An Analysis of Students' Error in Solving Critical Thinking Problems in Integral Calculus Course based on Newman Error Analysis Theory Viewed from Gender Differences and Habits of Mind

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Abstract: This study aims to describe the types of students' error in solving mathematical critical thinking problems in Integral Calculus course based on Newman Error Analysis theory and viewed from gender differences and habits of mind. The method of the research is a descriptive quantitative research. The research subjects were 47 students from the third semester who have taken Integral Calculus course. The instrument of data collection was a test using the indicators of mathematical critical thinking skills and a questionnaire on the habit of mind. The data collection techniques are test and non-test techniques. The data was analysed by using quantitative descriptive technique. The result of this study indicated that: (1) The most dominant type of error is encoding (92.44%) and the least is decoding (6.08%); (2) The most dominant type of error by male and female students is encoding (96.43%) and (86.24%) and the least is decoding (24.28%) and (6.76%) ; (3) The most dominant type of error in terms of habits of mind with very good, good, and fair criteria is encoding (88.28%), (94.43%), and (77.7%) and the least one is decoding (10.56%), (19.76%), and (54.28%).

1 INTRODUCTION

Calculus is a course that exists in almost every university that offers mathematics and science majors. In addition, calculus must be taken and completed by students in exact sciences, especially Mathematics. In Mathematics Education Study Program, calculus is a compulsory course divided into three subjects, such as Differential Calculus, Integral Calculus and Multivariable Calculus. Calculus 1 (Differential Calculus) is provided in the first semester, Calculus 2 (Integral Calculus) in the second semester and Advanced Calculus (Multivariable Calculus) in the third semester.

Given the importance of Calculus 2 course, students are expected to have a good mastery and understanding of the course. For this purpose, lecturers can conduct an investigation to find out how the students' ability can be improved.

One of the ways to investigate is to find out their error in solving Calculus 2 problems. This is in line with SofriRizka Amalia's statement (2017) students' mistakes in problem solving need to be analyzed to determine their error and why these errors occur. Furthermore, students' mistakes need further analysis, in order to get a clear and detailed picture of students' weakness in solving story problems (Nurussafa'at et al., 2016).

Based on the experts' opinions above,the final result of this investigation can provide an overview of the types of error, so that lecturers can take more appropriate steps to solve because the focus of improvement is narrower and more apparent. The students' problem solving answers will reveal the error, especially in the form of essay questions that are included in High Order Thinking Skill (HOTS) category. One of the HOT skills is critical thinking. Subsequently, the researchers would like to create mathematical critical thinking problems in the form of essay to examine students' ability in Calculus 2 course.

Errors are deviations from the right things which are systematic, consistent, and incidental in certain areas. Consistent and systematic errors are caused by students' competence, while the incidental ones are not a result of their low mastery of the subject (Abidin, 2012).

Learning error can be caused by: (a) low intellectual ability; (b) emotional disorder (c) lack of learning motivation; (d) students' immaturity in learning; (e) too young; (f) supporting social background that does not support; (tid) (g) poor

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study habits; (h) low memorization; (i) disruption of the sensory devices for the development of puberty (Rahimah, 2012).

Furthermore, there are several errors in learning mathematics, namely; (a) lack of understanding of symbols; (b) concerning place value; (c) use of the wrong process; (d) error in calculations; (e) writing error. Students' error in solving Mathematical problems can be analyzed with several methods. One of the methods is Newman Error Analysis theory (NEA). Newman Error Analysis was first introduced by Allan Leslie White as a simple diagnostic procedure to observe students' behaviour in solving story problems. In line with that, researchers also plan to use the procedure of the Newman theory in diagnosing the students' error in solving the problems of critical thinking skill in Calculus 2 course.

Furthermore, the error in mathematical problem solving can be influenced by several factors, one of which is the presence of gender differences. Gender differences in creativity were areas of controversy (Indrawati and Tasni, 2016) .Abra and Valentine French in Nenny Indrawati and Nurfaidah Tasni (2016) stated that some experts suggest that men are more creative than women, but other experts reveal that women are more creative than men. Moreover, Nenny Indrawati and Nurfaidah Tasni (2016) stated that some researchers believe that the influence of gender in mathematics is due to biological differences in the child's brain that are known through observation.

Another factor that can affect students' error in Integral Calculus problem solving is called habits of mind. Habit of mind is a characteristic of intelligent people when faced with problems whose solutions cannot be identified easily (Costa and Kallick, 2008). Habit of mind is a group of skills, attitudes, and values that allow people to bring up performance or behavioral intelligence based on the stimulus to guide students to face or resolve existing issues (Marita, 2014). Based on these explanations, it can be concluded that habit of mind is a very important aspect to be explored, especially on students' problem solving error in Integral Calculus course. Therefore, the researcher was interested in analyzing students' error based on Newman's theory viewed from gender differences and habits of mind.

2 RESEARCH METHODS

The research used in this study is descriptive. According to Nana Syaodih Sukmadinata (2010). descriptive research is the most basic research, intended to describe the existing phenomena, both natural and man-made. Meanwhile, Descriptive research is a research that intends to describe situations or events (Suryabrata, 2014). If the study wants to describe the size, number or frequency, then the research is more appropriately named as quantitative descriptive research (Sukmadinata, 2010).

Based on several opinions above and referring to the research objective, this type of research is quantitative descriptive research. It generates the number, size or frequency of students who commit errors in solving mathematical critical thinking problems in Integral Calculus course by using Newman Error Analysis theory based on gender differences and habits of mind.

To obtain the data about the subject's ability to express opinions and ideas, the researchers needed an auxiliary instrument in the form of a test of mathematical critical thinking problems, which was referred as the first auxiliary instrument. Meanwhile, to get the information about the students' habit of mind, the researcher used a questionnaire sheet as the second auxiliary instrument. The data collection techniques were test and non-test techniques. The test technique used the first instrument and non-test technique used the second one.

The data analysis technique is a systematic process of searching and compiling data obtained from the result of written test. The data analysis process in this study was carried out with the following steps: (1) Analyzing written data by examining the answer error given by students to the test of mathematical critical thinking skill based on Newman Error Analysis theory ; (2) Analyzing students' error based on Newman Error Analysis theory in terms of gender differences; (3) Checking the answers to the students' Habits of Mind questionnaire to collect the scores; (4) Classifying students into three Habits of Mind categories (self-regulation , critical thinking, and creative thinking) based on the results of each student's questionnaire, as seen in Table 1 below.

Table 1: Classification of Students' Habits of Mind

NO	Score	CRITERIA
1	0 – 20	Habits of Mind Very Bad
2	21 – 40	Habits of Mind Bad
3	41 – 60	Habits of Mind Fair
4	61 – 80	Habits of Mind Good
5	81 – 100	Habits of Mind Very Good

Source: Adapted from (Riduwan and Sunarto, 2013)

The procedure of this research was carried out with the following steps, such as:

- Prepare the instruments, such as test instruments with table of specification and alternative answers, and habits of mind questionnaire sheets,
- Provide questions that have been prepared for students to complete.
- Analyze students' error in solving critical thinking problems in Integral Calculus course based on Newman Error Analysis theory .
- Divide students in terms of gender differences.
- Analyze students' error in solving critical thinking problems in Integral Calculus course based on Newman Error Analysis theory viewed from gender differences.
- Distribute habits of mind questionnaire sheets to students.
- Calculate the scores of habits of mind questionnaires that have been distributed.
- Classify students based on habits of mind criteria.
- Analyze students' error in solving critical thinking problems in Integral Calculus course based on Newman Error Analysis theory viewed from habits of mind.

3 RESULTS AND DISCUSSIONS

3.1 Result

The subjects in this study were 2nd semester students of Mathematics Education Study Program who were taking Calculus 2. The researchers only taught one class, class A, with a total of 47 students. Therefore, the subjects were 47 students from the second semester in the academic year of 2017/2018.

3.1.1 Students' Error based on the Newman Error Analysis Theory in Terms of the Test Items.

The questions were prepared using the indicators of mathematical critical thinking skills and referred to the teaching material in Integral Calculus course. Table 2 shows the distribution of teaching materials and indicators used in the development of the research instruments.

The test was carried out in two stages. Test I was conducted after the teaching material in test 1 was completed, while Test II was held after finishing the teaching material in Test II. The types of error that students committed in Test 1 and Test II can be seen in Table 3.

3.1.2 Student's Error based on the Newman Error Analysis Theory Viewed from Gender Differences

The following table 4 is presents the data regarding the percentage of students in terms of gender differences.

Table 4: Percentage of Students based on Gender Differences

Gender	Total	Percentage (%)
Male	6	12.80%
Female	41	87.20%
Total	47	100%

Table 4 indicates that the number of male and female subjects has a very significant difference, which is equal to 74.4%. However, according to the researcher, it can still be used as a source of data to be used as a reference in looking at the types of error made by the subjects of the study. The following table 5 shows the data related to the types of error viewed from gender differences. '

In addition to Test I, the researchers also conducted a second test. The following table 6 presents the data regarding the percentage of subjects in terms of gender differences in Test II.

3.1.3 Students' Error based on the Newman Error Analysis Theory Viewed from Habits of Mind

To obtain the data about the students' habits of mind, researchers distributed questionnaire sheets. The following table 7 presents the data related to the students' habits of mind.

Table 7: Number and Percentage of Students in terms of Habits of Mind

Habits of Mind Criteria	Number of Students	Percentage (%)
Very Good	18	37.5
Good	26	54.2
Fair	4	8.3
Bad	0	0
Very Bad	0	0
Total	48	100

Source: Processed Data

Table 8 reveals the students' habits of mind viewed from gender differences (male and female).

Table 2: Details of Teaching Materials and Indicators of Mathematical Critical Thinking Ability Used in the Development of Test Items in Integral Calculus Course

Teaching Materials	**Indicators of Mathematical Critical Thinking Ability**	**Test Items**
IndefiniteIntegral	The ability to identify and justify concepts, namely to provide reasons for mastering concepts.	No. 1 (Test 1)
Integration Technique by partial integral	The ability to identify and justify concepts, namely to provide reasons for mastering concepts.	No. 2 (Test 1)
Integration technique by trigonometry substitution	The ability to analyze algorithm, namely to evaluate or examine an algorithm.	No. 3 (Test 1)
Integration technique by trigonometry function	The ability to generalize, namely to complete the data or supporting information.	No. 4 (Test 1)
Integration technique by trigonometry substitution	The ability to generalize, namely to complete the data or supporting information.	No. 1 (Test II)
Integration technique by rational function	The ability to identify and justify concepts, namely to provide reasons for mastering concepts.	No. 2 (Test II)
Application of Definite Integral (Areas between Curves and Volumes of Solids)	The ability to analyze algorithm, namely to evaluate or examine an algorithm.	No. 3 (Test II)

Table 3: Percentage of Students' Error Based on Test Items (Newman Error Analysis Theory)

Newman Error Analysis (NEA) Stages	Percentage of Students' Error Based on Test Items (%)						
	Test I				Test II		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Decoding	9 22.50%	3 6.80%	11 2.40%	5 10.90%	0 0%	0 0%	0 0%
Comprehension	19 47.50%	4 9.10%	16 34.80%	22 47.80%	0 0%	4 8.30%	0 0%
Transformation	28 70%	11 25%	23 50%	30 65.20%	4 8.90%	27 56.30%	26 66.70%
Process Skill	39 97.50%	37 84.10%	36 78.30%	38 82.60%	11 24.40%	37 80.40%	37 94.90%
Encoding	39 97.50%	41 93.20%	42 91.30%	42 91.30%	17 73.80%	48 100%	39 100%

Source: Processed Data
Description :
1. In Test 1 Question No. 1, the amount of data analyzed was 40 out of 48 students
2. In Test I Question No. 2, the amount of data analyzed was 44 out of 48 students.
3. In Test I Question No. 3, the amount of data analyzed was 46 out of 48 students.
4. In Test I Question No. 4, the amount of data analyzed was 46 out of 48 students.
5. In Test II Question No. 1, the amount of data analyzed was 45 out of 48 students.
6. In Test II Question No. 2, the amount of data analyzed was 48 out of 48 students.
7. In Test II Question No. 3, the amount of data analyzed was 39 out of 48 students.

Table 8: Number and Percentage of Students' Habits of Mind Based on Gender Differences

Habits of Mind Criteria	**Number and Percentage of Student's Habits of Mind based on Gender Differences**	
	Male	**Female**
Very Good	2 (33.3%)	16 (38.1%)
Good	2 (33.3%)	24 (57.1%)
Fair	2 (33.3%)	2 (4.8%)
Bad	0 (0%)	0 (0%)
Very Bad	0 (0%)	0 (0%)
Total	6 (12.5%)	42 (87.5%)

Source: Processed Data

The following table shows the distribution of types of students' error according to Newman's error analysis theory based on habits of mind, see Table 9.

3.2 Discussion

Based on the results of this study, the most dominant type of error according to Newman Error Analysis theory is encoding and the least one is decoding. In this study, encoding error occurs when students cannot write correct answers in the form of numbers, symbols or words even though they have gone through the "treatment" stage . Therefore, it can be stated that most students cannot express the correct answers to the questions, neither viewed from gender differences nor habits of mind. From the analysis of the answers, it was found that most of them were unable to identify an appropriate solution to the problem. Only a small number of students solved the problems correctly. Furthermore, the least dominant

Table 5: Students' Error According to the Newman Error Analysis Theory Viewed from Gender Differences in Test 1.

Newman Error Analysis (NEA) Stages	Percentage of Students' Error Viewed from Gender Differences (%)							
	Test I							
	Q1		Q2		Q3		Q4	
	M	F	M	F	M	F	M	F
Decoding	3 60%	6 20%	1 20%	2 5.10%	5 50%	6 15%	2 40%	3 7.20%
Comprehension	4 80%	15 40%	2 40%	2 5.10%	6 100%	10 25%	4 80%	18 43.90%
Transformation	5 100	23 70%	2 40%	9 23.10%	6 100%	17 42.50%	5 100%	25 61%
Process Skill	5 100	34 97.10%	5 100%	32 82.10%	6 100%	30 75%	5 100%	33 80.50%
Encoding	5 100	34 97.10%	5 100	36 92.30%	6 100%	36 90%	5 100%	37 90.20%

Source: Processed Data
Description:
1. In Test 1 Question No. 1, the amount of data analyzed was 40 (5 men and 35 women) out of 48 students.
2. In Test 1 Question No. 2, the amount of data analyzed was 44 (5 men and 39 women) out of 48 students.
3. In Test I Question No. 3, the amount of data analyzed was 46 (6 men and 40 women) out of 48 students.
4. In Test I Question No. 4, the amount of data analyzed was 46 (5 men and 41 women) out of 48 students.

Table 6: Students' Error According to the Newman Error Analysis Theory Viewed from Gender Differences in Test II.

Newman Error Analysis (NEA) Stages	**Percentage of Students' Error Viewed from Gender Differences (%)**					
	Test II					
	Q1		**Q2**		**Q3**	
	M	**F**	**M**	**F**	**M**	**F**
Decoding	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Comprehension	0 0%	0 0%	0 0%	4 -9.50%	0 0%	0 0%
Transformation	2 50%	2 -4.90%	5 83.3%)	22 -52.40%	2 -50%	24 -68.60%
Process Skill	2 50%	9 -22%	6 -100%	31 -73.80%	4 -100%	34 -97.10%
Encoding	3 -75%	14 (34.1%)	6 -100%	42 -100%	4 -100%	35 -100%

Source: Processed Data
Description:
1. In Test II Question No. 1, the amount of data analyzed was 45 (4 men and 41 women) out of 48 students.
2. In Test II Question No. 2, the amount of data analyzed was 48 (6 men and 42 women) out of 48 students.
3. In Test II Question No. 3, the amount of data analyzed was 39 (4 men and 35 women) out of 48 students.

type of error is decoding. It occurs because students cannot recognize the terms in the problem, recognize symbols nor comprehend the questions. This type of error is the least dominant one which means that most students are able to recognize symbols or to understand the questions well, yet they can't finish it correctly.

Based on the explanation above, it can be concluded that from all the questions presented, male and female students did all types of error according to Newman Error Analysis theory, but the percentage of male subjects is higher than that of female students. Gender differences do not separate the students from making types of error.

According to Subanti (2014), women in general are better at remembering, while men are better at logical thinking. Generally, men and women are the same, but male students have better abstraction than female students, allowing male students to be better than female students in the field of mathematics in terms of abstract understanding. Furthermore, Abra and Valentine-French in Neni Indrawati and Nurfaidah Tasni (2016) stated that men are more creative than women, but many researchers expressed

Table 9: Types of Students' Error According to the Newman Error Analysis Theory Based on Habits of Mind in Test I

Newman Error Analysis (NEA) Stage	Percentage of Students' Error in Each Test based on Habits of Mind(%)											
	Test I											
	Q1			Q2			Q3			Q4		
	VG	G	F	VG	G	F	VG	G	F	VG	G	F
Decoding	2 13.30%	4 17.40%	2 100%	2 13.30%	1 4.20%	0 0%	1 5.60%	8 34.5	2 40	2 9.5	6 26.1	2 100
Comprehension	6 40%	9 39.10%	2 100%	2 13.30%	1 4.20%	1 20%	5 27.80%	9 39.1	2 40	3 14.3	5 21.7	2 100
Transformation	11 73.30%	14 60.90%	2 100%	4 26.70%	5 20.80%	1 20%	5 27.80%	13 56.5	2 40	5 23.8	7 30.4	2 100
Process Skill	14 93.30%	23 100%	2 100%	11 73.30%	21 87.50%	3 60%	15 83.3	15 62.5	3 60	5 23.8	15 65.2	2 100
Encoding	14 93.30%	23 100%	2 100%	12 80%	24 100%	3 60%	18 100%	20 87	3 60	15 71.4	20 87	2 100

Source: Processed Data
Description:
1. In Test 1 Question No. 1, the number of data analyzed were 40 (15 HOM VG, 23 HOM G people, 2 HOM F people) out of 48 students.
2. In Test I Question No. 2, the number of data analyzed were 44 (15 HOM VG people, 24 HOM G people, 5 HOM F people) out of 48 students.
3. In Test I Question No. 3, the number of data analyzed were 46 (18 HOM VG people, 23 HOM G people, 5 HOM F people) out of 48 students.
4. In Test I Question No. 4, the number of data analyzed was 46 (21 HOM VG, 23 HOM G, 2 HOM F) out of 48 students.

Table 10: Types of Students' Error Based on Habits of Mind in Test II

Newman Error Analysis (NEA) Stages	Percentage of Students' Error in Each Test based on Habits of Mind(%)								
	Test II								
	Q1			Q2			Q3		
	VG	G	F	VG	G	F	VG	G	F
Decoding	2 13.30%	4 17.40%	2 100%	2 13.30%	1 4.20%	0 0%	1 5.60%	8 34.5	2 40
Comprehension	6 40%	9 39.10%	2 100%	2 13.30%	1 4.20%	1 20%	5 27.80%	9 39.1	2 40
Transformation	11 73.30%	13 54.20%	2 100%	4 26.70%	5 20.80%	1 20%	5 27.80%	13 56.5	2 40
Process Skill	14 93.30%	23 100%	2 100%	11 73.30%	21 87.50%	3 60%	15 83.3	15 62.5	3 60
Encoding	14 93.30%	23 100%	2 100%	12 80%	24 100%	3 60%	18 100%	20 87	3 60

Source: Processed Data
Description:
1. In Test 1 Question No. 1, the number of data analyzed were 40 (15 HOM VG people, 23 HOM G people, 2 HOM F people) out of 48 students.
2. In Test I Question No. 2, the number of data analyzed were 44 (15 HOM VG people, 24 HOM G people, 5 HOM F people) out of 48 students.
3. In Test I Question No. 3, the number of data analyzed were 46 (18 HOM VG people, 23 HOM G people, 5 HOM F people) out of 48 students.

that women are more creative than men. Some researchers believe that the gender influence in mathematics is related to biological differences in their brains. Through observation, women in general are superior in language and writing, while men are superior in mathematics because of their better spatial ability. Both of these opinions contradict the findings of this study. According to the analysis of researchers, the level of ability of both male and female students might be influential. Based on the final test results of Integral Calculus course,all male students had lower scores than female students. Therefore, the results from two previous studies contradict what the researchers found.

Furthermore, the habits of mind of the students do not affect the level or type of error. Students as the research subjects have very good, good and fair criteria with five types of error. Therefore, it can be stated that the habits of mind cannot distinguish the types of error made by the students as well.

4 CONCLUSIONS AND SUGGESTIONS

Based on the research, it can be concluded that: (1) The most dominant type of error based on Newman Error Analysis theory is encoding (92.44%) and the least dominant type of error is decoding (6.08%); (2) Viewed from gender differences, the most dominant type of error by male students is encoding (96.43%) and the least type of error is decoding (24.28%). On the other hand, the dominant type of error by female students is encoding (86.24%) and the least dominant one is decoding (6.76%); (3) In terms of habits of mind, the type of error by students with Very Good criteria is encoding (88.28%) and the least dominant type of error is decoding (10.56%). Then, the type of error by students with Good criteria is encoding (94.43%) and the type of error is decoding (19.76%). Lastly, the type of error by students with Fair criteria is encoding (77.7%) and the least dominant type of error is decoding (54.28%).

Furthermore, the researchers propose the

following suggestions such as: (1) Further studies should be conducted on the causes of the types of error, both based on gender differences and habits of mind; (2) An in-depth study can be conducted through non-test interviews, either unstructured or structured interviews.

REFERENCES

Abidin, Z. (2012). Analisis kesalahan mahasiswa prodi pendidikan matematika fakultas tarbiyah iain ar-raniry dalam mata kuliah trigonometri dan kalkulus 1. *JURNAL ILMIAH DIDAKTIKA: Media Ilmiah Pendidikan dan Pengajaran*, 13(1).

Costa, A. L. and Kallick, B. (2008). *Learning and Leading with Habits of Mind 16 Esential Characteristic for /Success*. Virginia: Association for Supervision and Curriculum Development.

Indrawati, N. and Tasni, N. (2016). Analisis kemampuan pemecahan masalah berdasarkan tingkat kompleksitas masalah dan perbedaan gender. *Saintifik*, 2(1):16–25.

Marita, R. A. S. (2014). *Identification of Practical Student Habits of Mind in Discussions and Their Effects on Mastery of the Organ System Concept*. Tesis pada Sekolah Pascasarjana UPI Bandung: tidak diterbitkan.

Nurussafa'at, F. A., Sujadi, I., and Riyadi, R. (2016). Analisis kesalahan siswa dalam menyelesaikan soal cerita pada materi volume prisma dengan fong's shcematic model for error analysis ditinjau dari gaya kognitif siswa. *Jurnal Pembelajaran Matematika*, 4(2).

Rahimah, D. (2012). *Identification of student error in solving the main questions of integral calculus in integral calculus courses*, volume X. ISSN : 1412-3612.

Riduwan and Sunarto (2013). *Pengantar Statistika untuk Penelitian Pendidikan, Sosial, Ekonomi, Komunikasi, dan Bisnis*. Alfabeta, Bandung.

Sukmadinata, N. S. (2010). *MetodePenelitian Pendidikan*. UPI Press, Bandung.

Suryabrata, S. (2014). *MetodologiPenelitian*. PT, Jakarta.