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

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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.

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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.

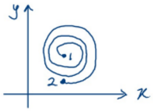
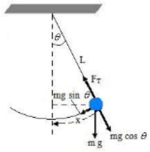
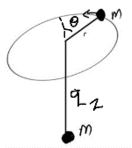
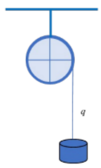
In analytical mechanics, it shows truly a significant resemblance with mathematics. Since the analysis on the analytical mechanics solely depends on a high level of mathematic tools [6], it is understandable to adopt the research on [2-5] to be done in analytical mechanics. We expect this research can 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).

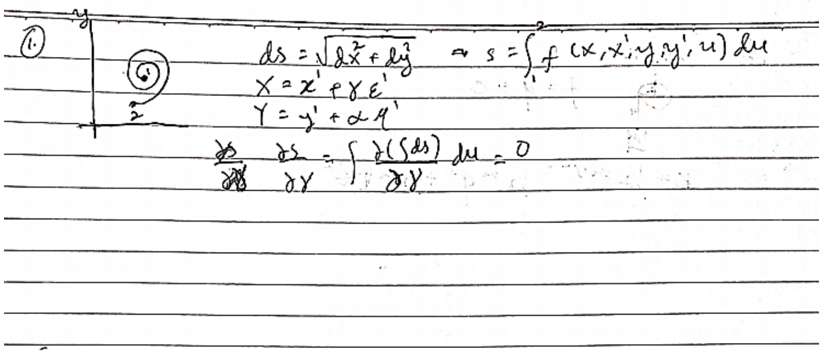


Figure 1. Answer on student RS in question 1.

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..

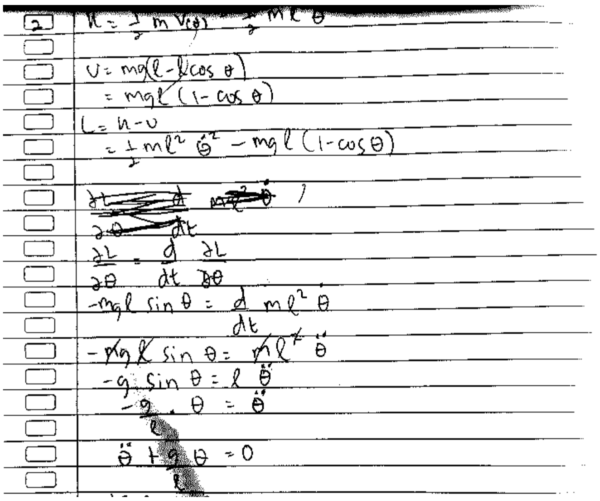


Figure 2. Answer on student MTF on question 3.

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.

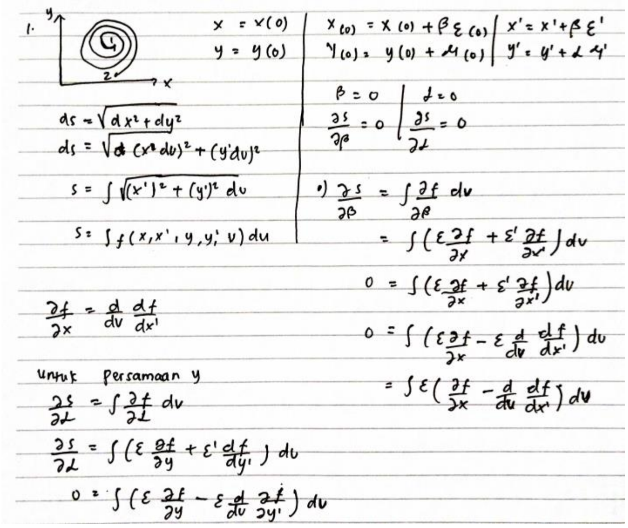


Figure 3. The answer of Student TP on question 1.

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

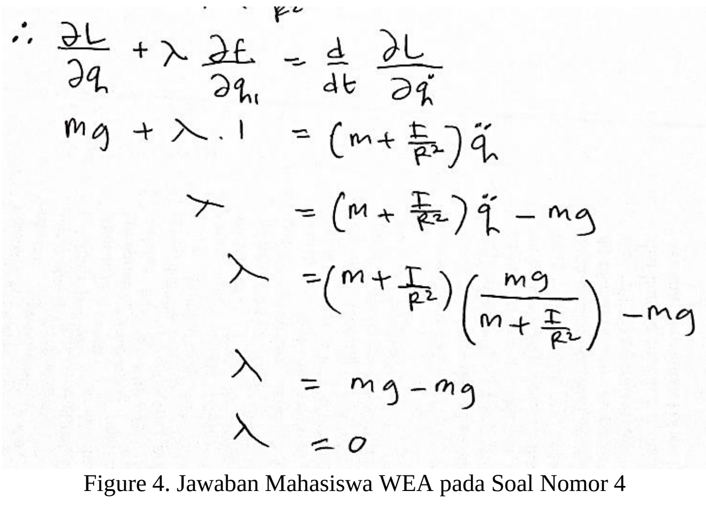


Figure 4. Jawaban Mahasiswa WEA pada Soal Nomor 4

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.

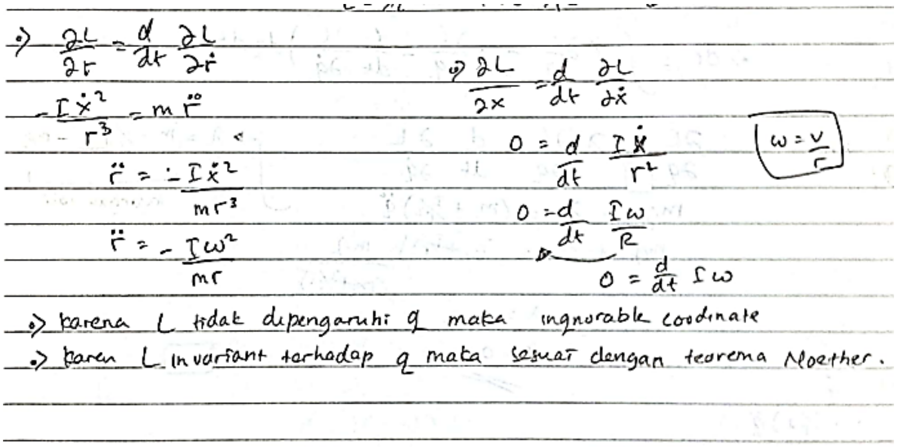


Figure 5. Answer by Student FKH on question 3.

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.

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Analysis of High School Students' Learning Difficulties in Understanding the Mechanics Concept

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ABSTRACT
Students have difficulty learning to understand the concept of mechanics. This is due to not having mastered the prerequisite skills. This study aims to determine the difficulties of students in understanding and mastering mechanical material. This study uses a descriptive method with quantitative and qualitative approaches. The subjects of this study were 18 high school students, both private and public in Yogyakarta, which were taken using a stratified random sampling technique. The steps of this research include finding references, determining subjects, making questionnaires, distributing questionnaires, analyzing data, and concluding. The instrument used is a questionnaire with answers that can be in the form of choices, opinions, and/or suggestions. The results of the study show that most students considered physics to be a difficult subject, especially the concept of mechanics. The concepts of mechanics that are considered difficult are rotational dynamics and rigid body equilibrium; impulse, momentum, the law of conservation of energy, and fluid dynamics. The learning method applied by the teacher is not appropriate because it only provides material without a more complete explanation. Students have difficulty physics learning on mechanics material because of their perception and inappropriate learning methods.

INTISARI
Banyak siswa yang mengalami kesulitan belajar dalam memahami konsep mekanika. Hal ini disebabkan tidak dikuasainya keterampilan prasyarat. Penelitian ini bertujuan mengetahui kesulitan siswa dalam memahami dan menguasai materi mekanika. Penelitian ini menggunakan metode deskriptif dengan pendekatan kuantitatif dan kualitatif. Subyek penelitian ini yaitu 18 siswa SMA baik swasta maupun negeri di Yogyakarta yang diambil dengan teknik stratified random sampling. Langkah penelitian ini meliputi mencari referensi, menentukan subyek, membuat kuisioner, menyebarkan kuisioner, menganalisis data, dan menyimpulkan. Instrumen yang digunakan berupa angket dengan jawaban dapat berupa pilihan, pendapat, dan/atau saran. Hasil penelitian menunjukkan kebanyakan siswa menganggap fisika merupakan mata pelajaran yang sulit khsusunya pada konsep mekanika. Adapun konsep mekanika yang dianggap sulit yaitu dinamika rotasi dan kesetimbangan benda tegar; impuls, momentum, dan hukum kekekalan energi, serta fluida dinamis. Metode pembelajaran yang diterapkan oleh guru kurang tepat karena hanya sekadar memberikan materi tanpa penjelasan yang lebih lengkap. Siswa mengalami kesulitan belajar fisika pada materi mekanika karena persepsi yang mereka ciptakan sendiri dan metode pembelajaran yang kurang tepat.

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A. Introduction

Physics is one of the topics that discusses natural phenomena, both real and abstract which are packaged in a collection of facts, concepts, and principles [1-3]. In physics learning, students need to understand basic concepts, so that they are able to solve the problems they face. However, there are still many students who think that physics is one of the difficult subjects to understand [4]. Most of the difficulties in learning physics are because the basic concepts given are not in line with existing theories [5]. This concept error must be avoided in learning physics.

In physics learning, problem solving ability is one of the indicators in understanding physics concepts. In fact, students more often directly use mathematical equations without doing analysis, guessing formulas, and memorizing sample questions to work on physics questions given by the teacher [6]. This causes students to have difficulty when dealing with complex problems. In addition, students still often use a plug and chug and memory based approach in solving physics problems [7,8]. In fact, one of the goals of learning physics is to create people who can solve complex problems by applying their knowledge and understanding to everyday situations.

Physics lessons taught by teachers to high school students also teach some basic material in physics, one of which is mechanics. Mechanics is a branch of physics that studies the motion of objects and the effects of forces in motion [9]. Given that mechanics is a basic material in physics, students are required to understand and master the concepts of mechanics. Furthermore, mechanics consists of two branches, namely kinematics and dynamics. Kinematics is a science that studies how objects move without regard to the causes of object movement, while dynamics is a science that studies the motion of objects by paying attention to the causes of object movement [10]. The concepts of mechanics include vectors, straight motion, circular motion, parabolic motion, Newton's law, gravitational force, torque, angular momentum, moment of inertia, center of gravity, static fluid, dynamic fluid, work, energy, momentum, and impulses. Meanwhile, the concepts of mechanics which include kinematics include straight motion, circular motion, and parabolic motion. While other concepts include dynamics [11].

Mechanics is also one of the materials that for high school students is physics material that is difficult to understand. Whereas mechanics is a classical physics study whose objects are macroscopic and can be observed directly by the eye [12]. The difficulty experienced by students in understanding the concept of mechanics is a condition in the learning process which is marked by obstacles in understanding mechanics, so that learning outcomes are not achieved maximally [13]. This difficulty in understanding the concept of mechanics appears as a learning difficulty caused by not mastering the prerequisite skills in mechanics. One of the prerequisite skills that students must have in understanding the concept of mechanics is that students are able to understand the concepts of line coordinates, integrals, derivatives, and Newton's laws of motion [14].

Mechanical material also requires basic materials such as basic mathematics and basic physics. Therefore, the concepts that are prerequisites for learning further concepts are important to master and understand. Based on an explanation of the background of this problem, the purpose of this study is to find out the difficulties experienced by students in understanding and mastering mechanical material. Meanwhile, the research questions to be answered in this study are, Q1: How do students understand mechanics? Q2: What materials do high school students find difficult? Q3: How important is mathematics in mechanics?

B. Method

This study uses descriptive research methods with quantitative and qualitative approaches. The data of this research are in the form of quantitative and qualitative data. Quantitative data analysis was interpreted with pie and bar charts. Meanwhile, qualitative data were analyzed from open questions in the questionnaire. Meanwhile, the research subjects used in this study were 18 high school students in Yogyakarta who were determined by stratified random sampling technique. These eighteen samples are considered to have represented high school students in Yogyakarta because they came from private high schools and public high schools. The questionnaire method through Google Form was chosen by the researcher because at the time of this study it was not possible to take the questionnaire directly due to the COVID-19 pandemic.

The answers to the questionnaire items can be in the form of choices, opinions, and/or suggestions. The questions in the questionnaire are used to identify mechanics concepts that are considered difficult by high school students. At the end of the questionnaire, a blank column is provided which must be filled in by students regarding opinions and suggestions regarding appropriate learning methods to improve understanding of mechanics concepts. The questions in this questionnaire can be presented in Table 1.

Table 1. Questions in the questionnaire

No.	Question	Option
1.	Is studying physics difficult?	Answer Options: a. Very difficult b. Difficult c. Normal d. Easy e. Very easy
2.	Did you know that in physics there is material about mechanics?	Answer Options: a. Yes b. No

No.	Question	Option
3.	Choose the mechanics concept that you find difficult!	Answer Options: a. Vector b. Straight motion, circular motion, and parabolic motion. c. Newton's Law d. Gravitational force e. Rotational dynamics and rigid body equilibrium f. Static fluid g. Dynamic fluid h. Work and Energy i. Collisions, impulses and the law of conservation of momentum
4.	From the choices above, explain why the concept you chose was difficult?	Open question
5.	Explain why the concept you didn't choose was easy for you!	Open question
6.	How do you overcome difficulties in understanding the concept?	Open question
7.	What is the method used by your teacher in learning physics?	Open question
8.	In your opinion, is the learning method applied by your teacher appropriate?	Answer Options: a. Yes b. No c. Maybe
9.	Explain your reasons for answering the previous question!	Open question

Based on Table 1, it can be seen the details of the questions in the questionnaire given to the sample. The steps taken to collect this data were looking for references, determining subjects, making questionnaires via Google Form, distributing questionnaires to research subjects, analyzing data, and concluding the data. Furthermore, the results of data collection using this Google Form will be presented in the results and discussion.

C. Results and Discussion

This research was conducted on high school students from both public and private high schools. All respondents already know that in physics there are concepts of mechanics. However, the respondents were asked for their opinion on the level of difficulty in learning physics. The results of high school students' perceptions of the level of difficulty in learning physics can be presented in Figure 1.

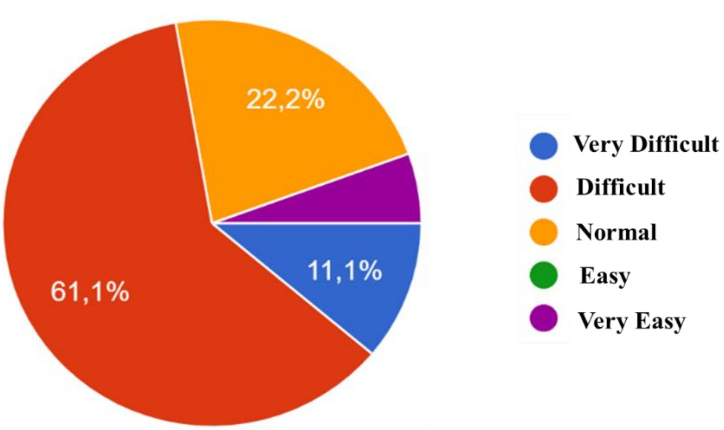

Figure 1. Students' perceptions of physics learning

Based on Figure 1, it can be seen that 61.1% of respondents consider physics to be a difficult subject to understand, 22.2% of respondents consider physics to be an ordinary subject, 11.1% of respondents consider physics to be a very difficult subject and the rest think physics is very easy. These results indicate that high school students in Yogyakarya think that physics is a difficult subject. However, all respondents who are high school students in Yogyakarta know that there is mechanics in physics. Meanwhile, students' views on the concepts of mechanics that are considered difficult can be presented in Figure 2.

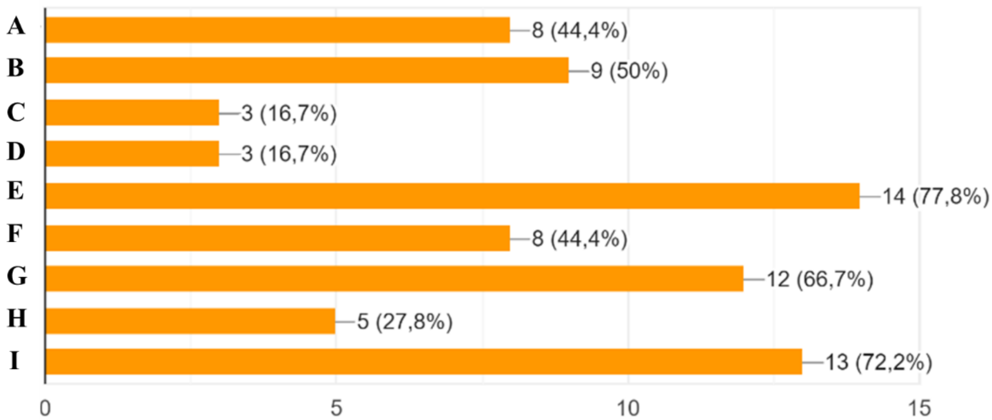

Figure 2. Students' perceptions of the mechanics concept

The information in Figure 2 includes, A is vector and B is straight motion, circular motion, and parabolic motion. C is Newton's law and D is the gravitational force. E is rotational dynamics and rigid body equilibrium. F is a static fluid. G is dynamic fluid and H is work and energy. In addition, I is collisions, impulses and the law of conservation of momentum. Based on the data presented in Figure 2, it can be seen that there are three mechanics concepts that are considered the most difficult by high school students, namely fourteen students chose the concepts of rotational dynamics and rigid body equilibrium as the most difficult mechanics concepts. Collisions, impulses, and the law of conservation of momentum are difficult materials other than rotational dynamics and rigid body equilibrium because they were chosen by thirteen respondents. Meanwhile, twelve respondents also chose dynamic fluid as a difficult mechanics concept. Physics concepts that are considered difficult because of the many variations of questions and the lack of clarity and detail of the teacher in explaining. These results are in accordance with the findings of previous studies which showed that two important and difficult parts to understand in learning at school include the law of conservation of energy and optics [15]. In addition, dynamic fluid matter is included in the field of mechanics which is at the top of the misconceptions [16].

Some 11th graders also have misconceptions about rotational dynamics [17]. One of the students wrote down the reasons why the three concepts were difficult because so many formulas were used. Other students wrote down the three concepts that were difficult because they had varied questions. This causes students to have difficulty applying the existing formulas to solve problems of the three concepts. In this study, students also expressed their ways of overcoming difficulties in understanding the three concepts, among others, by asking teachers and friends, increasing practice questions, and looking for other learning media. Based on Figure 2 also obtained two concepts that are considered easy by students because of the eighteen respondents only three students chose this concept as difficult.

Two concepts that are considered easy are Newton's law and the force of gravity. The reason students choose the concept is easy because the material has been taught since junior high school, so it is easier to understand the basic concepts. Another reason is that the material is considered small and easy to find in practice questions. This shows that it is easier for students to understand and solve the problems of the two concepts. Meanwhile, the results of students' opinions regarding the accuracy of the physics learning method applied by the teacher can be presented in Figure 3.

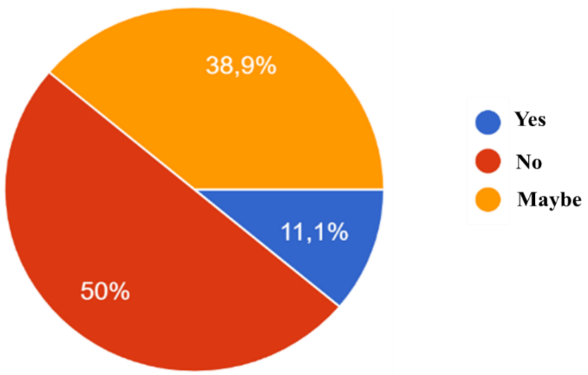

Figure 3. Students' opinions about the learning methods applied by physics teachers

Based on Figure 3, it can be seen that 50% of students considered the method applied by their physics teacher to be inappropriate, 38.9% of students answered it was possible, and 11.1% of students considered the method applied by their physics teacher to be correct. Based on these data, it can be said that most high school students in Yogyakarta view that the learning methods applied by physics teachers are not appropriate. Based on student responses to the questionnaire, the methods used by physics teachers in learning physics are such as providing material in the form of presentations, learning videos, and using online learning applications. Based on the students' arguments, the method was not appropriate because the teacher did not explain the material in detail and did not prioritize students' understanding. The learning method that is expected and deemed appropriate by students is that after giving the material, the teacher is expected to give an explanation slowly and in detail and provide examples of varied questions.

Based on the results of this study, it is hoped that the module makers will increase the variety of sample questions on materials that are considered difficult, such as rotational dynamics and rigid body equilibrium; impulse, momentum, and the law of conservation of momentum; and fluid dynamics. After this research, it is hoped that physics teachers will also know about the difficulties faced by students related to the concepts of the material. This research is also expected to know about the learning methods that should be applied by teachers and other teachers. In addition, it is hoped that from this research students are also more active in learning about physics, especially the concepts of mechanics.

D. Conclusion

The results of this study indicate that most high school students think that physics is a difficult subject. However, all students have known that mechanics is included in physics subjects. The concepts of mechanics that are considered difficult by students are rotational dynamics and rigid body equilibrium; impulse, momentum, and the law of conservation of energy, and fluid dynamics. While the concepts of mechanics that are considered easier by students are Newton's laws and the force of gravity. Based on this study, it was also found that according to students, the learning method applied by the teacher was currently not appropriate because it only provided material without a more complete and detailed explanation. Students expect the learning method applied by the teacher is to provide a complete explanation and provide examples of varied questions. Meanwhile, this research can be used as a reference in the compilers of physics modules in order to increase the number of questions that can improve students' understanding. With the module that refers to this article, it is hoped that it will make it easier for physics teachers in delivering mechanics material that is considered difficult by students.

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Development of Digital Distance Measurement Instrument Based on Arduino Uno for Physics Practicum

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ABSTRACT
Measurement in physics is absolute because it affects the results of theoretical and experimental proofs. Retrieval of distance measurement data for physics experiments also requires high accuracy and a relatively long time because the accuracy in the measurements determines the valid results. Sometimes the available measurement instrument is difficult to access for novice researchers because of the high cost of these measurement instruments. These problems often result in errors and limitations in the implementation of measurements. The relatively long time also slows down data retrieval. This study aims to develop a digital distance measurement instrument based on Arduino Uno for physics practicum. This research is qualitative research using library research methods, field research, designing instruments, and testing hardware and software instruments. Instruments and materials used in this research include the ultrasonic sensor HC-SR04, Arduino Uno r3 kit, LCD, potentiometer, and Arduino IDE software. The result of this research is the digital distance measurement instrument based on Arduino Uno for physics practicum can be a solution for measuring objects with large distances and lengths. This measurement instrument has the smallest value of 1 cm. The design of the Arduino uno-based digital distance measuring device for physics practicum is a practical measurement instrument with the smallest measuring value of 1 cm which can assist students in measuring distances in physics practicum.

INTISARI
Pengukuran dalam fisika bersifat mutlak karena mempengaruhi hasil pembuktian teoritis dan eksperimental. Pengambilan data pengukuran jarak untuk eksperimen fisika juga membutuhkan ketelitian yang tinggi dan waktu yang relatif lama karena ketelitian dalam pengukuran menentukan hasil yang valid. Terkadang instrumen pengukuran yang tersedia sulit diakses oleh peneliti pemula karena mahalnya instrumen pengukuran tersebut. Permasalahan tersebut seringkali mengakibatkan kesalahan dan keterbatasan dalam pelaksanaan pengukuran. Waktu yang relatif lama juga memperlambat pengambilan data. Penelitian ini bertujuan untuk mengembangkan alat ukur jarak digital berbasis Arduino Uno untuk praktikum fisika. Penelitian ini merupakan penelitian kualitatif dengan menggunakan metode penelitian kepustakaan, penelitian lapangan, perancangan instrumen, dan pengujian perangkat keras dan perangkat lunak. Instrumen dan bahan yang digunakan dalam penelitian ini antara lain sensor ultrasonik HC-SR04, kit Arduino Uno r3, LCD, potensiometer, dan software Arduino IDE. Hasil dari penelitian ini adalah alat ukur jarak digital berbasis Arduino Uno untuk praktikum fisika dapat menjadi solusi untuk mengukur benda dengan jarak dan panjang yang besar. Alat ukur ini memiliki nilai terkecil yaitu 1 cm. Perancangan alat ukur jarak digital berbasis arduino uno untuk praktikum fisika merupakan alat ukur praktis dengan nilai ukur terkecil 1 cm yang dapat membantu mahasiswa dalam mengukur jarak pada praktikum fisika.

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A. Introduction

Physics is the study of natural phenomena and what happens in them. In physics, there are theoretical and experimental sciences which are the two main factors in supporting it [1-2]. The theory is a system of concepts that shows the relationship between other concepts to help understand the phenomenon. Meanwhile, experimental science is an activity to prove and apply physical theory in real-life reality [3]. Experimental activities are support in increasing understanding and proving the concept of physics material. Furthermore, experimental activities in physics are also often termed practicum activities to practice the truth of physical theories that have been proposed by physicists. Furthermore, the use of experimental or practicum activities can train students' 3 skills, namely cognitive, affective, and psychomotor skills [4-5].

In physics practicum activities, the activity of measuring physical quantities will involve the use of measurement instruments. This is by the statement submitted by Yudha and Sani [6] that measurement is a process to obtain information on the physical quantity of an object in the form of numbers because of comparison with a standard quantity. In carrying out measurements, measurement instruments need to be calibrated first so that the physical quantities measured produce valid data [7]. Furthermore, physics practicum activities are usually not only carried out once but are carried out repeatedly to a certain extent. This is done to avoid research subjectivity and obtain accurate and precise research data.

One type of measurement is measuring length using a ruler, tape measure, or other distance measurement instrument. The use of a distance measurement instrument is usually used to measure the distance, length, and height of objects. The use of rulers and meters in measurement will be effective if the distance, length, or height of the object is relatively small [8-10]. However, if the object being measured has a large length, then using a ruler and tape measure to measure the length of the object will be ineffective and will take a long time. This will certainly interfere with the implementation of physics practicum activities.

Apart from physics practicum which requires a variety of manual measurement instrument such as rulers or meters, there are also electronics-based physics measurement instruments. One of the physics measurement instrument based on electronics is the Arduino Uno. Arduino Uno can be set according to the wishes of users and researchers according to the purpose of measuring physical quantities [11-12]. Furthermore, the Arduino Uno can assist researchers in simplifying and shortening the duration of data collection in practical activities or physics experiments. Arduino Uno is a platform for physical computing that functions as a developer instrument and a measurement instrument for physics that requires a programming language [13-15]. In addition, Arduino Uno is also one of the small ATmega328 microcontroller-based board instrument complete with breadboard support [16]. The display of Arduino Uno can be presented as shown in Figure 1 [17].

Figure 1. Display of Arduino Uno

One example of the use of Arduino Uno in the field of physics research is that it is used in the manufacture of the digital distance measurement instrument. The use of digital distance measurement instrument in practicum can make the physics learning process run effectively and require a short time. In addition, the use of a digital distance measurement instrument can also measure distant objects and the length of objects that have large values. Therefore, the researcher conducted research that developed a digital distance measuring device based on Arduino Uno for physics practicum. It is hoped that by taking advantage of the development of electronics in physics research and learning, students will be helped in conducting practical measuring distances and lengths of objects.

B. Method

This research is qualitative research with library research methods, field research, designing measurement instruments, and testing measurement instruments in the form of hardware and software. The library research method is carried out by conducting a preliminary study which includes a study of various literature sources regarding the development of distance measurement instrument, physics practicum, and Arduino Uno. The stage of library research is to carry out the coding process by designing a distance measurement instrument based on Arduino Uno according to the results of a literature review. After obtaining various explanations regarding the development of the distance measurement instrument based on Arduino Uno, the next step is to conduct a review of the availability of object distance measurement instrument in the laboratory. After obtaining data regarding the distance measurement instrument which is dominated by a simple distance measurement instrument in the form of a ruler or meter, the next step is to develop a distance measurement instrument based on Arduino Uno.

The stages involved in developing the measurement instrument are making the design of the measurement instrument, determining the design of the measurement instrument, determining the components needed, and assembling all the components according to the design that has been developed. Meanwhile, the components needed to support the manufacture of digital distance measurement instrument based on Arduino Uno include the ultrasonic sensor HC-SR04, Arduino Uno r3 kit, LCD (liquid crystal display), potentiometer, and Arduino ide software. After all these components are assembled, the next step is to make a programming language or often called the coding process. After the coding stage has been completed, it is continued with the testing stage of the development measurement instrument. The testing stage is carried out in several stages starting from pushing the on/off button and adjusting the position of the measurement instrument. After this step, the sensor will detect the distance followed by data processing on the Arduino. In the next stage, the LCD will display the results of measuring object distances and processing the measurement data manually. Furthermore, the workflow for developing a digital distance measurement instrument based on Arduino Uno can be presented in Figure 2.

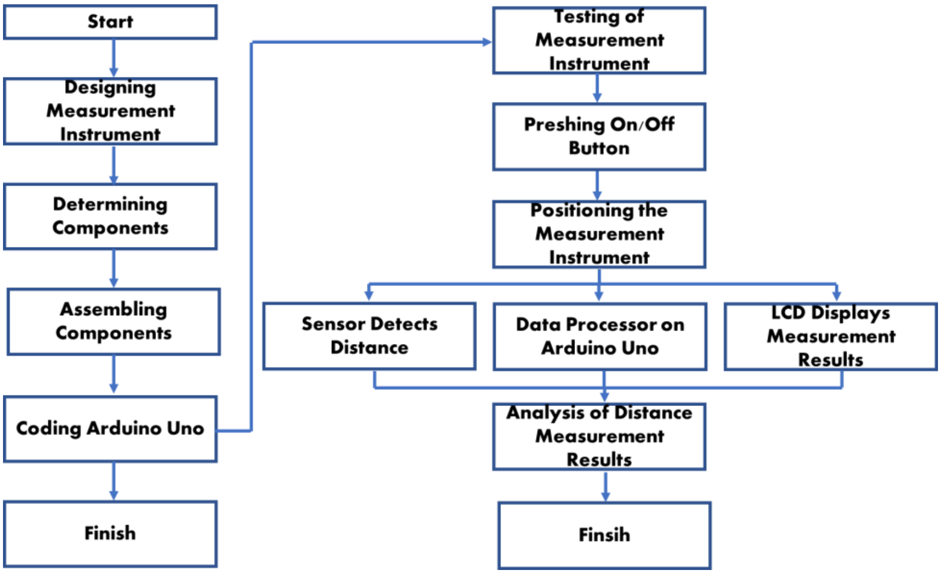

Figure 2. Workflow of the digital distance measurement instrument

C. Results and Discussion

Research on the development of a digital distance measurement instrument was carried out using the main components in the form of an ultrasonic sensor HC-SR04 and Arduino Uno. The development of this digital distance measurement instrument uses the HC-SR04 proximity sensor with the reason that the sensor functions in detecting distance using objects or obstacles that are used as reflecting fields when pulses are sending and receiving processes [18]. Furthermore, the display of the results of components series for measurement distances digitally can be presented in Figure 3.

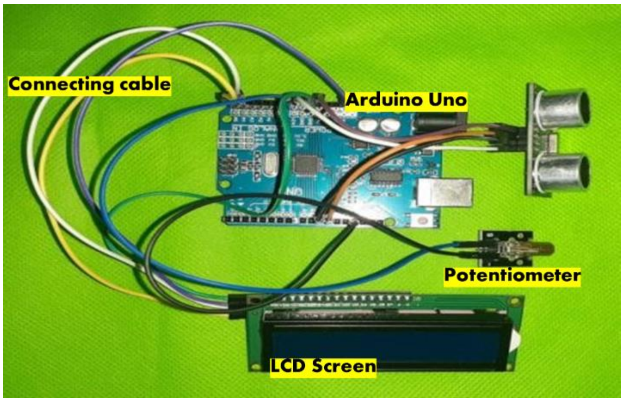

Figure 3. The results of components series for measurement distances digitally

Based on Figure 3, it can be shown that the main components used to digitally assemble the object distance measurement instrument include the ultrasonic sensor HC-SR04, Arduino Uno, LCD screen, connecting cable, and potentiometer. Furthermore, the digital object distance measurement instrument developed in this study has several advantages over the distance measurement instruments already available in the laboratory or the market. One of the advantages is that this digital distance measurement instrument based on Arduino Uno can measure the distance of distant objects and the length of objects that have large values. This digital distance measurement instrument can increase students' understanding of the process of developing a measurement instrument, strengthen science process skills, and introduce students to the coding process. Meanwhile, the display of the results of developing a digital object distance measurement instrument based on Arduino Uno can be presented in Figure 4.

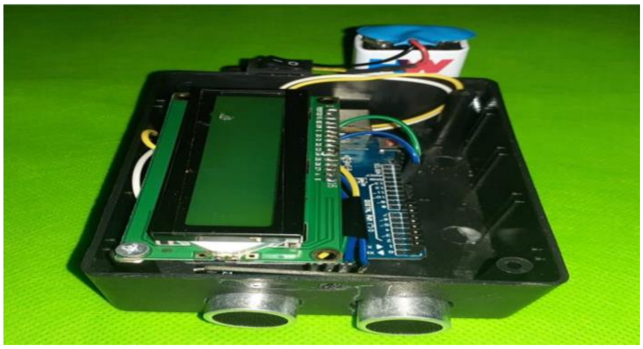
Figure 4. Display of digital distance measurement instrument based on Arduino Uno

The developed digital distance measurement instrument as shown in Figure 4 can be used as a variety of measurement instrument in student practicum activities in the laboratory. This distance measurement instrument can be used to measure distances quickly, accurately, and precisely than other distance measurement instrument. Meanwhile, after the digital object distance measurement instrument based on

Arduino Uno has been developed, the distance measurement instrument is ready to be used in measuring distance. The steps taken to measure the distance of objects using a measurement instrument resulting from this development are by directing the ultrasonic sensor part of the HC-SR04 towards the object to be measured. After that, the object distance will be detected by the ultrasonic sensor HC-SR04 and display the results through the LCD screen. The display of a digital object distance measurement instrument when used to measure object distance can be presented in Figure 5.

Figure 5. (a) display of object distance measurement and (b) display of comparison of distance measurement instrument digitally with a ruler

Based on Figure 5, it can be seen that the arrangement of the distance measurement instrument digitally with the object to be measured is displayed. The position of the object distance measurement instrument can be changed according to the will of the researcher to measure how far away the object is. Meanwhile, Figure 5. (b) shows the comparison of a digital object distance measurement instrument with a ruler that is used simultaneously to measure the distance of the same object. The two distance measurement instruments are used simultaneously to know the accuracy of the results of measuring object distances. Furthermore, the results of measuring object distances using a digital object distance measurement instrument with a ruler can be shown in Table 1.

Table 1. Results of distance measurements using digital distance measurement instruments and ruler

Distance Measurement	Object Distance	
	Digital Distance Measurement Instrument	**Ruler**
First	2 cm	3 cm
Second	8 cm	9 cm
Third	11 cm	12 cm
Fourth	14 cm	15 cm
Fifth	18 cm	19 cm

Based on Table 1, it can be observed that the digital object distance measurement instrument based on Arduino Uno has the smallest measuring value of 1 cm. It can be shown in Table 1 that according to the results of measuring the distance of objects using a digital distance measurement instrument and a ruler, the difference in results is 1 cm. The results of measuring the distance of objects using a distance measurement instrument digitally show the measurement results whose value is 1 cm smaller than measuring the distance of objects using a ruler. Therefore, when the digital object distance measurement instrument is used by researchers or students in physics practicum activities, it is necessary to add a value of 1 cm from the distance measurement results listed on the LCD screen. This is done with the aim that the results of measuring object distances using a digital object distance measurement instrument are as accurate as of the results of measurements using a ruler. This means that the digital object distance measurement instrument based on Arduino Uno has limitations which include being less accurate in measuring object distances as far as 1 cm. This is also like the findings of Putranta et al. [19] who developed an object distance measurement instrument based on Snell's law of reflection of light with measurement results that have less accurate limitations of 0.75 cm than using a ruler.

This digital distance measurement instrument based on Arduino Uno can be used as a variety of measurement instrument in physics practicum activities. This is because this digital object distance measurement instrument is practical in its use. In addition, this Arduino Uno-based digital object distance measurement instrument is also capable of measuring the distance of objects that are quite far away that ordinary rulers cannot measure. However, the digital distance measurement instrument has limitations which include less precision in measuring distances with a difference of 1 cm in precision than using a ruler. That is, when measuring the distance of objects using the digital measurement instrument, the value listed on the screen cannot be directly used as the object distance value and this value must be added to the value of 1 cm. Furthermore, this digital distance measurement instrument can be used to support object distance measurements in the fields of physics education, civil engineering, and land affairs. Through the use of this digitally developed object distance measurement instrument, it can facilitate and provide variations on measurement instruments in physics practicum activities. This digital distance measurement instrument can be used to measure the length and width of buildings and land.

D. Conclusion

This research was conducted to design or develop a digital object distance measurement instrument based on Arduino Uno that can be used in physics practicum activities. This digital distance measurement instrument was developed by combining hardware including a series of electronic components and software including Arduino IDE. This Arduino IDE-based software is used to run programs that have been coded according to the plan to measure object distances. All devices in the development of this digital object distance measurement instrument are combined into a single unit in the form of a box with an LCD screen on the front. This digital distance measurement instrument can be used to measure distance, height, and other units of length. Based on the results of testing and measuring object distances, the results of measuring object distances using a digital distance measurement instrument whose value is almost close to the results of distance measurements using a ruler with a difference of 1 cm. This study has several advantages which include measuring the distance of digital objects that are practically used in physics practicum activities because the measurement instrument is in the form of a box and makes the measurement time more efficient. Researchers or students only need to point the sensor at the object to be measured and then can see the data generated through the LCD layer. Meanwhile, the limitations of this study include the selection of the type of ultrasonic sensor that is not suitable for use in measuring object distances, the unavailability of a water pass as a differentiating instrument for measuring physics with other measuring devices. Future research can be carried out by replacing the ultrasonic sensor type HC-SR04 with type Y401 and equipping the instrument box with a water pass so that the measured distance results have a small difference from the distance measurement results using a ruler.

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E-Comic as an Alternative Learning Media for Analytical Mechanic Course During COVID-19 Pandemic

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ABSTRACT

The covid-19 pandemic era causes teaching and learning activities to be carried out online. Thus, many variations of learning media are used to conduct teaching and learning activities in the pandemic era. This research developed one learning media that uses e-comics or electronic comics. The comic is expected to be a learning medium worth using in the pandemic era. This research aims to develop the medium of learning physics comics on the history of analytical mechanics. The research method used is the research and development method, covering data stages, product design, product testing. The software used in creating comics was ibisPaint X and MediBang Paint. The findings of this study are that E-comic improves reading culture. E-comics as an alternative learning media in analytical mechanics courses during the covid-19 pandemic is very worthy of being used as learning media.

INTISARI

Era pendemi covid-19 menyebabkan kegiatan belajar-mengajar dilakukan secara daring. Dengan begitu, banyak variasi media pembelajaran yang digunakan untuk melakukan kegiatan belajar-mengajar di era pandemi. Penelitian ini mengembangkan salah satu media pembelajaran yaitu menggunakan e-komik atau komik elektronik. Komik tersebut diharapkan dapat menjadi media pembelajaran yang layak digunakan di era pandemi. Penelitian ini bertujuan untuk mengembangkan media pembelajaran komik fisika pada sejarah mekanika analitik. Metode penelitian yang digunakan adalah metode penelitian dan pengembangan, meliputi tahapan data, perancangan produk, pengujian produk. Adapun software yang digunakan dalam pembuatan komik yaitu *ibisPaint X* dan *MediBang Pain*. Temuan dalam penelitian ini adalah e-komik dapat meningkatkan budaya membaca. E-komik sebagai media pembelajaraan alternatif pada mata kuliah mekanika analitik di masa pandemi covid-19 sangat layak digunakan sebagai media pembelajaran.

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Physics; comic; media; analytical mechanics

KATA KUNCI
Fisika, komik, media, mekanika analitik

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A. Introduction

Technological advancement brings various impacts on learning activities. Based on the interview results, most learning activities only make the students listen to the lecturers and note the materials shared by lecturers. However, students are not interested in these teaching styles. The students prefer learning via various learning media to listening and noting the lectures from the observation. An analytical mechanic learning process requires supportive media to learn autonomously. It also needs interesting presentations because the analytical mechanic course is challenging. Thus, it will be difficult if the students only receive theoretical materials.

Comics is an excellent medium for the analytical mechanic course because it provides many interesting figures to learn. The comic is a learning medium to share materials and courses [1-2]. In this context, learning media mediates the communication process between students and the comic's learning source. The comic has some strong points, such as motivating students during the teaching-learning process, increasing the quality of the learning, having a permanent nature, motivating students to read, especially for those who do not like reading, being a popular part of a culture [3-4]. Comics can also improve the students' reading skills [5-6]. It can also improve the student's interest, activity, and learning outcome. Thus, the comic is useful as a learning medium.

The most primitive science is mechanics because this discipline discusses motion. Thus, mechanics become the basic science and physics [7-8]. The mechanic system is usually more complex than Newton's mechanic. The advanced mechanic development emerges from famous figures of classical mechanics. Classical mechanic implementation is not efficient in solving simple mechanic problems. From the explanation, the researchers found the students needed effective and efficient learning media to motivate their learning. Physics comic learning media with an Analytical Mechanic history could be an alternative and learning source for the students.

B. Method

The applied research method is research & development to produce comics. The researchers used Borg & Gall's [9] model in this research. The first stage was data collection. In this stage, the researchers collected the data and determined the materials for the comic. The second stage was designing the product. In this stage, the researchers synthesized the storyboard as the framework of comic production for physics. The researchers also determined the topics and discussed the title to have a systematic story plot and material relevance. The designed characters included excellent and smart characters to motivate readers.

Then, the researchers tested the product by distributing the questionnaire sheet as an evaluation medium. From this questionnaire, the researchers could also find out the students' understanding during analytical learning mechanics with the comic as the learning media. The questionnaire distribution was useful to obtain analytical data.

The researchers used analytical techniques to analyze the quantitative data in this research. The researchers obtained the assessment data from experts. Then, the researchers analyzed the data descriptive qualitatively. The analysis results were useful to revise the products. In this research, the experts' judgment used a validation sheet. Then, the results on the sheets were useful to develop the designed product. The researchers used the Likert scale to assess and judge all measured aspects.

In this research, the researchers used a response questionnaire for the students, material reliability validation, and product reliability validation. In this research, the researchers classified the answers of each instrument into five options. Each measured indicator has a score scale from 1 until 5. The scale of 5 refers to the attributes of very excellent, relevant, reliable, and clear. The scale of 4 refers to fairness, relevance, reliability, and clarity attributes. The scale of 3 refers to the attributes of below average, less adequate, less reliable, and less clear. The scale of 2 refers to the attributes of not excellent, inadequate, unreliable, and unclear). Then, the scale of 1 refers to extremely not excellent, extremely inadequate, extremely unreliable, and extremely unclear.

After collecting the data, the researchers calculated each weight of the responses by calculating the average score. Here is the applied formula to calculate.

$$\bar{x} = \frac{\sum x}{n} \quad [.\ 1]$$

Remarks :

$\bar{x}$ = average score

n = the numbers of the assessors

$\sum x$ = total scores of each item

For the percentage result formula, the researchers calculated with the following formula.

$$\text{Result} = \frac{\text{Total skor yang diperoleh}}{\text{Skor maksimum}} \text{x}100\% \quad [.\ 2]$$

The reliability categories are based on these criteria [10].

Table 1. Reliability Criteria of the Media

No	Scores in percentages (%)	Reliability Categories
1	< 21 %	Extremely unreliable
2	21– 40 %	Unreliable
3	41– 60 %	Fairly reliable
4	61– 80 %	Reliable
5	81– 100 %	Very reliable

C. Results and Discussion

The researchers collected the data from the instruments of the experts and the respondents. The questionnaire results were useful to determine the reliability of the developed learning media. Before the respondents tested the given instrument judgment, each respondent did the test toward the e-comic as the alternative learning media for the analytical mechanic course during the COVID-19 pandemic.

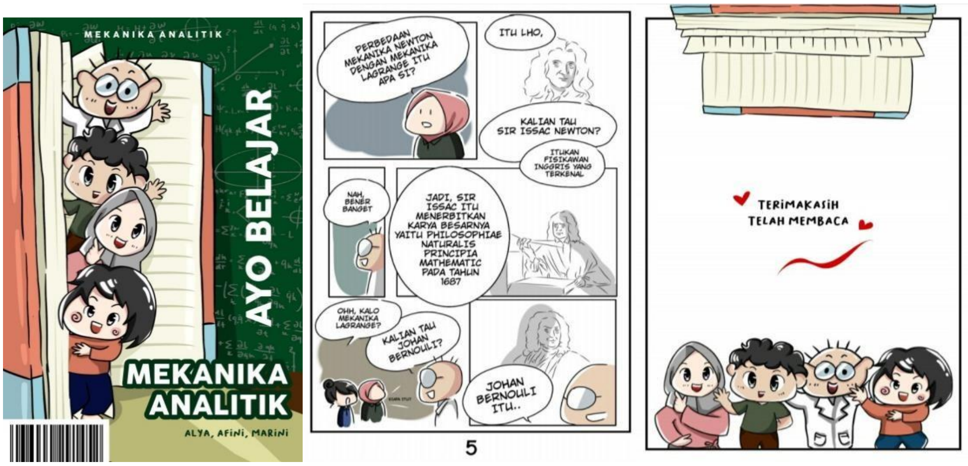

Figure 1. The appearance of analytical mechanic history e-comic

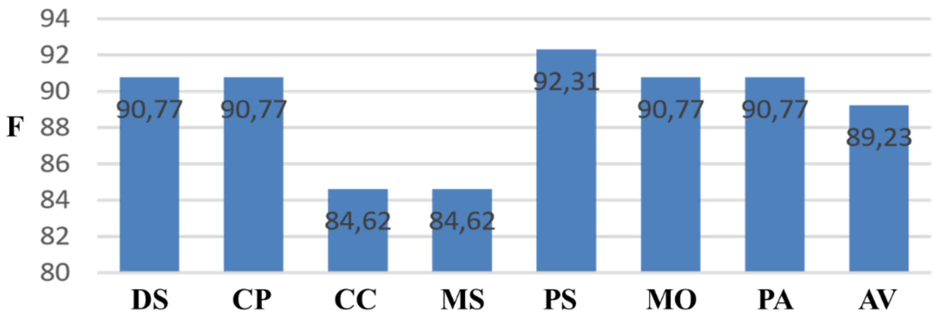

Figure 2. The results of material indicator validation test

Based on Figure 2 it can be seen that F is the frequency and DS is describing the history. CP is the presence of the component and CC is the content conformity. MS is the material suitability and PS is the systematic presentation. MO is the material organization and PA is presentation accuracy. Meanwhile, AV is average. The results of the reliability test showed the average percentage from all aspects. The developed electronic comic was reliable because the percentage reached 89.23%. The developed electronic comic had relevant content illustrations based on analytical mechanic histories. In this stage, the experts suggested the researchers discuss the learning objectives by using e-comic. This suggestion deals with the material relevance aspect.

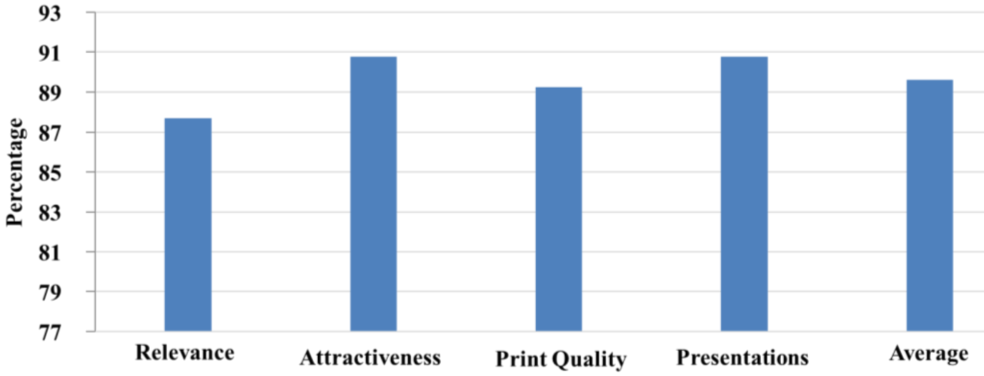

Figure 3. The Validation Results of Presentation Indicator

The table shows the presentation aspect of the e-comic base don the experts' judgment. The results show an average presentation score is 96.53%, categorized as reliable. The experts argued that the product had excellent relevance, attractiveness, appearance, and figure presentation quality. The results are observable from the experts' judgment on each aspect that mostly obtains 4 and 5. The experts suggested the researchers type a phrase of "Ayo Belajar" without using shadow effects on the e-comic cover appearance.

The results of students' responses

In this stage, the researchers conducted field testing for 25 students of Physics Education (see graphic 1).

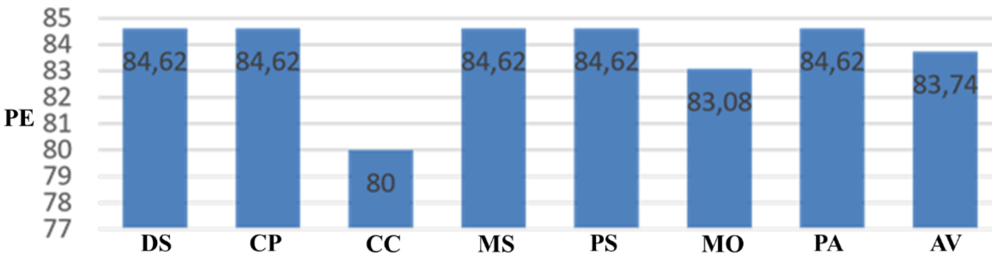

Figure 4. The Result of Average Judgment based on the Students' Responses

All aspects show that the developed electronic comic was reliable because the percentage reached 83.74%. Thus, the developed product could be an alternative learning medium for students of analytical mechanic course during the COVID-19 pandemic.

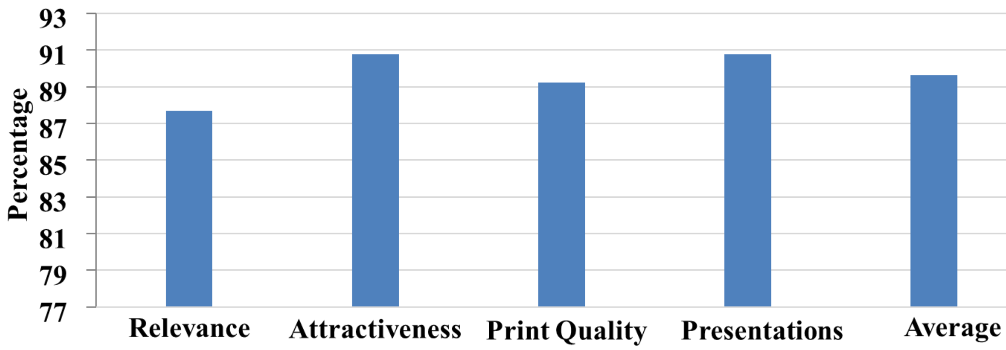

Figure 5. The Analysis Results of Average Judgment based on the Students' Responses

The graphic shows the average percentage results, 89.61%. The percentage indicates that the developed product could be an alternative learning medium for students of analytical mechanic course during the COVID-19 pandemic because the product is reliable based on the presentation aspect.

Table 2. The Validation Results of Language Indicator

The tested aspects	Percentage	Interpretation
Understandable language for students	96.67%	Very reliable

The table shows that the applied language in the e-comic as an alternative learning media during the COVID-19 pandemic is very reliable. Most respondents shared their judgment with scales of 4 or 5. Two respondents judged the product on a 4 (reliable) scale, while ten respondents judged the product with 5 (very reliable). The validation test obtains a percentage of 96.67%). The researchers validated and analyzed the e-comic production's objective. The objective of this product development was to create a reliable e-comic product with analytical mechanical history material.

The researchers expect the e-comic could motivate and facilitate physics education students to study. Most comments from the students indicated that the product was reliable as a learning alternative because of the understandable language and attractive presentation. Learning analytical mechanic history is more joyful because the comic is funny. However, the experts suggested the researchers discuss the comic's objective and the differences and similarities of Lagrange and Hamilton's equations.

D. Conclusion

From the reliability test with the indicators of material, presentation, and language, the developed product, e-comic as an alternative learning media of analytical mechanic course during the COVID-19 pandemic, was reliable as the teaching material for physics education students.

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The Development of Project-based Learning Instrument Assisted by Lego® Mindstrom®

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ABSTRACT

An alternative solution to using STEM (Science, Technology, Engineering, and Mathematics) in learning is - by offering relevant contextual learning and integration of STEM knowledge via project-based learning with an educative robot kit as the learning instruments. This research developed a project-based learning instrument assisted by Lego® Mindstorm®, implemented by teachers in a physics lesson, specifically on friction material. The research's novelty dealt with the use of Lego® Mindstorm® as the visual aid with the STEM approach. This research used Borg & Gall's Research & Development model, consisting of 10 stages. The researchers focused this R&D only on student worksheets and lesson plans. In this research, the researchers involved five experts in judging the reliability of the learning instruments: the student worksheet and lesson plan applied in the learning process. The validation result of the developed student worksheet showed that the reliability judgment of material expert was 94.6%, while the expert of media with 79.7%. Then, the lesson plan's validation result was 76% based on the material expert's judgment. Then, the validation result of the evaluation instrument indicated an excellent category. Thus, the learning instruments were reliable to be implemented in the classroom to facilitate teachers in optimizing the learning technology.

INTISARI

Penelitian ini bertujuan untuk menyediakan perangkat pembelajaran berbasis proyek berbantuan Lego® Mindstorm® yang siap diimplementasikan oleh pendidik di sekolah, khususnya pada pembelajaran fisika pada pembahasan materi Gaya Gesek untuk siswa kelas X. Hal baru yang ada pada pembelajaran menggunakan perangkat ini terletak pada penggunaan Lego Mindstorm sebagai peraga dengan pendekatan STEM. Pengembangan yang dilakukan mengacu pada prosedur penelitian Borg and Gall. Hasil validasi ahli menunjukkan bahwa perangkat pembelajaran berupa LKPD dan RPP yang telah dikembangkan layak untuk digunakan dalam proses pembelajaran. Hal ini ditunjukkan oleh hasil validasi ahli untuk LKPD dari ahli materi yang memperoleh hasil 94,6% dan ahli media 79,7% dengan skala likert. Sedangkan hasil validasi ahli media untuk RPP menunjukkan hasil 76% dengan skala likert. Kemudian hasil validasi instrumen evaluasi dinyatakan dalam kategori baik. Perangkat pembelajaran ini diharapkan dapat diimplementasikan di kelas dan membantu pendidik dalam mengoptimalkan teknologi pada pembelajarannya.

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Kit Robot; Lego Mindstorm; Perangkat Pembelajaran; Project-Based Learning; STEM.

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A. Introduction

Current education patterns bring challenges for educators to prepare and facilitate their learners to compete in this opened-information era of the 21st century. Nowadays, learners must master four basic competencies, critical thinking and problem solving, creativity, communication, and collaboration [1]. In Indonesia, education also encounters challenges of the 5.0 Society era that demands new learning patterns in classrooms.

The 5.0 society refers to "smart community," a term proposed by the Japanese cabinet in 2016. This term describes the situation in which people encounter virtual-physical integrated word technology [2]. The 5.0 society technology also develops artificial intelligence with Big Database and robots to promote and support human's jobs. Salgues [3] explains that industrial development plan during 5.0 society includes big data, cloud computing, augmented reality, e-education, and robotics. These development influence all sectors, including education [4]. The influence of 5.0 society in the educational field encourages the importance of new literacy to prepare more competitive graduates. Thus, the generation will be ready to deal with the 5.0 society era.

This new literacy movement includes analysis, digital data literacy, engine mechanism understanding, and new technology skills. New technology applications deal with coding, artificial intelligence, engineering principle, communication, and design, or human literacy [5]. However, education in Indonesia has shown a satisfying result because of a decreased indicator from 2015, based on PISA sore data (Programme for International Student Assessment) in 2018 [6]. Figure 1 shows the PISA Lesson Score in Indonesia from 2012, 2015, and 2018.

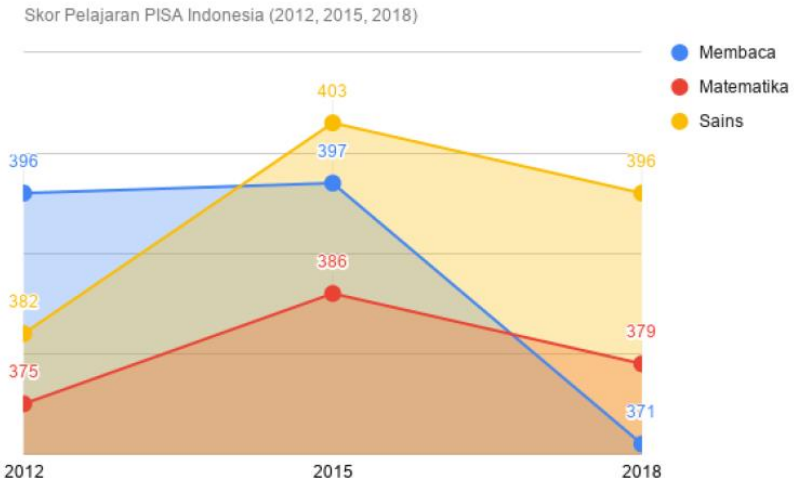

Figure 1. The PISA Lesson Score in Indonesia from 2012, 2015, and 2018
Source: www.zenius.net/blog/23169/pisa-20182-2019-standar-internasional

Figure 1 shows the PISA lesson scores in Indonesia decreased from 2015 until 2018. This score decrease includes three aspects: reading, mathematics, and science. The decrease of these three aspects becomes a concern for our education. Thus, it is important to improve student's literacy skills.

One of them is by providing various learning and integrating science, language, and mathematic literacy based on the students' needs. STEM (Science, Technology, Engineering, and Mathematics) could be a science learning alternative. STEM is a learning approach designed to combine science, technology, engineering, and mathematics to understand nature. The approach design aims to apply and practice the principles of STEM for learners to deal with daily life.

Sagala et al. [7] found that physics learning with STEM effectively improved learners' creativity. STEM in physics learning could facilitate learners to use technology and integrate the experimental activity. Thus, they can prove a law or conceptual knowledge. However, the researchers found teachers still found difficulties in using STEM in their learning.

An alternative solution to using STEM (Science, technology, engineering, and mathematics) in learning is by offering relevant contextual learning and integration of STEM knowledge via project-based learning with an educative robot kit as the learning medium. Project-based learning involves learners' activity to learn. Learners can use a robotic kit. They can assemble the robotic kit to stimulate their concepts and thinking methods in a STEM field. A robotic kit is also useful for allowing learners to participate in the learning process and develop their computational thinking skills. A robotic kit has a certain program to run or combine related activities with physics concepts, such as force and mass, velocity and distance, and friction. On the other hand, educators also encounter difficulties designing the learning by optimizing technology and involving learners' activity in the learning process. Thus, the educators require learning an instrument to facilitate the learning implementation in the classroom.

Therefore, this research developed project-based learning assisted with a robotic kit. In this research, the researchers used a robotic kit as a learning medium to adopt the STEM approach based on Khoiriyah's [8] definition of STEM literacy (see Table 1). The applied robotic kit in this research was Lego® Mindstorm® EV3. This robotic kit was an educative kit to train STEM skills. Lego® Mindstorm® EV3 has some sensors, such as gyroscopic sensor, angular size sensor, and distant measurement sensor. In this research, the researchers used material about friction for tenth graders. The researchers invited the learners to assemble a robot of Lego® Mindstorm® EV3. Then, they experimented to determine the static friction coefficient.

Table 1. STEM Definition

Literacy	Definition
Science	Skills to identify scientific information and to apply the information in the real world in seeking a solution
Technology	Skills to use, develop, and analyze various influential technologies toward learners' cognition
Engineering	Skills to develop a more creative and innovative technology design by combining various disciplines and creating a relevant concept with real-world for learners
Mathematics	Skills to analyze and deliver notion, formulation, and solution mathematically along with the applications

For most physics classroom lessons, both teachers and learners perceive the static and kinetic friction coefficients as the given measurement without doing experiments. Physics teachers tend to only note the static and kinetic friction coefficients from the learning sources without further information for learners about discovering the coefficients. This difficulty was due to a complex experiment to determine friction coefficient, especially in an inclined plane. An accurate direct observation was useful to report the angular size of the inclined plane when an object would move. It was useful to determine the static friction coefficient. Besides that, the manual measurement used a stopwatch to determine the sliding-traveling time of an object in a relatively short track. These complexities of determining friction coefficient require solutions involving an educative robotic kit with Lego® Mindstorm® EV3.

B. Method

This Research & Development used Borg & Gall's model. The model consisted of ten stages: 1) research and information collection; 2) planning; 3) develop a preliminary form of product; 4) preliminary field testing; 5) main product revision; 6) main field testing; 7) operational product revision; 8) operational field testing; 9) final product revision, and 10) dissemination and implementation. This research only focused on the sixth stage [9]. However, the developed product had been revised in the previous stages. The results of product revision showed the product was reliable to use.

In this research stage, the researchers involved lecturers and teachers as the field experts. The other experts were content material, media, and evaluation experts. The applied instruments in this research were (1) content material evaluation sheet to determine the suitability of the material in worksheet, (2) evaluation sheet of media experts to determine the worksheet and lesson plan, and (3) evaluation sheet for evaluation experts to obtain information about evaluation instrument quality of the developed learning instruments. The developed learning instruments were only a lesson plan and worksheet. The obtained data in this research included: (1) validation data of the product judgment by a content material expert, (2) validation data of product judgment by a design material expert, and (3) validation data of evaluation instrument judgment by an evaluation expert.

C. Result and Discussion

Researching and collecting information

In this stage, the researchers identified the problems by observing the classroom learning, interviewing the lesson teacher, and reviewing previous studies about learning promotion with technology use optimization at school. The identification results showed some potentials and problems, such as teachers' difficulties in designing learning with optimized technology and active participation of the learners. On the other hand, the teachers and learners perceived the material about static and kinetic frictions already had the given measurements. Thus, they thought it was not important to further experiment on the measurement. They also thought the experiment about friction coefficient was complicated and required accurate observation to report the angular size of a moving object. The researchers used Lego® Mindstrom® as a learning medium. However, the teachers and learners were not familiar with this learning medium. Therefore, the researchers developed learning instruments by integrating technology and active participation in student worksheets. The researchers also attached the lesson plan in project-based learning and prepared Lego® Mindstrom® as the learning medium.

Designing the product

In this stage, the researchers designed the learning materials, such as core competence, learning objective, and indicator of competence achievement. Then, the researchers designed the learning instruments in the form of student worksheets and lesson plans.

The initial product development design

The learning instruments were the lesson plan and student worksheet in this stage. The researchers developed the learning instruments based on the applied guideline. The important development parts were designing the student worksheet attachment, designing the learning stages, and determining the instrument to measure or evaluate the learning outcomes in the form of a test. The researchers provided the student worksheet attachment in a Quick Response Code or QR-code to attract the learners. QR-code is a two-dimensional code to collect, store, and display information. Then, the applied learning stages were STEM-Pjbl syntax [10]. It consisted of five stages: reflection, research, discovery, application, and communication. The researchers adjusted the evaluation instrument with the learning objectives. The realizations of the evaluation instrument were multiple choice and essay.

Initial field test/product validation

The researchers invited experts, material, and media experts to judge the developed learning instruments. On the other hand, the researchers invited an evaluation expert to judge the evaluation instrument. The judgment or validation processes used an observational instrument with the Likert scale. The observational results were suggestions and recommendations. The researchers tested the product reliability with two material experts, three media experts, and two evaluation experts. Table 2 shows the validation or judgment results.

Table 2. Experts' Judgment

Number	Instruments	Experts	Percentage (%)	Categories
1	Lesson Plan	Media Expert	76.00	Very Excellent
2	Student Worksheet	Media Expert	79.70	Very Excellent
		Material Expert	94.60	Very Excellent
Mo3	Evaluation Instrument	Evaluation Expert	55.30	Excellent

Product Revision

After judging the product, the experts shared suggestions and recommendations to revise the developed product. Here are the inputs for further revisions:
1) the student worksheet should describe diagrams about force as the materials;
2) the lesson plans should describe the activities;
3) the student worksheet should provide report-writing instructions;
4) the developed product should present learning outcome assessment and learning evaluation.

Limited test

After revising the product, the researchers tested the product for X graders of SHS that received physics lessons with friction. The researchers promoted this stage online due to the COVID-19 pandemic spread preventive regulation.

D. Conclusion

The researchers developed the learning instruments with a project-based learning model assisted by Lego® Mindstorm® for a physics lesson with friction. The learning instruments were student worksheets and lesson plans. The content material and media experts judged the worksheet very excellent. The media expert also judged the lesson plan very excellent. For the evaluation instrument, the evaluation expert judged it excellent. Thus, the applied learning instruments in this research were reliable for the teaching-learning process.

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Feasibility Analysis of Animation Video Learning Media Based Powtoon on Lagrange Mechanics

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ABSTRACT
Physics learning related to mathematical equations needs to be arranged in an interesting, fun, and easy way to understand the material. Learning that is packed with fun will attract students' interest in learning more. This study aims to test the feasibility of animation video learning media based Powtoon on Lagrange mechanics material. This research is research and development using the ADDIE model design (analysis, design, development, implementation, and evaluation). The feasibility test data were analyzed using descriptive statistical analysis. The results showed that the animated video learning media based Powtoon was feasible to use in physics learning for Lagrange mechanics. The findings of this study can be used as a further reference for researchers who will conduct Lagrange mechanics learning experiments using animated videos based on Powtoon.

INTISARI
Penelitian ini bertujuan untuk memfasilitasi peserta didik agar mudah memahami konsep mekanika analitik serta peserta didik tidak bosan dengan penjelasan yang diberi kan. Dalam pembelajaran yang berhubungan dengan angka kita harus menyusun atau membuat pembelajaran sedemikian rupa hingga menarik dan kita dapat memahami materi tanpa rasa beban. Pembelajaran yang menarik akan lebih menarik minat siswa untuk mempelajarinya. Metode penelitian yang digunakan yaitu Research and Development atau R&D (Penelitian dan Pengembangan). Penelitian dan pengembangan pendidikan (research and development) bertujuan untuk menghasilkan produk baru melalui proses pengembangan. Prosedur pengembangan yang dilakukan pada penelitian ini adalah sebagain dari model ADDIE (Analysis, Design, Development, Implementation, Evaluation). Yang dimaksud dengan sebagian yaitu kita tidak menggunakan semua metode tersebut melainkan hanya sampai uji kelayakan. Hasil penelitian menunjukan bahwa media pembelajaran video animasi yang dibuat peneliti layak digunakan.

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A. Introduction

Physics is one of the subjects taught in high school in Indonesia. Physics is a branch of natural science that studies physical phenomena that occur in everyday life [1]. Furthermore, physics is the study of matter and energy such as heat, sound, and light [2]. Physics is also one of the basic sciences that underlie various other sciences. The object of study studied in physics includes objects and their movements and their benefits for human life. While based on history, physics is the oldest science that begins with observing objects in the sky, their period, how old they are, and their trajectories [3]. Therefore, physics is one of the basic natural sciences and is widely used as a basis for other related sciences.

In physics, there is a branch of science that studies the motion of objects called mechanics. One of the branches of mechanics that studies the motion of objects analytically with a mathematical coordinate approach is analytical mechanics [4]. Furthermore, the study of analytical mechanics is also approached with two main approaches, namely the Lagrange and Hamilton approaches. The Lagrange approach or what is often referred to as Lagrangian mechanics is an approach in analytical mechanics that uses general coordinates and corresponding general velocities in the configuration space [5]. In addition, Lagrangian mechanics is also an analytical method in mechanics that does not consider the presence of forces in the resulting motion. The main considerations in the analysis of Lagrangian mechanics are kinetic energy and potential energy [6].

Meanwhile, Hamilton's approach or what is often referred to as Hamiltonian mechanics is an approach in analytical mechanics that uses appropriate coordinates and moments in phase space [7]. These two approaches in analytical mechanics are equivalent to the Legendre transformations of general coordinates, velocity, and momentum. Therefore, both contain the same information to describe the dynamics of an object's system. In describing the dynamics of an object system, sometimes the Lagrangian and Hamiltonian approaches are taught separately in physics lessons. This is because the two approaches contain material that is quite difficult for students to learn [8]. Although the analytical mechanics material is a study of classical physics, many students consider this material to be one of the difficult physics materials to understand [9]. This is evident from the results of the learning evaluation obtained by students for analytical mechanics material from high school to university level which is still low [10].

One of the reasons why Lagrange and Hamilton's material is difficult to understand is that both materials contain second-order differentials and integrals [11]. Another reason why physics is difficult to learn is that students have instilled the mindset that physics is difficult. This results in many students being lazy to study physics because the material is considered difficult which only struggles with numbers and formulas [12]. Meanwhile, steps that can be used to make it easier for students to learn analytical mechanics material are by developing more fun physics learning. In developing a fun physics learning atmosphere, steps that can be taken are to create learning media that attracts interest and makes it easier for students to understand Lagrange and Hamilton's material [13]. The media used in learning has a function as a tool to clarify the material message conveyed by the teacher [14].

The use of learning media in conveying the concept of the material also needs to be adjusted to the needs of students and the readiness of supporting facilities and infrastructure. Learning media that suits the needs of today's students are computer-based learning media [15]. One of the learning media that attracts students' interest and makes it easier for students to understand analytical mechanics material is through animated videos [16]. Furthermore, the animation is a combination of three elements, namely sound, image, and text [17]. In the development of learning media in the form of animated videos, there is one free software that is often used, namely Powtoon. Learning media-based Powtoon is one of the multimedia applications that can be used as learning media because it can attract interest and make it easier for students. This is because Powtoon features handwritten animation, cartoon animation, and more vivid transition effects, and very easy timeline settings [18]. Thus, this research will develop animation video learning media based Powtoon on Lagrange mechanics material. Research on the development of animated video learning media-based Powtoon aims to facilitate students to easily understand the concept of analytical mechanics. It is hoped that students will not get bored with the explanation of analytical mechanics given by the teacher.

B. Method

This research is a research development or R&D that is used to produce a product and test the effectiveness of the product. Each product developed requires different research procedures. The development procedure carried out in this study implements part of the ADDIE model stages (analysis, design, development, implementation, evaluation) [19]. Some of the stages of the ADDIE development approach used in this research include analysis, design, and development. The implementation and evaluation stages are not used in this development research, but only in the product feasibility test stage. Meanwhile, the product developed is in the form of learning media in the form of based animated videos based on Powtoon. The details of the product development stage in this study include analysis, design, development, and feasibility testing. The analysis phase is carried out by analyzing the teaching materials and media used in learning Lagrange mechanics. At this stage, observations were also made on analytical mechanics learning activities.

Observation activities aim to find out the obstacles that occur when students are learning, both in terms of material and analytical mechanics media used by teachers. Meanwhile, the design stage is carried out by determining the elements that will be included and developed into animated videos based on Powtoon. In facilitating the development of animated video media-based Powtoon, the steps taken are by compiling a storyboard that contains an outline of animated video-based Powtoon content. The main part of the storyboard includes template design and Lagrange mechanics material. Meanwhile, the development stage is carried out by making an animated video based on Powtoon according to the instructions that have been compiled on the storyboard. After the animation video-based Powtoon has been developed, the next step is to conduct a feasibility test for the animated video-based Powtoon. This feasibility test phase was carried out to know whether the animated video media-based Powtoon was worthy of being used as an alternative learning media for Lagrange mechanics material or not.

The feasibility test stage is carried out using a survey to students by filling out a questionnaire developed via Google forms. The questions contained in the Google form include the initial appearance of the media, the ease of starting the media, the suitability of the typeface in the media, the display of images contained in the media, understanding the material after using the media, learning independence with the help of media, the interest in learning by using the media, whether is animated video media suitable for learning Lagrange mechanics? In addition, the reasons, and suggestions for learning Lagrange mechanics with the animated video were also asked the students. The prepared questions were given to 46 students. The questions posed to the students were based on two main indicators, namely video assessment, and material understanding by using animated video media-based Powtoon [20]. Furthermore, the details of the number of questions posed to students consisted of 10 questions with details as presented in Table 1.

Table 1. Media eligibility indicators

Indicator	Number	Total
Video assessment	1, 2, 3, 4	4
Understanding the material using media	5, 6, 7, 8, 9, 10	6

Based on Table 1, the ten questions contained in the questionnaire were used to collect data on the feasibility of animation videos based on Powtoon on Lagrange mechanics material. The assessment of the responses or answers given by the students on each question item refers to a five-scale assessment [21]. The five-scale assessment used in the feasibility assessment of animation videos based Powtoon on Lagrange mechanics material can be presented in Table 2.

Table 2. Rating scale five

Category	Value
Very Feasible	5
Feasible	4
Quite Feasible	3
Unfeasible	2
Very Unfeasible	1

C. Result and Discussion

The physics learning product developed in this research is an animated video learning media-based Powtoon to facilitate the understanding of Lagrange mechanics material. The product developed in this study refers to two main indicators of learning media development, namely video assessment, and understanding of material using media. Meanwhile, the two indicators were then formulated into ten questions that were answered by students. The questions given to students to determine the feasibility of the learning media developed were regarding the initial appearance of animated video learning media-based Powtoon. The results of student responses regarding the feasibility of the media in terms of the initial appearance of the media can be shown in Figure 1.

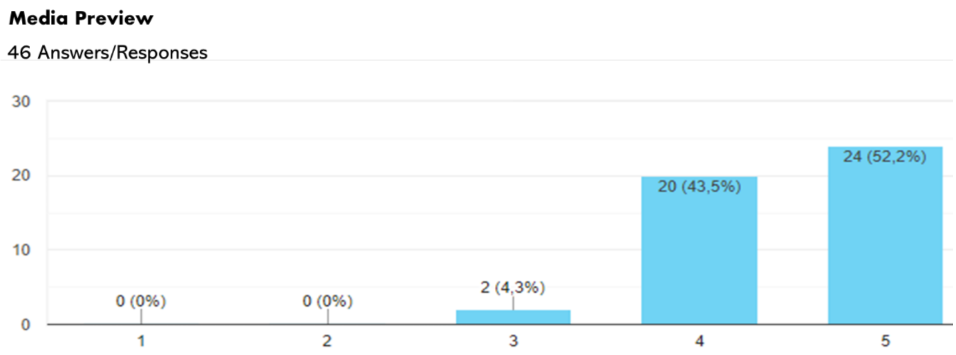

Figure 1. Student responses to the media preview

Based on Figure 1, it can be shown that the initial appearance of animated video learning media based Powtoon is generally very suitable to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 4.3% of 46 respondents who stated that it is quite feasible; 43.5% said it was feasible; 52.2% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of the media in terms of ease of starting the media can be shown in Figure 2.

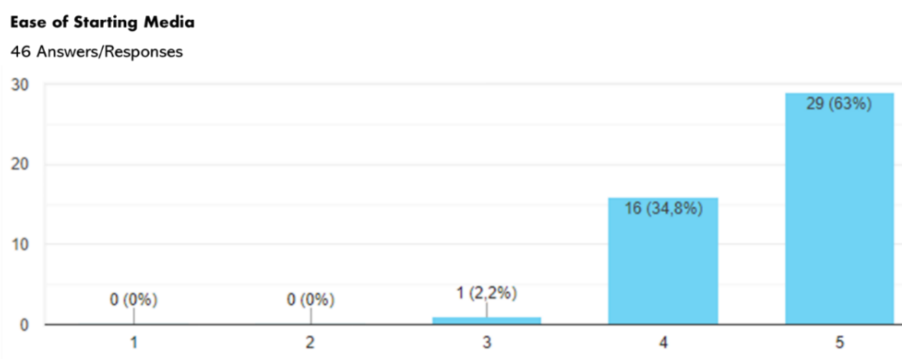

Figure 2. Student responses to the ease of starting media

Based on Figure 2, it can be shown that the ease of starting animated video learning media based Powtoon is very feasible to use as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 2.2% of 46 respondents who stated that it was quite feasible; 34.8% said it was feasible; 63% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of the media in terms of the suitability of the typeface in the media can be shown in Figure 3.

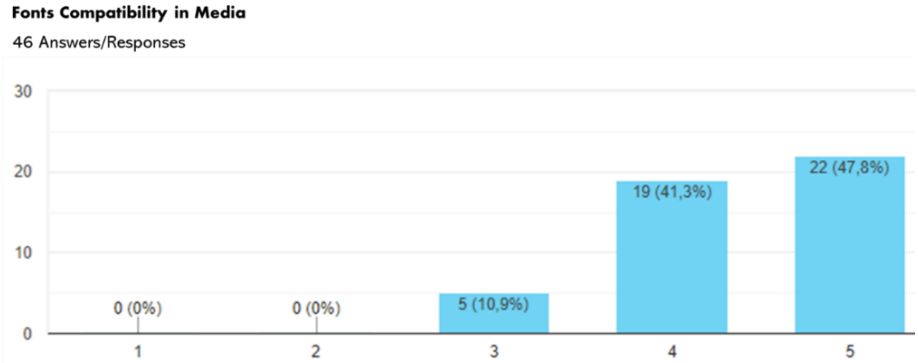

Figure 3. Student responses to font compatibility in the media

Based on Figure 3, it can be shown that the suitability of the typeface in animated video learning media based Powtoon is generally very suitable to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 10.9% of 46 respondents who stated that it is quite feasible; 41.3% said it was feasible; 47.8% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of the media in terms of the appearance of the images contained in the media can be shown in Figure 4.

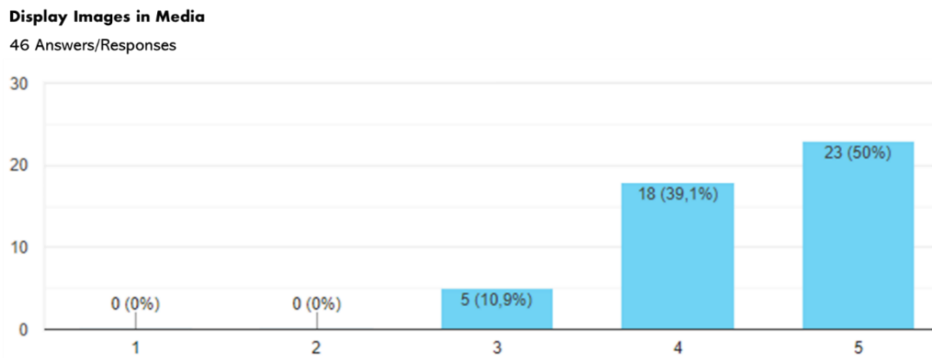

Figure 4. Student responses to the display images in the media

Based on Figure 4, it can be shown that the display of images contained in animated video learning media based Powtoon is very suitable to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 10.9% of 46 respondents who stated that it is quite feasible; 39.1% said it was feasible; 50% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of the media in terms of understanding the material after using the media can be shown in Figure 5.

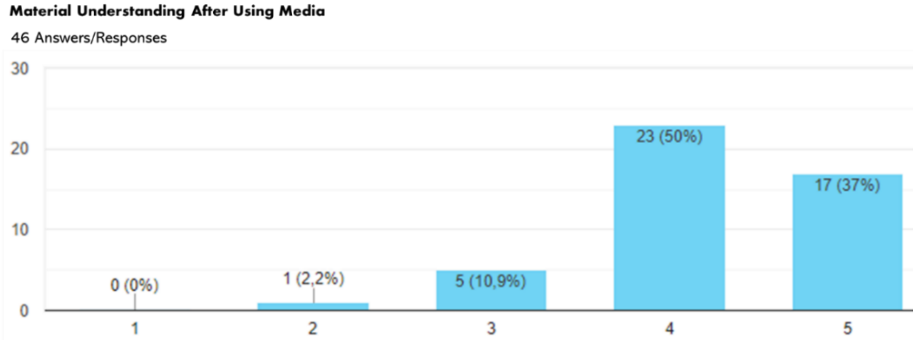

Figure 5. Student responses to material understanding after using the media

Based on Figure 5, it can be shown that understanding the material after using animated video learning media based Powtoon is generally feasible to use as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 2.2% of 46 respondents who stated that it is not feasible; 10.9% said it was quite feasible; 50% declared eligible; 37% said it was very feasible. The results in this aspect are only in the appropriate category and make this aspect the lowest response to the questions asked to the respondents. This is because students still argue that Lagrange mechanics remains a difficult material to understand [22]. Furthermore, with variations in learning media in the form of animated videos based on Powtoon, it does not necessarily make Lagrange material an easy level material, but only makes it easier to understand the material. Meanwhile, the results of student responses regarding the feasibility of the media in terms of independent learning with the help of the media can be shown in Figure 6.

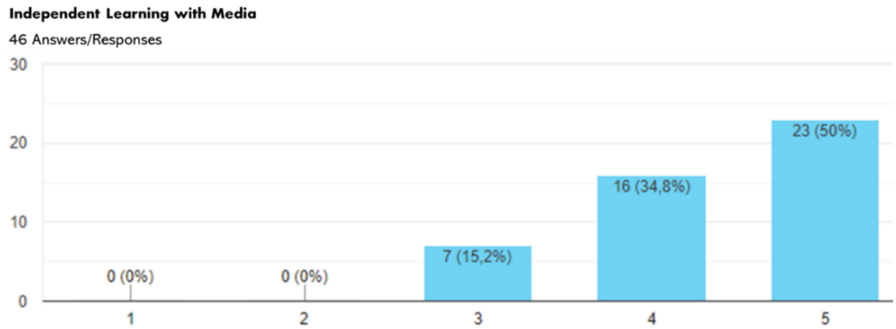

Figure 6. Student responses to independent learning with the media

Based on Figure 6, it can be shown that independent learning with the help of animated video learning media based Powtoon is generally very suitable to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 15.2% of 46 respondents stating it is quite feasible; 34.8% said it was feasible; 50% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of the media in terms of attractiveness in learning using media can be shown in Figure 7.

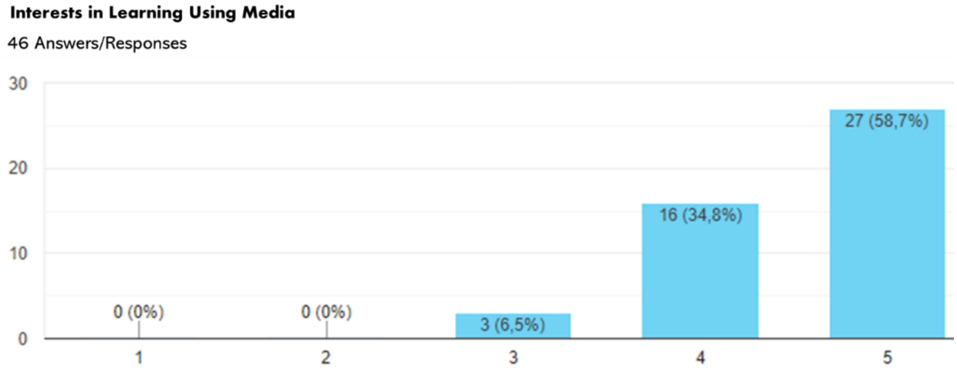

Figure 7. Student responses to the interest in learning using media

Based on Figure 7, it can be shown that the interest in learning by using animated video learning media based Powtoon is generally very feasible to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 6.5% of 46 respondents who stated that it was quite feasible; 34.8% said it was feasible; 58.7% said it was very feasible. Meanwhile, the results of student responses regarding the feasibility of media from a summary of the ten questions posed to students can be shown in Figure 8.

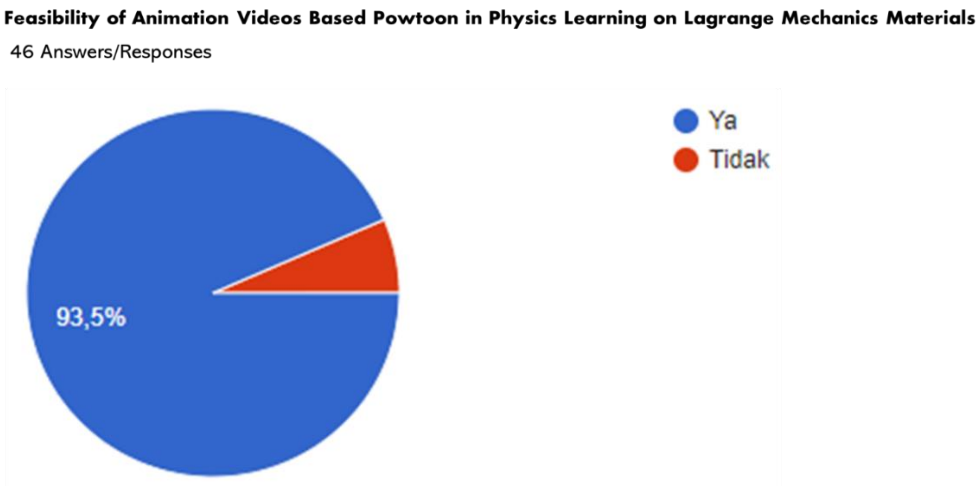

Figure 8. Feasibility of animation videos based Powtoon in Lagrange mechanics

Based on Figure 8, it can be shown that animated video learning media-based Powtoon is generally feasible to be used as an alternative learning media that facilitates understanding of Lagrange mechanics material. This is evidenced by 93.5% of 46 respondents or about 43 respondents stating yes or worthy of being used as a medium for physics learning on Lagrange mechanics material. Meanwhile, 6.5% of 46 respondents or about 3 respondents stated that it was not suitable to be used as a medium for physics learning in Lagrange mechanics material. The learning media developed in this study has several advantages.

The advantages contained in the animation video learning media-based Powtoon used in physics learning on Lagrange mechanics material include more colorful video displays, making them more interesting to watch. This animated video is also made creatively so that students are more interested in using it. In addition, the Lagrange mechanics material in this animated video is made simpler. This is intended to make it easier for students to understand Lagrange mechanics material. The variety and innovation used in each lesson can certainly make learning fun [23]. This is strengthened by the argument that students sometimes experience boredom in participating in learning that only uses printed books [24]. Students also want to learn physics and get different experiences both in the use of models and learning media. This will later affect the interest, motivation, and learning outcomes of students [25]. This statement is certainly by the results of student responses which revealed that the learning media developed in this study was very suitable to be used in facilitating Lagrange mechanics material.

D. Conclusion

Based on the findings in this study, it can be concluded that animation videos based on Powtoon on Lagrange mechanics material are feasible to use in making it easier for students to learn Lagrange mechanics material. These findings can be seen from the responses given by students to aspects of video assessment and understanding of the material by using media which shows a very feasible response to be used in physics learning on Lagrange mechanics material. However, there are slightly different results from the ten questions given to students, namely on questions about understanding the material after using the media. On these questions, students only gave responses that were on a scale of four or appropriate. While on the other questions, the students gave very appropriate responses on a scale of five. This is because the variety of learning media in the form of animated videos based on Powtoon does not change the status of Lagrange mechanics material as easy-to-understand material but only makes it easier to help understand the material.

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