Profile of Metacognition of Mathematics and Mathematics Education Students in Understanding the Concept of Integral Calculus

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Abstract. This study describes the metacognition profile of mathematics and mathematics education students in understanding the concept of integral calculus. The metacognition profile is a natural and intact description of a person's cognition that involves his own thinking in terms of using his knowledge, planning and monitoring his thinking process, and evaluating his thinking results when understanding a concept. The purpose of this study was to produce the metacognition profile of mathematics and mathematics education students in understanding the concept of integral calculus. This research method is explorative method with the qualitative approach. The subjects of this study are mathematics and mathematics education students who have studied integral calculus. The results of this study are as follows: (1) the summarizing category, the mathematics and mathematics education students can use metacognition knowledge and metacognition skills in understanding the concept of indefinite integrals. While the definite integrals, only mathematics education students use metacognition skills; and (2) the explaining category, mathematics students can use knowledge and metacognition skills in understanding the concept of indefinite integrals, while the definite integrals only use metacognition skills. In addition, mathematics education students can use knowledge and metacognition skills in understanding the concept of both indefinite and definite integrals.

1. Introduction

Integral calculus is one of the compulsory courses programmed by students of Mathematics Department and Mathematics Education Department. When viewed from the graduates of the Department of Mathematics Education is to produce a bachelor candidate for high school mathematics teacher, so it is expected to be able to comprehend integral calculus material, in addition to apply it to everyday life, and other relevant courses, also can teach it to students in high school. While the graduates of Department of Mathematics are producing pure mathematics scholars, so it is expected to be able to comprehend the material of integral calculus, and can apply it to everyday life, as well as other relevant subjects [4].

Based on the difference of interest of students in the selection of Mathematics Department and Mathematics Education Department, it is possible to differentiate students' metacognition in understand mathematical concepts. This can be seen from the difference of mathematics learning outcomes of students in high school and in the first semester of Mathematics Department or Mathematics Education Department. When viewed from the average value of the national exam of high school mathematics, for students better mathematics education than math students (63.58> 59.0), while the average achievement index first semester, mathematics students better than mathematics education students (3.17> 3.07).

The metacognition profile is a natural and intact description of a person's cognition that involves his own thinking in terms of his or her knowledge, and the ability to plan and monitor his thinking process, and evaluate the process and outcome of one's thinking when understanding a concept. According to Koriat, in Goh [8], Metacognition refers to what people know about cognition in general and about their own cognitive processes, in particular, as well as how they use this knowledge to adjust their informational processes and behavior. While cognitive understanding is a
process that occurs internally within the central nervous system at the time of human thinking (Gagne [7]). Then Neisser [14] says that cognition is the acquisition, arrangement, and use of knowledge.

The concept of integral calculus that is examined in this paper is the concept of integral indeterminate and integral of course. To understand the concept of integral calculus using the Bloom theory developed by Anderson et al. [1], and Mayer [12], and can be seen in Table 1.

| Table 1: Categories in understand concepts by Anderson et al. and Mayer |
|-----------------------------------------------|--------------------------------------------------------|
| Categories                            | Indicator                                                                                     |
| 1. Interpreting                       | Clarifying, Paraphrasing , Representing , and Translating.                                     |
| 2. Exemplifying                       | Illustrating, and Instantiating                                                                |
| 3. Classifying                        | Categorizing and Subsuming                                                                     |
| 4. Summarizing                        | Abstracting, and generalizing                                                                  |
| 5. Inferring                          | Concluding, Extrapolating, Interpolating, and Predicting                                       |
| 6. Comparing                          | Contrasting, Mapping, and Matching                                                             |
| 7. Explaining                         | Constructing models                                                                          |
|                                      | Changing from one form of representation to another                                           |
|                                      | Finding a specific example or illustration of a concept or principle.                         |
|                                      | Determining that something belongs to a category                                              |
|                                      | Abstrating a general theme or major point(s)                                                  |
|                                      | Drawing a logical conclusion from presented information                                        |
|                                      | Detecting similarities and differences between two or more objects, events, ideas, problems, or situations |
|                                      | Constructing a cause and effect model of a system                                              |

This paper discusses only two categories of conceptual understanding, summarizing and explaining. The metacognition profile in understanding the concept of integral calculus especially the summarizing and explaining category can be seen from 2 components of metacognition, ie cognitive knowledge consists of declarative knowledge, procedural knowledge, and conditional knowledge (Flavell [6]) and metacognition skills consisting of planning, monitoring and evaluating (Dawson [5], Livingston [10], and CCD Malaysia [3]).

The students’ metacognition profile review was distinguished between mathematics students and mathematics education students. Thus, the purpose of this study was to produce the metacognition profile of mathematics and mathematics education students in understanding the concept of integral calculus.

2. Method
This research method is the explorative method with a qualitative approach. This explorative research is intended to explore the metacognition of mathematics students and mathematics education in understanding the concept of integral calculus so as to obtain a large profile of students' metacognition. The subjects of study (RS) are students of the mathematics department and Mathematics Education department who are studying integral calculus, consisting of 1 mathematics student and 1 student of mathematics education. Selection of the subject of this study based on the highest score of the Mathematics Ability Test (score >70), and consider the value of student achievement. The main data collection of this research was obtained by using interview technique. In addition, there is supporting data which is the result of written work of the research subject in understand integral calculus task. The data analysis process follows analysis model of Miles and Huberman[13], consisting of: (1) data reduction, data presentation, and (3) conclusion. Interpretation of data carried out simultaneously with data presentation activities. In this activity, researchers do an interpretation of research data (answers RS at the time of interview). Making conclusions and recommendations based on the results of data processing to answer research questions, namely finding the profile of students' metacognition in understanding the concept of integral calculus.

3. Results and Discussion
The results of this study reveal the metacognition profile of mathematics and mathematics education students in understanding the concept of integral calculus, especially the categories of summarizing...
and explaining. To reveal the metacognition profile of the students, first, look at the understanding of mathematics and mathematics education students about the concept of integral calculus based on the students’ answers in completing the task of understanding the concept of integral. Second, through interviews can reveal the metacognition of students in understanding the concept of integral calculus.

3.1. Understanding of mathematics and mathematics education students on the concept of integral calculus on the Summarizing Category

The answers of mathematics and mathematics education students in understanding the concept of integral calculus in the summarizing category can be seen in Table 2.

| Form of task | Mathematics | Mathematics Education |
|--------------|-------------|-----------------------|
| a. \( D_1[x^4] = 4x^3 \); \( D_2[x^4 + 3] = 4x^3 \) | \( \int 4x^3 \, dx = x^4 + C \) | \( \int 4x^3 \, dx = x^4 + C \) |
| Define \( \int 4x^3 \, dx \) | | |

Based on the results of the answers in Table 2, mathematics and mathematics education students can summarize the main points given in the form of indefinite integrals so that the answer is correct. Meanwhile, the main points given in the form of definite integrals cannot be summarized so the answer is wrong.

3.1.1. Results of mathematics student interviews about understanding the concept of integral calculus on the summarizing category

Results of mathematics student interviews about understanding the concept of integral calculus on the category of summarizes consists of the concept of indefinite integrals and definite integrals:

3.1.1.1. The Indefinite Integral Concepts

The results of mathematics student interviews in understanding the concept of indefinite integrals in the Summarizing category as follows: (1) Students of mathematics can summarize the main points given in the form of improper integrals correctly i.e \( \int 4x^3 \, dx = x^4 + C \). (2) The mathematics students can give the reason that \( \int 4x^3 \, dx = x^4 + C \) is based on the pattern that some \( x^4 \) functions are added with a different number but the derivatives are the same. (3) Student of mathematics can use procedure to get \( \int 4x^3 \, dx = x^4 + C \), that is \( \int 4x^3 \) anti derived from function \( x^4 \) although have different konstata, so result \( x^4 \) in added C. (4) Students of mathematics have not been able to determine the hook elements about the results obtained from the indefinite integral whether a function or not a function, (5) Students of mathematics can explain easily from the summary of the main points given in the form of indefinite integrals, and (6) Students of mathematics can emphasize that summarizing the main points given in the form of indefinite integrals to \( \int 4x^3 \, dx = x^4 + C \) is true.

Thus, results of mathematics student interviews in understanding the indefinite integral concepts indicate that they have used metacognition knowledge and metacognition skills in
understanding the concepts of indefinite integrals in the summarizing category. Only metacognition skills in the planning component are not yet visible.

3.1.1.2. The Definite Integral Concepts

The results of mathematics student interviews in understanding the definite integral concepts on summarizing category as follows: (1) Students of mathematics cannot summarize the main points given in form the definite integrals $\int_{-2}^{2} (x + 2) \, dx + \int_{-2}^{2} (x + 2) \, dx = 4$ is wrong (2) The mathematics student can not give the reason that the area of the function $|x + 2|$ on the interval $[-2,2]$ is above the $x$-axis, (3) Math students are less able to use the procedure to obtain the area of function $|x + 2|$ at the interval $[-2,2]$, (4) Math students have not been able to explain the reasons in calculating the area of the function $|x + 2|$ at the interval $[-2,2]$, i.e. $\int_{-2}^{2} |x + 2| \, dx = \int_{-2}^{2} (x + 2) \, dx$, and (6) Students of mathematics have not mastered the procedure to obtain results from $\int_{-2}^{2} |x + 2| \, dx = 8$.

Thus, the Results of mathematics student interviews in understanding the concept of integral certainly in the Summarizing category has not shown metacognition knowledge and metacognition skills.

3.1.2. Results of mathematics education student interviews about understanding the concept of integral calculus on the summarizing category

Results of mathematics education student interviews about understanding the concept of integral calculus on the category of summaries consists of the concept of indefinite integrals and definite integrals:

3.1.2.1. The Indefinite Integral Concepts

The results of mathematics education students interviews in understanding the concept of indefinite integrals in the summarizing category as follows: (1) Students of mathematics education can summarize the main points given in the form of improper integrals correctly i.e $\int 4x^3 \, dx = x^4 + C$, (2) The mathematics education students can give the reason that $\int 4x^3 \, dx = x^4 + C$ is based on the pattern that some $x^4$ functions are added with a different number but the derivatives are the same. (3) Student of mathematics education can use procedure to get $\int 4x^3 \, dx = x^4 + C$, that is $\int 4x^3 \, dx$ anti derived from function $x^4$ although have different konstata, so result $x^4$ in added $C$, (4) Mathematics education students can determine the hook elements about the results obtained from the indefinite integral is a relation, because the value of $C$ is not single, (5) Students of mathematics education can explain easily from the summary of the main points given in the form of indefinite integrals, and (6) Students of mathematics education can emphasize that summarizing the main points given in the form of indefinite integrals to $\int 4x^3 \, dx = x^4 + C$ is true.

Thus, the result of the mathematics education student’s interview in understanding the indefinite integrals concepts indicate that it has used metacognition knowledge and metacognition skills in understanding the concept of indefinite integrals in the summarizing category.

3.1.2.2. The Definite Integral Concepts

The results of interviews of mathematics students in understanding the concept of definite integrals on summarizing category as follows: (1) Students of mathematics education cannot summarize the main points given in form the definite integrals $\int_{-2}^{2} (x + 2) \, dx + \int_{-2}^{2} (x + 2) \, dx = 4$ is wrong (2) The mathematics education students cannot give the reason that the area of the function $|x + 2|$ on
the interval [-2,2] is above the x-axis, (3) Students of math education are less able to use procedures to obtain the area of function |x + 2| at the interval [-2,2], (4) Students of mathematics education can review their understanding that the area of function |x + 2| on the interval [-2,2] is above the x-axis, (5) Students of mathematics education can explain the steps of calculating the area of function |x + 2| at the interval [-2,2], i.e \[ \int_2^3 (x + 2) dx \], and (6) Students of mathematics education can master the procedure to obtain results from \[ \int_2^3 |x + 2| dx = 3. 

So, the result of student interviews mathematics education in understanding the concept of definite integrals on summarizing category does not show knowledge of metacognition. After being reminded again of the concepts of definite integrals, students can use their metacognitive skills to understand the concepts of definite integrals that.

3.2. Understanding of mathematics students and mathematics education on the concept of integral calculus on the explaining category

The answers of mathematics and mathematics education students in understanding the concept of integral calculus in the explaining category can be seen in Table 3.

| Table 3: Answers to mathematics and mathematics education students in understanding the concept of integral calculus in the explaining category |
| --- |
| Form of task | Mathematics | Mathematics Education |
| a. Is known for the linearly properties of the definite integrals, i.e if f and g have antiderivatives, then \[ \int [f(x) + g(x)] dx = \int f(x) dx + \int g(x) dx \]. Based on your knowledge of the polynomial function, and if f the polynomial function then try to explain whether \[ \int [f(x)] dx \] apply this trait. | Let \( f(x) \) be a polynomial function with the form \( f(x) = x^2 + 2x + 3 \). To integrate the function of this polynomial can be done one by one \[ \int (x^2 + 2x + 3) dx = \int x^2 dx + \int 2x dx + \int 3 dx \]. | Let \( f(x) \) be a polynomial function with the form \( f(x) = a_0x^0 + a_1x^1 + \ldots + a_nx^n \). To integrate the function of this polynomial can be done one by one \[ \int (a_0x^0 + \ldots + a_nx^n) dx \] |
| b. Is known of property of additivity for definite integrals, i.e if \( f \) is integral to an interval containing three dots \( a, b, \) and \( c \) respectively, then \[ \int f(x) dx = \int f(x) dx + \int f(x) dx \]. Based on your knowledge of the definitions of definite integrals, and the sequence properties of the real numbers, try to explain whether this property applies also to certain intervals containing four consecutive points \( a, b, c, \) and \( d \) when \( f \) is integrated at that interval. | If \( f \) on the interval \([a, d]\) contains for dots \( a, b, c, \) and \( d \) respectively, illustrated \[ \int f(x) dx \]. Then \( L = \int_a^b f(x) dx + \int_b^c f(x) dx + \int_c^d f(x) dx \]. | If \( f \) on the interval \([a, d]\) contains for dots \( a, b, c, \) and \( d \) respectively, illustrated \[ \int f(x) dx \]. Then \( L = \int_a^b f(x) dx + \int_b^c f(x) dx + \int_c^d f(x) dx \]. |

Based on the results of the answers in Table 3, the mathematics student can explain a model of the consequences of a given property of either indefinite integrals or definite integrals, but the explanation is very brief and not detailed. While of mathematics education students can explain a model of the consequences of a given property of either indefinite integrals or definite integrals, with a very detailed explanation.
3.2.1. Results of mathematics student interviews about understanding the concept of integral calculus on the explaining category

Results of mathematics student interviews about understanding the concept of integral calculus on the category of explaining consists of the concept of indefinite integrals and definite integrals:

3.2.1.1. The Indefinite Integral Concepts

The results of the mathematics student interviews in understanding the concept of indefinite integrals in the explaining category as follows: (1) Students of mathematics can explain a model of an indefinite integral with a polynomial function based on the linearity properties, i.e., \( \int (x^2 + 2x + 3)dx \) be \( \int x^2dx + \int 2xdx + \int 3dx \). (2) Students of mathematics can give the reason that the polynomial function applies the linearity properties so that \( \int (x^2 + 2x + 3)dx \) can be changed to \( \int x^2dx + \int 2xdx + \int 3dx \). (3) Students of mathematics can use the procedure to explain \( \int (x^2 + 2x + 3)dx \) changes to \( \int x^2dx + \int 2xdx + \int 3dx \). (4) Students of mathematics can show that the polynomial function applies the linearity properties, (5) Students of mathematics can show results from \( \int (x^2 + 2x + 3)dx \) same with result \( \int x^2dx + \int 2xdx + \int 3dx \), and (6) Students of mathematics can conclude that the function of polynomial is a linear function then apply the linearity properties, so that \( \int (x^2 + 2x + 3)dx = \int x^2dx + \int 2xdx + \int 3dx \).

Thus, the results of mathematical student interviews in understanding the concepts of indefinite integrals indicate that it has used metacognition knowledge and metacognition skills in understand the concept of indefinite integrals in the explaining category.

3.2.1.2. The Definite Integral Concepts

The results of interviews of mathematics students in understanding the concept of definite Integrals in the Explaining category as follows: (1) The mathematics student can explain a model of the definite integrals of function \( f \) at intervals \( [a, d] \) based on the sequence properties of the real numbers with \( f \) can be integrated into \( [a, b] \), \( [b, c] \), and \( [c, d] \), (2) The mathematics student can give the reason that the interval \( [a, d] \) contains four dots \( a, b, c \) and \( d \) respectively and \( f \) can be integrated at \( [a, d] \) so apply \( \int f(x)dx + \int f(x)dx + \int f(x)dx \). (3) Students of mathematics can use the procedure with the help of graphs to obtain the area of each interval \( [a, b], [b, c], \) and \( [c, d] \), (4) The mathematics student has not been able to explain that if \( f \) can be integrated into \( [a, d] \), then \( f \) can also be integrated into each interval \( [a, b],[b, c], \) and \( [c, d] \), (5) The mathematics student has not been able to explain the integral form at each interval \( [a, b], [b, c], \) and \( [c, d] \) i.e., \( \int f(x)dx + \int f(x)dx + \int f(x)dx \). (6) The mathematics student can conclude that a function \( f \) on the interval \( [a, d] \) contains four dots \( a, b, c \) and \( d \) sequentially with \( f \) can be integrated into \( [a, d] \), is \( \int f(x)dx = \int f(x)dx + \int f(x)dx + \int f(x)dx \).

Thus, the results of the mathematics student’s interview in understanding the definite integral concepts of the explaining category indicate that they have used metacognition knowledge, but have not used metacognition skills especially in planning and monitoring.

3.2.2. Results of mathematics education students interviews about understanding the concept of integral calculus on the explaining category

Results of mathematics education student interviews about understanding the concept of integral calculus on the category of explaining consists of the concept of indefinite integrals and definite integrals:
3.2.2.1. The Indefinite Integral Concepts

The results of the mathematics education student interviews in understanding the concept of indefinite integrals in the explaining category as follows: (1) Students of mathematics education can explain a model of an indefinite integral with a polynomial function based on the linearity properties, ie \( \int(a_nx^n + \ldots + a_1x + a_0)dx \) be \( \int a_nx^n dx + \ldots + \int a_1x dx + \int a_0 dx \). (2) Students of mathematics education can give the reason that the polynomial function applies the linearity properties so that \( \int(a_nx^n + \ldots + a_1x + a_0)dx \) can be changed to \( \int a_nx^n dx + \ldots + \int a_1x dx + \int a_0 dx \). (3) Students of mathematics education can use the procedure to explain \( \int(a_nx^n + \ldots + a_1x + a_0)dx \) changes to

\[
\int a_nx^n dx + \ldots + \int a_1x dx + \int a_0 dx.
\]

(4) Students of mathematics education can show that the polynomial function applies the linearity properties. (5) Students of mathematics education can show results from \( \int(a_nx^n + \ldots + a_1x + a_0)dx \) same with result \( \int a_nx^n dx + \ldots + \int a_1x dx + \int a_0 dx \), and (6) Students of mathematics education can conclude that the function of polynomial is a linear function so that it behaves the linearity properties, so apply \( \int(a_nx^n + \ldots + a_1x + a_0)dx = \int a_nx^n dx + \ldots + \int a_1x dx + \int a_0 dx \).

Thus, the result of the mathematics education student interview in understanding the indefinite integral concepts indicate that it has used metacognition knowledge and metacognition skills in understand the concept of indefinite integrals in the explaining category.

3.2.2.2. The Definite Integral Concepts

The result of interview of mathematics education students in understanding the concept of definite integral in Explaining category as follows: (1) The mathematics education student can explain a model of the definite integrals of function \( f \) at intervals \([a, d]\) based on the sequence properties of the real numbers with \( f \) can be integrated at \([a, d]\), ie

\[
\int_a^d f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx + \int_c^d f(x)dx.
\]

(2) The mathematics education students can give the reason that the interval \([a, d]\) contains four dots \( a, b, c \) and \( d \) respectively and \( f \) can be integrated at \([a, d]\) so apply

\[
\int_a^d f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx + \int_c^d f(x)dx.
\]

(3) Students of mathematics education can use the procedure with the help of graphs to obtain the area of each interval \([a, b], [b, c], \) and \([c, d]\), (4) Students of mathematics education can explain that if \( f \) can be integrated into \([a, d]\) then \( f \) can also be integrated into each of the intervals \([a, b], [b, c], \) and \([c, d]\). (5) Students of mathematics education can write integral forms at each interval \([a, b], [b, c], \) and \([c, d]\) ie

\[
\int_a^b f(x)dx + \int_b^c f(x)dx + \int_c^d f(x)dx.
\]

(6) Students of mathematics education can conclude that a function \( f \) on the interval \([a, d]\) contains four dots \( a, b, c \) and \( d \) sequentially with \( f \) can be integrated into \([a, d]\), is

\[
\int_a^d f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx + \int_c^d f(x)dx.
\]

Thus, the result of the mathematics education student interview's understanding the definite integral concepts shows that it has used metacognition knowledge and metacognition skills in understand the concept of definite integrals in the explaining category.

The results above show that there are differences in metacognition profile between mathematics students and mathematics education students in understanding the concept of integral calculus, especially the integral concept of both the summarizing category and the explaining category. In the summarizing category, mathematics education students can review their understanding that the area of function \( |x + 2| \) at interval \([-2,2]\) is above the x-axis, and can explain the steps of calculating the area of the function \( |x + 2| \) at the interval \([-2,2]\). While the mathematics student has not been able to review his understanding of the area of function \( |x + 2| \) at interval \([-2,2]\) and can not yet explain the steps to calculate the area of the function area. This is because math students are not yet accustomed to drawing graphs of functions of absolute values. Although the mathematics students are theoretically directed to think mathematics, because they are not familiar with the concept they are doing, the result
is not good. This is in the opinion of Masami & Katagiri [11], there is no way a person could teach in such a way as to cultivate mathematical thinking without first understanding the kinds of mathematical thinking that exist. On the other hand, Wittrock [15], stated that some studies have found no effects of summarization and the conditions below are not well understood.

Then, in the explaining category, Mathematics education students can explain and write the integral form that if \( f \) is integral to \([a, d]\) then \( f \) can also be integrated into each of the intervals \([a, b], [b, c], \) and \([c, d]\). While the mathematics student can write the integral form, but can not yet explain that if \( f \) is integral to \([a, d]\) then \( f \) can also be integrated into each of the intervals \([a, b], [b, c], \) and \([c,d]\). This is because math students are not accustomed to voicing their thoughts. He is only skilled at completing a concept, but it is very difficult to reveal the results of his work to others.

Therefore, mathematics students need to learn about how to express their thoughts to others. This is as stated by Hattie et al. [9], teaching metacognitive strategies to the student can lead to marked improvement in their achievement. Then, Butler & Winn [2], suggests that Students can be learning to think their own thinking processes and apply specific learning strategies to think themselves through difficult task.

4. Conclusion

Based on the results of research and discussion above, it can be concluded that:

The summarizing category, mathematics students, and mathematics education students can use knowledge and metacognition skills in understanding the concept of indefinite integrals. While the definite integral concepts, mathematics students have not been able to use his/her knowledge and skills of metacognition. And mathematics education students only use skills metacognition.

The explaining category, mathematics students can use knowledge and skills of metacognition in understanding the concept of indefinite integrals, while the definite integral concepts only use metacognition skills. Meanwhile, mathematics education students can use knowledge and skills of metacognition in understanding the concept of both indefinite and definite integrals.

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