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Final Semester Students' Perception of Difficulties in Solving Proof Problems in Real Analysis Course

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ABSTRACT

The Real Analysis course is a core course that emphasizes mathematical proof skills as indicators of students' deductive thinking. However, various findings show that proving is still a major difficulty, including for final-semester students. This study aims to describe the perceptions of final-semester students regarding the difficulties in solving proof problems in a Real Analysis course. This study used a descriptive qualitative approach with subjects being final-semester students of the Mathematics Education Study Program who had taken the Real Analysis course. Data were analyzed using thematic analysis and triangulation techniques to ensure data validity. The results show that students perceive difficulties in proving, especially in the stages of determining the initial steps of the proof, using formal definitions, and arranging a logical and systematic proof flow. In addition, negative perceptions of mathematical proof and procedural learning experiences reinforce these difficulties. This study concludes that difficulties in proving in Real Analysis courses are multidimensional, encompassing conceptual, structural, and affective aspects. These findings are expected to serve as a basis for developing Real Analysis learning strategies that are more focused on the proof process and students' needs.

Keywords: Mathematical Proof, Real Analysis, Student Perception.

I. Introduction

The Real Analysis course is a core course that plays a strategic role in developing advanced mathematical thinking skills in students of both mathematics education and pure mathematics study programs. (Qomariyah & Rosyidah, 2022) This course emphasizes formal understanding of concepts, use of precise definitions, and deductive reasoning through mathematical proofs. Therefore, students' success in Real Analysis is often used as an indicator of the achievement of abstract and logical thinking skills in higher education mathematics. (Septiati, 2018) One of the main competencies emphasized in Real Analysis is the ability to solve mathematical proof problems. Proofs require students to formally understand definitions, connect relevant theorems, and systematically construct logical arguments. (Murni et al., 2025). However, in learning practice, proofs often become the most difficult part for students, especially for those who are not yet accustomed to a deductive and abstract thinking approach to proofs.

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Mathematical proof in Real Analysis requires not only the ability to perform symbolic manipulation but also a deep understanding of the structure of mathematical logic, the relationships between concepts, and the ability to use definitions and theorems accurately. (Septiati, 2021) Students are required to be able to identify assumptions, formulate proof strategies, and construct arguments coherently and systematically. The complexity of these demands makes proof a high-level cognitive activity that often becomes a major obstacle for students, especially when they lack sufficient experience in deductive and formal reasoning. (Dewi et al., 2024)

Based on the initial observations conducted by the researcher in the Real Analysis course, it was found that the majority of final-semester students still experienced difficulties in completing proof problems. These difficulties are evident in students' inability to determine the initial steps of a proof, choose the relevant theorem, and organize the proof logically and consistently. This finding is reinforced by the results of assignments and exams, which show that many proofs presented by students are incomplete, unsystematic, or do not conform to the rules of formal proofs. In addition, initial data obtained through academic discussions and class reflections indicated that final-semester students tended to feel anxious and lacked confidence when faced with proof problems. Although they have completed most prerequisite courses, their conceptual understanding is often not yet internalized in the form of the ability to construct formal proofs. This condition indicates the presence of latent and ongoing problems in the process of learning to write mathematical proofs. This phenomenon indicates a gap between the expected learning outcomes of the Real Analysis course and the actual abilities of students in practice. To date, teaching and evaluation have tended to focus on the final results in the form of academic grades, while the processes and experiences of students in dealing with difficulties in proofs have received little attention. Consequently, the root problems faced by students are often not comprehensively identified. (Anisah et al., 2025)

Previous studies have generally examined the difficulties of mathematical proofs from a cognitive perspective, such as logical errors, misconceptions of basic concepts, or weak mastery of mathematical prerequisites. However, research that specifically investigates students' perceptions, especially those of final-year students, regarding the difficulties in solving proof problems is still relatively limited. Students' perceptions play an important role in shaping their attitudes, motivation, and learning strategies. Final-semester students have academic characteristics that differ from those of students in the early stages of study. In this phase, students face the demands of completing their final projects, complex academic workloads, and psychological pressure as they approach graduation. These factors have the potential to influence how students perceive the difficulty level of mathematical proofs; however, this aspect has not yet been widely focused on in Real Analysis research (Prahastia Kurnia Putri et al., 2022).

Based on these conditions, research is needed to examine in depth the perceptions of final-semester students regarding the difficulties in solving proof problems in the Real Analysis course. This study is important for identifying the types of difficulties experienced by students and for understanding the factors underlying these difficulties from the students' perspective. The novelty of this research lies in its focus on placing the perceptions of final-semester students as the main object of analysis, rather than merely on proof errors or learning outcomes alone. This approach is expected to provide a new perspective on understanding the issues of mathematical proof, particularly at the final stage of higher education, which has received relatively little attention thus far. Thus, the results of this study are expected to provide theoretical contributions to the development of research on mathematical proofs as well as practical contributions for lecturers and program administrators. The findings of this study can serve as a basis for designing Real Analysis learning strategies that are more adaptive, reflective, and oriented toward the needs and learning experiences of students.

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II. Literature Review and Hypothesis Development

2.1. Mathematical Proof in Higher Education

Mathematical proof is a core competency in mathematics education at the university level, particularly in courses with core subject status, such as Real Analysis. Proof activities aim to ensure the logical and systematic correctness of a mathematical statement and serve as the main means of developing students' deductive reasoning. The Real Analysis course places great emphasis on proofs because the topics discussed, such as limits, continuity, and series, are abstract and non-intuitive; therefore, understanding the concepts themselves depends on strong proof skills. Many students experience difficulties in understanding and developing proofs, which are marked by mistakes in reading proof problems, choosing strategies, and systematically arranging proof steps. The literature mentions that common student difficulties include a lack of precision in proof steps, errors in selecting assumptions, and the use of incorrect definitions in mathematical proofs. (Winda et al., 2024) Findings from previous studies provide a foundation that proving is not merely an academic activity but a higher-order thinking skill that must be explicitly developed in advanced mathematics learning, such as Real Analysis. This opens up space for a deeper study of students' perceptions as a psychological variable that influences their proving abilities.

2.2. Students' Difficulties in Mathematical Proofs

The difficulties faced by students in conducting mathematical proofs have been the focus of many studies. From a cognitive perspective, students often do not know how to start a proof, choose the appropriate principle or theorem, or organize their logical arguments in a coherent manner. Research conducted on students taking a real analysis course shows that various types of difficulties can arise, including the inability to connect statements with formal definitions or to apply the correct proof logic structure. For example,Mujib (2019) found that real analysis students showed difficulties in starting proofs, effectively using definitions and concepts that had been learned, and often began proofs with what they wanted to prove, which epistemologically indicates a weakness in deductive thinking. More specifically, in the context of proof in Real Analysis, research by Harsh Bahadur (Hasanah et al., 2024) also reports that students often experience difficulties in logically connecting statements, applying definitions and theorems correctly, and understanding symbolic language in long and complex mathematical proofs.

2.3. Proof in the Context of Real Analysis

Mathematical proofs in the Real Analysis course have their own characteristics because they often involve concepts that are far from concrete contexts and require an understanding of formal definitions such as epsilon-delta, function continuity, and infinite series. Some empirical studies reveal that students' mastery of proofs in Real Analysis is still low, influenced by mistakes in understanding the premises of the problems, incorrect use of definitions, and unsystematic argument structures. For example, Murni et al. (2025) reported that approximately 44.83% of students have difficulty understanding proof questions, 52.49% have difficulty in the proof process itself, and 65.52% in drawing conclusions from the proofs they construct. These findings are consistent with other research showing that proof in Real Analysis is a major obstacle to the academic success of mathematics students, making the study of factors that influence proof ability, including students' perceptions of the difficulty of proofs, very important.

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2.4. Student Perceptions and Their Influence on Proof-Based Learning

Students' perceptions of academic activities are psychological factors that can either strengthen or weaken their engagement in learning. In the context of mathematical proofs, negative perceptions of the material's difficulty can lead to anxiety, decreased learning motivation, and a tendency to avoid proof-related tasks, even if students' cognitive understanding is quite good. An international study found that many students consider proofs to be a very challenging aspect of their mathematics studies, and that early negative experiences can exacerbate this tendency. (Sri Ariani, 2019). In addition, students' perceptions can influence the learning strategies they choose: students with a positive perception of proofs are more likely to use reflective strategies, group learning, and intensive proof practice, whereas students who view proofs as irrelevant or too abstract tend to use memorization strategies and avoid proof problems. The influence of perception on mathematical proof ability is not only cognitive but also affective and metacognitive in nature. Previous research in the context of mathematical proofs has shown that students' limitations include aspects of reading proofs, constructing arguments, and selecting effective proof strategies. Studies from various country contexts indicate that many students still fail to meet the expectations of formal proofs in Real Analysis classes, reflecting a similar phenomenon across institutions and academic cultures (Sentosa, 2014). In addition, literature studies, such as a Systematic Literature Review (SLR) by Winda et al. (2024), indicate that the dominant difficulties experienced by students in proof include misconceptions about questions, weaknesses in logical reasoning, and carelessness in proof steps. Thus, this study seeks to expand on that research by focusing more specifically on the perceptions of final-semester students rather than solely on their proof abilities, thereby providing a new contribution to the mathematics education literature.

III. Research Method

This study used a descriptive qualitative approach (Sugiyono, 2017) to thoroughly uncover the perceptions of final-semester students regarding the difficulties in solving proof problems in the Real Analysis course. This approach was chosen because the research focuses on students' subjective meanings of their learning experiences and the academic difficulties they face, rather than on quantitatively measuring their abilities. The research subjects were final-semester students of the Mathematics Education Study Program who had taken and passed the Real Analysis course. The selection of subjects was carried out using purposive sampling, with the criteria that students had completed all Real Analysis materials and had direct experience solving proof problems. The number of subjects was adjusted to the depth of data needed until saturation was reached.

Data collection techniques included semi-structured interviews, open-ended questionnaires, and document analysis in the form of students' answer sheets on Real Analysis proof questions. Interviews were used to explore perceptions, experiences, and the factors causing difficulties in proofs, while open-ended questionnaires served to reinforce perception data in written form. Document analysis was conducted to confirm the alignment between students' perceptions and the difficulties evident in their proof work results. Data analysis was conducted using a thematic analysis model, which includes stages of data reduction, data presentation, and drawing conclusions (Miles and Huberman, 1994). Data from various sources were analyzed triangulatively to enhance the findings' validity. Data validity was ensured through technique and source triangulation, as well as member checks with the research subjects. With this procedure, the research results are expected to have high credibility and trustworthiness.

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IV. Results and Discussion

4.1. Result

Based on the analysis of data obtained through semi-structured interviews, open questionnaires, and document analysis of students' answers, relatively consistent patterns of difficulty were found among the research subjects. The analysis was conducted by grouping the data into main themes that repeatedly emerged and reinforced each other across the data sources. The first finding indicates that most students encountered difficulties in the initial stage of proving. Survey data showed that the majority of respondents reported confusion in determining the initial steps of the proof, particularly in identifying the known assumptions and the goals that need to be proven. This finding is reinforced by the results of the document analysis, where many students' answers did not begin with writing down relevant assumptions or definitions, but rather proceeded directly to statements that did not yet have a clear logical basis.

The second finding relates to the use of formal definitions and concepts in the proofs. The interview results indicate that most students understand the concepts of Real Analysis intuitively but struggle when they have to translate them into formal definitions. Document analysis shows that the most common errors are the use of incomplete definitions, definitions taken out of context, or definitions that do not correspond to the statement being proven. This pattern consistently appeared across various types of proof problems analyzed. Furthermore, this study found that the structure of students' proof processes tends to be unsystematic. Based on the analysis of written answers, many proofs were arranged without a clear logical order, with step jumps that were not accompanied by explanations. Some students started the proof from the conclusion that should be proven or mixed assumptions with the final result. These findings indicate a weak understanding of the basic structure of deductive proofs among students. From an affective perspective, interview and questionnaire data indicate a tendency toward negative perceptions of mathematical proofs. Most students perceive proofs as difficult, time-consuming, and carrying a high risk of error. This perception is reflected in students' statements expressing feelings of doubt, anxiety, and lack of confidence when working on proof problems, even though they have taken prerequisite courses.

The next finding indicates that previous learning experiences contribute to the difficulties in proofs. Students stated that proofs were often learned through procedural examples during lectures. As a result, when faced with proof problems in different contexts or structures, students experienced difficulty adapting the proof strategies they learned. This pattern appears to be consistent between students' statements and the forms of written answers analyzed. Overall, the research results indicate that the difficulties faced by final-year students in solving proof problems in the Real Analysis course are multidimensional, covering conceptual, structural, and affective aspects. The consistency of the findings from various data sources shows that these difficulties are not merely individual but reflect a common pattern experienced by final-year students in learning Real Analysis.

4.2. Discussion

Research findings indicate that final-year students still face significant difficulties in solving proof problems in Real Analysis courses. This suggests that mathematical proof skills do not develop automatically as semesters progress but require a structured and continuous learning process. These findings are in line with the view of Andreas L. Stylianides (2007), who stated that proof is a competence that must be explicitly developed through learning that focuses on the process of mathematical thinking, not just the final result. Students' difficulties in determining the initial steps of a proof indicate a weak ability to identify the assumptions and objectives of the proof. This finding is consistent with the research results (Septiati, 2018), which reported that students often experience confusion at the early stage of a proof, particularly in

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connecting the problem statements with the relevant definitions or theorems. This suggests that the students did not fully understand the basic structure of deductive proofs in Real Analysis. Difficulties in using formal definitions, such as those of limits and continuity, indicate a gap between students' intuitive and formal understanding. This finding supports Tall's theory regarding concept image and concept definition (Jatisunda, 2021), where students often have an intuitive picture of a concept but struggle to connect it with the formal definition in the context of proofs. In Real Analysis, the inability to properly operationalize formal definitions directly affects the failure to construct valid proofs.

Findings regarding an unsystematic proof flow indicate that students have not yet mastered the structure of mathematical-logic proof. Proof patterns that jump around or start from the conclusion that should be proven indicate a weak understanding of the principles of logical reasoning. These results are in line with Weber's findings, which emphasize that many students understand theorems declaratively but fail to construct coherent deductive arguments when asked to prove them. From an affective perspective, students' negative perceptions of mathematical proofs contribute to low self-confidence in solving proof problems. This finding reinforces previous research showing that math anxiety and negative perceptions of proofs can hinder students' cognitive engagement. The perception that proof is a difficult and high-risk activity causes students to be reluctant to try more exploratory proof-writing strategies.

The perception of final-year students regarding the difficulty of proofs is also influenced by their prior learning experiences. Research findings indicate that proof learning tends to be procedural, with an emphasis on example proofs that must be followed by students. This aligns with previous research findings, which state that an imitation-based learning approach can hinder students' ability to transfer skills when solving proof problems in different contexts. The characteristics of final-semester students facing academic pressure as graduation approaches further reinforce the perception of difficulty in proofs. The burden of final projects and limited time can reduce students' opportunities to reflect deeply on the proof process (Sentosa, 2014). This finding expands on previous studies by showing that the difficulty of proof stems not only from cognitive aspects but also from students'situational and psychological factors. The results of this study confirm that the difficulty of proving in Real Analysis courses is multidimensional, encompassing conceptual, structural, and affective aspects. These findings align with literature reviews stating that proof ability cannot be understood partially but rather as the result of the interaction between concept understanding, logical reasoning, and attitudes toward mathematics. Therefore, efforts to improve proof ability must be conducted holistically. From a theoretical perspective, this study reinforces the relevance of mathematical proof and learning perception theories in the context of higher education mathematics. Focusing on the perceptions of final-semester students provides a new contribution to understanding the issues of mathematical proof at the final stage of study, which has so far been more frequently examined solely from the cognitive ability aspect. Practically, the results of this study imply the need for a more process-oriented approach to teaching Real Analysis, such as discussion-based proof learning, reflection on proof steps, and exploration of various proof strategies. By considering students' perceptions and experiences, mathematical proof learning is expected to become more meaningful and effective in developing students' deductive reasoning skills.

V. Conclusion

Based on the results and discussion of this study, it can be concluded that final-semester students still experience significant difficulties in solving proof problems in the Real Analysis course. These difficulties stem not only from cognitive aspects, such as understanding concepts and using formal definitions, but also from weaknesses in constructing a logical proof flow and negative perceptions of mathematical proofs. These findings indicate that the ability to perform mathematical proofs does not develop automatically with increasing academic experience but rather requires conscious and systematic learning that emphasizes deductive and reflective thinking processes. The implications of this research emphasize the need to

strengthen Real Analysis learning strategies that focus on the proof process rather than merely the final result. Instructors are advised to develop learning based on proof discussions, explore various proof strategies, and provide feedback that emphasizes logical structure and the use of formal definitions. Additionally, attention to students' perceptions and affective aspects should be part of learning planning so that mathematical proofs are not perceived as intimidating activities, but rather as a means of developing higher-level mathematical thinking skills.

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