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Analyzing Mathematics Education Students' Misconceptions on Limit Functions : A Case Study at Alkhairaat University

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Abstract: The purpose of this study was to determine the misconceptions made by Unisa Mathematics Education students about the concept of limit. The research method used was a descriptive qualitative approach or survey design, where data were collected through comprehension tests, interviews, and observations of 16 students. The results showed that students consider limit as something that is not reached, limit is an estimate, limit is a boundary, and a function will always have a limit at a certain point. Other misconceptions are that students consider limit as a substitution process, even though the substitution process causes the denominator to become 0, students still write 0, and they think that when the function has a limit value, the function is defined at a certain point and must be continuous. These findings are expected to contribute to the development of more effective learning strategies to overcome misconception in Mathematics Education students and improve their understanding of calculus concepts, especially function limit.

Keywords: limit concept, limits of functions, misconceptions.

▪ INTRODUCTION

Mathematics plays a fundamental role in education, serving as a foundation in the development of analytical skills and problem solving abilities essential for success in various disciplines, one of which is calculus (Boom-Cárcamo et al., 2024; Rios et al., 2024). Calculus is one of the compulsory courses in the programme for students of the Mathematics Education Study Programme at FKIP Alkhairaat University.. This calculus is divided into 3 levels, namely differential calculus, integral calculus, and advanced calculus. There have been many studies on calculus that show a series of continuous sequences of concepts that as a whole cause problems for students, such as student difficulties with abstract concepts of rate of change, limit, tangent, function, sequence, and convergence (Nursupiamin & Rochaminah, 2024; Sari et al., 2018; White, 1996) and move on to understanding derivatives (Nurwahyu et al., 2020) . This is supported by Thompson who argues that students' errors and misconceptions in calculus are caused by teachers who focus more on teaching about mathematical rules, algorithms, and procedures at the expense of developing a conceptual understanding of calculus concepts (Jameson et al., 2023; Weldeana et al., 2023).

Concepts are fundamental to the teaching and learning of mathematics. Other concepts cannot be taught and understood by students unless the material that underlies the concepts is clearly understood. For example, a student cannot understand the concept of derivative before understanding the concept of limit, because limit is the basis for learning derivative and other concepts in calculus. This is emphasised by Bernard Cornu who says that the mathematical concept of limit occupies a central position which permeates all mathematical analysis as the basis of approximation theory, continuity and

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differential and integral calculus. He argues that this mathematical concept is a very difficult idea, typical of the kind of thinking required in advanced mathematics (Cornu, 1991). In line with the opinion of an expert who wrote in an article The History of Limits that the concept of limit is the most fundamental thing in the concept of calculus, namely that every concept in calculus, namely continuity, derivative, integral, convergence or divergence, is defined in the limit (Denbel, 2014).

The concept of limit is fundamental to understanding calculus, but many studies have confirmed that students have many misconceptions about the concept of limit (Areaya, 2012; Denbel, 2014; Jufri, 2022; Kamid et al., 2020; Nurdin et al., 2021). Williams stated that there are 4 problems that often become problems in the concept of limits (Denbel, 2014), yaitu: 1) a function can reach its limit, 2) limit is the boundary, 3) limits are dynamic processes or static objects, and 4) limits are inherently related to the concept of motion. This problem is also a problem for students of the Mathematics Education at Alkhairaat University Palu in learning the concept of limits.

Based on the researcher's experience in teaching calculus about limits and the results of observing the work of students on the UNISA Mathematics Education programme in each batch of semester 1 (one), it is evident that 75% of the students make conceptual errors in relation to function limits. For example, when solving limit function problems, students do not write the symbol lim, but directly substitute the value of x, even though this results in the denominator becoming 0. Another example of misconception relates to understanding that the ∞ sign on the limit result is an infinite number, the ∞ sign on the limit result should indicate that the limit is undefined at some point. In addition, students sometimes have misconceptions in understanding the definition of the limit of a function, both algebraically and geometrically.

The concept of function limit begins with an intuitive presentation of the concept before the formal definition of function limit is taught, where students tend to express the meaning of function limit notation based on intuitive understanding compared to the formal definition (Baye et al., 2021; Nurdin et al., 2021). When students are asked to explain the definition of a limit function based on the formal definition of a limit function, many of them cannot explain the definition of a limit function in their own words. So, as a lecturer, we need to find a solution to this problem so that it does not continue and have an impact on the next material, as one lecturer has done in developing learning concepts in teaching limit functions (Arsyad et al., 2017; Mulyono et al., 2019) .

There have been many studies of students' misconceptions and errors about mathematical concepts, for example student errors in the concept of limit related to symbolic (Jameson et al., 2023; Munyaruhengeri et al., 2024), student errors on derivative material related to errors in concepts, principles and procedures (Hajerina et al., 2022), student misconception in exponential (Cangelosi et al., 2013), and student error of systems of linear equations in two variables and interviews (Eva Wulanningtyas et al., 2024). However, there has been no research on student misconceptions on limit function material conducted at Alkhairaat University by conducting a case study approach, so that researchers are interested in analysing the misconceptions of students of the Mathematics Education Study Program at Alkhairaat University Palu on limit function material, with the aim that lecturers can find out students‘ understanding of limit functions and misconceptions that may be made by students, so that lecturers can choose and develop appropriate learning strategies to overcome problems in order to improve students’ understanding of the concept of limit functions. This research is to answer What are the types of misconceptions held by mathematics education students at Alkhairaat University related to the concept of limit function?

▪ METHOD

Participants

The research was conducted at Alkhairaat University, Faculty of Teacher Training and Education, Mathematics Education Study Program in October 2023. The population in this study were all first semester students TA. 2023/2024 which totalled 16 students. The research sample was 3 students who were selected from all students who were given the test and made the most mistakes.

Research Design and Procedures

This research is a descriptive quantitative research, that is, research that aims to provide a clear and detailed description of the data collected so that it can facilitate interpretation and decision making based on the existing data (Eskiyurt & Özkan, 2024). The research design used is survey research. In this survey, students' understanding of the concept of limit can be determined by identifying students' misconceptions through a test on the concept of limit. When answering the test, students' answers on the test do not always show their true level of understanding. Sometimes they understand more than the answers they write down. Sometimes they use the right words but do not understand what they have written. This is where the use of in-depth interviews is very useful. This type of content-based interview is not just an oral test, but a way of delving deeper into the complexity of students' understanding of the concept of limit.

Instruments and Data Collection Techniques

The instrument used in this research is a test in the form of questions on function limits adapted from research (Areaya, 2012) and interview guidelines. The questions consisted of 5 items with the aim of measuring mathematical problem-solving skills which include to see student errors related to the concept of limit function.

The data collection used is cross-sectional. This is because the data is collected at one point in time. Cross sectional is very important in the survey method to collect data at a certain point in time, which means that it describes the nature of existing conditions, can be compared or determine the relationships that exist between certain events. Therefore, this study will also use a quantitative descriptive design (survey) and cross-sectional data collection to achieve the research objectives.

Data collection was carried out in two stages. In the first stage, tests were used to collect data from a sample of students about their understanding of boundaries. The responses were checked and analysed. The test was administered to the sample group as a whole. In the second stage, interviews were conducted with students selected on the basis of the level and number of errors they made in answering the test. The interviews were conducted on a pre-arranged day after the tests had been examined. During the interviews, the researcher took good notes and listened carefully. The answers were then transcribed and analysed.

Data Analysis

The data was analysed to identify the misconceptions that students have about the concept of limit. Open coding was used to analyse the data. Open coding is a part of analysis that deals specifically with naming and categorising phenomena through careful examination of the data (Denbel, 2014). During open coding the data was separated, examined and compared to find differences and similarities in the misconceptions that students held. In addition, percentages and averages were used to determine the number of students who had misconceptions. This was to help the researcher make generalisations

▪ RESULT AND DISSCUSSION

The first step in this study was to give a test to first semester TA students. 2023/2024 Mathematics Education Study Programme, Alkhairaat University, Palu, a total of 16 people. The test consists of 5 questions related to function limits. The description of the results of the test answers and interviews is presented below. The number of students' correct and incorrect answers to the above questions is shown in Table 1 below.

Question 1

Identify the following statements as true or false!

a. A limit is a number that cannot be exceeded by a function value.
b. A limit is a number that the function value approaches but never reaches.
c. A limit is an estimate that can be made as accurate as you want.
d. The limit of a function may not exist at a certain point.

Table 1. Student answer to question 1

Statement	Correct	False	Not Answered
1.a	9*	7	0
1.b	11*	5	0
1.c	15	1*	0
1.d	9*	7	0

Notes: * Correct answer to question 1

Based on table 1, some of the mistakes made by students are: 1) In item 1.a, 7 students (43.75%) disagreed with statement 1.a, stating that the limit is the number that can be exceeded by the value of the function, forgetting the definition of the limit of the function, which is the value reached by the function as the independent variable approaches a certain value, not the value reached by the function at that point, 2) In item 1.b, 5 students (31.25%) disagreed with the statement that the limit is a number whose function value is close but never reached. The students who disagreed were students who also disagreed with statement 1.a because they still thought that the limit could be exceeded by the function value, 3) In item 1.c, 15 students (93.75%) got it wrong by answering that limit is an estimate that can be made as precisely as you want, whereas limit is a mathematical concept used to approximate a value that cannot be reached or measured precisely, and 4) In item 1.d, 7 students (43.75%) disagreed that the limit of a function cannot exist at a certain point. These students argued that there must always be a limit at some point in a function, forgetting about discontinuities.

Data analysis of data interpretation provides an explanation of how students think about function limits. The misconceptions found in this study are similar to the findings of previous researchers who discussed the limit. The findings of the study showed that students' knowledge and understanding mostly relied on isolated facts and procedures and students' conceptual understanding of limits and continuity was still lacking. This is in line with the problem found (Nurdin et al., 2021) namely that they still have difficulty interpreting the definition of limit. Then, misconceptions occured when understanding the value of L, where student understood that the value of L is right at $f(x)$ and required the function f to be defined in c (Kamid et al., 2020).

Question 2

> Given a function *f* and a number *C*. Explain in your own words what it means that the limit of the function *f* as *x*→*C* is *L*?

In this question, most students found it difficult to answer, as shown by their answers which simply rewrote the statement in question 2. Some of the incorrect answers given by the students are :

- Hz: The limit of the function exists or can be defined. This pupil associates the limit with the definition of continuity.
- AT: 'If f is a function and *C* is a real number, then *C* = *L*. For example, $\lim_{x\to 1} f(x) = 1$. This student assumes that the function $f(x)$ is a constant function because the function equation is not written down
- AY: 'f is a function and *C* and *L* are adjacent numbers'.

In understanding the meaning of a limit definition, students find it difficult to convey the meaning of the definition in their own words. This is also experienced by many Unisa mathematics education students, while 56.25% of the students who took the test only wrote the question back. Students' difficulties and mistakes in giving their opinions include not understanding the meaning of the question, students having difficulty recognising the symbols in the limit definition, and errors in interpreting the notation. This is in line with research conducted (Kautsar Qadry et al., 2021) which revealed students' errors and difficulties in understanding and negating the definition of limit functions. The responses of 16 students to question 3 are presented in table 2 below.

Question 3

> Let f be a function and $c \in R$. If $\lim_{x\to c} f(x)$ does not exist, which of these statements is true?
>
> a. $\lim_{x\to c^+} f(x)$ exist, but in contrast to $\lim_{x\to c^-} f(x)$
> b. *f(x)* becomes quite large when *x* gets closer to *c*.
> c. This function has a vertical asymptote at *x* = *c*.
> *d.* *f(x)* defined at *x* = *c*.
> e. None are correct.
>
> Provide an explanation!

Table 2. Student answer to question 3

Statement	Total Respondents	%
3.a*	5	31.25
3.b	2	12.5
3.c	0	0
3.d	1	6.25
3.e	8	50

Based on table 2. above, we can see that: 1) Only 5 students (31.25%) chose answer 3.a which is the correct answer. Mereka mengingat bahwa $\lim_{x\to c} f(x)$ ada jika $\lim_{x\to c^+} f(x) = \lim_{x\to c^-} f(x)$. Namun ada seorang mahasiswa yang menjawab benar, namun dalam penjelasannya masih keliru, dia mengganggap bahwa $\lim_{x\to c^+} f(x)$ dari arah kanan dengan nilai x positif, dan $\lim_{x\to c^-} f(x)$ dari arah kiri dengan nilai x negatif, 2) 2 students (12.5%) chose 3.b as the correct answer, they thought that as x gets closer or reaches the point c, the limit value of *f(x)* gets bigger. They explained this in the interview by saying that they saw the limit as a substitution process, so if *x* becomes larger, then when it is substituted into the function, the limit of the function will also become larger, 3) No student response option 3.c, 4) One student (6.25%) chose 3.D. This student stated that $\lim_{x\to c} f(x)$ does not exist, but *f(x)* is defined at $x = c$ because *f* is a function and there are *c* members of the real number, so *f* is defined at the point $x = c$ even though the limit does not exist. So *f(x)* is disconnected, but *f(c)* is contained in one of the sections of the curve, and 5) 8 students (50%) answered no to the correct statement with the reason that $\lim_{x\to c} f(x)$ does not exist, meaning that the limit of the function cannot be defined at $x = c$.

In learning function limits, students experience misconceptions or misunderstandings that appear in several forms. As in this study, the limit is the same as the value of the function at a point, that is, the limit can be found by the substitution method. This is in line with research (Mulyono & Hapizah, 2017) which found that students always use the substitution method to determine the limit of a function at a point, but they do not check whether the function continues or not at that point. In addition, the misconception also made by students in this study is that when students divide 0 by 0, the result is 0, although some students know that other numbers divided by 0 are undefined. This misconception was also found by (Denbel, 2014) in his research on Dilla university students' misconceptions of the concept of limit. The responses of the 16 students to question 4 are presented in Table 3 below.

Question 4

Given a function *f* such that $\lim_{x\to 2} f(x) = 3$. Which of the following statements must be true about the function *f*?

a. $f(2) = 3$
b. $f(x)$ defined at $x = 2$
c. f is continuous at the point $x = 2$
d. $\lim_{x\to 2^+} f(x) = 3$
e. None are correct.

Provide an explanation!

Table 3. Student answer to question 4

Statement	Total Respondents	%
4.a	4	25
4.b	0	0
4.c	2	12.5
4.d*	2	12.5
4.e	1	6.25

Based on table 3. above, it can be seen that: 1) Only 2 students (12.5%) chose 4.d, which is the correct answer. They realised and remembered whether $\lim_{x \to c} f(x)$ exist, then $\lim_{x \to c^+} f(x) = \lim_{x \to c^-} f(x)$, 2) 4 students (25%) responded that statement 4.a was correct because $\lim_{x \to 2} f(x) = 3$ means that as *x* approaches 2, *f(x)* approaches 3, so substitute *x = 2* so that *f*(2) = 3. This shows that they view the limit as a substitution process, 3) No students answered 4.b as the correct statement, 4) 2 students (12.25%) answered 4.c as the correct statement with the reason because $\lim_{x \to 2} f(x) = 3$, then when *x* is replaced with 2, the value of the function is 3 as well, so it is continuous, 5) 1 student (6.25%) who answered that none of the statements were correct and did not write the reason. This is because the student did not understand and just chose, 6) 7 students (43.75%) chose a,b,c, and d as the correct answers, with the reason being that the limit value and the function value are the same which is 3. They assume that $\lim_{x \to 2} f(x) = 3$, so when substituted *x* = 2, then *f*(2) = 3. So when a function has a limit, the function is defined at that point so it is continuous. This is the reason they chose all true statements.

Many students assume that the limit value of a function at a point is the same as the value of the function at that point. The limit actually describes the behaviour of the function as the point approaches a value, not the value of the function at that point. While the limit may be equivalent to the value of the function at that point, it is not always the case. In addition, another finding in this study is that students understand that a function has a limit if the limit value from the right direction is equal to the limit value from the left direction, but students' understanding of this concept is that when approached from the right direction $\lim_{x \to c^+} f(x)$, then *x* is positive, but from the left direction $\lim_{x \to c^-} f(x)$ then *x* is negative.

Question 5

Sketch the graph of the function $f(x) = \frac{x^2-9}{3x-9}$, and answer the following questions:

a. What happens to the graph of *f* at the point *x*=3?
b. What is the limit of *f* at *x*=3?
c. What is the value of the function at *x*=3 or *f*(3) ?

In question 5, students were asked to graph a function and answer questions based on the graph. The results of students' answers are shown in table 4. below :

Table 4. Student answer to question 5

Statement	Correct	False	Not Answered
Graph	1	8	7
5.a	8	5	3
5.b	1	13	2
5.c	10	4	2

Based on data in Table 4, 93.75% of the students had difficulty in sketching the graph of the function in question 5 given. 7 students (43.75%) did not even try to sketch the graph and consequently could not answer the questions on the graph easily. Some of them ignored the point $x = 3$ because they did not know how to handle the discontinuity at that point. To try something, some of them made $y = 0$ and produced the intersection point sb. x at $x = -3$.

Common wrong answers by students include: 1) 31.25% of students incorrectly said that the value of the function *f(x)* becomes 0 at the point $x = 3$ instead of being undefined at that point, 2) 81.25% of students in item 5.b answered incorrectly by writing that the limit value of the function is undefined, they see the limit as a substitution rule, they forget the factoring rule in solving the limit concept, and 3) In item 5.c, 4 students answered 0. They forgot that 0/0 is undefined, not 0.

The most difficult thing was also done by students in this study, namely in sketching the graph of a function. As many as 93.75% of students experienced difficulties and errors in sketching the graph, and some did not even try to draw a graph. This difficulty is often found in solving mathematical problems that require drawing graphs, such as in algebra, geometry or trigonometry. (Jaelani, 2017) in his research found students who were still wrong in drawing a graph of a function. Another thing was also found by (Archi Maulyda & Khairunnisa, 2019) in their research on student errors in drawing function graphs, namely errors in determining asymptotes and intersection points. These errors are also the findings in this study related to creating a graph universe, so it is wrong to calculate the value of a function based on the graph.

▪ CONCLUSION

Data analysis and data interpretation provided an explanation of how students think about limits. The misconceptions identified are almost the same as the findings of previous researchers. The findings of this study indicate that students‘ knowledge and understanding are largely based on isolated facts and procedures and students’ understanding of function limits is still limited. Misconceptions made by students related to function limit are that students consider limit as something unreachable, limit is an estimate, limit is a boundary, and a function will always have a limit at a certain point. Another misconception is that when students are asked to determine the limit value of a function, they view the limit as a substitution process, so they immediately insert the point into the function without paying attention to whether the denominator becomes 0 or not. This is most often done by students When dividing a number by 0, the result is 0. But some students also know that 0 divided by 0 is undefined. In addition, students assume that when a function has a limit value, it is defined at a certain point and must be continuous. Another misconception that many students have is in drawing the graph of a function.

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