IMPULSE: Journal of Research and Innovation in Physics Education
Volume 1, Issue 2, 63 – 71

ISSN: 2798–1762 (*Print*); ISSN: 2798–1754 (*Online*)
http://ejournal.uin-suka.ac.id/tarbiyah/impulse

Investigating the Students' Errors When Solving Analytical Mechanics Using Newman's Error Analysis

Wafiq Mujahidul Haqq[1,*], Rodeo Bagus Pratama[2], Muhamad Mi'da Farkhan[3], Bayu Setiaji[4]

[1, 2, 3, 4] Department of Physics Education, Universitas Negeri Yogyakarta

ABSTRACT
One of the problems in learning is the appearance of errors. These errors are clasified into five parts considering Newman's Error Analysis. The purpose of this research is to analyze the errors in analytical mechanics using Newman's Error Analysis (NEA) prior to the construction of the future effective and efficient learning. This research is using descriptive and qualitative research with test and interview. Based on the analysis, in analytical mechanics class, the students' performance is low. From the Newman's Error Analysis (NEA), we found the errors are belong to the several categories of NEA. In the whole aspect, the errors done by the students are correspond to the five aspects of Newman's Error Analysis (NEA) which are connected to each other aspects. One can also note, the students' performance in analytical mechanics class is low.

INTISARI
Salah satu masalah dalam pembelajaran adalah munculnya kesalahan. Kesalahan ini diklasifikasikan menjadi lima bagian dengan mempertimbangkan Analisis Kesalahan Newman. Tujuan dari penelitian ini adalah untuk menganalisis kesalahan-kesalahan dalam mekanika analitik menggunakan Newman's Error Analysis (NEA) sebelum dibangun pembelajaran yang efektif dan efisien di masa depan. Penelitian ini menggunakan penelitian deskriptif kualitatif dengan tes dan wawancara. Berdasarkan hasil analisis, pada mata kuliah mekanika analitik, prestasi belajar siswa tergolong rendah. Dari Analisis Kesalahan Newman (NEA), kami menemukan kesalahan termasuk dalam beberapa kategori NEA. Secara keseluruhan, kesalahan yang dilakukan siswa sesuai dengan kelima aspek Newman's Error Analysis (NEA) yang saling berhubungan satu sama lain. Dapat juga dicatat, kinerja siswa di kelas mekanika analitik masih rendah.

ARTICLE HISTORY
Received: July 3, 2021
Accepted: September 3, 2021

KEYWORDS
Newmans' Error Analysis; Categories; Error; Analytical Mechanics

KATA KUNCI
Newman's Error Analysis; Categories; Kesalahan; Mekanika Analitik

* Corresponding author:
Wafiq Mujahidul Haqq, Department of Physics Education, Universitas Negeri Yogyakarta, Indonesia.
✉ wafiqmujahidul.2019@student.uny.ac.id

A. Introduction

Problems in teaching have always been interesting to be discussed. Problems in teaching can arise between teachers and students. However, even after the teaching method has been upgraded along the way, the problem which lies in students can hinder the teaching during the class. One of the problems could be explained as the students' errors which play a role during the teaching. These students' errors mostly happen in encoding and comprehension [1]. Hence, instead of putting the new method on teaching, it is also effective to identify the students' self errors during the class.

One of the methods to describe the students' error is Newman's Error Analysis (NEA) [1]. This method can show the common errors from the students. In practice, this method divides the students' understanding of the problem sets into some stage or level. This way, one can analyze the errors of the students and categorize them in which part(s) the errors occur. Also, it is a notable aspect to solve the problem solely by identifying the errors on the students. Thus, by these errors, teachers can manage to construct a better method. The errors identification on students has been investigated so far, see e.g. [2-5], in mathematics class. This research successfully identifies the students' errors with some degrees of similar results. It shows the problems much likely to happen in the non-simple questions, for instance, the questions implied in the story.

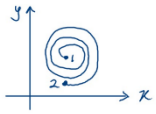
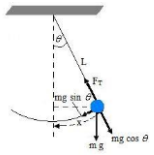
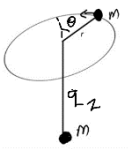
In analytical mechanics, it shows truly a significant resemblance with mathematics. Since the analysis on the analytical mechanics solely depends on a high level of mathematic tools [6], it is understandable to adopt the research on [2-5] to be done in analytical mechanics. We expect this research can truly show the students' errors in a similar way to the previous research. In some sense, the problems on the students' errors are expected to occur the same way.

B. Method

This research is using the descriptive-qualitative method. In qualitative research [7], we expect to obtain the results in students' perception, motivation, action, etc. With this, we will find the errors of the students more accurately. After such conditions, we will investigate the students' errors by using NEA. This method will be used on the 21 undergraduate students of physics education (class C) in their 3rd year of Universitas Negeri Yogyakarta with the subject of analytical mechanics.

The data is obtained by using tests and interviews. For the test, there will be 4 questions, The questions are obtained by the result of the students' interview. Students choose 4 questions based on their preferences. Also, the interview consists of understandable and non-understandable topics, difficulties, also other preferences. The topics on behalf of analytical mechanics which are considered in this research contain geodesic, Lagrange equation, Euler-Lagrange equation, Lagrange multiplier. The type of questions in this research can be seen in table 1.

Table 1. Test to measure students' understanding.

Topic	Question
Geodesic and Euler-Lagrange equation	Determine the equation of motion by using the Euler-Lagrange equation! 
Euler-Lagrange, Mekanika Lagrange, and Lagrange Multiplier	Determine the equation of motion of this pendulum by using XY coordinates and find the Lagrange multiplier λ! 
Lagrange, Euler-Lagrange, and two-body problem.	Determine the equation of motion using Lagrange equation and find that that equation is fulfilling Noether theorem! 
Lagrange equation and Lagrange multiplier	Determine the equation of motion and Lagrange multiplier based on this picture! 

During the analysis of data, the qualitative approach is used using NEA. There are 5 levels of NEA that we used. Thus, we will classify the students' errors belonging to which levels. The levels corresponding to our NEA method are depicted in table 2 and the details of the assessment are depicted in table 3 which is based on ref. [1].

Tabel 2. The NEA assessment

Step	Errorness
Reading	Students cannot understand the question briefly.
Comprehension	Students cannot comprehend the question.
Transformation	Students understand the question but cannot solve the necessary steps required.
Process Skill	Students understand and can solve the problem but the final answer is still wrong.
Encoding	Students make a simple mistake when finalizing and making a conclusion.

Tabel 3. The assessment requirement to NEA

Assesment	Indicator
Reading	▪ Can Identify the information and mathematical symbols completely. ▪ Can identify the information and mathematical symbols correctly. ▪ Cannot identify information and mathematical symbol. ▪ No answer.
Comprehension	▪ Correctly writes what is known and what is asked from the problem. ▪ Incorrectly write what is known and what is asked from the problem. ▪ Wrongly write what is known and what is asked from the problem. ▪ No answer.
Transformation	▪ Completely writes the mathematical model. ▪ Incompletely write the mathematical model. ▪ Wrongly write the mathematical model ▪ No answer
Process Skill	▪ The process is right the answer is right. ▪ The process is right the answer is wrong. ▪ The process is wrong the answer is wrong. ▪ No answer.
Encoding	▪ The conclusion is right. ▪ The conclusion is not quite right. ▪ The conclusion is wrong. ▪ No answer.

C. Results and Discussion

During the interview, students show different responses when experiencing the analytical mechanics class. Some aspects may differ but we obtain some similarities from the analysis. During the lesson, students show more interest in Lagrangian mechanics compared to the others. Since Lagrangian mechanics are basic and less complex, it is understandable if students choose this topic. In addition, Lagrangian mechanics is introduced at the beginning of the class, so the student concentration is at its peak. In the contrary, the two-body is the least. As it is more in complexity and the mathematical derivation is extremely advanced compared to the other. However, one should also notice, since, after the pandemic, the lesson is less effective due to conversion from offline to online. Due to this reason, it is expected to get fewer results compared to the pre-pandemic. Finally, based on our results from the interview, 20 out of 21 students have problems corresponding to analytical mechanics.

From the assessment of the errors of the students, there are some data corresponding to this matter. One can see Table 4 for details. Based on Table 4, most students have a problem in the encoding stage. Our funding shows that the student's ability on solving the problems is quite low. However, it is very critical when students fail in the first stage, reading. These mistakes or errors can trigger another errors in the next stage. So we insist that the first stage is very important. The analysis of each stage is depicted as follows:

Tabel 4. The error assessment of the students

No	Reading		Comprehension		Transformation		Process Skill		Encoding	
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%
1	8	38,1	6	28,5	7	33,3	18	85,7	18	85,7
2	2	9,6	3	14,3	11	52,4	13	61,9	16	76,2
3	6	28,6	5	23,8	5	23,8	3	14,3	7	33,3
4	1	4,8	1	4,8	4	19,1	4	19,1	16	76,2

Analysis on the Reading

The errors by the student mostly happen in the question number 1, followed by 3, 2, and 4. Fig 1 shows the error in the reading aspect. For example, a student with the initials RS answered question 1 by only identifying the picture only and missed the question briefly. In Fig. 1, RS can only identify the equation of motion. Thus, show the following mistakes are happening due to the mistakes or errors from the previous step(s).

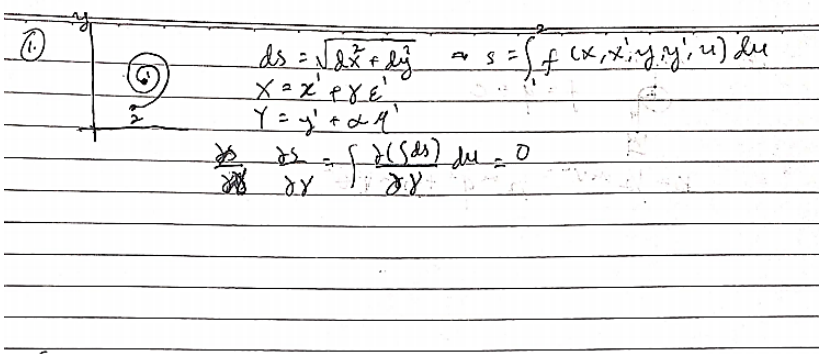


Figure 1. Answer on student RS in question 1.

Analysis of the Comprehension

The errors mostly happened in questions 1, followed by 3, 2, and 4. This error is strongly related to the whole understanding of the students of the questions. One can see Fig. 2 of the errors made by a student with the initials MTF..

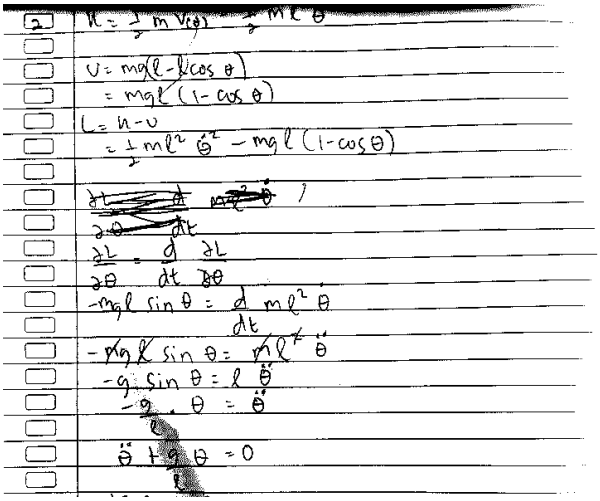


Figure 2. Answer on student MTF on question 3**.**

Fig. 2 shows MTF made an error in the process of answering which is not in accordance with the question. In this picture, the student worked in the polar coordinates from which the question must be answered by the cartesian coordinates. It shows the error on the student to execute the question, even though he/she didn't fail to identify the question, but made a careless step in the end.

Analysis on the Transformation

Based on table 2, the errors happened mostly in number 2 followed by 1, 4, and 3. One can see Fig. 3 in detail. A student with the initials TP made a *transformation* and solve the process correctly. He/She can identify the picture correctly, but the error

is made in solving the Euler-Lagrange. All previous steps are correctly done but failed in this step. This error is happened due to the lack of concept of Euler-Lagrange by the student. Thus, failed to construct the equation of motion by the Euler-Lagrange equation.

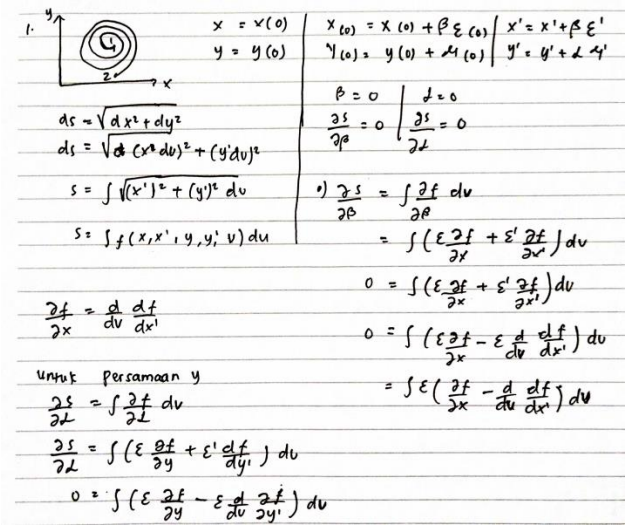


Figure 3. The answer of Student TP on question 1.

Analisis on the Process Skill

Process skill error mostly happened in question 1. Although in a smaller degree also happened in another question. For example, we take question number 4, which student with initials WEA works following the Fig. 4

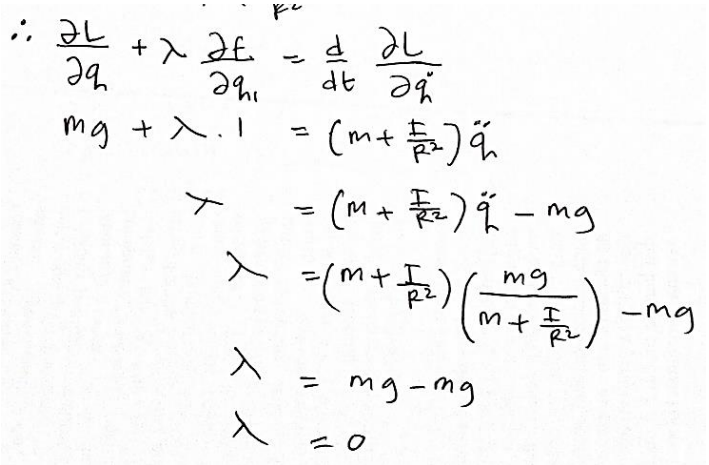


Figure 4. Jawaban Mahasiswa WEA pada Soal Nomor 4

In Fig. 4, the process done by the student WEA showed a good result in obtaining the Lagrange multiplier. However, He/She made a severe mistake at the end of the calculation. This way, the student showed a certain degree of carelessness during the answering.

Analysis of the Encoding Aspect

In Fig. 5, one can find the encoding error corresponds to the work of the student. For a student with the initials name FKH on question 3, the student already identifies correctly the question. He/She can also derive the equation correctly. However, the small mistake happened in the last conclusion in the ignorable coordinate, which is theta (θ). Thus, this error is due to the carelessness when checking the question.

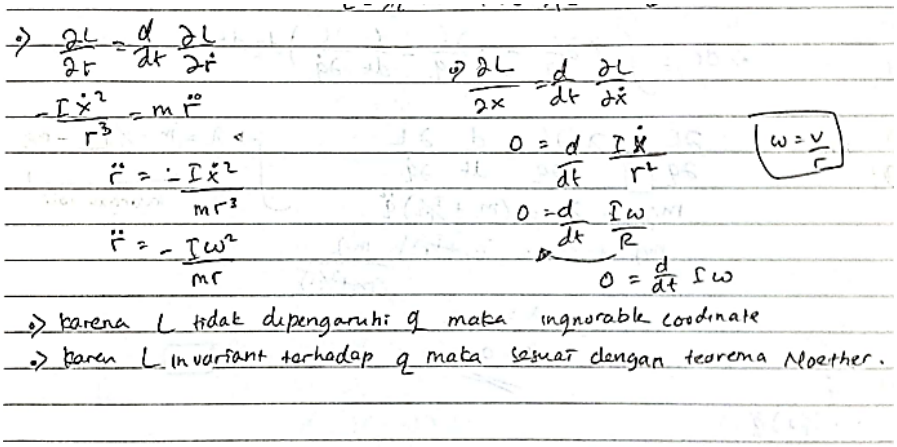


Figure 5. Answer by Student FKH on question 3.

D. Conclusion

We analyse the errors made by 21 students who taken analytical mechanics class. Our analysis found that the students understanding of this subject is still low. The reason is strongly due to the errors made by the students. There are many errors of the students when solving the analytical mechanics. By using NEA, we already separate their errors into 5 categories: reading, comprehension, transformation, process skill, and encoding. We found, the errors most likely happen in encoding stage. This is happen due to the difficulty level of this step is beyond the rest and its understandable. With NEA, we can easily determine when students make errors and which part the errors are occur. This classification, is truly beneficient to the teacher for the future teaching method corresponding this subject.

References

[1] I. Junaedi, "Tipe Kesalahan Mahasiswa dalam Menyelesaikan Soal-Soal Geometri Analitik Berdasar Newman's Error Analysis (NEA)," *Kreano, J. Mat. Kreat.*, vol. 3, no. 2, pp. 125–133, 2012, doi: 10.15294/kreano.v3i2.2872

[2] D. E. Febriani and Mukhni, "Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Cerita Matematika Berdasarkan Analisis Kesalahan Newman Pada Siswa Kelas Viii Smp Negeri 7 Padang," *J. Edukasi dan Penelit. Mat.*, vol. 7, no. 4, pp. 24–29, 2018.

[3] D. Rahmawati and L. D. Permata, "Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Cerita Program Linear Dengan Prosedur Newman," *J. Elektron. Pembelajaran Mat.*, vol. 5, no. 2, pp. 173–185, 2018.

[4] D. Oktaviana, "Analisis Tipe Kesalahan Berdasarkan Teori Newman Dalam Menyelesaikan Soal Cerita Pada Mata Kuliah Matematika Diskrit," *Edu Sains J. Pendidik. Sains Mat.*, vol. 5, no. 2, p. 22, 2018, doi: 10.23971/eds.v5i2.719.

[5] E. R. Ngura, S. Rahayuningsih, and F. Khasanah, "Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Aljabar Siswa Kelas X SMK Shalahuddin 1 Malang," *J. Penelit. dan Pengkaj. Ilm. Mhs.*, vol. 1, no. 1, pp. 33–40, 2020.

[6] G. Ding and S. Tao, "Attention should be paid to physical significance in study of analytical mechanics," *J. Dyn. Control*, vol. 17, no. 5, 2019, doi: 10.6052/1672-6553-2019-058.

[7] Moleong, Lexy J. Metodologi penelitian kualitatif. PT Remaja Rosdakarya, 2021.