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Analysis of Students' Problem-Solving Ability in Solving Improper Integral Problems

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Abstract

This study aimed to determine the student's problem-solving-ability using Polya stages in solving Improper Integral questions in online Integral Calculus Learning through zoom applying Student-Centered Learning. It is very rare to find the research that examines students' problem-solving abilities in solving improper integral problems. The research method used in this study was ex-post facto research. The research subjects were 14 students from class B in the third semester of the Mathematics Study Program FKIP UNIB 2020/2021 getting grades A and A- in Integral Calculus Learning. The analysis in Polya stages consisted of Understanding the Problem (P1); Devising a Plan (P2); Carrying out the Plan (P3); and Looking Back (P4. The instruments used to collect data were improper integral test sheets, analysis guide sheets, and open questionnaires. The result showed the mean score of the student's problem-solving ability was 74.02. The mean value in each stage: P1 = 79.91; P2 = 79.46; P3 = 72.77; and P4 = 65.18. It was concluded that students already had good abilities in understanding problems and planning solutions.

Kata Kunci:

Pemecahan masalah;
Tahapan Polya;
Integral tak wajar

Abstrak

Penelitian ini bertujuan untuk mengetahui kemampuan pemecahan masalah siswa menggunakan tahapan Polya dalam menyelesaikan soal-soal integral tak wajar pada Pembelajaran Kalkulus Integral daring melalui penerapan zoom Student-Centered Learning. Sangat jarang ada penelitian yang membahas kemampuan pemecahan masalah siswa dalam menyelesaikan masalah integral tak wajar. Metode penelitian yang digunakan dalam penelitian ini adalah penelitian ex-post facto. Subjek penelitian adalah 14 siswa kelas B semester tiga Program Studi Matematika FKIP UNIB 2020/2021 *yang memperoleh nilai A dan A- pada Pembelajaran Kalkulus Integral. Analisis pada tahapan Polya terdiri dari: Memahami Masalah (P1); Membuat Rencana (P2); Melaksanakan Rencana (P3); dan Melihat ke Belakang (P4). Instrumen yang digunakan untuk mengumpulkan data adalah lembar soal integral tak wajar, lembar pedoman analisis, dan angket terbuka. Hasil penelitian menunjukkan nilai rata-rata kemampuan pemecahan masalah siswa adalah* $74{,}02$. *Nilai rata-rata pada setiap tahapan:* $\mathrm{P1} = 79{,}91$*;* $\mathrm{P2} = 79{,}46$*;* $\mathrm{P3} = 72{,}77$*; dan* $\mathrm{P4} = 65{,}18$. *Disimpulkan bahwa siswa sudah memiliki kemampuan yang baik dalam memahami masalah dan merencanakan solusi.*

INTRODUCTION

Integral Calculus is a compulsory subject in the undergraduate mathematics education study Program, FKIP UNIB with 4 (3-1) credits. Through this course students are expected to develop thinking skills critical thinking, problem-solving, and ability to understand concepts integral (Hartono & Subali Noto, 2017). This is in line with the goals to be achieved after a student learns Calculus which are to acquire the basic knowledge and mathematical mindset, in the form of (1) critical, logical, and systematic thinking of scientific thinking; (2) the trained in reasoning and creativity after studying the various strategies and tactics in solving the calculus problem; (3) trained in designing simple mathematical models; (4) skilled in standard technical math supported by correct concepts, reasoning, formulas, and methods (Koko, 1999).

Many students face some difficulties in solving integral problem. Parma and Parma & Saparwadi (2015) through their research in Lombok revealed that students still find calculus difficult because it requires high level of mathematical problem-solving. According to Khoiriyah (2016) a student was not able to describe pictures well and difficult to understand the picture. In addition, another student could describe the pictures well but could not analyze the picture which lead him to inappropriate problem-solving method. However, these results are depended on many factors such as students' concept, comprehension, problem-solving ability, and others.

The factors which dominated the ability to solve mathematical problem was executing the act on strategies and followed by explore possible strategies, identify problem, define goal, and look back (Dwianjani et al., 2018). Thus, problem-solving ability becomes one of the skills that is important to be mastered by the students in learning calculus integral.

Unfortunately, learning process in the classroom should be canceled due to the Covid pandemic. The case of Covid pandemic which has been going on since the end of 2019 that hit the world, caused the Government to release a policy called Work from Home (WFH). Face-to-face learning has been replaced by online learning. Communication with students was done through WhatsApp, Google Classroom, and Zoom. This situation made all lecturers should find a way to keep the learning process effective even though students and lecturer only meet though the video meeting and other applications. To make the students active and construct their understanding about calculus integral, the researcher assisted by AM in Integral Calculus Academic Year 2020/2021 implemented student-centered learning. Student-centered learning requires students to be active and have discussions with the teacher who acts as a facilitator if they encounter difficulties. Besides, active students are expected to be able to foster a sense of student creativity (Antika, 2014). By applying this model, students were active in constructing the material. Each student was responsible for presenting the Integral Calculus material assigned to him via Zoom. Lecturers act as mentors who were ready to assist them when it was needed.

Improper integrals are one of the materials of Integral Calculus. This material is the most difficult of all other materials. The researcher gave additional assignments to 3 students to discuss improper integral material. They were very active during the previous lesson and mastered the material that had been studied. The following was an explanation of improper integrals. For a function f the Riemann integral to the interval $[a, b]$, the definite integral definitions are $\int_a^b f(x)\, dx = \lim_{|P|\to 0} \sum_{i=1}^{n} f(c)\, \Delta x_i$ means only when a and b are finite. This concept will be expanded to the case of the origin region of function f in the form: Finite interval $(a, b]$, $[a, b)$, and

$[a,c) \cup (c,b]$, or a combination of cases; Infinite interval $[a,\infty)$, $(-\infty,b]$, and (-∞,∞) which can also load the hose case up (Arfi & Wiryanto, 2018; Koko, 1999; Polya, 1988; Varberg et al., 2007). Further explanation of the improper integral was explained by the speaker into the PowerPoint (PPt) slide as shown in Figure 1.

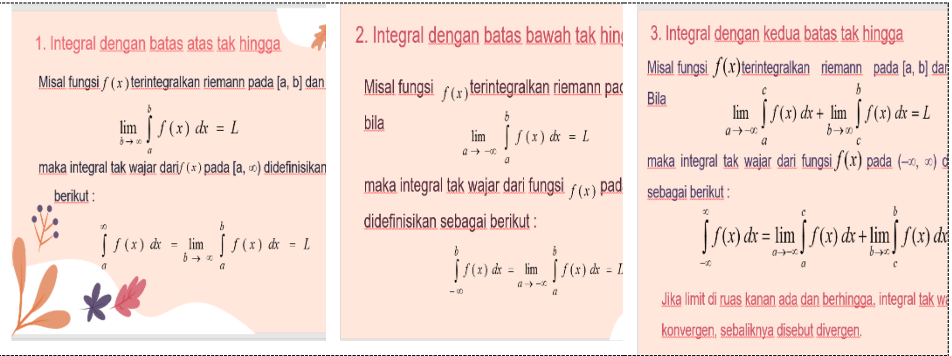


Figure 1. Example of Improper Integral Material for Presenting Group

The material presented at zoom had been uploaded in Google Classroom. Other students downloaded and studied independently. When zoomed online, all students had read the material and solved practice questions. Practice questions were done interactively by involving students who were doing the presentations. This method was effective to determine the mastery of the material by the speaker and to find out students who were actively participating in learning. Assistance was given by the lecturer if students had difficulty solving the problems discussed together on zoom.

Based on this, the authors were interested in researching the Problem-Solving Ability (PSA) of the Polya stages of students in solving improper integral problems. Polya define problem-solving as an attempt to find a way out of a difficulty to achieve a goal that was not immediately achievable. It is important to see students' ability in solving a problem. As a result of the problem-solving process, students are encouraged to use various answers and build their own personal study techniques (Ersoy, 2016). Polya stages were chosen to be analyzed because many students tend to jump directly to the third step, "carrying out a plan," without first "understanding the problem" or "devising a plan." Since they are blindly trying to plug numbers into a random formula or arithmetic procedure, they fail to solve the problem (Yuan, 2013).

Problem-solving in mathematics consisted of four main steps, namely understanding the problem, preparing/thinking plans, implementing plans, and re-examining. The analysis of students' problem-solving ability using Polya stages of improper integral questions consisted of Understanding the problem (P1); Devising a Plan (P2); Carrying out the Plan (P3); and Looking Back (P4) (Polya, 1988). Improper integral material is often left behind by lecturers to be taught in the undergraduate mathematics education study program. So that, it is very rare to find the research that examines students' problem-solving abilities in solving improper integral problems. In fact, there are many things that must be done by students in solving improper integral problems, students are required to be able to analyze the location of the improperness of integral questions, analyze the formula used to calculate the unreasonable integral, and choose the integration technique used. Thus, it is difficult to find reference articles about students' problem-solving abilities in solving improper integral problems.

RESEARCH METHODS

This research was ex-post facto research. Ex post facto is a study conducted to examine events that had occurred and then traced back to find out the factors that could cause these events (Sugiyono, 2012). The data collected in the form of quantitative and qualitative data. The instruments used to collect data were test sheets, analysis guide sheets, and open questionnaires. The improper integral test was conducted online via email on January 20, 2021. It was carried out after the Integral Calculus score was out, the final exam of Integral Calculus was conducted on December 29, 2020.

The research subjects were third semester students of class B Mathematics Education Study Program, FKIP UNIB TA 2020/2021 who had attended Integral Calculus lectures, and obtained a final grade of A or A-, totaling 14 people. Of 14 people, 3 students were purposively chosen to be analyzed in depth in this study.

The research data were analyzed descriptively qualitatively to analyze the Polya stages problem-solving ability by students in solving improper integral problems to use the analysis guidelines of problem-solving ability as Table 1.

Table 1. Guidelines for Analysis of Problem-Solving Ability (PSA) using Polya Stages in Improper Integral Problem

No	Question	Indicator	Score
1	$\int_0^{\infty} x^{-5/4}\, dx$	P1: Knowing the location of the improper integral at the upper limit	1
		P2: Be able to convert $\int_0^{\infty} x^{-5/4}\, dx = \lim_{a\to\infty} \int_0^{a} x^{-5/4}\, dx$	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations marked with the correct result	1
2	$\int_{-\infty}^{1} x^{-3}\, dx$	P1: Knowing the location of the improper integral at the lower limit	1
		P2: Be able to convert $\int_{-\infty}^{1} x^{-3}\, dx = \lim_{b\to-\infty} \int_b^{1} x^{-3}\, dx$	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations marked with the correct result	1
3	$\int_{-\infty}^{\infty} \frac{x}{(x^2 + 9)^3}\, dx$	P1: Knowing the location of the improper integral in the upper and lower bounds	1
		P2: Be able to change $\int_{-\infty}^{\infty} = \int_{-\infty}^{0} + \int_0^{\infty} = \lim_{b\to-\infty} \int_b^{0} + \lim_{a\to\infty} \int_0^{a}$	1

No	Question	Indicator	Score
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations marked with the correct result	1
4	$\int_{-\infty}^{\infty} \frac{x}{\sqrt{1+\ x^2}}\ dx$	P1: Knowing the location of the improper integral in the upper and lower bounds	1
		P2: Be able to change $\int_{-\infty}^{\infty} = \int_{-\infty}^{0} + \int_{0}^{\infty} = \lim_{b\to-\infty} \int_{b}^{0} + \lim_{a\to\infty} \int_{0}^{a}$	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations which are marked with the correct result	1
5	$\int_{-1}^{1} x^{-1/3}\ dx$	P1: Knowing the location of the improper integral at the point between -1 and 1	1
		P2: Be able to make a settlement plan by changing $\int_{-1}^{1} = \int_{-1}^{0} + \int_{0}^{1} = \lim_{b\to-\infty} \int_{b}^{0} + \lim_{a\to\infty} \int_{0}^{a}$	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations which are marked with the correct result	1
6	$\int_{0}^{3} \frac{x}{\sqrt[3]{(x^2-1)^2}} dx$	P1: Knowing the location of the improper integration between points 0 and 3	1
			1

No	Question	Indicator	Score
		P2: Be able to make a settlement plan by changing the problem with a certain limit and using the limit to calculate	2
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	1
		P4: Be able to re-examine the results of improper integral calculations which are marked with the correct result	
7	$\int_{-1}^{1} x^{-3/4}\, dx$	P1: Knowing the location of the imperfection of the integrand	1
		P2: Be able to make a settlement plan by changing the problem with a certain limit and using the limit to calculate	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Able to re-examine the results of improper integral calculations which are marked with the correct result	1
8	$\int_{3}^{6} \frac{dx}{(4-x)^2} dx$	P1: Knowing the location of the imperfection of the integrand	1
		P2: Be able to make a settlement plan by changing the problem with a certain limit and using the limit to calculate	1
		P3: a. Be able to determine the right integration technique b. Be able to calculate the limit of integral calculation results	2
		P4: Be able to re-examine the results of improper integral calculations which are marked with the correct result	1

The data analysis technique obtained was using these following steps:

1. Summing up the total score of each respondent from all indicators namely P1-P4 with the maximum score of each question is 5.
2. Giving value by (Sugiyono, 2012):

$$Score = \frac{Obtained\ Score}{Maximum\ Score} \times 100$$

Based on the score obtained, the student's problem-solving ability can be qualified using Table 2 (Mawaddah & Anisah, 2015).

Table 2. Qualification of Problem-Solving Ability

Score	Qualification
$80 - 100$	Very Good
$65 - 80$	Good
$55 - 65$	Enough
$40 - 55$	Not Enough
$0 - 40$	Very Less

RESULTS AND DISCUSSION

Improper integral problems can be obtained that the highest score was 100, the lowest score was 14.3, the average student's problem-solving ability was 74.02, and included in good qualification.

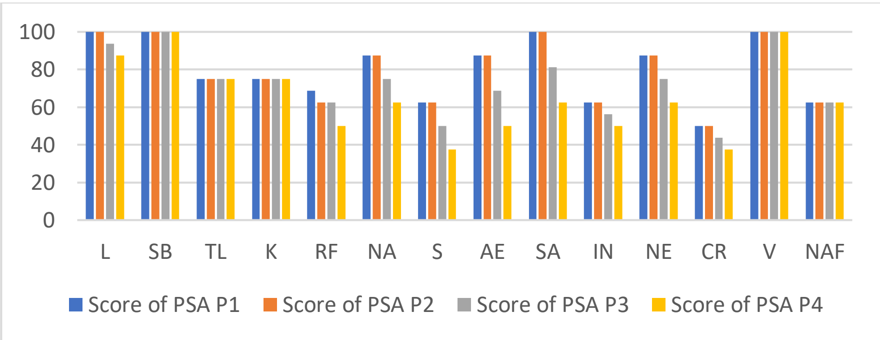
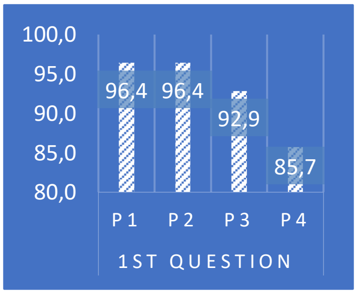
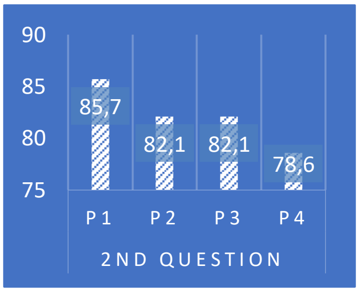
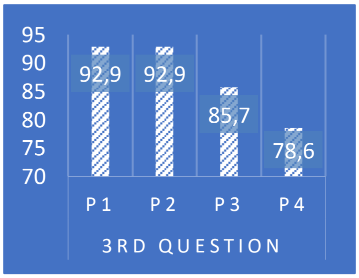


Figure 2. Students' PSA Average Score for Each Polya Stages

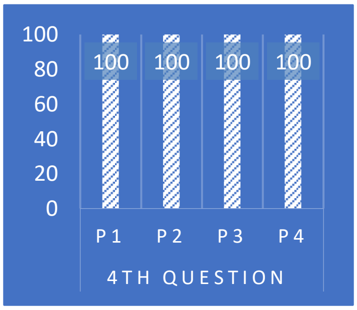
Figure 2 shows the students' PSA average score for each stage. The horizontal line represents the subject and the vertical line represent the average score of Polya stages. It was obtained from Figure 2 that the average of student's problem-solving ability value of the P1 stage students was 79.91, and included in good qualification. The average value student's problem-solving ability in the P2 stage was 79.46, and included in good qualification. The mean value of P3 was 72.77, and included in good qualification. The average value of student's problem-solving ability in stage P4 was 65.18, and included in good qualification. Perfect scores were obtained by three students named SB, V, and L. All three were presenters at zoom in learning Integral Calculus. L was not careful in the last line. Besides that, the average score of all students who took the PSA test can be seen in Table 3.

Table 3. Results of Student PSA Analysis for Each Improper Integral Problem

No	Student PSA Analysis Results on Improper Integral Problem	Information
1		1. PSA P1 = 96,4 and included in very good qualification. 2. PSA P2 = 96,4 and included in very good qualification. 3. PSA P3 = 92,9 and included in very good qualification. 4. PSA P4 = 85,7 and included in very good qualification. 5. Mean score for students' problem-solving ability for question 1 was 92,85 and included in very good qualification.

No	Student PSA Analysis Results on Improper Integral Problem	Information
2		1. PSA P1 = 85,7 and included in very good qualification. 2. PSA P2 = 82,1 and included in very good qualification. 3. PSA P3 = 82,1 and included in very good qualification. 4. PSA P4 = 78,6 and included in good qualification. 5. Mean score for students' problem-solving ability for question 2 was 82 and included in very good qualification.
3		1. PSA P1 = 92,9 and included in very good qualification. 2. PSA P2 = 92,9 and included in very good qualification. 3. PSA P3 = 85,7 and included in very good qualification. 4. PSA P4 = 78,6 and included in good qualification. 5. Mean score for students' problem-solving ability for question 3 was 87,52 and included in very good qualification.

<table>
<tr><th>No</th><th>Student PSA Analysis Results on Improper Integral Problem</th><th>Information</th></tr>
<tr><td>4</td><td>



</td><td>

1. PSA P1 = 100 and included in very good qualification.
2. PSA P2 = 100 and included in very good qualification.
3. PSA P3 = 100 and included in very good qualification.
4. PSA P4 = 100 and included in very good qualification.
5. Mean score for students' problem-solving ability for question 4 was 100 and included in very good qualification.

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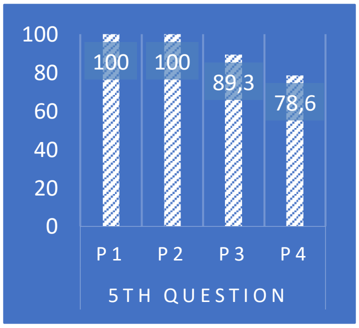
<tr><td>5</td><td>



</td><td>

1. PSA P1 = 100 and included in very good qualification.
2. PSA P2 = 100 and included in very good qualification.
3. PSA P3 = 89,3 and included in very good qualification.
4. PSA P4 = 78,6 and included in good qualification.
5. Mean score for students' problem-solving ability for question 5 was 92 and included in very good qualification.

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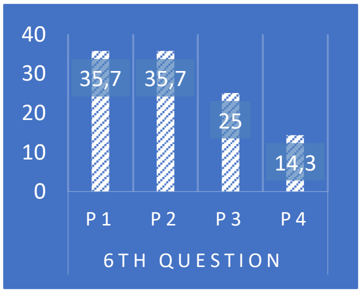
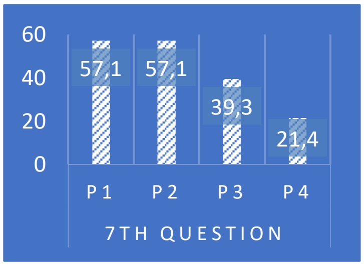
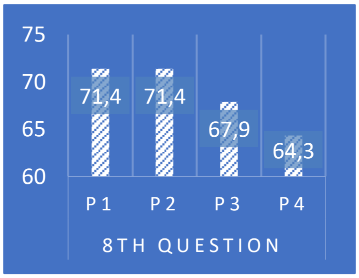
No	Student PSA Analysis Results on Improper Integral Problem	Information
6		1. PSA P1 = 35,7 and included in very less qualification. 2. PSA P2 = 35,7 and included in very less qualification. 3. PSA P3 = 25 and included in very less qualification. 4. PSA P4 = 14,3 and included in very less qualification. 5. Mean score for students' problem-solving ability for question 6 was 28 and included in very less qualification.
7		1. PSA P1 = 57,1 and included in not enough qualification. 2. PSA P2 = 57,1 and included in not enough qualification. 3. PSA P3 = 39,3 and included in very less qualification. 4. PSA P4 = 21,4 and included in very less qualification. 5. Mean score for students' problem-solving ability for question 7 was 43,725 and included in very less qualification.

No	Student PSA Analysis Results on Improper Integral Problem	Information
8		1. PSA P1 = 71,4 and included in good qualification. 2. PSA P2 = 71,4 and included in good qualification. 3. PSA P3 = 67,9 and included in good qualification. 4. PSA P4 = 64,3 and included in enough qualification. 5. Mean score for students' problem-solving ability for question 8 was 68,75 and included in good qualification.

Based on Table 3, it could be seen that question number 4 was able to be solved correctly by all students. Question number 5 was understood by students where the function was unreasonable, students also knew how to solve the problem. However, some students were not able to solve the problems correctly and did not re-check their work. Question number 6 was the most difficult question and the fewest could be answered correctly. It could be seen in Table 3 that the graph of question 6 showed 35,7 of students were unable to determine where the function was undefined, so they were unable to determine the completion plan. For those who were able to plan a solution, it turned out some of them were not able to solve the problem properly. The students had completed the questions correctly was 14,3 and included in very less qualification.

Figure 2 shows that V and SB got perfect scores, meanwhile L made a small mistake in the final step of question number 6. These results indicate that they were understand the concept of improper integral. Apparently, V, SB, and L were the students who acted as presenters to explain the materials to their friend at class. This is in line with the statement that most of students were able to understand the concept of indefinite forms and improper integrals (Syafa'atun & Nurlaela, 2022). In addition, this result proved that Dale's Cone of Learning theory was proven true. Figure 3 is a Picture of Dale's Learning Cone.

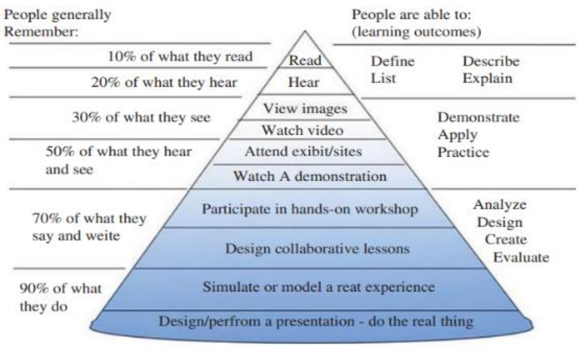


Figure 3. Dale's Cone of Experience (Diana, 2021)

Speakers V, BS, and L who presented the material, as seen in Figure 1, all three of them had perfect problem-solving ability compared to other friends. The presentation in Figure 3 was at the highest level where 90% of what they presented they remembered (Davis & Summers, 2015; Diana, 2021). To find out how each of them learned the improper integral material that was imposed on them to present at zoom with the preparation only for two weeks, the researcher gave the open questions sent via WhatsApp and the answers sent by email.

In addition to the test sheet, a special open questionnaire was given to presenters V, L, and SB. Question 1: "Explain briefly how to study and how to divide tasks for improper integral material?". The answers of S, V, and L were "In the beginning, SB, V, and L discussed beforehand. After that, we compiled teaching materials from several sources that had been collected and divided the tasks for preparation of presentations. After that, they learned their respective parts, SB herself learned improper integral material by watching some learning videos on YouTube because it was easier to understand. After understanding those materials, SB was looking for other sources on the internet or calculus books. The book SB used was

Purcell's Calculus Ninth Edition and work on some sample questions to understand better, then practice presenting the material." V added "I searched for material from various sources on the internet and collected them into one, the sources that could be combined with PPt available on E-learning then the material was divided equally based on NPM such as improper integral material with infinite integration limits explained by V, improper integrals with discontinuous integrals were explained by SB, and the matter of convergence was explained by L.

The answer from SB, V, and L shown that they found many resources of learning at home and their understanding was completed by the other students' explanation through the presentation. The Figure 4 below is the one of the examples of students' answer sheet in solving improper integral.

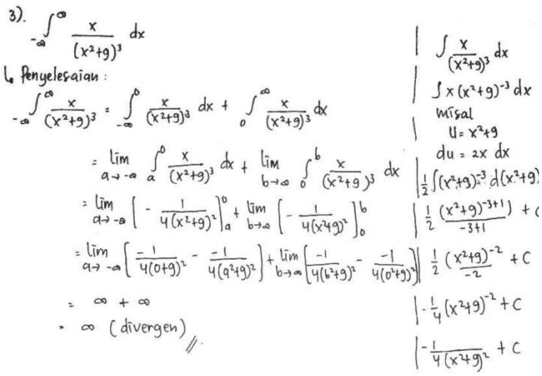


Figure 4. An Example of Student's Sheet Answer

From the Figure 4, it was shown that this student understood how to apply the concept of improper integral and be able to solve it. Through the process of finding material and sources, learning individually, discussing in a group, and presenting the material. Everything they have been learned were construct on their mind so that they remember and understand how to use it while solving the improper integral problem and this is how Dale's Cone of Experience works.

The explanation above were in accordance with the expert opinion about learning in groups (Suryadi, 2010). Besides that, this actions also showed that students' involvement in the learning activity were an effective strategy to understand the topic (Pateşan et al., 2016). Students' involvement will enhance students understanding because the chance they can remember well what they have learned is bigger. In addition, great academic achievement requires personal initiative, craft, persistence, and self-direction skills or self-regulation (Dharmayana et al., 2012). Students can fulfill their needs in understanding the problem by finding materials, doing discussion, and exploring more materials. Applying student-centered learning is needed to bring about quality in education (Oinam, 2017). As for the case of the rest subject which did not get the perfect score or failed to answer the question correctly, the factor that made them have some difficulties were influenced by the internal factor that support those students to learn and solve the problem. According to (Dwianjani et al., 2018) the factors that influence and are the most dominant in influencing problem-solving abilities are internal factors. The reason why students lack in doing problem-solving is because students are also less accustomed to carrying out the correct stages of problem-solving such as identifying problems (identify), determining problem objectives (define), determining possible strategies (explore), implementing strategies (act), and re-examine (look) which lead students to a low mathematical problem-solving ability.

CONCLUSION

Based on the results of the research above, it can be concluded that the average value of the problem-solving ability of the Polya stages for improper integral questions was 74.02. The average value of student's problem-solving ability in stage P1 was 79.91. The average value of student's problem-solving ability in stage P2 was 79.46. The mean value of stage P3 was 72.77. The average value of student's problem-solving ability in stage P4 was 65.18. These results indicated that these students' abilities were very good in understanding and planning the completion of improper integral problems, but not all of them could carry out the solutions correctly, this indicated that students did not re-check their answers. In accordance with what Dale described in the learning cone that the presenters (SB, V, and L) who presented improper integral material at zoom could remember 90% of the material they presented. These results also showed that the presenters could solve improper integral problems with perfect values.

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