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Misconceptions among Undergraduate Students in Determining Sequence Limits

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ABSTRACT

Misconceptions related to limits remain a significant challenge in undergraduate calculus learning and may hinder students' understanding of advanced mathematical concepts. Although misconceptions in calculus have been widely studied, research focusing specifically on sequence limits among science undergraduates remains limited. This study aimed to identify and classify students' misconceptions when determining sequence limits. A qualitative document analysis approach was employed involving 126 undergraduate science students enrolled in a Calculus course at Srinakharinwirot University, Thailand. Data was collected from students' written responses to a midterm examination question and analyzed using content analysis guided by an error analysis framework. The findings revealed five major categories of misconceptions: misapplication of limit theorems, improper algebraic cancellation, incorrect use of dominant-term strategies, symbolic transcription errors, and inappropriate application of the Ratio Test. These misconceptions reflect deeper conceptual difficulties related to convergence, infinity, algebraic structure, and the distinction between sequences and series. Interpreted through the Concept Image and Concept Definition framework, the findings suggest that conflicts between intuitive reasoning and formal mathematical definitions contribute to students' errors. The study highlights the importance of strengthening conceptual understanding alongside procedural competence in calculus instruction and provides implications for addressing misconceptions in learning sequence limits.

INTRODUCTION

The concept of limit is one of the most fundamental ideas in calculus and serves as the foundation for understanding continuity, differentiation, and integration. A sound understanding of limits is therefore essential for students pursuing studies in science, technology, engineering, and mathematics (STEM). However, despite its importance, numerous studies have reported that students encounter substantial difficulties in developing a meaningful understanding of limit concepts, often resulting in persistent misconceptions that hinder subsequent learning in advanced mathematics courses (Bansilal & Mkhwanazi, 2021; Luneta, 2022).

Among the various topics in calculus, the limit of a sequence presents unique conceptual challenges. Unlike function limits, sequence limits require students to reason about the behaviour of terms as the index approaches infinity. Many students rely on procedural rules without understanding the underlying meaning of convergence, divergence, and infinitesimal behaviour. Consequently, they frequently misinterpret symbolic representations, apply inappropriate algorithms, or fail to distinguish between related concepts such as sequences and series (Sari et al., 2022; Ervynck, 1994).

Research on mathematical misconceptions has shown that students often construct personal interpretations of mathematical concepts that differ from formal definitions. According to Tall and

Vinner (1981), misconceptions may arise when students develop concept images that are inconsistent with accepted mathematical concept definitions. In the context of limits, students frequently build intuitive beliefs based on finite experiences and then incorrectly generalize those beliefs to infinite processes. Such misconceptions tend to be resistant to change and may continue to influence students' reasoning even after formal instruction.

Several studies have investigated misconceptions related to calculus concepts, including limits, continuity, derivatives, and integrals (Bansilal & Mkhwanazi, 2021; Frank & Thompson, 2021; Fernandez & Mohammed, 2021). However, previous studies have primarily focused on identifying general difficulties in calculus learning or misconceptions associated with function limits. Comparatively fewer studies have examined the specific misconceptions students exhibit when determining the limits of sequences, particularly through systematic analysis of authentic examination responses. Furthermore, little evidence is available regarding the patterns of misconceptions demonstrated by science undergraduates in Southeast Asian higher education contexts.

Understanding the nature of students' misconceptions is important because it enables instructors to design targeted interventions that address conceptual difficulties rather than merely correcting procedural errors. By identifying specific misconception patterns, educators can develop instructional approaches that promote deeper conceptual understanding and improve students' mathematical reasoning.

Therefore, this study aims to investigate the misconceptions exhibited by undergraduate science students when determining the limits of sequences. Specifically, the study seeks to identify and classify the types of misconceptions evident in students' written examination responses and to discuss instructional strategies that may help address these misconceptions. The findings are expected to contribute to the growing body of research on calculus education and provide practical implications for improving the teaching and learning of sequence limits.

LITERATURE REVIEW

Misconceptions in Mathematics Learning

Misconceptions are widely recognized as one of the major obstacles to meaningful mathematical learning. A misconception refers to an understanding or interpretation that differs from accepted mathematical concepts and procedures. Unlike simple computational errors, misconceptions are often deeply rooted in students' prior experiences and intuitive reasoning, making them resistant to change (Tall & Vinner, 1981). Research in mathematics education suggests that students frequently construct personal meanings of mathematical concepts that conflict with formal definitions, particularly when learning abstract topics such as limits, continuity, and infinity.

Tall and Vinner (1981) introduced the distinction between concept image and concept definition. Concept image refers to the total cognitive structure associated with a concept, including mental pictures, examples, and intuitive beliefs. Concept definition, on the other hand, refers to the formal mathematical definition accepted by the mathematical community. Misconceptions occur when students rely primarily on their concept images while neglecting or misunderstanding formal concept definitions. This theoretical perspective has been extensively used to explain students' difficulties in advanced mathematical thinking.

Misconceptions in Calculus Learning

Calculus is widely regarded as one of the most challenging subjects in undergraduate mathematics education because it requires students to reason about dynamic and infinite processes. Numerous studies have documented misconceptions related to limits, continuity, derivatives, and integrals (Denbel, 2014; Bansilal & Mkhwanazi, 2021). Students often develop procedural competence without achieving conceptual understanding, leading to difficulties when they encounter unfamiliar problems.

Bansilal and Mkhwanazi (2021) reported that many undergraduate students possess fragmented understandings of limits and rely heavily on memorized procedures. Similarly, Luneta (2022) found that misconceptions about limits frequently originate from intuitive beliefs developed during secondary education and continue to influence students' reasoning at the university level. These findings indicate that misconceptions are not merely calculation errors but reflect deeper conceptual difficulties.

Misconceptions Related to Limits of Sequences

The concept of a sequence limit requires students to understand the behaviour of infinitely many terms and to interpret convergence as a dynamic process. Previous studies have shown that students often experience difficulties distinguishing between finite and infinite processes. Many students incorrectly assume that a sequence must eventually reach its limit, while others believe that oscillating sequences cannot exhibit meaningful limiting behaviour (Luneta, 2022).

Another common misconception concerns the distinction between sequences and series. Sari et al. (2022) reported that students frequently confuse convergence criteria for sequences with convergence tests for series, leading to inappropriate application of techniques such as the Ratio Test. Ervynck (1994) further demonstrated that procedural fluency in solving limit problems does not necessarily imply conceptual understanding of convergence and infinity.

Students also tend to overgeneralize algebraic procedures. For example, inappropriate term cancellation, incorrect simplification, and misuse of dominant-term strategies are frequently observed when students attempt to determine limits of sequences. Such errors suggest that students often apply familiar procedures without considering the mathematical conditions required for their validity.

Concept Image and Concept Definition Framework

This study adopts the Concept Image and Concept Definition framework proposed by Tall and Vinner (1981) as a lens for interpreting students' misconceptions. According to this framework, students' incorrect solutions may reflect conflicts between intuitive mental images and formal mathematical definitions. When students rely on incomplete or incorrect concept images of convergence, infinity, or limit processes, they may apply inappropriate procedures and arrive at erroneous conclusions.

Using this framework, the present study seeks to identify and classify misconceptions exhibited by undergraduate science students when determining limits of sequences. Understanding these misconceptions may contribute to the development of more effective instructional strategies that support conceptual understanding and reduce persistent learning difficulties in calculus.

METHODOLOGY

Research Design

This study employed a qualitative document analysis approach to investigate students' misconceptions in determining the limits of sequences. The study focused on analysing students' written responses to an examination problem involving sequence limits. Qualitative document analysis was considered appropriate because the objective of the study was to identify, classify, and interpret patterns of misconceptions reflected in students' written work rather than to measure achievement quantitatively (Cohen et al., 2018). The study was guided by an error analysis perspective (Radatz, 1979), which emphasizes the identification of systematic patterns of incorrect reasoning that reveal underlying conceptual misunderstandings.

Participants and Context

The participants were 126 undergraduate science students enrolled in a Calculus course at Srinakharinwirot University, Bangkok, Thailand. The course is a compulsory subject for students in science-related programs and introduces fundamental concepts including limits, continuity, differentiation, and integration. Participants were selected through convenience sampling because they were enrolled in the course during the semester in which the study was conducted. All students had received formal instruction on sequence limits before taking the examination.

Data Collection

The primary data source consisted of students' written responses to a midterm examination question concerning the limit of a sequence. Examination scripts were selected because they represent authentic evidence of students' conceptual understanding under standard assessment conditions. The analysed item required students to determine the limit of a sequence and provide a complete solution process. Students' responses were collected after the examination and anonymized prior to analysis to ensure confidentiality.

Data Analysis

Data were analysed using content analysis informed by the error analysis framework proposed by Radatz (1979). The analysis was conducted in four stages.

First, all examination scripts were reviewed and classified into four categories: correct responses, blank responses, random responses, and responses containing misconceptions. Second, the responses identified as containing misconceptions were examined line by line to identify patterns of reasoning and procedural errors. Third, similar errors were grouped into categories through inductive coding. Categories were refined through repeated comparison among student responses until stable themes emerged. Finally, each category was interpreted using the Concept Image and Concept Definition framework proposed by Tall and Vinner (1981) to explain possible sources of misunderstanding.

To enhance trustworthiness, two researchers independently coded a subset of the responses representing approximately 20% of the dataset. Discrepancies were discussed until consensus was reached. The level of agreement between coders was 91%, indicating a high level of consistency in the classification process (Landis & Koch, 1977).

RESULT AND DISCUSSION

Result

Overall Performance of Students

The analysis of 126 examination scripts revealed varying levels of conceptual understanding regarding sequence limits. As presented in Table 1, 60 students (47.62%) produced correct solutions, indicating an adequate understanding of the concept. However, 49 students (38.89%) demonstrated misconceptions that resulted in incorrect solutions. In addition, 12 students (9.52%) submitted blank responses, while 5 students (3.97%) provided responses that were categorized as random answers.

Table 1. Categorizing test outcomes in this study according to test question

Midterm Exam Results		
Group	Number of students	Percentage %
Correct Answers	60	47.62
Submitted blank papers	12	9.52
Random Answers	5	3.97
Misunderstood limits	49	38.89

These findings suggest that although nearly half of the students were able to determine the limit correctly, a substantial proportion experienced conceptual difficulties. The relatively high percentage of misconception-based responses indicates that understanding sequence limits remains a challenging topic for many undergraduate science students. Therefore, a closer examination of the specific misconceptions exhibited by students is necessary.

Types of Misconceptions Identified

Content analysis of the 49 misconception responses revealed five major categories of misconceptions. These misconceptions reflect different forms of conceptual and procedural difficulties encountered by students when determining the limits of sequences. Representative examples of each category are presented in Figures 1–5.

Type 1: Misapplication of Limit Theorems

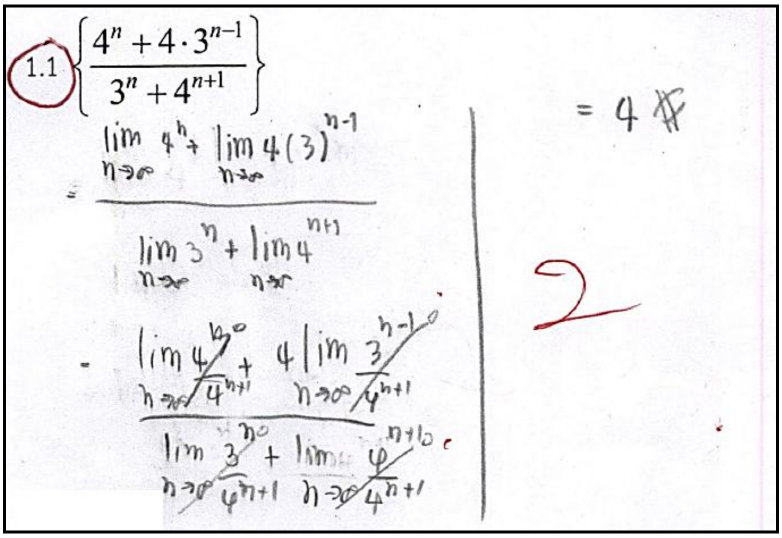

Figure 1. First type of misconception

The first category of misconception involved the inappropriate application of limit theorems for sequences of the form r^n where $-1 < r < 1$. Students frequently recognized the presence of an exponential term and immediately concluded that the sequence converged to zero without examining whether the entire expression satisfied the conditions of the theorem.

This misconception suggests that students relied on memorized rules rather than conceptual understanding of convergence conditions. The result indicates a tendency to associate particular symbolic forms with predetermined outcomes, even when those forms appear within more complex expressions.

Type 2: Improper Cancellation

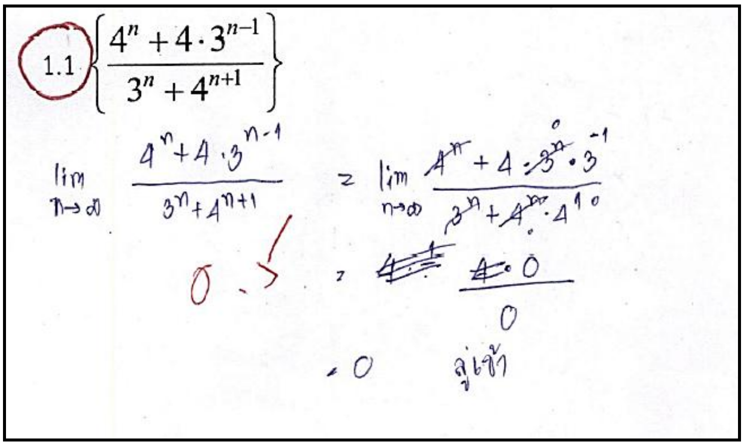

Figure 2. Second type of misconception

The second category involved improper cancellation of terms during algebraic simplification. Students attempted to cancel additive terms across numerators and denominators as if they were common factors. Such procedures resulted in mathematically invalid transformations and incorrect limit values.

This misconception indicates a weak understanding of the structural properties of algebraic expressions. Students appeared to apply familiar simplification procedures without considering the mathematical conditions required for valid cancellation.

Type 3: Incorrect Use of Dominant-Term Strategy

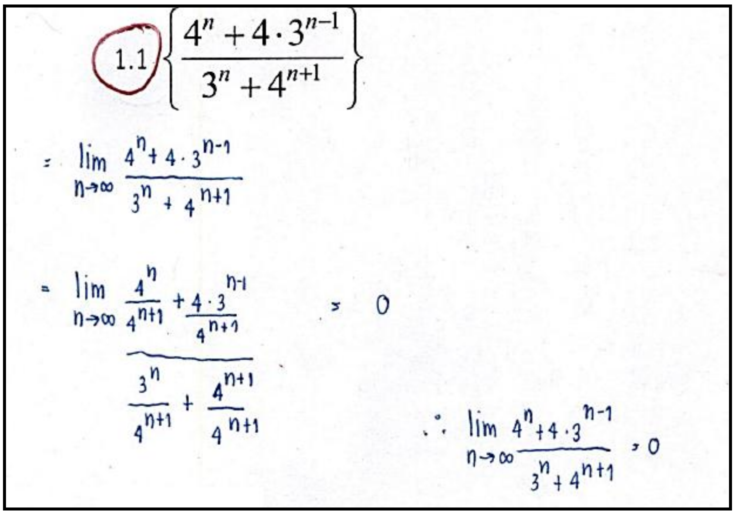

Figure 3. Third type misconception

The third category was associated with errors in applying the dominant-term strategy. Although students correctly identified the highest-order term and attempted to divide the numerator and denominator accordingly, errors frequently occurred during the subsequent simplification process.

Unlike the previous category, this misconception did not necessarily reflect a lack of procedural knowledge. Instead, it suggests incomplete conceptual understanding of how lower-order terms behave as the sequence approaches infinity.

Type 4: Problem Transcription Errors

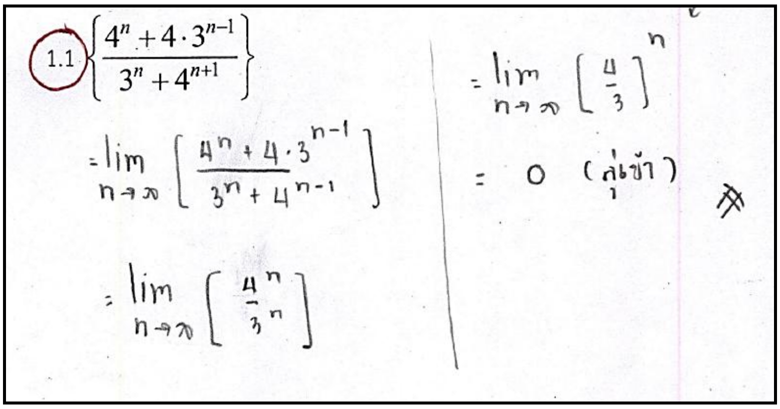

Figure 4. Fourth type misconception

The fourth category consisted of errors resulting from incorrect transcription of the original problem. Students miscopied signs, coefficients, or algebraic expressions before beginning the solution process. Although some students subsequently followed correct procedures, the initial transcription error inevitably led to incorrect final answers.

This finding highlights the importance of symbolic accuracy in mathematical reasoning. Even when conceptual understanding is adequate, errors in interpreting or reproducing mathematical notation may interfere with successful problem solving.

Type 5: Misuse of the Ratio Test

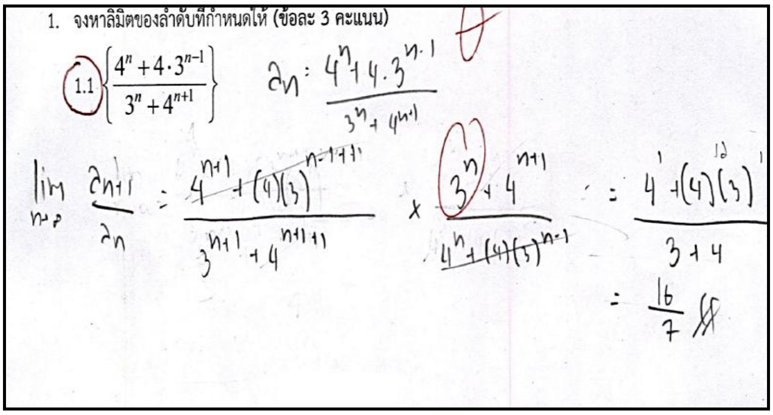

Figure 5. Fifth type of misconception

The fifth category involved the inappropriate application of the Ratio Test. Students attempted to use a convergence criterion designed for infinite series to determine the limit of a sequence. In several cases, students interpreted the resulting ratio as the limit value of the sequence itself.

This misconception demonstrates confusion between the concepts of sequences and series. The findings suggest that students may transfer previously learned procedures to new contexts without fully understanding the underlying mathematical concepts governing those procedures.

The detailed analysis of students' written responses revealed five recurring categories of misconceptions. Although each misconception exhibited distinct characteristics, they can be summarized according to the underlying mathematical concepts involved. Table 2 provides an overview of the identified misconception categories.

Table 2. Summary of Identified Misconceptions

Misconception Type	Description	Related Concept
Type 1	Misapplication of r^n theorem	Convergence
Type 2	Improper cancellation	Algebraic reasoning
Type 3	Incorrect dominant-term strategy	Infinity and limits

Misconception Type	Description	Related Concept
Type 4	Problem transcription	Symbolic representation
Type 5	Misuse of Ratio Test	Sequence versus series

As summarized in Table 2, the identified misconceptions extend beyond procedural errors and involve several fundamental mathematical ideas, including convergence, algebraic reasoning, symbolic representation, and the distinction between sequences and series. The findings suggest that students' difficulties originate not only from computational weaknesses but also from incomplete conceptual understanding of limit-related concepts. These issues are discussed in greater detail in the following section.

While Table 2 summarizes the observable categories of misconceptions, understanding the underlying causes of these errors requires a deeper theoretical interpretation. To provide a more comprehensive explanation, the identified misconceptions were examined through the Concept Image and Concept Definition framework proposed by Tall and Vinner (1981). This framework helps explain how conflicts between students' intuitive understandings and formal mathematical definitions may contribute to incorrect reasoning. The interpretation of each misconception category is presented in Table 3.

Table 3. Interpretation of Identified Misconceptions Using the Concept Image and Concept Definition Framework

Misconception Type	Possible Cause	Concept Image Conflict
Type 1	Overgeneralization of theorem	Incomplete understanding of convergence
Type 2	Invalid algebraic simplification	Misinterpretation of algebraic structure
Type 3	Misunderstanding infinity behaviour	Weak concept of asymptotic reasoning
Type 4	Symbolic representation errors	Inaccurate mathematical encoding
Type 5	Transfer of inappropriate procedure	Confusion between sequences and series

As shown in Table 3, the identified misconceptions can be interpreted as manifestations of deeper conceptual conflicts rather than isolated computational mistakes. The framework suggests that students' difficulties originate from incomplete or inaccurate concept images related to convergence, infinity, algebraic structure, and the distinction between sequences and series. These findings are discussed in detail in the following sections.

Discussion

Misconceptions Related to Convergence and Infinity

The findings revealed that one of the most common misconceptions involved the inappropriate application of limit theorems for sequences of the form r^n when $-1 < r < 1$. Students frequently associated the presence of an exponential expression with convergence to zero without verifying whether the conditions of the theorem were satisfied. This finding suggests that students relied on memorized procedures rather than conceptual understanding of convergence.

From the perspective of the Concept Image and Concept Definition framework proposed by Tall and Vinner (1981), students appeared to develop incomplete concept images of convergence. Their reasoning was influenced by previously learned rules that were applied mechanically without consideration of the underlying mathematical conditions. Similar findings were reported by Denbel (2014) and Luneta (2022), who found that students often possess intuitive but mathematically inaccurate interpretations of limit processes. The present study supports previous evidence that understanding infinity and convergence remains a significant challenge for undergraduate students.

Misconceptions Related to Algebraic Reasoning

The second and third categories of misconceptions were associated with algebraic manipulation. Students frequently performed invalid term cancellations or incorrectly applied dominant-term strategies when simplifying expressions. These errors indicate that students may understand the general procedure for finding limits but lack a deeper understanding of the algebraic principles underlying those procedures.

The findings are consistent with Ervynck (1994), who argued that procedural fluency does not necessarily imply conceptual understanding. Students often apply familiar algebraic operations automatically without evaluating whether the required mathematical conditions are satisfied. In the present study, students appeared to focus on obtaining a simplified expression rather than reasoning about the mathematical validity of each transformation. Such behaviour suggests that procedural knowledge and conceptual knowledge were not fully integrated.

From the perspective of mathematical reasoning, these misconceptions may also reflect difficulties in understanding the behaviour of lower-order terms as n approaches infinity. Although students recognized the dominant term, they frequently misinterpreted the limiting behaviour of the remaining components of the sequence. This finding highlights the importance of emphasizing conceptual explanations alongside procedural techniques when teaching sequence limits.

Misconceptions Related to Symbolic Interpretation

Another important finding concerned errors resulting from incorrect transcription of mathematical expressions. Although this category may initially appear to be a simple procedural mistake, the results suggest that symbolic representation plays a critical role in students' mathematical thinking. Students who incorrectly copied signs or coefficients often proceeded with otherwise valid solution methods but ultimately obtained incorrect results.

This finding supports previous research indicating that successful mathematical problem solving depends not only on conceptual understanding but also on accurate interpretation and representation of mathematical symbols. Mathematical notation functions as a language through which concepts are communicated. Consequently, inaccuracies in symbolic representation may disrupt reasoning processes and lead to incorrect conclusions even when students possess adequate conceptual knowledge.

Misconceptions Related to Knowledge Transfer

The fifth category of misconception involved the inappropriate use of the Ratio Test to determine sequence limits. Students transferred a procedure learned in one mathematical context to a different context where the procedure was not applicable. This finding suggests confusion between the concepts of sequences and series, which has also been reported in previous studies (Sari et al., 2022).

According to Tall and Vinner (1981), misconceptions frequently emerge when students construct concept images based on superficial similarities between mathematical topics. In the present study, students appeared to associate the Ratio Test with any problem involving infinite processes without recognizing the distinction between convergence tests for series and limit determination for sequences. This tendency illustrates how prior knowledge may sometimes interfere with new learning when conceptual boundaries are not clearly understood.

Implications for Teaching Sequence Limits

The findings of this study have several implications for calculus instruction. First, instructors should emphasize conceptual understanding of convergence rather than focusing exclusively on procedural techniques. Students need opportunities to explore why limit theorems work and under what conditions they can be applied.

Second, learning activities should explicitly address common misconceptions related to algebraic simplification, convergence, and the distinction between sequences and series. Presenting incorrect examples alongside correct solutions may help students identify and challenge their own misconceptions.

Third, instructional approaches should encourage students to justify each step of their reasoning rather than merely producing final answers. Requiring explanations can help reveal underlying misconceptions that might remain hidden when assessment focuses only on procedural accuracy.

Finally, visual representations, multiple examples, and guided discussions may support the development of more accurate concept images of limits and infinity. By strengthening students' conceptual understanding, instructors may reduce the persistence of misconceptions and improve learning outcomes in calculus courses.

CONCLUSION

This study investigated misconceptions exhibited by undergraduate science students when determining the limits of sequences. Analysis of 126 examination scripts revealed that although nearly half of the students successfully solved the problem, a substantial proportion demonstrated misconceptions that interfered with their ability to determine limits correctly. Five major categories of misconceptions were identified, namely misapplication of limit theorems, improper algebraic cancellation, incorrect use of dominant-term strategies, symbolic transcription errors, and inappropriate application of the Ratio Test.

The findings suggest that students' difficulties extend beyond procedural mistakes and are rooted in deeper conceptual misunderstandings related to convergence, infinity, algebraic structure, and the distinction between sequences and series. Interpreted through the Concept Image and Concept Definition framework, these misconceptions appear to arise from conflicts between students' intuitive understandings and formal mathematical definitions. The study therefore contributes to the growing body of research on calculus learning by providing a systematic classification of misconceptions associated with sequence limits and offering theoretical explanations for their occurrence.

From a practical perspective, the findings highlight the importance of emphasizing conceptual understanding alongside procedural competence in calculus instruction. Learning activities that encourage students to justify their reasoning, analyze incorrect solutions, and compare related concepts may help reduce persistent misconceptions and promote deeper mathematical understanding.

This study has several limitations. The data were collected from a single institution and were based on students' responses to one examination task, which may limit the generalizability of the findings. In addition, the analysis relied solely on written responses and did not include interviews that could provide deeper insight into students' reasoning processes. Future research may investigate misconceptions across different institutions and educational contexts, incorporate multiple assessment tasks, and explore the effectiveness of instructional interventions designed to address the misconceptions identified in this study.

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