. P3's Answer of Number 2

Based on the answers to TKR question number three, P3 was able to solve the problem correctly. Following the IDI interview, it was discovered that P3 saw the pattern correctly in problem number 3, but when the pattern was developed by combining the next two patterns by changing the upper and lower limits, P3 was unable to determine the next pattern. So, P3 correctly solved problem 3 by chance rather than understanding the pattern. This is consistent with the assertion made by Nurhayati, et al., (2023) that what is written in the participant's response cannot be justified completely because it cannot express what is on their mind. The correct answer does not necessarily imply that the participant understands the problem, and the incorrect answer or failure to respond does not necessarily imply that the participant does not understand the problem.

Furthermore, the results of TKR number 4 for P3 had similar issues as P2. Based on the results of the IDI interview, P3 worked on this problem using the textbook. However, because no one directed whether what P3 learned from the book was correct or not, P3 did not believe what was done was true. The initial error was believing that $2x^2$ was a coefficient that could be obtained from the integral operation on the *x* variable. P3 made the same mistake by directly integrating each of $3x^3$ and 4 against *x*, regardless of the power of 4 that is part of the function. P3 felt right about what had been done after being traced through interviews. In addition, when it came to confirming the substitution process, P3 was unable to explain why it was done in that manner. P3 only gave answers from the source book that was readP3 did not experience any difficulty because, while P3 was able to solve the problem, P3 did not understand whether or not what was done was correct. P3 then indicated a didactical learning obstacle. P3 engages in mental action by reading and working on the problem using perceptual knowledge. P3 used what he/she had read and associated with the problem to perform interioriation. However, P3 did not encapsulate and deencapsulate the thought process on the object of understanding the integration technique on the definite integral, so P3 did it with other material that came to mind in memorial knowledge, namely algebraic understanding.

When calculating the integral, students frequently make the mistake of not writing the operator completely. This is demonstrated by P3's TKR results for problem number 5. P3 wrote the answer to the car's displacement as $\int_1^5 3t^2 - 24t + 36$ without writing "dt" at the end as a symbol for the integration variable. Despite the fact that P3 can solve the problem correctly until a distance of 20 km is obtained. P3 took a mental action and then interiorized it into a thought process about the integral formula. Furthermore, encapsulation of mental objects was formed here to solve the problem, so that a scheme for the use of integrals in everyday problems was formed. However, P3 did not believe any mistakes were made in any of the processes that occurred. This is what causes the stages of the process to be neglected. From this, it is clear that the scheme is not fully formed, because a process is skipped, resulting in an incomplete mental object obtained during the thinking process. P3 is convinced that what was learned from the lecturer was similar. This demonstrates that P3 is experiencing didactical learning obstacles. The Satriani et al., (2020) discovered the same matter: students were insufficient in writing integral operations as a solution to a problem. Regardless of whether students finish to the end correctly or fail to finish to the end. If not corrected as soon as possible, this inaccuracy can lead to other errors.

Table 2 summarizes the learning obstacles faced by the three participants, as revealed in their IDI interviews. Prospective teacher students often encounter didactical obstacles, particularly when textbooks emphasize procedural knowledge. Many students struggle with problems that deviate from textbook examples, highlighting the critical role of lecturers in designing effective learning trajectories. A well-designed didactic approach fosters students' understanding of mathematical concepts, thereby minimizing learning obstacles.

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Table 2.
Learning Obstacle Findings and APOS Analysis

Participants	TKR Question Number 1	2	3	4	5	Types of Learning Obstacles
P1	Action	Action	Action	Action	Action	Didactical
	Interiorization	Interiorization	Interiorization	Interiorization	Interiorization	
	Process	Process	Process	Process	Process	
	Encapsulation	Encapsulation	Encapsulation	Encapsulation	Encapsulation	
		Deencapsulation	Deencapsulation	Deencapsulation	Deencapsulation	
		Scheme	Scheme		Scheme	
P2	Action	Action	Action	Action	Action	Didactical and Ontogenical conceptual
	Interiorization	Interiorization	Interiorization	Interiorization	Interiorization	
	Process	Process	Process	Process	Process	
	Encapsulation	Encapsulation			Encapsulation	
	Deencapsulation					
P3	Action	Action	Action	Action	Action	Didactical and Ontogenical Psychology
	Interiorization	Interiorization	Interiorization	Interiorization	Interiorization	
	Process	Process	Process	Process	Process	
	Encapsulation				Encapsulation	
	Deencapsulation				Deencapsulation	

IV. CONCLUSION

Students who aspire to become mathematics teachers experience several types of learning obstacle. First, there are didactic learning obstacle, namely the inappropriate hypothetical learning trajectory. Second, there are conceptual ontogenic learning obstacle, especially algebra material as a prerequisite for integral learning that has not been well understood which can hinder learning definite integrals. Third, ontogenic psychological learning obstacle. Students experience learning obstacle because of a lack of confidence in solving definite integral calculation problems. As a suggestion, this can be overcome by creating a didactic design related to epistemic integral learning. Methods for preparing lecturers to motivate and encourage students in didactic situations. Providing direction and triggers before starting learning can be used as design input. In the hypothetical learning path (HLT), the basic thing that can be done is to predict responses and anticipate didactically. Basic concepts that are a priori needed in definite integral learning can be included in the HLT design. This can be stated in the initial design of the HLT that will be made.

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