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ANALYSIS OF STUDENT'S MISCONCEPTIONS IN SOLVING MATHEMATIC LOGIC PROBLEMS

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Abstrak

Karakter matematika bersifat hierarkis, yaitu adanya keterkaitan antar satu konsep dengan konsep lainnya, sehingga akan sangat fatal jika mengalami miskonsepsi seperti keliru membuat sebuah generalisasi pada materi Logika Matematika dalam mata kuliah Matematika Dasar. Jika terjadi miskonsepsi secara terus menerus dapat menimbulkan kegagalan pemahaman konsep pada mata kuliah selanjutnya, seperti Kalkulus dan Matematika Diskrit. Penelitian ini bertujuan untuk mengidentifikasi miskonsepsi pada peserta mata kuliah Matematika Dasar di Program Studi Pendidikan Matematika Universitas Bengkulu pada tahun akademik 2021/2022 sebanyak 69 mahasiswa pada materi Logika Matematika. Jenis penelitian ini adalah penelitian analisis deskriptif terhadap hasil tes diagnostic berbentuk essay, dan tingkat keyakinan dalam menjawab dengan menggunakan *Certainty Response Index* (CRI) berbentuk persentase. Teknik pengumpulan data yang digunakan berupa tes. Analisis data dilakukan terhadap uraian jawaban serta tingkat keyakinan dalam memebrikan jawaban. Hasil penelitian menunjukkan bahwa pembelajaran Logika Matematika memberikan dampak miskonsepsi pada peserta mata kuliah Matematika Dasar dengan kisaran 4 sampai 43% dengan identifikasi miskonsepsi tertinggi terjadi pada pokok bahasan tentang penyimpulan suatu pernyataan dan uji validitas argument mengguakan hukum premis. Tingkat miskonsepsi terendah terjadi pada uji argument menggunakan tabel kebenaran. Rata-rata persentase tingkat miskonsepsi mahasiswa sebesar 21%.

Kata kunci : *Certainty Response Index*; Logika Matematika; miskonsepsi; tes diagnostic.

Abstract

It will be disastrous if there is a failure to comprehend the concepts or experience a misperception because mathematics has a hierarchical nature, so there is a relationship between one notion and another. One of the common errors making students in Mathematical Logic courses for Basic Mathematics is concluding or making erroneous generalizations. The University of Bengkulu's study program in mathematics education requires the completion of this course. Continuous misconceptions may make it difficult to understand the concept in later studies, including calculus and discrete mathematics. This study aims to identify misconceptions in participants in the Basic Mathematics course at the Mathematics Education Study Program at Bengkulu University in the 2021/2022 academic year as many as 69 students in Mathematical Logic material. This type of research is descriptive analysis research on the results of diagnostic tests in the form of essays, and the level of confidence in answering using the Certainty Response Index (CRI) in the form of percentages. To collect data, test sheets that were distributed to students during the final semester exams were used. On the description of the answers and the degree of confidence in providing answers, data analysis was done. The findings indicated that learning mathematical logic had an impact on participants in the Basic Mathematics course in terms of misconceptions ranging from 4 to 43%, with the highest identification of misconceptions occurring on the topics of concluding a statement and determining the veracity of arguments using premise law. The argument test employing the truth table has the lowest level of misinterpretation. There were 21% average misconceptions among students.

Keywords*: Certainty Response Index, Diagnostic Tests, Misconceptions, and Mathematical Logic.*

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INTRODUCTION

A universal science, mathematics supports the development of contemporary technology, plays a significant role in many fields, and fosters the advancement of human thought (Rosyidah, 2020); (Yensy, 2020) (Yensy, 2019). Due to the more abstract nature of mathematics, which ranges from concrete to semi-abstract to abstract knowledge, it is taught in phases starting with the simpler stages and progressing to the more sophisticated stages (Khusna & Rosyadi, 2021); (Goldin-Meadow, 2015). Conceptual knowledge, or the capacity to comprehend an idea and the connections between concepts in mathematics, is one of the knowledge areas in mathematics (Lui & Bonner, 2016); (Muhtarom et al., 2019). Because these ideas are connected, it will affect how well you comprehend other ideas if you don't understand one (Ijuddin & Fitriawan, 2022).

Misconceptions are misunderstandings brought on by ideas not supported by accurate knowledge (Elvia et al., 2020); (Abas et al., 2020). The assimilation of accurate concepts is hampered by misconceptions. This misunderstanding or misconception is the result of an idea that was independently developed by a process involving reasoning, intuition, and the culture in the area, but the concept was not the same as the actual concept (Ay, 2017). Making an incorrect generalization or conclusion to an argument is one type of misconception that is frequently practiced by students (Fitria, 2014). This is frequently encountered in basic mathematics courses, where one of the topics covered is mathematical logic, which addresses how to prove an assertion.

This course has quite abstract characteristics, and it contains quite several theorems that must be mastered and understood, even though they are still simple basic concepts (Romadiastri, 2012). Mathematical reasoning is used in many areas by human beings to make conclusions and solve problems (Solow, 2014).

According to the results of examinations given to 69 undergraduate students studying mathematics education, 34 students still struggled to correctly answer questions about the reliability of demonstrating an argument. Students also don't care and thoroughly comprehend the questions' meanings, which results in their failure to respond to questions.

To avoid a series of conceptual blunders that can occur at the following level of education, it is crucial to identify students' misconceptions (Juliawan & Putra, 2021). If not corrected right once, incorrect conceptual understanding will have an impact on how well students learn, and these errors will persist as they go up the educational ladder (Disnawati & Deda, 2022), (Naseer, 2015), (Ojose, 2015).

Several studies have guided the examination of common misconceptions, but there have never been any studies on the argument of mathematical logic. Additionally, the main's techniques involve a diagnostic test in the form of a two-tier multiple-choice, which has two levels of questions. The first level is the substance of a question with two possible answers, while the second level must explain why the first level's responses arechosen as the focus (Kshetree, MP; Acharya, BR; Khanal, 2021). The Certainty Response Index (CRI) method is applied here because

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CRI can separate students' abilities into three categories, as well as understanding the concept, not understanding the topic because of a lack of understanding, and experiencing misconceptions. However, this method still has weaknesses because it has not been able to distinguish whether students make mistakes, is caused misunderstanding, or do not understand the concept (Fadillah, 2017). By assessing the confidence level in each response, the CRI technique can discriminate between pupils who have misconceptions and those who understand the idea. This study looked at students' misconceptions when utilizing the CRI technique to answer questions involving mathematical logic.

METHODS

This study employed a qualitative descriptive methodology, which involved looking at research subjects under actual circumstances as opposed to controlled as in experiments. In addition, the research's findings are reported thoroughly without any inferences will be made from the result of the study (Rusdiana & Ratnawulan, 2014). The actual research process was as follows:

1. Selecting research participants, namely the two classes of Basic Mathematics students enrolled in the 2021–2022 academic year (A and B) which totaled 69 students in the Mathematics Education Study Program, Bengkulu University ;
2. Design a test that consists of six questions on mathematical logic (the material consists of implications, biimplications, tautologies, contradictions, drawing conclusions using premises and truth tables), with a *CRI index* for each question to indicate the degree of student confidence in each response;
3. Test the validity of questions by colleagues and use the AIKEN index;

$$CVI = \frac{\sum(r_i - l_o)}{n(c-1)} \qquad (1)$$

r = the number given by the validator
l_0 = the lowest validity rating score
c =the highest validity rating score
n = Number of validators
i = Integers 1, 2, 3, 4 and 5

4. Validity test using Pearson's Correlation, reliability test using Cronbach's alpha, test the difficulty level of the questions and test the differentiating power of the questions.
5. Providing 69 pupils with test questions (classes A and B combined);
6. Reviewing test results for students.

Table 1. Criteria for *certainty response index* (CRI)

CRI	Kriteria
0	Not Sure
1	Not Sure
2	Sure Right

(Kefi et al., 2021)

Since students are categorized based on whether they understand concepts, have misconceptions about topics, or do not understand concepts, the Certainty Response Index (CRI) criteria in Table 1 do not employ percentages. Students who are unsure of their responses select a scale of 0, students who are not sure of their answers choose a scale of 1, and students who are certain of their responses select a scale of 2.

Students that correctly respond by selecting a scale of 2 show that they have a solid understanding of the

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concept, whereas incorrect responses reveal misconceptions on the part of the class. Table 2 lists the criteria for concepts that are understood, not understood, and misconceptions.

Table 2. Criteria for students who have misconceptions,understand concepts, and do not understand concepts

Answer Criteria	***Certainty Response Index* (CRI)**		
	Not sure	*Not sure*	*Sure Right*
Correct answer	Don't Know Concept	Don't Know Concept	Understand Concept
Wrong answer	Don't Know Concept	Don't Know Concept	Misconceptions

Source : (Ramadhan et al., 2020)

Based on the results of identifying students who have misconceptions, understand concepts and do not understand concepts, then the percentage of students' understanding of concepts is calculated using the following equation (Halim et al., 2017):

$$P = \frac{S}{Js} x100\% \qquad (2)$$

Information:

P = the proportion of students who correctly grasp, incorrectly understand, and have misconceptions about the concept.

S = stands for the number of pupils who understand, don't understand, and have misconceptions about the concept.

Js = is the number of students in total

Additionally, criteria are employed as shown in Table 3 to determine the level of misconceptions.

Table 3. Percentage Level of Misconceptions

Category	**Percentage**
Low	0% - 30.99%
Enough	31% - 60.99%
High	61% - 100%

Source: (Ramadhan et al., 2020)

RESULTS AND DISCUSSION

Based on the results of the study, the percentage of students who understood the concept, did not understand the concept and had misconceptions was obtained as shown in Table 4.

Table 4. Percentage of students who understood the concept, did not understand the concept and had misconceptions for each item

Question Number	**Concepts Analyzed**	**Percentage (%)**		
		Under-stood	**Did not Understand**	**Misconcep-tions**
1	Test the Validity of Arguments Using the Law of Premises	57,9	13,1	29.0
2	Concluding an Argument When the Facts Are Known	36,2	20,3	43.5
3	Test the validity of the instrument using a truth table	94,2	1.5	4,3
4	Make Quota Statements	74.0	13.0	13.0
5	Determining the Negation of a Compound Statement	84,1	4,3	11,6
6	Defining Tautologies and Contradictions	66,7	10,1	23,2
	Average	**68,9**	**10,4**	**20,8**

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Based on Table 4, it can be seen that even though more than the majority of students on average understand the concept of Mathematical Logic, namely 68.9% or as many as 48 people out of 69 students who understand the concept, there are still students who experience misconceptions about each problem. The most misconceptions are making conclusions about an argument when the premises are known (second question), as much as 43.5%. On average, students experience misconceptions about Mathematical Logic material as much as 20.8% (including the low category), while the percentage of students who do not understand the concept because they are unsure of the answer is 10.4%.

The results obtained are because students still misunderstand premise laws in Mathematical Logic, such as the laws of modus ponen, modus tolens and syllogisms, so that when given a compound statement students tend to have difficulty connecting them into symbols in logic and reduce the known premise to become a new premise. The following is an example of student misconceptions on the first question. Before that, the question in this case is: *"Jika hari tidak panas maka Ani memakai topi. Ani tidak memakai topi atau ia memakai paying. Ani tidak memakai paying. Oleh karena itu hari tidak panas. (Benarkah argument tersebut? Gunakan hukum premis dan ekuivalensi"*. Beside that, the answer confidence level are: 1) not sure (score 0); 2) little sure (score 1); 3) sure right (score 3). The student's answer for this question can be seen in Figure 1.

Figure 1 showed that students had chosen the confidence level of the answer, namely in the category of being sure it was right, while the student's answers were wrong because they only wrote logical symbols or only exchanged the premise statement into symbolic, without reducing the premise to become a new premise, so students did not conclude whether the argument was valid or not. The example of the correct answer to the first question can be seen in Figure 2.

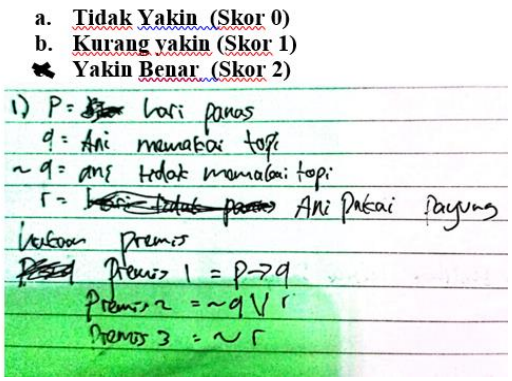

Figure 1. Misconceptions in the First Question (Wrong Answer, Student Believes Correct)

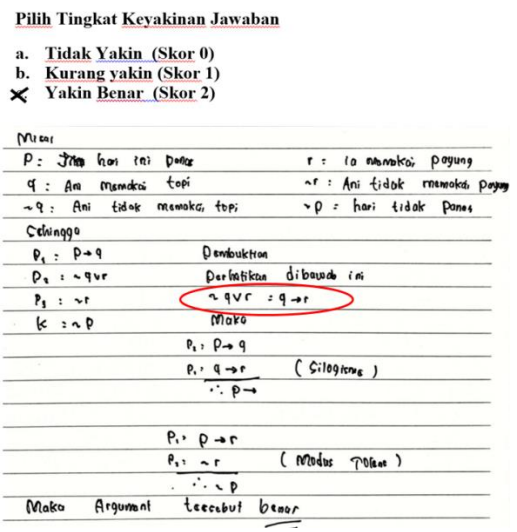

Figure 2. Answers of students who understood the concept in the first question (correct answer, students believe it is correct).

Based on Figure 2 can be seen that students excepting for being able to convert statements into logical symbols, students can also derive known premises into new premises by using the

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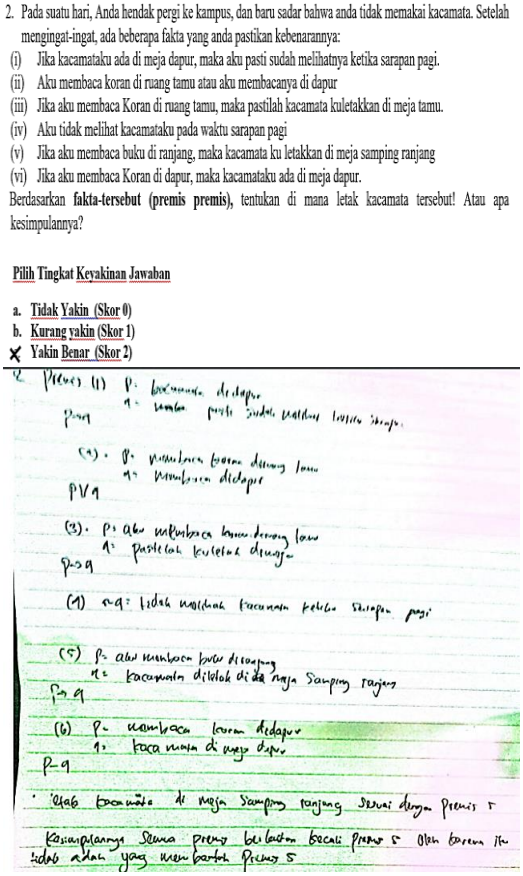
equivalence property, for example, changing the premise ~qVr (disjunction) to q→r (implication). In addition, students can use premise laws known as a premise, such as the law of syllogisms and modus tollens, and conclude that arguments are valid. Students also believed that the answer was correct. Thus students understood the concept correctly, and no misconceptions occur.

The following was a student's misconception in the second question about making a conclusion of an argument when the facts were known:

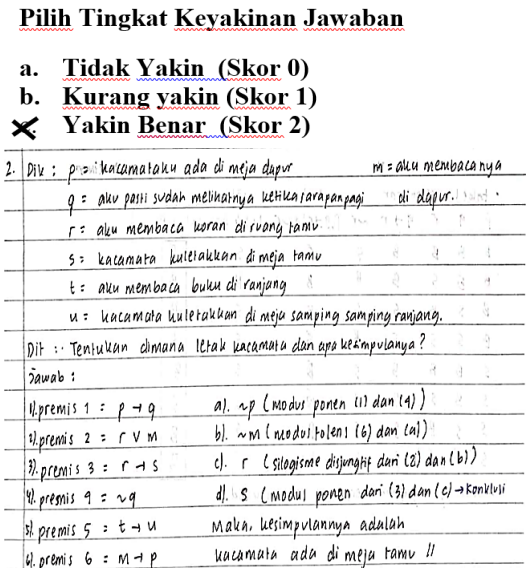

2. Pada suatu hari, Anda hendak pergi ke kampus, dan baru sadar bahwa anda tidak memakai kacamata. Setelah mengingat-ingat, ada beberapa fakta yang anda pastikan kebenarannya:
(i) Jika kacamataku ada di meja dapur, maka aku pasti sudah melihatnya ketika sarapan pagi.
(ii) Aku membaca koran di ruang tamu atau aku membacanya di dapur
(iii) Jika aku membaca Koran di ruang tamu, maka pastilah kacamata kuletakkan di meja tamu.
(iv) Aku tidak melihat kacamataku pada waktu sarapan pagi
(v) Jika aku membaca buku di ranjang, maka kacamata ku letakkan di meja samping ranjang
(vi) Jika aku membaca Koran di dapur, maka kacamataku ada di meja dapur.
Berdasarkan **fakta-tersebut (premis premis),** tentukan di mana letak kacamata tersebut! Atau apa kesimpulannya?

Pilih Tingkat Keyakinan Jawaban

a. Tidak Yakin (Skor 0)
b. Kurang yakin (Skor 1)
✗ Yakin Benar (Skor 2)

Figure 3. Misconceptions in the Second Question (Wrong Answer, Students Believe it is Correct)

In Figure 3 can be seen that students chose the level of confidence in their answers, namely in the category of being sure it was true, however students' answers were wrong because they made false premises into logical symbols, derived false premised, did not use the premise law and made the wrong conclusion. Here students also make the mistake of making a compound statement because they use the same symbols, namely p and q, even though each premise is different. So, students experience misconceptions that start from making premises in the form of logical symbols to making wrong conclusions. The example of the correct answer to the second question can be seen in Figure 4.


Pilih Tingkat Keyakinan Jawaban

a. Tidak Yakin (Skor 0)
b. Kurang yakin (Skor 1)
✗ Yakin Benar (Skor 2)

Figure 4. Answers of students who understand the concept in the Second question (correct answer, student believe it is correct).

Figure 4 indicated that students have a good understanding of the concept of concluding arguments by knowing the facts. This can be seen from the completion stages carried out, namely starting from changing each premise into the form of logical symbols, namely p, q, r, s, t, u, and m. Next, students rewrite the statement in the form of the symbols, are exemplified before, such as p → q (implication), r V m (conjunction), ~q

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(negation of q), and so on, the students used existing premise laws, namely the law of modus ponens, modus tollens, and disjunctive syllogism so that new premises had obtained, namely premises a, b, c, and d until a conclusion had to get because the last premised can no longer have reduced to new premises. In other words, the process is complete. Thus the student's answer is correct, and the student is also sure that the answer is correct based on the option of confidence level criteria chosen by the student, namely with a score of 2. It means that the student already understands the concept, and there are no misconceptions.

Table 5 showed the percentage of students' understanding of the mathematical logic material.

Table 5. Percentage of students' understanding of mathematical logic material

Student Understanding Level	Number of Students	Percentage (%)
Understand Concept	48	69
Don't Understand the Concept	7	10
Misconceptions	14	21

Table 5 had indicated that the majority of students understand the concept of mathematical logic well, but the number of students who experience misconceptions is also quite large compared to the number of students who do not understand the topyc, which is twice as much. It means that students still have difficulty understanding the concepts learned in mathematical logic material. Based on the previous results, it can be seen that students experience the most misconceptions, namely making conclusions about an argument when the premises are known and testing the validity of the argument using the premise laws and equivalence properties. Besides that, there are also misconceptions when determining tautologies and contradictions. Most students are also not careful in making a truth table for a premise, causing wrong conclusions to be drawn. Furthermore, proving the validity of the argument using a truth table, students understand more than if they use the premise law. It can be seen that almost all students understand the concept of this subject, only a few students experience misconceptions, namely only 3 students or 4.3%.

The findings are consistent with what Mutia (2017) claimed about students' misconceptions and errors when solving mathematical logic problems, particularly when compound statements are involved. These errors include mistranslating logical symbols, incorrectly assigning truth values to statements, and misconceptions when making conclusions. It is due to pupils' inconsistent usage of logical symbols and their interpretation of the provided sentence or statement. When converting a letter was presented in mathematical logic into assertions about finding conversions, inverses, and contrapositions, many students have made a blunder. Although they can change it, inverse, and contrapose in symbols, students can not do so in the form of sentences.

Rochmad et al. (2018) constructs the same claim that the usage of incorrect notions repeatedly and their storage in students' minds can affect the prevalence of mathematical misconceptions. Triliana & Asih (2019)

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adds that misunderstandings arise from students sequencing the stages of problem-solving and failing to grasp the problem's overall intent. For instance, At here, students selected the incorrect premise law when the modus ponens premise had been used. Instead, students choose other, less major premise laws.

According to Sarwadi & Shahrill, (2014) & Rosyid (2019), students' misconceptions were not created by chance but rather as a result of their prior knowledge and experiences. Because learning mathematics is cumulative, or that new knowledge is related to prior knowledge, gaps in learning concepts and misunderstandings result if a learner cannot assimilate and accept this. Additionally, according to Wasito & Kurniawan (2018); Kula & Güzel (2014) students are frequently unable to assess problems that have just been experienced and are not routine, and are generally confused about which concept to employ to solve problems.

Because it can help students develop other mathematical thinking skills, Ruswana (2019) and Lase (2021) contend that the ability of understanding is the most fundamental talent that students must possess. Thus, it is believed that there will be no longer be any misunderstandings among students, particularly misunderstandings of concepts in basic material such as mathematical logic material, which plays numerous roles and aids in the comprehension of other material.

CONCLUSION AND SUGGESTION

Based on the research and data analysis performed, it can be said that students taking Basic Mathematics courses for the 2021–2022 academic year have misconceptions about the subject matter of Mathematical Logic as a whole, with levels of misconception ranging from 4–43%. The greatest degree of misconception surrounds the subject of drawing a conclusion and determining an argument's viability utilizing the premise law. In the argument test employing the truth table, the lowest amount of misconception occurs. Students have an average of 21% misunderstandings.

It is advised to have a thorough understanding of the factors that lead to misunderstanding or conceptual errors in particular topics so that it can be expected that all course participants can comprehend the material being studied, in order to reduce misconceptions that occur for students in Basic Mathematics courses. Additionally, it is advised that subject teachers adopt the appropriate model during the learning process to reduce misconceptions.

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