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Artificial Intelligence Integration: Error Self-Reflection in Solving Integral Problems

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ABSTRACT

Integrity has had plenty of impact on human civilization development, especially in the development of human technology. The primary role of an integral is not well supported by students' skill in solving integral problems. Due to this fact, mathematics educators need solutions. Artificial Intelligence (AI) integration is one of the solutions that mathematics educators can choose. This qualitative descriptive research aims to explore students' mistakes in solving integral problems with the help of Photomath. This research will describe student mistakes and explain how students realize mistakes during rework assisted by Photomath. This research involved ten mathematics students who joined an integral course at a university in Indonesia. The errors were analyzed based on Newman error analysis. Errors found based on research results include (1) Comprehension and transformation, (2) Process skills, and (3) Encoding. This research found that comprehension errors have implications for transformation. Students who make comprehension errors will cause transformation errors. Meanwhile, the subject's errors in the previous stage affect the encoding stage. Apart from the errors already mentioned, errors were also found due to carelessness, which was not a significant part of Newman's error analysis.
Keywords: AI integration, Error Self-reflection, Newman error Analysis

ABSTRAK

Integral mempunyai banyak dampak terhadap perkembangan peradaban manusia, khususnya perkembangan teknologi manusia. Peranan besar integral tidak didukung dengan baik oleh kemampuan siswa dalam memecahkan masalah integral. Oleh karena itu, diperlukan solusi dari para pendidik matematika. Integrasi AI merupakan salah satu solusi yang dapat dipilih oleh para pendidik matematika. Penelitian deskriptif kualitatif ini bertujuan untuk mengeksplorasi kesalahan siswa dalam menyelesaikan masalah integral dengan bantuan *Photomath*. Penelitian ini akan mendeskripsikan kesalahan siswa dan mendeskripsikan bagaimana siswa menyadari kesalahan pada saat pengerjaan ulang berbantuan *Photomath*. Penelitian ini melibatkan 10 mahasiswa matematika yang mengikuti mata kuliah integral lanjut di Universitas Katolik Santo Agustinus Hippo. Kesalahan dianalisis berdasarkan analisis kesalahan Newman. Kesalahan yang ditemukan berdasarkan hasil penelitian antara lain (1) Pemahaman dan transformasi, (2) Keterampilan proses, dan (3) *Encoding*. Hasil penelitian menunjukkan bahwa kesalahan pemahaman berimplikasi pada transformasi. Mahasiswa yang melakukan kesalahan pemahaman akan menyebabkan kesalahan transformasi. Sedangkan kesalahan subjek pada tahap sebelumnya berimplikasi pada tahap pengkodean. Selain kesalahan yang telah disebutkan, kesalahan juga ditemukan karena kecerobohan yang bukan merupakan bagian utama dari analisis kesalahan Newman.
Kata kunci: Integrasi AI, Kesalahan Refleksi Diri, Analisis kesalahan Newman

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Introduction

Integrals are a sub-topic in calculus, one of the fields of mathematics (Purcell et al., 2007). Integrals are also known as antiderivatives, so usually this topic is taught at universities after students have studied derivatives (Sulaiman, 2015). This refers to Newton's discovery that he started studying this topic after derivatives even though Leibniz started from integrals to derivatives (Burton, 2011). This topic is interesting because the development of human civilization involves integrals and derivative processes in developing new discoveries (Katz, 2009). This causes Integrals to get involved in fields of study other than mathematics, such as health and engineering (Faulkner et al., 2020; Viera-Martin et al., 2022). So it can be concluded that integrals are a very important mathematics topic to be mastered, especially by mathematics students.

The urgency of mastering integral concepts for students is inversely proportional to students' mathematical abilities in solving integral problems (Monariska, 2019). Students also experience difficulty in solving integral problems regarding the area and volume of rotating objects (Ahmad, 2019). This difficulty occurs because students' ability to create graphic illustrations of curves is relatively low (Septian & Prabawanto, 2020). Other research states that this difficulty is caused by students not understanding the concept of a definite integral as a sum (Thompson & Harel, 2021). The meaning of several integral symbols in a theorem is one of the obstacles in understanding the integral concept itself, in this case is the fundamental theorem of calculus (García-García & Dolores-Flores, 2021). Academics and practitioners are challenged to create innovations related to several students' difficulties in solving integral problems

In attempts to understand science and technology, mathematics, one of the fundamental sciences, is crucial in both practical and reasoning contexts (Miranda et al., 2022). Technology can provide assistance for students in understanding the difficulties in learning mathematics (Viberg et al., 2023). Technology has had a major impact on the field of mathematics education (Cuoco & Goldenberg, 1996). The role of technology in mathematics learning was obviously felt during COVID-19 pandemic (Borba, 2021). Post-pandemic, mathematics education academics and practitioners are challenged to continue to innovate in integrating technology with mathematics learning (Bakker et al., 2021; Borba et al., 2023). Several research results show that the integration of technology in mathematics learning has had many positive impacts on student development (Siswono et al., 2022). The integration of technology in mathematics learning can help students improve problem solving skills and creative thinking skills (Cai et al., 2020; Inoferio et al., 2024; Li et al., 2023). Thus, technology integration can significantly improve students' abilities in mathematics (Alin & Rafianti, 2024).

One of technology kinds that can be integrated into mathematics learning is artificial intelligence (AI) (Auna & Hamzah, 2024; Hwang & Tu, 2021). AI is an artificial intelligence whose development includes communication skills, internal knowledge, universal knowledge, intention and creativity (Schank, 1991). One AI-based program that can be used in learning is Photomath (Damayani & Yahfizham, 2024). This program can solve several types of mathematical problems, such as derivatives and integrals, along with a sequence of steps and explanations (Wijayanti & Hasanudin, 2023). Photomath is a program used to explain mathematical topics ranging from basic mathematics to calculus and trigonometry (LlenadaSantos, 2022). However, Photomath cannot solve all mathematical problems (Avanda & Putri, 2020). The application of Photomath in mathematics learning can improve student performance in solving calculus problems (Capinding, 2023).

This research will explore the use of photomath in helping integral class students in solving integral problems. The focus of this research is students' mistakes in solving integral problems using Photomath. These student errors will be analyzed based on Newman's error analysis which includes (1) reading errors, (2) understanding errors, (3) transformation errors, (4) processing skills errors, and (5) writing answer errors. (Pomalato et al., 2020; Reid O'Connor & Norton, 2022).

Research Methods

This qualitative descriptive research aims to explore students' mistakes in solving integral problems with the help of Photomath. This research will describe student mistakes and describe how students realize mistakes during rework assisted by Photomath.

This research involved 10 mathematics students at Universitas Katolik Santo Agustinus Hippo. The students were taking an integral calculus course. They have been asked for agreement and voluntarily want to be involved in this research.

Subjects will be asked to complete a test containing the following integral problems.

Solve this following definite integral

$$\iiint_B x^2yz \; dB$$

$$B = \{(x, y, z): 1 \leq x \leq 2, 0 \leq y \leq 1, 0 \leq z \leq 6\}$$

The research instrument also involved Photomath application and interview guide. The main instrument of this research is researcher. Researcher will conduct interviews with several selected students and analyze the results.

Data collection is carried out by giving an integral test first. The results of the students' answers will be analyzed for purposive sampling. The sampling process produces 10 subjects who will then be interviewed. The sampling was purposive sampling with intensity type. This type of sampling will select subjects who are rich in cases to select and interview (Siswono, 2019). Before the interview, the subject will be asked to solve the problem again using the think-aloud method assisted by Photomath. Then, after working on the think aloud method, the subject will be interviewed. The think aloud and interview methods are triangulation between methods to increase data validity (Cohen et al., 2007). Subjects who have been selected are asked to resolve the problem by think-aloud method and assisted by Photomath. Then, the subjects are interviewed. Test results, think aloud observation results, and interview results will be used as data for analysis and conclusions.

The analysis used is qualitative research analysis by Miles and Hubberman which includes reduction, presentation and conclusions (Miles & Hubberman, 1984). Student errors will be analyzed based on Newman's error categories (Rachmawati et al., 2023; Suseelan et al., 2023) and the indicators (Kurniawati & Hadi, 2021; Mulyani & Muhtadi, 2019) can be seen at Table 1.

Table 1. Newman's error category and the indicators

No	Error Categories	Indicators
1	Reading	1. Reading difficult-mean words uncorectly
2	Comprehension	1. Error in understanding the given from problem 2. Error in understanding the asked from problem
3	Transformation	1. Transforming the problem into mathematical sentences uncorrectly
4	Process skill	1. Error in counting 2. Error in calculate mathematical operation
5	Encoding	1. Error in writing the final answer 2. Error in concluding the problem

Result and Discussions

The test and sampling results produced ten subjects who made errors based on Newman's error analysis. Based on the results obtained, not all categories were carried out by each subject. The mistakes most often made by subjects were process skill and encoding errors. No subjects were found who made reading errors.

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Table 2. Subject composition error

Categories	Subject	Percentage
Reading	-	0%
Comprehension	S7, S9	20%
Transformation	S7, S9	20%
Process skill	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10	100%
Encoding	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10	100%

Next, a description of each category will be presented based on the results of interviews and think-aloud.

Reading

Reading errors were not found in this study. However, reading errors were initially indicated through the results of S2 and S3 answers before the interview. The subject

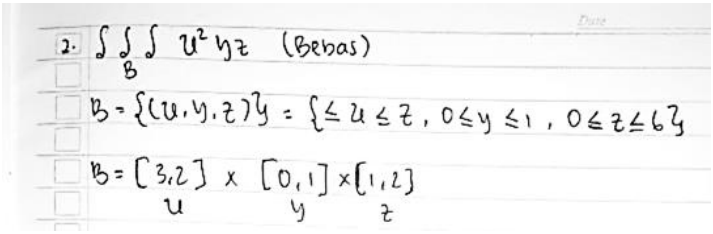

Figure 1. S2 Result

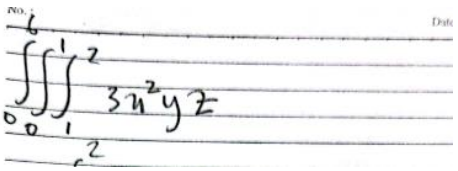

Figure 2. S3 Result

test results can be seen in Figure 1 and Figure 2. Figure 1 and Figure 2 show the questions that students will solve. There are two different questions to see the results of students' solutions.

The subject does not mention and place the boundaries of each variable precisely. For example, the limit for x should be in the closed interval 1 to 2 but because the subject wrote it wrong, the limit written is the closed interval 3 to 2. This is confirmed by the following interview quote.

Researcher : *do you know your error?*
S2 : *I was in a hurry to write the question, ma'am, so I wrote the boundaries wrong*

Researcher : How should it be?
S2 : The x should be from 1 to 2

Through this quote, it can be seen that the subject did not read the questions carefully. Meanwhile, the mistake made by S3 was not being careful in writing the questions, so the subject added coefficient 3 to the given integran. Based on interview quotes and test results, it can be seen that this error is not categorized as a reading error.

This finding strengthens other categories which are special categories in Newman's Error Analysis, namely carelessness and errors due to motivation (Reid O'Connor & Norton, 2022). The research states that these two categories will be found in some students but are exclusive of other categories. These results strengthen the findings from other research which found no errors by students at the reading stage (Mamba, 2022). Previously, this mistake was made by elementary school students because they are limited by their reading skill (Singh et al., 2010). So this error can be found in children who are just learning language and need to understand some difficult words. Other research does not include a specific reading category as an error experienced by students in solving problems (Pomalato et al., 2020).

Comprehension and Transformation

Comprehension and transformation errors are discussed in one sub-chapter because they are made by the same subject and are related to each other. The subjects who

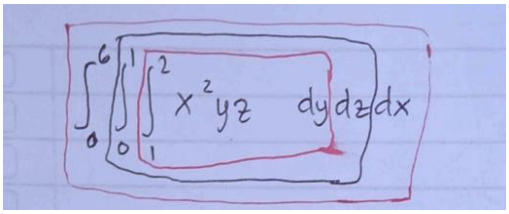

Figure 3. S9 comprehension error

made the error were S7 and S9. The S9 test results can be seen in Figure 3.

Subjects do not order the differentials of each variable according to the variable limits. The limits in question are correct but do not match the differentials correctly. The subject stated that initially the given limits were ordered according to what was known but the differential ordering was based on the lowest rank of the integran variables. Based on this statement, it can be concluded that the subject does not understand the given well. The error made by subject S9 caused the subject express the given into a wrong mathematical expression.

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Meanwhile the Subject S7 error can be seen in Figure 4.

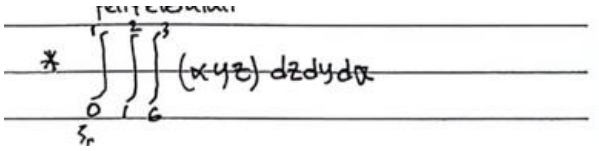

Figure 4. S7 Transformation error

S7 error was made because the subject could not express the known limits in integral form. Subject S7 wrote that the limits of the variable z were from 6 to 3. Meanwhile, the subject did not correctly order the differentials for variables y and x. The subject places them both inversely. This error is similar to error S9 which also results in writing incorrect mathematical expressions.

Comprehension errors in subject S7 and subject S9 have implications for the Transformation stage. So, subjects S7 and S9 made transformation errors too. This finding strengthens other research findings, that comprehension errors will lead subjects to make transformation errors as well (Wardhani & Argaswari, 2022).

Process Skill

Process skill errors were made by all research subjects. Based on the results obtained, two types of errors were found including the integration process and integral limit substitution. An inappropriate integration process can be seen in Figure 5.

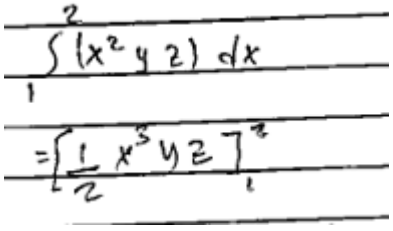

Figure 5. S5 error in integration process

The subject realized his mistake that "*The integral of* x^2*should be* $\frac{1}{3}x^3$ *ma'am*". Subject can't get the integral of x correctly because x^2 that should be integrated into $\frac{1}{3}x^3$, is integrated into $\frac{1}{2}x^3$. The coefficient of x is still not correct even though the exponent is correct. Based on this quote, it can be concluded that the subject's mistake was failing to integrate correctly. Apart from S5, a similar error was made by Subject S8 which can be seen in Figure 6.

Subject S8 made a mistake in integrating the variable x. This is reinforced by the following quote.

Researcher	*: What variable do you integrate first?*
S8	*: x first ma'am*
Researcher	*: Do you get the raight answer?*
S8	*: No, it should be* $\frac{1}{3}x^3yz$
Researcher	*: Why don't you?*
S8	*: because I just move the power of the variable become the divisor before adding by one.*

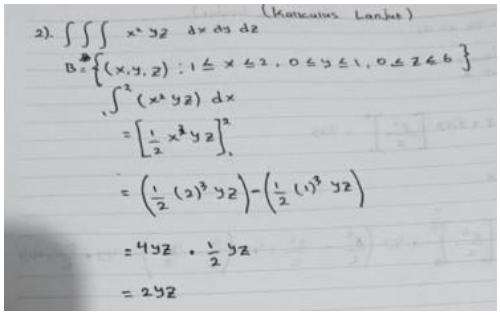

Figure 6. S8 error in integration process

Based on the quote, the subject realized that when integrating one should be added first before the exponent becomes the divisor. So, the answer written by S1 is $\frac{1}{2}$ because it is derived directly from the initial power. Apart from these errors, Subject S8 made an error in the limit substitution process. In Figure 6, Subject S8 substituted not subtracted but multiplied. So, the integral result for variable x is certainly correctly, but the results of the substitution for the upper limit and lower limit were incorrect.

From Figure 7, the error made by S6 can be seen when S enters the upper limit and obtains the result of substitution by 2. The result of subject substitution is $\frac{1}{24}\ yz$. The subject stated that the mistake he made was multiplying $\frac{1}{3}$ by 8, which should have resulted in $\frac{8}{3}$ but because the subject multiplied 8 by the divisor he obtained $\frac{1}{24}$. So, these results show that the error made by S6 was an error in substituting the definite integral limits.

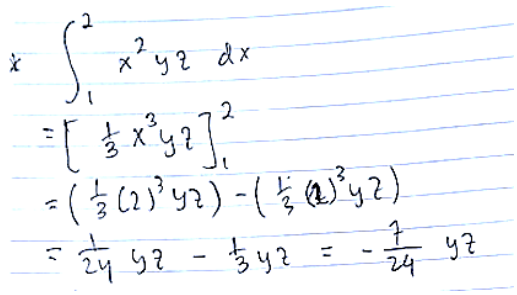

Figure 7. S6 error in substitution

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Based on these results, it can be concluded that in solving integral problems, process skill errors are divided into two, including (1) errors in integrating, and (2) errors in substituting definite integral limits. In line with these findings, process skill errors were also found in the three students who did not master the formula correctly in working on the given problem (Mirawati et al., 2024). Students created active learning subjects in order to boost interest and learning ability. Pupils are instructed to actively acquire skills and knowledge in accordance with their aptitude (Harmini et al., 2022). This is the same as research findings that students' mistakes at the process skill stage were mistakes in integrating because they did not master how to integrate. Errors in substituting integral limits which include calculation errors are findings that are in line with other research findings which state that students fail to operate numbers with correct results. (Noutsara et al., 2021).

Encoding

All research subjects experienced encoding errors. This error is caused because the subject failed in the previous stage. The subject stated "Because I integrated incorrectly, the answer down to the bottom was wrong, including the conclusion." The subject's statement can indicate that the subject's final answer or the subject's conclusion is incorrect because there was an error in the previous stages. This is in line with other research findings, that encoding errors occur due to errors in the previous stage (Siskawati et al., 2021).

Conclusion

This research describes subjects' reflecting process on their mistakes in solving integral problems by Photomath help. Errors found based on research results include (1) Comprehension and transformation, (2) Process skills, and (3) Encoding. This research found that comprehension errors have implications to transformation. Students who make comprehension errors will cause transformation error. Meanwhile, the subject's errors in the previous stage have implications to encoding stage. Apart from the errors already mentioned, errors were also found due to carelessness which were not a major part of Newman's error analysis. This research is limited to reflecting students' mistakes independently on integral topics with simple problems. Other findings may be obtained by increasing the complexity of a given problem or using problems with different topics. Further research regarding the impact of AI in improving students' abilities is needed to find out how AI is applied in mathematics learning.

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