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STUDENT'S ERRROR ANALYSIS IN SOLVING DEFINITE INTEGRAL PROBLEM BASED ON MULTIPLE INTELLIGENCES

Fatimah Ihza Aulia
Program Studi Pendidikan Matematika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Surabaya, fatimah.18042@mhs.unesa.ac.id

Ika Kurniasari
Program Studi Pendidikan Matematika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Surabaya, ikakurniasari@unesa.ac.id

Abstrak

Salah satu faktor siswa mengalami kesalahan dalam menyelesaikan soal matematika adalah kecerdasan siswa. Gardner menyebutkan terdapat delapan tipe kecerdasan siswa yaitu kecerdasan linguistik, logis matematis, gerak tubuh, musikal, spasial, interpersonal, intrapersonal dan naturalis. Kesalahan siswa dapat dianalisis dengan menggunakan analisis kesalahan milik Newman yang terdapat lima jenis kesalahan yaitu kesalahan membaca, kesalahan memahami soal, kesalahan transformasi masalah, kesalahan keterampilan proses, dan kesalahan penulisan jawaban. Penelitian ini termasuk penelitian kualitatif deskriptif yang bertujuan untuk mendeskripsikan jenis kesalahan siswa dalam menyelesaikan soal integral tentu ditinjau dari kecerdasan majemuk. Subjek dari penelitian ini adalah tiga siswa kelas 12 SMA Negeri di Sidoarjo yang masing-masing memiliki kecerdasan yang berkaitan erat dengan matematika yaitu kecerdasan logis matematis, kecerdasan linguistik serta kecerdasan spasial. Pengumpulan data dilakukan dengan pemberian tes kecerdasan majemuk, soal integral dan wawancara. Teknik analisis data yaitu reduksi data, penyajian data, dan verifikasi data. Hasil penelitian menunjukkan bahwa: (1) siswa dengan kecerdasan logis matematis melakukan jenis kesalahan transformasi masalah, kesalahan keterampilan proses dan kesalahan penulisan jawaban; (2) siswa dengan kecerdasan linguistik melakukan jenis kesalahan membaca, kesalahan memahami soal, kesalahan transformasi soal, kesalahan keterampilan proses dan kesalahan penulisan jawaban; (3) siswa dengan kecerdasan spasial melakukan jenis kesalahan membaca, kesalahan transformasi masalah dan kesalahan penulisan jawaban.
Kata Kunci: analisis kesalahan, integral tentu, kecerdasan majemuk

Abstract

One of the factors that students perform errors in solving mathematic problem is student's intelligence. Gardner mentioned there are eight types of multiple intelligences, there are linguistic, logical mathematical, kinesthetic, musical, spatial, interpersonal, intrapersonal and naturalistic. Student's error can be analyzed using Newman's error analysis which contains five types of errors, there are reading error, comprehension error, transformation error, process skill error, and encoding error. This research is descriptive qualitative research which aims to describe the types of student's error in solving definite integral based on multiple intelligences. The subjects of this research are three grade XII senior high school students in Sidoarjo whom have intelligences related to mathematic, there are logical mathematical intelligence, linguistic intelligence and spatial intelligence. Data was collected by giving multiple intelligences test, definite integral problems and interview. Data analysis technique are data reduction, data presentation and data verification. The result of this research showed that: (1) students with logical mathematical intelligence perform transformation error, process skill error and kesalahan encoding error; (2) students with linguistic intelligence perform reading error, comprehension error, transformation error, process skill error and encoding error; (3) students with spatial intelligence perform reading error, transformation error and encoding error.
Keywords: error analysis, definite integral, multiple intelligences

INTRODUCTION

One of the characteristics of mathematics is that the object is abstract (Evi, 2011). Objects in mathematics do not always exist in real life. Some of the material is also difficult to find in everyday life and difficult to visualize. This mathematical abstraction causes many students to experience difficulties and errors in solving math problems. Based on research by Jana (2018), students' mistakes when working on math problems are due to the subject matter that requires accuracy in understanding questions, accuracy in using formulas and concepts and accurate calculations. Therefore, students' mistakes in solving math problems are something that needs the teacher's attention.

Various studies have mentioned students' errors in various mathematics materials. Based on research by Mirna (2018) that 67.80% of students face difficulties in solving problems related to flat-shaped materials. Research by Sari & Wutsqa (2019) also stated that 38% of students made mistakes in solving problems related to the Pythagorean theorem. Other studies have stated that students at the university level experience difficulties and errors in solving problems related to definite and indeterminate integrals (Haripersad & Naidoo, 2008; Li Li et al., 2017; Muzangwa & Chifamba, 2012; Susilo et al., 2019; Tasman et al., 2018). Based on the research that has been done on the analysis of student errors, there has never been a research on the analysis of student errors in solving integral problems for high school students.

Integral and differential are essential sub-materials in science, technology and other sciences (Li Li et al., 2017). Integral is used as a solution in several everyday problems, for example to calculate the area, determine the volume of a rotating object, calculate arc length, and others. When students learn about integrals, students are expected to be able to relate the concepts of Riemann sum, limit, and area properly in order to build an understanding of integrals (Serhan, 2015). Based on the importance of this integral sub-material, it is felt that student errors in solving integral problems are crucial so that student error analysis needs to be carried out.

Research by Sahriah et al. (2012) stated that by conducting an error analysis it can be seen what students' mistakes are. To analyze student errors, Newman's error analysis can be used which has been introduced since 1977. In Newman's error analysis there are 5 types of student errors, namely reading errors, comprehension errors, and transformation errors. , process skill error and encoding error.

According to Singh et al. (2010), reading errors occur when students fail to recognize the words or symbols in the questions. Comprehension errors occur when students are able to read the questions but do not understand the contents, which ultimately causes students to fail to find solutions to the problems. Transformation errors occur when students are able to understand the components of the problem but fail to identify the mathematical operations used in solving the problem. Process skill errors occur when students are able to use the correct mathematical operations but fail to carry out the procedure correctly. Encoding errors occur when students have used mathematical operations and carried out procedures correctly but the final results are written incorrectly (Singh et al., 2010).

There are two factors that cause errors made by students in their learning outcomes, there are internal factors and external factors (Suhendri, 2011). One of the internal factors is student's intelligence (Basuki, 2015). In the book Multiple Intelligences in The Classroom by Armstrong (2008), Gardner states that students do not only have one type of intelligence, but there are eight other intelligences that students have which are called multiple intelligences. The types of intelligence are linguistic, logical mathematical, kinesthetic, musical, spatial, interpersonal, intrapersonal and naturalistic.

According to Suarca et al. (2016) a child with logical mathematical intelligence involves the ability to analyze problems logically, create or find mathematical formulas or models and investigate problems scientifically. They also like to solve abstract problems and sometimes conduct trials in the form of trial and error (Maftoon & Sarem, 2012). The characteristics above mention that logical mathematical intelligence is related to mathematics. Research by Irvaniyah & Akbar (2014) states that logical mathematical intelligence is closely related to linguistic intelligence in the description of logical reasons. Children with linguistic intelligence are good at telling stories, active and passive speakers are good listeners. Children with this intelligence like word games and have a wide vocabulary (Suarca et al., 2016). Spatial intelligence also has a relationship with mathematics, namely geometry. Children with spatial intelligence have the ability to imagine geometric or three-dimensional shapes, imagine visuals in graphics or pictures and direct themselves in space appropriately (Maftoon & Sarem, 2012; Suarca et al., 2016). So that mathematical logical intelligence, linguistic intelligence and spatial intelligence are intelligences that are closely related to mathematics. Therefore, these three intelligences will be researched in this study.

Based on the description above, the researcher wants to analyze students' errors using Newman's error analysis in solving definite integral based on students' multiple intelligences, namely logical mathematical intelligence, linguistic intelligence and spatial intelligence.

METHOD

This research is a descriptive research with a qualitative approach. The selection of subjects in this research were 3 out of 33 students of class XII at the high school level in Sidoarjo, each of whom had logical-mathematical intelligence, linguistic intelligence and spatial intelligence with the lowest scores on integral questions, which showed that these students made the most mistakes and have good communication skills so that researchers can get clear informations during the interview.

The instruments needed in collecting research data are multiple intelligence tests, integral questions, and interview guidelines. Multiple intelligence tests were conducted to determine the type of student's intelligence. The multiple intelligences test used in this study was translated from the Multiple Intelligences for Adult Literacy and Education website (https://www.literacynet.org/mi/assessment/findyourstrengths.html). In the test given 56 statements that refer to one type of multiple intelligences. Students are asked to choose a score of 1-5 from each statement that indicates how well the statement describes them. The highest score obtained for certain types of intelligence indicates the type of student's intelligence.

Students who have been given multiple intelligence tests are then given questions with definite integral material. The integral problem given consists of three essay questions on definite integral material. The first question tests students' understanding of integration techniques and definite integrals. In the second problem, students are asked to draw and determine the solution area of the integral function. The last question is given a narration in the form of a story question and then students are asked to model it in a definite integral form and solve it.

The next step is to interview the selected research subjects. Interviews were conducted according to interview guidelines to obtain informations and explanations of student's work that were not obtained.

Student error analysis in this study is using Newman's criteria error analysis indicators based on 5 types of errors, as follows.

Table 1. Student's Error Analysis Indicator Based On Newman's Criteria

Types of errors	Error Indicators	Code
Reading Error	Student can't read unit correctly	A_1
	Student can't read symbol correctly	A_2
Comprehension Error	Student writes what is known from the problem incorrectly	B_1
	Student don't write what is known from the problem	B_2
	Student writes what is asked from the problem incorrectly	B_3
	Student don't write what is asked from the problem	B_4
Transformation Error	Student can't make mathematical models from the information obtained	C_1
	Student make mathematical model from the information obtained incorrectly	C_2
	Student chooses the wrong technique in solving the problem	C_3
Process Skill Error	Student does the calculation incorrectly	D_1
	Students skip one or more stages in solving problems	D_2
Encoding Error	Student write a conclusion incorrectly	E_1
	Student can't make a conclusion	E_2
	Student write the unit in final answer incorrectly	E_3
	Student don't write the unit in final answer	E_4

The data obtained were then analyzed using data analysis techniques developed by Miles and Huberman, namely data reduction, data presentation, and data verification.

RESULT AND DISCUSSION

Based on multiple intelligence tests conducted on 33 high school students of class XII in Sidoarjo, it was found that 2 students had logical mathematical intelligence, 5 students had linguistic intelligence and 1 student had spatial intelligence. Students with these types of intelligence are then each selected one student with the lowest score and students who have good communication skills. The selected research subjects are as follows.

Table 2. Research Subject

No.	Name	Score	Type of intelligence
1.	SM	77	Logical mathematical
2.	SL	18	Linguistic

No.	Name	Score	Type of intelligence
3.	SS	44	Spatial

Student's Error Analysis with Logical Mathematical Intelligence

In solving integral problem number 1, SM can choose the right integration technique and perform calculations correctly. SM also wrote the answer according to the right stages and wrote the correct conclusion. The results of the interview also show that SM can read the symbols given correctly. This means that SM did not make a mistake in solving the integral number 1. Of the three questions given, SM made an error in the integral number 2 and number 3. The description of SM's answer for question number 2 is presented in Figure 1.

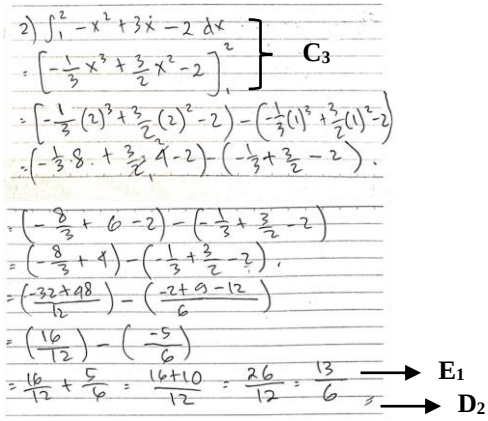

Figure 1. SM's worksheet for question number 2

Based on Figure 1., it can be seen that SM made a mistake in performing the integration technique (C_3). This is included in the problem transformation error. The following are the results of interviews by researchers with SM regarding the C3 error code in question number 2.

R : How do you do for question number 2?
SM : I integrated the function first
R : Why is the result of integral of 2 is remain 2?
SM : I don't know about that part (C_3)

As a result, the final answer obtained by SM is also wrong (E_1), in this case it is included in encoding error. SM also made a process skill error because SM did not draw the graph of the given integral function (D_2). This is also supported by the results of the researcher's interview with SM.

R : Why there is no function graph in your worksheet?
SM : I can't draw it (D_2)

The description of SM's answer for question number 3 is presented in Figure 2.

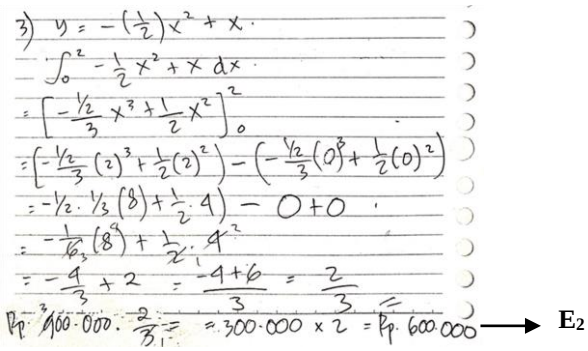

Figure 2. SM's worksheet for question number 3

In solving for question number 3, the error made by SM was only encoding error, that is not writing the conclusion (E_2). The following are the results of the researcher's interview with SM regarding the E2 error code in question number 3.

R : Why did you multiply the area and the price known in the question?
SM : Because we got the area is $\frac{2}{3}$, but then the price is in meter, so we multiply it.
R : Why didn't you write the conclusion?
SM : Oh sorry I forgot about that (E_2), I was in hurry.

Based on the description above, SM did not make errors in number 1. SM only made mistakes in question number 2, namely transformation errors, process skills errors, and encoding errors and in question number 3, namely encoding error. The description of SM's answer and interviews showed that students with mathematical logical intelligence made errors in transformation, processing skills errors and encoding error. This is confirmed by the research of Trapsilasiwi et al. (2018) which states that students with mathematical logical intelligence make a 20% processing skills error.

Student's Error Analysis with Linguistic Intelligence

The description of SL's answer for question number 1 is presented in Figure 3.

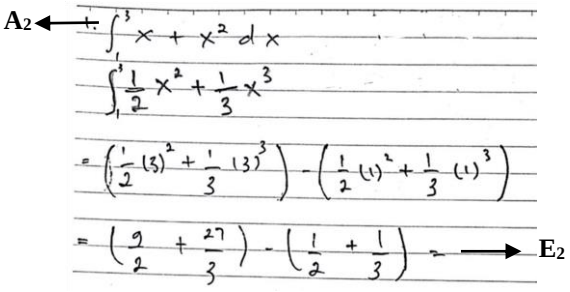

Figure 3. SL's worksheet for question number 1

Based on Figure 3., SL is able to perform the integration technique correctly. SL is even able to continue the steps that must be done. However, SL made an encoding error because SL was unable to write the conclusion or final

result of the question (E_2). Researchers conducted interviews with SL to get more information.

R : Please read the question

SL : Find the definite integral of… *(silence)(trying to remember)*

R : How to read this symbol?

SL : I forgot (A_2)

R : Then how do you solve this problem?

SL : I remember and know how to integrate this one. We integrate each for x and x^2, then we input the upper and lower limit.

R : Then why don't you write the final answer?

SL : I forgot how to operating fractions (E_2)

Based on the interview, when asked to reread the questions, SL was not able to read the integral symbol given correctly (A_2). This indicates that SL made a reading error. However, SL is able to perform integration techniques and calculations correctly.

The description of SL's answer for question number 2 is presented in Figure 4.

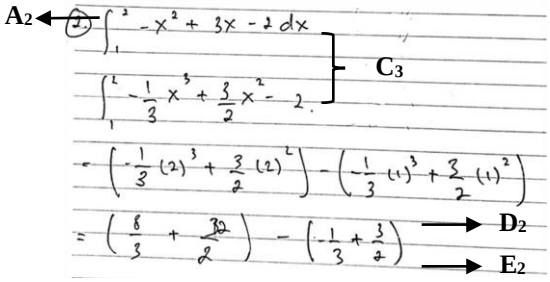

Figure 4. SL's worksheet for question number 2

Just like the previous question, SL made a reading error where he could not read the symbol correctly (A_2). The following are the results of the researcher's interview with SL related to reading errors in question number 2.

R : Now please read the question

SL : I also don't know how to read this one *(point out the integral symbol)* (A_2)

At this number, SL made an transformation, he incorrectly performing the integration technique (C_3). The integral of -2 should be $-2x$, but SL writes -2, which makes the final result wrong. SL also made a process skill error, namely SL could not continue calculating and drawing graphs (D_2). As a result, SL could not write a conclusion so he made an encoding error (E_2). These are confirmed by the results of interviews.

R : Is the technique of integration that you used is correct?

SL : Yes

R : How abut the result of integral of -2? Is it correct that it remains -2?

SL : Yes

R : It should be $-2x$

SL : Oh, sorry, I've just knew that (C_3)

R : Then why don't you continue your work?

SL : Same as previous question, I can't calculate the fractions (E_2)

The description of SL's answer for question number 3 is presented in Figure 5.

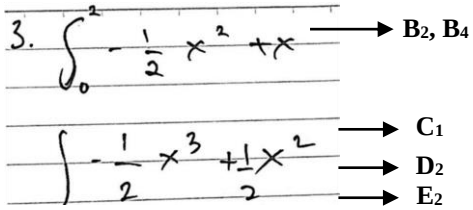

Figure 5. SL's worksheet for question number 3

It can be seen in Figure 5., that SL is only able to perform the integration technique correctly. SL did not write down what he knew and was asked in the questions (B_2 and B_4), so SL made a comprehension error. Although SL is able to perform the integration technique correctly, SL is not able to make a mathematical model from the information provided (C_1), so that SL makes an transformation error. SL is also not able to do the steps in solving the problem (D_2), then SL makes a process skill error. The encoding error made by SL was not writing the conclusion in the final answer (E_2).

Based on the description above, SL made errors in number 1, that is reading error. SL also made errors in number 2, namely reading errors, transformation errors, process skills errors, and encoding error also in number 3, namely reading errors, comprehension error, transformation errors, process skills errors and encoding error. The description of SL's answer and interviews showed that students with linguistic intelligence made all the errors in Newman's error analysis indicators, namely reading errors, comprehension error, transformation errors, processing skills errors and encoding error. It is contradict with the research of Septyaningsih (2018) which states that students with linguistic intelligence will find it easier to understand the meaning of the questions, write down what is known and asked and model the information known in the problem in mathematical form. This shows that SL has difficulty in performing fractional operations so that he can not continue his work.

Student's Error Analysis with Spatial Intelligence

The description of SS's answer for question number 1 is presented in Figure 6.

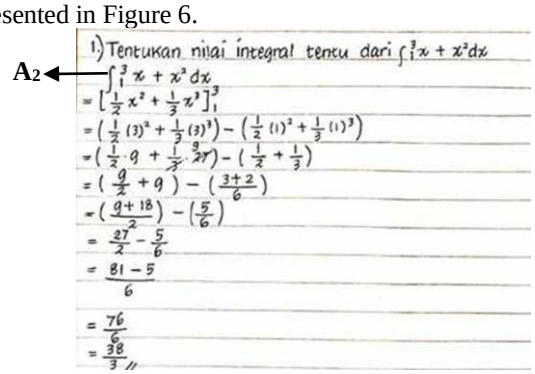

Figure 6. SS's worksheet for question number 1

In solving integral problem number 1, SS used integration techniques and performs calculations correctly. SS is also able to solve problems in correct stages and write conclusions correctly. Researcher interviews SS to get more information.

R : Please read the question

SS : Find the definite integral of… How to read this?

R : Do you know how to read this symbol?

SS : I don't know (A_2)

By doing interview, researcher got an information that could not read the symbol correctly (A_2). This showed that SS make a reading error.

The description of SS's answer for question number 2 is presented in Figure 7.

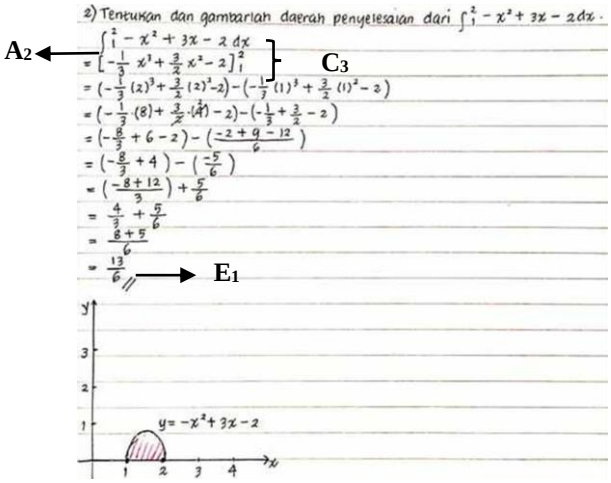

Figure 7. SS's worksheet for question number 3

Based on Figure 7., SS was right in doing the calculations but made a transformation error because SS was wrong in choosing the integration technique on the integral result of -2, which should be $-2x$ but SS wrote -2 (C_3). As a result, SS also made an encoding error, which was wrong in writing the conclusion (E_1). Same as in number 1, SS made a reading error, that he is not being able to read the symbol correctly (A_2). Those also supported by interview with SS as follows:

R : Please read the question

SS : Find definite integral and graph the area of … I also don't know how to read this symbol (A_2)

R : Is it correct that the result of integral -2 is -2?

SS : I guess it is wrong (C_3)

R : So the final answer is wrong?

SS : Yes. I'm not sure about the final answer (E_1)

After the interview, it is true that the SS made a reading error and encoding error. So that the SS made reading errors transformation errors and encoding error.

The description of SS's answer for question number 3 is presented in Figure 8.

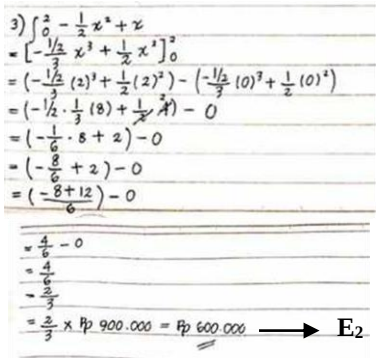

Figure 8. SS's worksheet for question number 3

In solving question number 3, SS can write down the correct steps in solving the problem. The first thing SS does is use the known function to find its area using integrals. Then SS can properly use the integration technique and perform the calculations. SS also can model from what is known in the problem to find what is being asked in the problem, namely the area that has been obtained from the integral function and then multiplied by the price per meter of glass, and the final result is correct. However, SS made a encoding error, namely not writing the conclusion correctly (E_2). To find out, the researcher interviews SS.

R : Why don't you write the conclusion?

SS : I've already write that the final answer is six hundred thousand rupiahs

R : What is that price for?

SS : It is a price that should be paid by Rudi. Oh I should have write that 600.000 is the price that should be paid by Rudi. I forgot to write that down (E_2)

Based on the description above, SS made an error in number 1, that is reading error. SS also made errors in number 2, namely a reading error, transformation error and encoding error also in number 3, encoding error. The description of SS's answer and interviews showed that students with spatial intelligence made reading errors, transformation errors and encoding errors. Students with spatial intelligence do not make process skill error where they are able to draw graphs correctly, this is in line with research by Achdiyat & Utomo (2018) which states that one of the characteristics of spatial intelligence is to provide a clear illustration when doing something. However, this study is not in line with research Maharani & Prihatnani (2019) which states that students with spatial intelligence do not make reading errors. This is because SS cannot read the integral symbol.

Based on the discussion above, the errors of the research subjects, namely SM, SL and SS based on Newman's criteria, can be presented in the table below.

Table 3. Subject's Error Based On Newman's Criteria

No.	Subject	Question	Types of Error				
			1	2	3	4	5
1.	SM	1	-	-	-	-	-
		2	-	-	√	√	√
		3	-	-	-	-	√
2.	SL	1	√	-	-	-	√
		2	√	-	√	√	√
		3	√	√	√	√	√
3.	SS	1	√	-	-	-	-
		2	√	-	√	-	√
		3	-	-	-	-	√

Descriptions :

Type 1 : Reading error
Type 2 : Comprehension error
Type 3 : Transformation error
Type 4 : Process skill error
Type 5 : Encoding error
√ : Make error
- : Did not make error

CONCLUSION

Based on the result and discussion, it can be concluded that:

1. Student with logical mathematical intelligence makes transformation error, process skill error and encoding error in solving definite integral problem
2. Student with linguistic intelligence makes reading error, comprehension error, transformation error, process skill error and encoding error in solving definite integral problem
3. Student with spatial intelligence makes reading error, transformation error and encoding error in solving definite integral problem

SUGGESTION

From the conclusions above, it is found that students with logical mathematical and spatial intelligence make the fewest mistakes while students with linguistic intelligence make the most mistakes. Therefore, it is suggested that teachers can provide appropriate scaffolding to the errors experienced by students based on the type of intelligence and teachers can give more attention to students who have intelligence other than logical mathematical and spatial in teaching and learning activities. It is also necessary to conduct research on analyzing student errors on other types of intelligence, namely musical intelligence, gestures, interpersonal, intrapersonal and naturalist to strengthen the results of student error analysis in solving integral problems.

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