



ROUTINES CONFLICT COMMOGNITIVE IN STUDENTS' WORK RESULTS ON THE MATERIAL OF INDEFINITE FORM LIMITS

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ABSTRACT

This research aims to describe cognitive conflicts that occur in first year students when solving indefinite form limit problems. This research is qualitative research with the researcher as the main instrument. Research method with stages of preparation, data collection, transcript and analysis. A total of 8 students from private universities were given mathematics problem sheets, containing limit questions of indefinite form consisting of one number and worked on for 30 minutes. Two students were selected as research subjects based on indicators of conflict in the components of routines and were interviewed in a semi-structured and in-depth manner to explore further information about the causes of conflict. The results of the research showed that the research subjects were able to solve the questions given but there were errors that triggered conflict, both ritualized and exploratory. . Ritualized due to weak understanding of material previously received in high school. Exploratory, which is a new or different method because it is not well understood, can cause cognitive conflict. Good mastery and understanding of the material can reduce the occurrence of cognitive conflicts in students' minds.

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1. INTRODUCTION

Mathematics learning at university is different from high school (Emanuel & Meilantifa, 2022; Putut et al., 2022; Putut et al, 2023). At university, students should be

creative, think critically when solving problems, and be able to communicate and elaborate well (Kim et al., 2019a; Thoma & Nardi, 2018). By having good communication skills, students will be encouraged to understand mathematical ideas (Thoma & Nardi, 2017). Communication can be done by students to themselves or their groups. Thinking and communicating are an inseparable unity, known as commognitive (Sfard, 2008, 2018, 2020).

Commognitive has four components, namely words use, visual mediators, narratives, and routines (Sfard, 2008). Words Use (WU) can be in the form of words or sentences, letters, symbols, and signs that are spoken in everyday life, for example, the X-axis, five, and area (Sfard, 2008). WU can also be mathematical, for example, the limit of a function, the area of a triangle, and logarithms (Emanuel & Meilantifa, 2022; Putut et al., 2022, 2023). In addition to WU, other components are visual mediators (VM). VM can be in the form of images, graphs, tables, or diagrams (Emanuel & Meilantifa, 2022; Putut et al., 2022, 2023). The third component is narratives (N), which can be a theorem or rule, for example, the Pythagorean theorem. The fourth component is routines (R), a repetitive pattern of steps in solving mathematical problems (Emanuel & Meilantifa, 2022; Putut et al., 2022, 2023). An example of routines is when students are given a contextual problem about matrix inverses, and the first step is to change the problem sentence into a mathematical sentence then determine the determinant and the inverse. These four components can be used in the analysis of student work results using the commognitive framework.

The commognitive framework has been widely used to analyze student work results (Ioannou, 2018; Kim et al., 2019b; Nardi et al., 2014). In the results of student work, there are often indications of commognitive conflict, namely errors in solving problems. Commognitive conflict is a situation where there are differences of opinion or perspective on the same problem (Putut et al., 2023). Commognitive conflict is seen from the narratives in the results of student work or the results of interviews with students based on the words used, narratives, visual mediators, or routines.

Based on the results of previous observations and research, the researcher suspects that there are still commognitive conflicts that arise in other materials (Emanuel & Meilantifa, 2022; Putut et al., 2022, 2023), namely the limit of indefinite form. This phenomenon prompted researchers to need to conduct research considering the many conflicts that occur, especially among first-year students and it is urgent to conduct this research because it affects the success of the learning process. The researcher's suspicion is based on the assumption that students are still experiencing a transition from school mathematics to university mathematics. The purpose of this study is to describe the commognitive conflict that occurs in first-year students in the material of indefinite form limits based on a review of routines, including exploratory and ritualized. After knowing the commognitive conflict that occurred, the teacher can take action to prevent the conflict from occurring and find out the sources of the conflict. Several previous studies on first-year students have been conducted by researchers. Commognitive conflict occurs in the results of student work when solving matrix algebra problems, especially in the components of words used (Putut et al., 2022). In addition, commognitive conflicts can occur in quadratic function material (Emanuel & Meilantifa, 2022) and division of integers (Putut et al., 2023), which is the researcher's previous research. However, there has been no research that describes commognitive conflict in the routines component in the material on indefinite form limits.

The problem used to find out the commognitive conflict in the routines component is the material of the indeterminate form limit. This material is included in the Calculus 1 course (Naduvath, 2016). This course is important because it is a prerequisite for taking courses in the following semester, including Calculus 2, Advanced Calculus, and Real Analysis. Therefore, this study describes the commognitive conflict that occurs in students

in the routines component when studying the material on the limit of indeterminate forms and explores the source of the cause of the conflict so that in subsequent learning the emergence of differences of opinion that occur due to differences in understanding as a trigger for conflict can be reduced even though the difference is part of the learning process.

2. METHOD

The research method used in this study is qualitative with a phenomenological approach to individuals suspected of experiencing commognitive conflict supported by in-depth semi-structured interviews. The key instrument is the researcher and the data is described according to the findings in the field as they are (Cresswel, 2013). The research began with preparation, namely preparing research instruments consisting of question sheets, observation notes, and interview sheets, which were validated by experts in the field of Mathematics education. Furthermore, the researcher gave one story problem about the material on the limit of indefinite forms to the participants as presented in Figure 1 below.

Diberikan pernyataan bahwa $\lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3\sqrt{x} - 2}}{x^2 - 16} = \frac{1}{64}$.
Selidikilah kebenaran dari pernyataan tersebut dan tuliskan langkah-langkah yang Anda lakukan dengan lengkap!

Figure 1. Question on Limits of Indefinite Forms

The story problem about the material of indefinite form limits was given a 30-minute working time to 8 first-year students who had taken the Calculus course to identify the problem phenomena to be studied. Indications of conflict are presented in Table 1 below.

Table 1. Description of Commognitive Conflict Component Routines

Routines	Description	Example	Coding
Ritualized	Using steps that are by the problem-solving procedures, but are contrary to the rules that should be followed	Solving indefinite form of limit, that is $\frac{0}{0}$, experienced an error in factoring or multiplying a pair	RR1
Exploratory	Using an unusual method, but there are differences with the applicable rules	Solving indefinite form of limit $\frac{0}{0}$, using differentials but making a procedural error in using differentials to solve indeterminate limits	RR2

The next step is to conduct in-depth semi-structured interviews between the researcher (P) and the research subjects, namely Subject 1 (S1) and Subject 2 (S2), to explore the sources of the conflict and analyze them (Endrayana et al, 2022; Putut et al., 2024; Putut et al, 2023). Next, method triangulation is carried out by comparing the analysis results obtained from tests, observations, and interviews. Method triangulation is carried out to test the validity of the research data obtained in order to draw conclusions based on research problems.

3. RESULTS AND DISCUSSION

3.1. Results

The results of the research related to commognitive conflict in Subject 1 and Subject 2 are described in this section. The following are the results of Subject 1's work (S1).

$$\begin{aligned}
 & \lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3\sqrt{x} - 2}}{x^2 - 16} \\
 &= \lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3\sqrt{x} - 2}}{x^2 - 16} \cdot \frac{\sqrt{x} + \sqrt{3\sqrt{x} - 2}}{\sqrt{x} + \sqrt{3\sqrt{x} - 2}} \\
 &= \lim_{x \rightarrow 4} \frac{x - (3\sqrt{x} - 2)}{(x^2 - 16)(\sqrt{x} + \sqrt{3\sqrt{x} - 2})} \\
 &= \lim_{x \rightarrow 4} \frac{(x + 2) - 3\sqrt{x}}{(x^2 - 16)(\sqrt{x} + \sqrt{3\sqrt{x} - 2})} \cdot \frac{\sqrt{x}}{\sqrt{x}} \quad \text{RR1} \\
 &= \frac{(4 + 2) - 3 \cdot 2}{0(2 + 2)} \cdot \frac{2}{2} \\
 &= \frac{0}{0} \\
 &\text{tidak terdefinisi karena } \frac{0}{0}. \\
 &\text{Jadi tidak benar bahwa } \lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3\sqrt{x} - 2}}{x^2 - 16} = \frac{1}{64}, \\
 &\text{karena limitnya tidak terdefinisi.}
 \end{aligned}$$

Figure 2. Result of S1's work

In **Figure 2**, it can be seen that there was an error in S1's work results. S1 made a mistake in the steps of the solution that were carried out. Starting from rewriting the part of the problem on the left side, S1 tried to do the steps usually done when solving limit problems. S1 began by multiplying the friends of the form given in the problem. However, after doing the multiplication of friends, S2 made a mistake in the solution steps, namely by multiplying the root form (RR1) which should not have been done. This indicates a commognitive conflict that occurred in S1's mind. The commognitive conflict was also seen when a semi-structured interview was conducted by the researcher (P) with S1. The source of the conflict is that S1 does not master the previous knowledge that has been obtained. The steps taken by S1 lead to wrong conclusions. Based on the semi-structured interviews conducted, it can be said that S1 experienced hesitation and doubt when solving problems and this triggered the commognitive conflict in his mind. The commognitive conflict in the usual steps (RR1/ritualized) is seen in the following interview excerpt.

- P : Please explain about this step (while pointing to the work result of S1/RR1)
- S1 : Okay, sir. After I multiplied it with a friend, I was then a bit confused and doubtful because there were still root forms obtained. Then, I thought for a moment, then I took the step of multiplying a friend of the existing root forms.
- P : Did you double check the results of the multiplication with the previous friend? Is the result an indeterminate form?

- SI* : Well, that's it sir. I did a check first and immediately multiplied it with a friend of the root shape because the shape was still $\frac{0}{0}$ (indication of RR1).
P : However, you substituted the value of $x = 4$ into the function, but you haven't done the compound multiplication yet. How would you explain this step?
SI : Because I remembered my previous knowledge, that after multiplying the pairs, we can immediately substitute the value of x , so I did the substitution, sir.
P : Even though it is still an indeterminate form, right? Should this step be allowed?
SI : Uhm, I think it's okay sir. According to what I know before (RR1).
P : How is the result? $\frac{0}{0}$?
SI : Yes, sir. And I think that's the limit result. So $\frac{0}{0}$ undefined..

Next, the results of Subject 2's (S2) work can be seen in **Figure 3**.

$$\lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3x-2}}{x^2 - 16}$$
 substitusi langsung, $\frac{2 - \sqrt{3 \cdot 2 - 2}}{0} = \frac{0}{0}$
 gunakan turunan karena bentuk $\frac{0}{0}$, didapat

$$\lim_{x \rightarrow 4} \frac{x^{1/2} - (3x^{1/2} - 2)^{1/2}}{x^2 - 16}$$

$$\lim_{x \rightarrow 4} \frac{\frac{1}{2}x^{-1/2} - \frac{1}{2}(3x^{1/2} - 2)^{-1/2}}{2x}$$

$$= \frac{\frac{1}{2 \cdot 2} - \frac{1}{2 \sqrt{3 \cdot 2 - 2}}}{2 \cdot 4} = \frac{0}{8} = 0 \quad \text{RR2}$$

$$\lim_{x \rightarrow 4} \frac{\sqrt{x} - \sqrt{3x-2}}{x^2 - 16} = 0 \neq \frac{1}{64}$$
 Jadi pernyataan soal salah

Figure 3. Result of S2's work

In Figure 3, the results of S2's work when solving the given problem are shown. After rewriting the given problem on the left side, S2 directly substitutes the value of $x = 4$ into the given function. S2 obtains the substitution result, namely $\frac{0}{0}$ that is undefined form. S2 then tried to recall the knowledge he had acquired in high school and S2 carried out the steps he had taken when solving the problem. S2 stated that because it was an undefined form, namely $\frac{0}{0}$, then S2 uses derivatives to solve the problem (RR2/exploratory). S2 rewrites the given problem into an exponential form. After changing

the writing of the problem, S2 then takes the next step by deriving the given function (RR2). However, when S2 takes this step, S2 makes a mistake when deriving the function. S2 did mistakes when derived $\left(3x^{\frac{1}{2}} - 2\right)^{-1/2}$. The mistake made by S2 triggered a commognitive conflict when the results obtained were different from the questions. S2 felt that his steps were correct. However, when the results obtained were different from the questions, S2 experienced hesitation and doubt. But in the end, S2 concluded that his steps were correct and indeed the results were different from those known in the questions and S2's conclusion was wrong.

S2 seemed confident with the steps to solve the problem based on the knowledge he had in high school. When clarified using a semi-structured interview by the researcher, the cause of the commognitive conflict in S2 was obtained. An excerpt from the interview between the researcher (P) and S2 is described as follows.

- P : Can you explain the steps to solve this part of the problem? (pointing to S2's work)*
- S2 : Okay, sir. So initially I checked with value substitution $x = 4$ into the question. It turns out that the form obtained $\frac{0}{0}$. Well, I remember, that if the form is $\frac{0}{0}$ then we can do Compound multiplication, factoring. However, I was taught by a teacher in another way, namely by using derivatives.*
- P : Taught by a teacher? Please, continue.*
- S2 : Yes, sir. Then, I changed it to the exponent form first, because I found it a bit difficult if it was in the root form. Then I did the derivative (RR2/exploratory), then because the result was not an indeterminate form, namely $\frac{0}{8}$, then I tried to check my steps again. I checked several times until I was confused and doubtful even though in the end, I concluded that the limit result was zero. And of course this is different from the question given.*
- P : Did you double check your descent steps? Is there anything you missed?*
- S2 : Yes, sir. And I am sure of my answer.*
- P : Okay then. When doing the derivation, there is a step that is still missing and finally the answer you get is different from the question, so you are confused and doubtful.*

3.2. Discussion

There are four commognitive components present in mathematical discourse (Presmeg, 2016; Sfard, 2008). The four components include words use, visual mediators, narratives, and routines (Heyd-Metzuyanim & Tabach, 2018; Ng, 2019). Based on the results of the work and interviews that have been conducted with research subjects, in the routines component, it was found that subjects were able to carry out steps to solve problems that they had previously carried out in high school (*ritualized*). This is in line with the statement that understanding in high school is often used to solve problems at university level (Pratiwi et al, 2020; Thoma & Nardi, 2018). When solving problems, subjects can use steps that are not usually done (exploratory). A similar opinion was expressed that students have unusual steps when solving problems (Lu et al, 2020; Nachlieli & Heyd-Metzuyanim,

2021; Thoma & Nardi, 2017). These steps are usually introduced by teachers to accelerate the speed in solving problems. However, these steps are often not accompanied by a good understanding of the concept of the material, so that it can trigger errors in its application.

The steps taken when solving a problem, ritualized and exploratory, can trigger conflict in the mind (Halim et al, 2020). This arises when the final result of the steps taken is different from the one given in the question. This difference is what triggers doubt and hesitation in the subject (Ioannou, 2018; Viirman & Nardi, 2019). In the end, the conclusions drawn can be wrong and the reasons or arguments presented are also very weak. These conclusions and arguments are very dependent on the steps taken when solving the problem. Solving the problem depends on each individual's understanding of the material being studied (Putut et al., 2024; Putut et al., 2023). Understanding the material given is very important in choosing the right strategy to solve the problem, a strategy that contains the steps to solve the problem correctly. Lack of understanding of the material being studied can cause errors when carrying out the steps to solve the problem and trigger a commognitive conflict in the mind.

The steps to solving the problem begin with understanding the problem and then being able to determine what needs to be solved (Emanuel et al., 2021). What is the right strategy and accuracy and precision in solving problems can affect the drawing of conclusions. Inaccuracy and carelessness in solving problems can trigger errors when drawing conclusions which ultimately trigger commognitive conflicts (Putut et al., 2024). Arguments stated against false conclusions can also cause commognitive conflicts in the mind. Supposedly, a good understanding of the concept will be able to reduce the source of commognitive conflicts in the steps when solving math problems.

4. CONCLUSION

Based on the results of the study and discussion, it can be concluded that first-year students have quite good knowledge but still experience commognitive conflict. This is because the lack of understanding of the steps to solve the problem causes errors in working on the problem. This triggers hesitation and doubt when there is a difference with what is known in the problem. Hesitation and doubt in the mind can trigger commognitive conflict. The source of commognitive conflict can be explored through semi-structured interviews. Commognitive conflict that occurs in the steps to solve the problem (routines) repeats previous patterns (ritualized) or new methods that have never been done (exploratory). The results of this study only focused on one component of commognitive, namely routines. Furthermore, it is expected that teachers can help students, especially first-year students, to be able to reduce the causes of commognitive conflict, not only in the routine's component, but also in the words use, narratives, and visual mediators' components.

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