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Analysis of Differences in the Use of Kahoot and Quizizz Applications in Improving Analytical Thinking of Physics Education Students, Universitas Negeri Yogyakarta

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ABSTRACT

Learning media is one of the important things in determining the results of the learning process. Interesting learning activities by focusing the interaction between lecturers and students will increase motivation in learning. Therefore, it needs to be packaged well, one of which is an interactive quiz after learning. There are several online quizzes that are often used, namely Kahoot and Quiziz, these quizzes provide services for users to create their own quizzes and can share them with others to take quizzes. The purpose of this study was to determine whether there was a difference in the use of the Kahoot and Quizizz quizzes in improving the analytical thinking of students of Physics Education C UNY 2020 on light interference material. The research method used is an experimental research method in quasi experiment with posttest only design where the research subject will do an analytical ability test given in the form of multiple choice questions given through Kahoot and Quizizz. After that, data analysis will be carried out using a t-test, the results of the analysis show that there are differences in the use of the two quizzes, namely Kahoot and Quizizz with a significance value of 0.642.

INTISARI

Media pembelajaran merupakan salah satu hal yang penting dalam menentukan hasil proses belajar. Kegiatan belajar yang menarik yaitu dengan memfokuskan interaksi antara dosen dan mahasiswa akan meningkatkan motivasi dalam belajar. Oleh karena itu, perlu dikemas dengan baik yaitu salah satunya dengan kuis interaktif setelah pembelajaran. Ada beberapa kuis online yang sering digunakan yaitu Kahoot dan Quizizz, kuis tersebut memberikan layanan bagi pengguna agar dapat membuat kuis sendiri dan dapat menyebarkan ke orang lain untuk mengikuti kuis. Tujuan penelitian ini yaitu untuk mengetahui apakah ada perbedaan penggunaan kuis Kahoot dan Quizizz dalam meningkatkan berpikir analitis mahasiswa Pendidikan Fisika C UNY 2020 pada materi interferensi cahaya. Metode penelitian yang digunakan yaitu metode riset eksperimen dengan desain kuasi eksperimen *posttest only* dimana subjek penelitian akan mengerjakan tes kemampuan analitis yang diberikan berupa soal pilihan ganda yang diberikan melalui Kahoot dan Quizizz. Setelah itu akan dilakukan analisis data dengan uji t, hasil dari analisis tersebut dihasilkan bahwa terdapat perbedaan dari penggunaan kedua kuis tersebut yaitu Kahoot dengan Quizizz dengan nilai signifikansi 0,64.

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A. Introduction

The existence of the Covid-19 pandemic has caused all activities to be limited in their implementation. One of the impacts is on learning activities that are transferred to online methods. Online learning is learning that uses the internet network with accessibility, connectivity, flexibility, and the ability to bring up various types of learning interactions[1]. Therefore, it is necessary to have the right learning media to support these problems. In this online learning method, various digital technology platforms are used in the learning model, starting from the Learning Management System (LMS), instant messengers such as WhatsApp, social media such as YouTube and Instagram, to conference platforms such as Zoom Meeting, Webex, Jitsi Meet, and Google Meet[2]. There are positive things from using technology during a pandemic, namely that many students will be more familiar with and explore the technology used in the current era.[3]. As stated by Sagala[4] that interesting learning media is a good motivation to increase students' interest in learning. The growing era of technological development can be a solution for creating interactive learning during a pandemic. Today's technology-based learning can stimulate students to be more enthusiastic in learning and working on various kinds of practice questions, because technology-based learning has various forms of animation, explanations in the form of graphics, and various colors that add to the real impression[5].

Learning media is an important part in the learning process. Aids or media for independent study in the era of technological advances are needed in the learning process. This is needed to create human qualities that do not only depend on verbal transfer of knowledge, whether carried out by schools or non-formal educational institutions at this time[6]. Good learning media will affect the teaching and learning process in the classroom. The lecture method that has been used so far tends to make students bored and sleepy in learning, especially online learning today. According to Rahmah[7] if in the learning process the teacher continues to use the lecture method from the beginning of the lesson to the end, it could be that students are less interested and do not understand what the teacher has conveyed. Then the lecture method is considered to be teacher centered which makes learning monotonous and less active. Therefore, it is necessary to have interesting learning media that can be reached by all students. The use of applications to support learning in this pandemic era is very useful as a form of variation in learning and can make learning more interesting and understand the material presented better.

However, the learning carried out is still with the same pattern as in offline learning, so it can cause the effect of boredom on students. Although online learning is applied in the industrial era 4.0 which is considered very relevant and suitable. However, in the implementation of online learning there are still obstacles or obstacles. Obstacles in online learning are still felt by some teachers and students. There are several obstacles, both from the emotional side of students and lecturers. as

well as technical problems[8]. Boring learning can affect student learning motivation. Therefore, educators must be more creative in making interactive learning media. Regular assignment of formative assessment tasks can support positive student engagement attitudes and behaviors towards learning. An application that has been commonly used for this purpose is Kahoot, Kahoot is a game-based learning platform used for reviewing knowledge, for formative assessment or as a break from traditional class activities[9].

The use of the Kahoot app in 2019 has more than 250 million users from 200 countries. During 2020, due to the transition from school to distance education due to the Covid 19 pandemic, the use of Kahoot increased rapidly in Spanish-speaking Regions, such as Spain and Latin America and increased by more than 100 positions in the list of educational applications reaching number 16 in Spain[10]. Kahoot's success is due to the fact that its main goal is to make learning fun through a learning platform based game[11]. According to research conducted by Young, et al[12], explained that the features in khoot can give an interesting impression so that users feel happy and not bored. The advantages of this application are systems designed using gamification techniques where users can use this application like playing a game. While the drawback of this application is that this e-learning-based system is not designed for individual knowledge.

In addition, there is an application that is almost the same as Kahoot, namely an application called Quizizz. According to Ulhusna[13] Quizizz is one of the digital media in the form of game practice questions and online presentations that help educators/teachers to distribute teaching materials to make it easier for students to understand. It can even increase students' interest and enthusiasm for learning certain materials when using this digital learning media. The use of Quizizz learning media, is one of the efforts to accommodate the problems of learning media in Indonesia that cannot be applied conventionally with other learningbased on Information Technology and Computers. In Kurnia's research[14], mentioned that the use of the quizizz application can help students complete quizzes and make presentation materials easy and fun.

This study will examine the differences in the level of analytical thinking skills on light interference material by presenting several questions that will be packaged in a quiz on the Kahoot and Quizizz applications. Light interference is the combination of two or more light sources to produce a lighter state (maximum interference) and a dark state (minimum interference). The condition for light interference is that the light must be coherent, namely the state of two or more light sources that have a fixed frequency, amplitude and phase difference[15].

The principle of interference is that if two waves are propagating in the same direction (almost the same) with a phase difference that remains constant with time, a situation can occur in such a way that the energy is not evenly distributed, but at

certain points the maximum value is reached, and at some points the maximum value is reached. other points reached the minimum price[15].

Analytical thinking indicators are generally shortened to Distinguishing, Organizing and Connecting, with the following description:

1. Distinguishing, the ability to distinguish includes grouping or classifying into certain parts, after classifying then communicating them into discussion groups, applying the concepts they have to an existing problem and predicting the outcome of a problem based on the concept reference that has been understood.
2. Organizing is a conscious activity to arrange and organize parts (people, objects, etc.), so as to form an orderly and unified whole. To achieve this ability, students are expected to design ideas or ideas (concepts) along with organizing steps, so that when organizing and arranging something, students are not confused because they have previously designed a concept.
3. Linking is the activity of linking one concept to another that is still related to one another.

Based on the explanation of the problems above, researcher wanted to find out whether there were differences in the use of the Kahoot and Quizizz applications. Those two media were used as learning media solutions in the midst of a pandemic. The aim of this research was to determine the difference in the use of the Kahoot and Quizizz quizzes in improving the analytical thinking of students.

B. Method

The type of research used is quantitative research through experimental research method using quasi experiment with posttest only design. The sample selection technique used is probability sampling with random sampling, the research subject is a student majoring in Physics Education C batch 2020, Universitas Negeri Yogyakarta. We tested 16 students of Physics C education, provided that 8 people worked with the Quizizz application and 8 others worked with the Kahoot application.

The instrument consists of taking data in the form of a test of students' analytical abilities that are contained in questions packaged with the Kahoot and Quizizz applications. The analytical ability test given is in the form of multiple choice questions given through Kahoot and Quizizz. The multiple choice test is a test that will measure the analytical thinking ability of students which includes 6 indicators of analytical thinking ability using 2 assessment instruments.

Table 1. Indicators and Instruments of Analytical Thinking Ability

Indicator	Information
Understanding Concept	• Reasoning the pattern of relationship concepts directly • Solving problems through reasoning connected with material concepts
Identify	• Determine relationship pattern • Make the completion of answers with concepts that have been understood systematically
Differentiate	• Splitting certain patterns • Making connections from existing patterns
Organize	• Applicable theoretical reasoning • Apply concepts and theories to problems
Connect	• Making connections between what is given and what is asked for • Determine the main focus of the problem
Applicative Ability	• Understand the concept concretely • Give examples that are closely related to the surrounding life

Researchers used 2 data collection techniques, namely the observation technique of giving questions directly). After the data is obtained, the analysis stage uses data analysis through a descriptive approach, namely extracting information from data that is in accordance with actual conditions. The data here is the analytical thinking ability of students. The data is processed using the t test which is used for n to determine the effect or determine the relationship between the independent and dependent variables, where one of the independent variables is fixed or controlled. So partial correlation is a number that shows the direction and strength of the relationship between two or more variables, after one variable that is thought to be able to affect the relationship between these variables. The t-test formula used in this research was [16].

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad (1)$$

Information
t : test value
r : correlation coefficient
r^2 : coefficient of determination
n : number of tables

C. Results and Discussion

In this study, we tested 16 students of Physics C education, provided that 8 people worked with the Quizizz application and 8 others worked with the Kahoot application. Each student will work on 12 questions that have been provided on Quizizz and Kahoot with the question criteria as described above. The scores obtained from the two applications will be continued with testing using the normality test and t test.

Table 2. Data on Quizizz Score Results with Kahoot

Quizizz		**Kahoot**	
Student Name	**Score**	**Student Name**	**Score**
PL	8170	H	9057
P	7830	P	8059
M	7300	N	6707
HV	5490	I	6058
K	4440	R	5992
INK	4060	F	5285
NA	3860	A	4615
SS	3530	J	2618

After getting scores from the two applications, the Normality test and t-test will be carried out on the two scores that have been obtained, here are the details of the results of the normality test and t-test using SPSS.

Table 3. Normality Test

Quiz	**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
	Statistics	**df**	**Sig.**	**Statistics**	**df**	**Sig.**
Result of Thinking Analysis 1.00	,226	8	,200*	,862	8	,127
2.00	,123	8	,200*	,862	8	,973

From the results of the normality test using Kolmogorov-Smirnov and Shapiro-Wilk, the results of the significance test exceed 0.05, so the data above meets the normality test. From this description, it can be seen that there are differences between Quizziz and Kahoot in Physics Education Students C, so that homogeneous tests and t tests can be carried out on this data.

Table 4. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means's		
Analytical thinking results	Equal variances assumed	f	Sig.	t	df	Sig.(2-talled)
	Equal variances not assumed	,163	,693	-,475	14	,642
				-,475	13,971	,642

The results above the F and Sig test values are more than 0.05 so that the two group variants are homogeneous, so it can be seen that there is an average difference between quizziz and kahoot in Physics C education students.

Based on the research we did with these two applications, there were 12 questions with interference material that we presented. When using the quizizz application, students can review the questions that have been done at the end of the quiz. so that students can find out the wrong answers answered when doing the quiz. As for the Kahoot application, students cannot review the questions that have been done, students can only find out the scores that have been obtained.

When viewed from the research that has been done, it was found that most of the participants' errors in answering questions were in the form of applying concepts to calculations, especially in the Kahoot Application. When analyzed in analytical thinking indicators, it is included in identifying indicators. This is because the Kahoot application cannot time settings so that each type of question is only given 20s, even though each question has a different level of difficulty. This is different from the Quizizz application which can set the processing time up to 3 minutes.

In addition, in the Kahoot application to start a quiz, the organizer must display questions so that face-to-face contact is necessary. In online conditions like this, there are obstacles, namely participants leaving the meeting room which causes participants to be unable to answer questions. This can reduce the effectiveness of this quiz in progress.

D. Conclusion

Based on the research that has been done, it was found that there were differences in the results of analytical thinking of students of Physics Education C 2020 in the use of the Kahoot and Quizizz application quizzes which were analyzed through a t-test with a significance value of 0.642.

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Enhancing Science Process Skills in Physics Education: The Impact of the Phyphox Smartphone Application in High School Laboratories

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ABSTRACT

This study explores the effectiveness of smartphones as measurement tools in physics laboratories, focusing on the science process skills of Class XI students at SMA Negeri 1 Wajo. Employing a Pre-Experimental One-Shot Case Study design, we integrated the Phyphox application into the curriculum and analyzed its impact on students' scientific understanding. Our methodology included purposive sampling of 24 students and data collection via science process skill tests, lesson plans, and student worksheets. Descriptive and inferential statistical analyses revealed a significant improvement in students' science process skills, with an average score of 72.08. The one-sample t-test showed an essential value of 0.000, indicating a positive effect of the Phyphox application. These findings suggest a potential shift towards technologically integrated learning environments in physics education, enhancing student engagement and comprehension. While promising, the study acknowledges its sample size and context limitations, highlighting the need for further research in diverse educational settings. This study contributes to the growing body of research advocating digital tools in education, aiming to prepare students for a technologically advanced world.

INTISARI

Penelitian ini mengeksplorasi efektivitas smartphone sebagai alat ukur dalam laboratorium fisika, dengan fokus pada keterampilan proses sains siswa kelas XI SMAN 1 Wajo. Menggunakan desain Studi Kasus One-Shot Pre-Eksperimental, kami mengintegrasikan aplikasi Phyphox ke dalam kurikulum dan menganalisis dampaknya terhadap pemahaman ilmiah siswa. Metodologi kami termasuk sampel purposif dari 24 siswa, dan pengumpulan data melalui tes keterampilan proses sains, rencana pelajaran, dan lembar kerja siswa. Analisis statistik deskriptif dan inferensial mengungkapkan peningkatan signifikan dalam keterampilan proses sains siswa, dengan skor rata-rata 72,08. Tes t-sampel tunggal menunjukkan nilai signifikan 0,000, mengindikasikan efek positif aplikasi Phyphox. Temuan ini menyarankan potensi pergeseran menuju lingkungan pembelajaran yang terintegrasi teknologi dalam pendidikan fisika, meningkatkan keterlibatan dan pemahaman siswa. Meskipun menjanjikan, penelitian ini mengakui keterbatasannya dalam ukuran sampel dan konteks, menyoroti kebutuhan penelitian lebih lanjut di berbagai lingkungan pendidikan. Studi ini berkontribusi pada tubuh penelitian yang berkembang yang mendukung

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alat digital dalam pendidikan, dengan tujuan mempersiapkan siswa untuk dunia yang berteknologi maju.

A. Introduction

Integrating technology in education, particularly in physics, represents a crucial paradigm shift for global society, the academic discipline, and addressing specific educational challenges. Modern education demands innovative approaches to leverage technology in learning processes, significantly impacting students' comprehension and engagement [1], [2]. In physics education, experiments are pivotal, offering hands-on experiences to solidify theoretical knowledge [1], [3]. However, the effective execution of these experiments faces substantial challenges, primarily due to resource limitations, highlighting a significant problem in educational institutions worldwide.

Previous research has extensively documented the effectiveness of smartphone technology in enhancing physics education. Studies show that smartphones, with various sensors, can effectively replace traditional laboratory equipment, providing an accessible and innovative approach to conducting experiments [4], [5]. This has been further corroborated by research demonstrating the positive impact of smartphone-based learning tools on students' theoretical and practical understanding of physics [6], [7].

Continuing this trend, other studies have explored the role of smartphones in facilitating experimental physics, emphasizing their cost-effectiveness and educational utility. For instance, smartphone sensors have been used to teach concepts such as kinematics, dynamics, and wave optics, with significant improvements in students' cognitive abilities and learning motivation [8]–[10]. These findings underscore the versatility of smartphones as practical educational tools in various physics topics.

In addition to cognitive gains, using smartphones in physics education has been linked to improved student engagement and independent learning. Projects like Smartphysicslab and studies on collaborative game models using smartphone sensors have revealed significant enhancements in students' test results and autonomous learning capabilities [11], [12]. These studies highlight the potential of integrating technology with traditional teaching methods to foster a more engaging and effective learning environment.

The literature also reveals a growing trend in using smartphones to address the challenges of online and offline physics teaching. The development of physics e-modules and learning applications for smartphones demonstrates their effectiveness in enhancing digital literacy, understanding of physics concepts, and independent

learning [13]–[15]. This trend points to the significant role of smartphones in reshaping the educational landscape, particularly in physics.

Despite these advancements, existing literature presents gaps and limitations that this study aims to address. Most research focuses on the general effectiveness of smartphone technology in physics education, with less emphasis on specific educational contexts or student groups. There is a need to investigate the impact of smartphone-based experiments on students' scientific process skills in a more targeted setting, such as SMA Negeri 1 Wajo [16], [17]. Additionally, while the potential of smartphones to enhance learning motivation and theoretical understanding is recognized, their impact on the development of scientific process skills in physics requires further exploration.

This study, therefore, focuses on evaluating the effectiveness of using smartphones as measuring tools in physics experiments, assisted by the Phyphox app, at SMA Negeri 1 Wajo. It aims to assess the impact on the scientific process skills of grade XI students and explore the potential influence of this approach on their learning experiences. By addressing the identified gaps, this research contributes to a deeper understanding of technology integration in physics education and its potential to enhance scientific literacy. The findings are expected to offer valuable insights into the practical application of smartphone technology in educational settings and its effectiveness in improving students' scientific process skills. Furthermore, this study will contribute to the ongoing discourse on innovative teaching methods in physics education, particularly in resource-constrained environments. The potential implications of this research extend beyond SMA Negeri 1 Wajo, providing a framework for implementing technology-enhanced physics education in similar contexts globally.

B. Method

The current study, conducted in Physics Education, adopted a Pre-Experimental Design (non-design) as its research methodology. The specific design used was the One-Shot Case Study, which involves applying an experimental treatment to a single group or class and observing the outcomes [20]. This approach is tailored to the objectives of this study, focusing on the application and impact of the Phyphox application in a classroom setting [18], [19]. The research was executed at SMAN 1 Wajo, aligning with the Physics class schedule for 11th-grade students during the odd semester of the 2023/2024 academic year. The target population consisted of all 122 students in the 11th grade, distributed across three classes.

For the sampling process, 24 students from one class were selected using purposive sampling. This technique was necessary due to the constraints related to permissions from the school authority, which prevented the formation of new experimental or control groups [21], [22]. In terms of data collection instruments, the study employed science process skill tests, lesson plans (RPP), and student worksheets

(LKPD) [23]. The data analysis involved a combination of descriptive analysis and inferential statistical analysis, which included conducting Basic Assumption Tests (Uji Prasyarat) and hypothesis testing [24], [25]. The selection of these analytical methods and instruments was driven by the study's objective to comprehensively understand the impact of the Phyphox application in a real-world educational setting. To ensure the reliability and validity of the study, careful consideration was given to the methodology, instrument selection, and data analysis techniques, albeit within the limitations of the chosen design and sampling method.

C. Result and Discussion

Based on the results of the science process skills test of the eleventh-grade students at SMA Negeri 1 Wajo on the topic of Harmonic Vibrations, the data on the science process skills of the students are obtained as presented in the frequency distribution table in Table 1 below:

Table 1: Frequency distribution of science process skills test scores for class XI students at SMA Negeri 1 Wajo

No	Grade	Fi
1	90	2
2	80	4
3	75	5
4	70	7
5	65	4
6	55	1
7	50	1
Total		24

The data in Table 1 above is presented as a reference in processing descriptive analysis. The results of the analysis can be seen in the Table 2 below:

Table 2: Results of the descriptive analysis of the science process skills of class XI students at SMA Negeri 1 Wajo

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
					Statistic	Std. Error		
KPS	24	40	50	90	72,08	1,878	9,198	84,601
Valid N (listwise)	24							

Based on Table 2 above, it can be explained that the maximum score is the highest science process skill score obtained by students after taking the post-test with a score of 90, while the minimum score is the lowest score obtained by students with a score of 50. The average or mean is the sum of all values in a distribution divided by the number of cases; in this case, the average value obtained is 72.08.

Apart from that, the standard deviation, variance, and expected error values are also visible. Standard deviation is a measure that describes the level of spread of data from an average value of 9.18. Furthermore, variance is a handy measure of diversity, or variance is the calculated average of the squared deviations of each data from the calculated average. Above, you can see a significant variance value of 84.60. The standard error estimates the standard deviation of a sample particular value used to calculate an estimator value, which can be seen above the value of 1.87. The table of results for the science process skills test results can be seen in Figure 1.

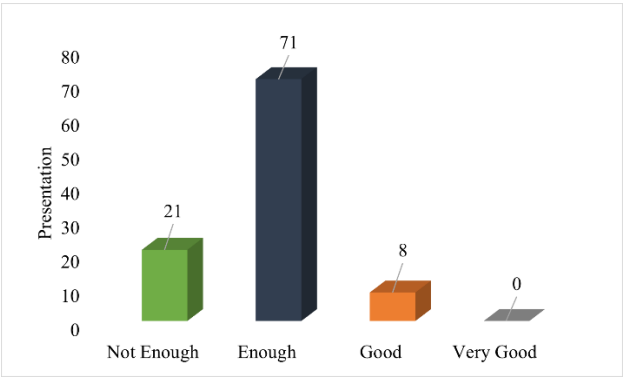

Figure 3: Results of the Science Process Skills Test

Figure 1 above shows the categorization of students' scores, where most students' science process skills scores are in a suitable category with a value range of 62.51 – 87.50.

Hypothesis testing aims to prove the hypothesis presented in this research. The hypothesis test used in this research is the *one-sample test*, at a significant level of $\alpha = 0.05$, which was analyzed using the application SPSS version 27 for Windows. The results obtained at the significance level of 0.000 are more minor than 0.005, so it can be said that H_0 was rejected and H_1 was accepted, i.e., There is an effect of using the Phyphox application on the science process skills of class XI students at SMA Negeri 1 Wajo, namely in the excellent category. These results can be shown in Table 3 below:

Table 3: One-Sample Test

	Test Value = 65					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
KPS	3,773	23	,001	7,083	3,20	10,97

A study is said to have a proven hypothesis if the significant value is smaller than 0.05, where H_1 is accepted, and H_0 is rejected. Based on Table 4, it is proven that the critical value is $0.000 \leq 0.05$. This means that the application Phyphox application influences the science process skills of class XI students at SMA Negeri 1 Wajo.

This study examined the impact of using smartphones as measuring tools in physics experiments on students' science process skills. Previous studies have highlighted the effectiveness of smartphone-based tools and methods in teaching physics and chemistry, enhancing both theoretical understanding and practical skills [4], [5]. Integrating technology in physics education, primarily through applications like Phyphox, has shown promising results in various learning environments [6], [26].

The results from the eleventh-grade students at SMA Negeri 1 Wajo demonstrate a significant improvement in science process skills. Most students scored in the 'good' category, with a mean score of 72.08 and a high maximum score of 90 (see Table 1 and Table 3). This outcome indicates a notable enhancement in students' abilities to apply scientific concepts practically, aligning with the growing trend of integrating smartphones in science education [7], [27].

Comparing these results with previous studies, the effective use of smartphone applications in physics education is evident. Similar experiments have improved students' conceptual understanding and cognitive abilities [11], [12]. However, this study's findings provide a more focused insight into the role of smartphones in enhancing specific science process skills, reinforcing the conclusions drawn by earlier research [28], [29].

The improvement in science process skills can be attributed to smartphone-based experiments' interactive and engaging nature. This approach allows students to observe and measure physical phenomena directly, bridging the gap between theoretical knowledge and practical application [10], [30]. However, caution must be exercised in interpreting these results. The dependence on smartphone literacy highlights a potential limitation, as high smartphone usage does not necessarily correlate with improved science literacy [16], [31]. Furthermore, the diversity in students' backgrounds and prior exposure to technology might influence their ability to effectively utilize these tools in an educational context [14], [15].

The implications of these findings are significant for the future of physics education. They suggest a shift towards more technologically integrated learning environments, where smartphones can enhance student engagement and

understanding [13], [32]. This study supports the growing body of research advocating for the incorporation of digital tools in education, emphasizing their potential to improve learning outcomes and prepare students for a technologically advanced world [33]–[35].

D. Conclusion

In this study, we aimed to assess the effectiveness of smartphones as measurement tools in physics laboratories, mainly focusing on the science process skills of Class XI students at SMA Negeri 1 Wajo using the Phyphox application. Our findings revealed a significant improvement in students' science process skills, with an average score of 72.08 and a notable positive impact indicated by the one-sample t-test considerable value of 0.000. These results underscore the potential of integrating technology, like smartphones and applications like Phyphox, to enhance student engagement and understanding in physics education. While the study presents a promising outlook for using digital tools in educational settings, it also acknowledges limitations such as the specific sample and context. It emphasizes the need for further research across diverse educational settings to validate these findings and explore the long-term effects of technology integration in education. This study aligns with current trends in academic research advocating for incorporating digital tools to improve learning outcomes and prepare students for a technologically advanced world, thereby suggesting a paradigm shift in physics education towards more technologically integrated learning environments.

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Development of TPACK-Based Physics Magazine as Teaching Material for High Schools: A Study on Rotational Dynamics and Rigid Body Equilibrium

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ABSTRACT

This study aims to develop a physics teaching magazine based on Technological Pedagogical and Content Knowledge (TPACK) for senior high school students, focusing on rotational dynamics and equilibrium of rigid bodies. Employing a Research and Development (R&D) approach with the 4-D model, the process encompassed definition, design, and development stages. The magazine's content and media aspects were validated by experts, achieving feasibility scores of 94% and 87.9%, respectively. The magazine was evaluated by students of SMAN 1 Lembah Seulawah Aceh Besar, with results indicating strong acceptance and effectiveness as a learning medium. While the study confirms the potential of TPACK-based interactive learning materials in science education, its limited scope and sample size suggest caution in generalizing the findings. Future research should expand the scope, involve larger samples, and integrate diverse technological tools. This research contributes to the discourse on digital competencies in science education, emphasizing the need for innovative materials and continuous professional development.

INTISARI

Penelitian ini bertujuan untuk mengembangkan majalah pengajaran fisika berbasis Technological Pedagogical and Content Knowledge (TPACK) untuk siswa SMA, dengan fokus pada dinamika rotasi dan kesetimbangan benda tegar. Dengan menggunakan pendekatan Penelitian dan Pengembangan (R&D) dan model 4-D, proses tersebut mencakup tahap definisi, desain, dan pengembangan. Aspek konten dan media majalah divalidasi oleh para ahli, mencapai skor kelayakan 94% dan 87,9%. Majalah dievaluasi oleh siswa SMAN 1 Lembah Seulawah Aceh Besar, dengan hasil yang menunjukkan penerimaan dan efektivitas yang kuat sebagai media pembelajaran. Sementara penelitian ini mengonfirmasi potensi bahan ajar interaktif berbasis TPACK dalam pendidikan sains, ruang lingkup dan ukuran sampel yang terbatas menyarankan kehati-hatian dalam menggeneralisasi temuan. Penelitian mendatang harus memperluas cakupan, melibatkan sampel yang lebih besar, dan mengintegrasikan berbagai alat teknologi. Penelitian ini berkontribusi pada diskursus kompetensi digital dalam pendidikan sains, menekankan kebutuhan akan bahan ajar inovatif dan pengembangan profesional yang berkelanjutan.

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A. Introduction

The rapid advancement of technology in the current era of revolution, particularly its increasing integration in educational contexts, represents a significant shift in teaching and learning practices worldwide [1]. In the realm of physics education, this transition is pivotal, as the subject inherently involves both process and product, necessitating not only the understanding of theoretical concepts but also the mastery of practical applications [2]. The development of educational materials, therefore, becomes crucial in enhancing the quality of student learning experiences, requiring resources that are systematically designed, engaging, and aligned with instructional norms [3], [4]. This necessity underscores the importance of innovative and technology-integrated educational materials in the field of physics education, especially at the secondary school level.

Observations in educational settings, such as SMAN 1 Leumbah Seulawah in Aceh Besar, have revealed that students often find physics challenging and unengaging. This perception could be attributed to the use of unappealing teaching materials [5]. The role of educators in developing innovative teaching materials using available technologies becomes vital in addressing this issue [6], [7]. For instance, the integration of physics content into magazine formats has shown potential in making the subject more accessible and enjoyable for students [8], [9]. Such innovations not only provide visual and textual content but also include educational information that can broaden students' perspectives and enhance their understanding of physics concepts [10], [11].

The concept of Technological Pedagogical and Content Knowledge (TPACK) emerges as a critical framework for integrating technology, pedagogy, and content knowledge in educational practices [12], [13]. TPACK facilitates educators in effectively utilizing technology to support teaching and learning activities [14], [15]. Previous studies have emphasized the importance of TPACK in the development of instructional materials, highlighting its role in enhancing teacher effectiveness and student engagement in physics learning [16]–[18].

In the context of physics education, the application of TPACK through mediums like physics magazines presents a unique opportunity to revolutionize teaching methods. Ekawati and Prastyo [19] found that project-based learning in micro-teaching courses improved TPACK capabilities, indicating the potential of such innovative approaches in physics education. Additionally, studies by Puspitasari et al. [20] and Masrifah et al. [21] support the effectiveness of TPACK-based educational resources in enhancing both teacher literacy and student learning outcomes. These findings underscore the need for educators to adapt and innovate their teaching practices to align with the evolving educational landscape.

Despite the promising aspects of TPACK-based educational materials, challenges and gaps still need to be addressed in their widespread implementation and

effectiveness. Akuma and Callaghan [22] identified gaps in teacher competencies in implementing inquiry-based practical work, highlighting the need for further development in this area. Similarly, Wahyuni et al. [23] and Syukri et al. [13] found that while physics teachers are capable of designing STEM-based lessons, certain aspects of TPACK abilities still pose challenges. These insights point to the need for ongoing research and development in the field of TPACK-based physics education.

The present study aims to address these gaps by developing a physics magazine-based teaching material grounded in the TPACK framework. This initiative seeks to bridge the identified limitations in current teaching practices and materials, particularly in enhancing the appeal and effectiveness of physics education for high school students. The focus is on creating a resource that is not only pedagogically sound and content-rich but also technologically integrated, catering to the diverse needs of today's learners. By doing so, this study endeavors to contribute to the growing body of knowledge in the field of physics education and technology-enhanced learning, offering a novel approach to teaching complex scientific concepts in an engaging and accessible manner.

The objective of this research is twofold: firstly, to develop a physics teaching material in the form of a magazine based on the Technological Pedagogical and Content Knowledge (TPACK) framework, and secondly, to assess the feasibility of this product through expert evaluation and to ascertain student responses to the TPACK-based physics magazine. This study aims to not only contribute to the field of educational technology and physics education but also to provide a practical and innovative resource for enhancing the teaching and learning of physics in high school settings. The anticipated outcome is a more engaging and practical approach to physics education, aligning with the needs and interests of contemporary students and the evolving landscape of educational technology.

B. Method

The method used in this research is the research and development method, abbreviated as R & D, with a 4-D model (four D model) which consists of 4 stages, namely stage Define, Design, Development and Dissemination in order to produce a product and test the effectiveness of the resulting product [24]. In general, this research was carried out in three stages, namely the definition stage, design stage, and development stage. At the definition stage, researchers are expected to obtain complete information related to students and material so that it can become a basic idea and the product can be designed well and attractively. The design stage aims to create the arrangement of learning tools, namely teaching materials in the form of magazines, according to the required materials and images. The development stage seeks to produce a product that has been revised based on expert input [25]. There are three activities carried out in this development stage, namely validation testing,

product revision, and trial stages. Meanwhile, the deployment stage was not carried out because it required a lot of time and significant funds.

The data collection instruments used in this research were validation sheets and student response questionnaires. The data collection techniques used in this research were expert validation sheets and student response questionnaires. Validation of teaching materials was carried out by two validators, namely three media experts and three physics experts. The validation sheet observed in the research was a validation sheet for physics teaching materials in the form of a magazine. The validator's assessment of physics teaching materials in the form of magazines consists of 5 categories, namely very suitable (1), right (2), quite right (3), not applicable (4), and very unsuitable (5). This questionnaire was given to 6 students after completing the activity or teaching and learning process and then filled in by the students to answer the questions. This questionnaire was used as an instrument to collect data in this research trial.

Data collection is analyzed using a predetermined formula:

$$\overline{X} = \frac{\Sigma X}{N} \quad (1)$$

With:

$\overline{X}$ = Average score of assessments by experts

ΣX= total score obtained by the expert

N = number of questions.

To change the average score of expert assessments in order to determine the feasibility/validity of the magazine. The results of the development of physics teaching materials in the form of magazines, which initially had value in the form of scores, were converted into qualitative data using the percentage formula:

$$\text{Eligibility percentage} = \frac{\text{Average of all aspects}}{\text{aspect of the highest score assessment}} = x100\ \% \quad (2)$$

Meanwhile, to determine the suitability of physics teaching materials in the form of magazines, researchers used percentage analysis based on categories as a reference for assessing data produced by expert experts. The percentage assessment scale can be seen in Table 1

Table 1. Expert Validation Sheet Criteria

Value Percentage (%)	Criteria	Number
81-100	Very worthy	5
61-80	Worthy	4
41-60	Not worth it	3
21-40	Not feasible	2
<21	Not really worth it	1

To calculate the average score of student responses, the following formula is also used:

$$\overline{X} = \frac{\Sigma X}{N} \quad (3)$$

With:

$\overline{X}$ = Average score of assessments by students

ΣX = total score obtained by students

N = number of questions.

Meanwhile, to change the average score of student responses into a criterion value, the following percentage formula is used:

$$\text{Eligibility percentage} = \frac{\text{Average of all aspects}}{\text{aspect of the highest score assessment}} = x100\ \% \quad (4)$$

For more clarity, see Table 2 regarding the criteria for evaluating teaching materials.

Table 2. Educator Response Percentage Criteria

Value Percentage (%)	Criteria	Number
81-100	Very interesting	5
61-80	Interesting	4
41-60	Not enough interesting	3
21-40	No interesting	2
<21	Very not interesting	1

C. Result and Discussion

The research used is using research and development to produce specific products and test the effectiveness of a product in the form of teaching materials in the form of magazines based on technological pedagogical and content knowledge (TPACK) in SMA/MA. This research uses a 4D model, which consists of several stages.

In the first stage, namely the definition stage, the research aims to obtain information from students regarding characteristics, problems of students during learning, learning methods used by teachers, other supporting media used during learning, and reviewing the curriculum used. At this stage, there are several steps, namely initial analysis; the researcher first determines the research subjects, namely class XI students at SMAN 1 Lembah Seulawah. Then, researchers carried out an analysis process of the curriculum and materials. The curriculum used by SMAN 1 Lembah Seulawah is the 2013 curriculum. The material that will be presented in the magazine is about rotational dynamics and equilibrium of rigid bodies.

After carrying out the analysis process, the researcher began the magazine design process by using the Canva application. First, the researcher collected reference material on rotational dynamics and equilibrium of rigid bodies from various reading sources in the form of books and learning websites. Second, researchers also collected images used in magazines, especially images related to that material. This image was obtained from the researcher's shots during observation and was taken from several sources on the internet. Below, Figure 1 is presented, which is a graphic design application that provides various and exciting features in it. The appearance of the Canva application can be seen in Figure 1.

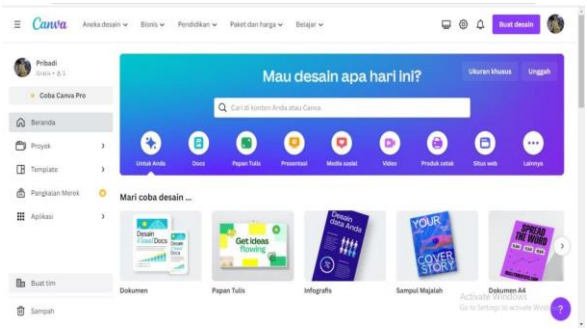

Figure 1. Canva application display

After carrying out the design process, the researcher carried out the development stage of the resulting TPACK-based magazine by asking for suggestions and comments from the supervisor. This stage is carried out as an improvement to the magazine made at the planning stage. Then, the revised magazine product entered the validity testing stage with 3 material experts and 3 media experts.

Table 3. Material Expert's Comments and Suggestion

No	Material Validator	Comments and Suggestions
1	V1	Cover improvements (illustrations, supervisor's name), writing typos, italics, paying attention to font size, image layout, inserting references with numbering [1], [2], adjusting to the bibliography, using equation editor formulas, using human icons which are Islamic.
2	V2	Please pay attention to each writing so that it is more organized
3	V3	Check again for typos, etc. (EYD), image layout, and enter reference formulas according to the rules.

Table 4. Media Expert's Comments and Suggestion

No	Media Validator	Comments and Suggestions
1	V1	They were developed in software form so that animations and videos can be clicked directly.
2	V2	The use of font type and size should be consistent; don't have too many font types, recheck the performance of the barcode, and make sure all barcodes can be accessed.
3	V3	This magazine is suitable as a teaching module. Scientific magazines have a particular format.

Overall, the experts stated that the TPACK-based magazine developed was valid and suitable for use by considering several improvements according to the suggestions and comments received. The feasibility of physics teaching materials in the form of a magazine based on TPACK on rotational dynamics and equilibrium of rigid bodies by two validation experts consisting of media experts and material experts can be seen in Table 5

Table 5. Validator Percentage Data

No	Validator	Percentage	Criteria
1	Media expert	87, 9 %	Very worthy
2	Material expert	94 %	Very Worth It
Total average score		90.95 %	Very Worth It

Furthermore, this assessment was assessed by 6 students at SMAN 1 Lembah Seulawah according to the student response sheet grid. In developing this magazine, 11 questions had to be answered by students. The following is data on the results of assessing students' responses to physics teaching materials in the form of TPACK-based magazines in SMA/MA.

Table 6. Student Response

Assessment Aspect	Criteria Evaluation	Validator						Score	∑ Each Indicator	Average	Percentage	Criteria
		1	2	3	4	5	6					
Question	1	4	5	5	5	5	5	29	316	4.78	95%	Very interesting
	2	5	5	5	5	5	5	30				
	3	5	4	5	5	5	5	29				
	4	5	5	5	5	5	5	30				
	5	4	5	5	5	4	5	28				
	6	5	5	4	4	4	4	26				
	7	5	5	4	5	5	4	28				
	8	5	5	5	5	5	5	30				
	9	5	5	5	5	5	5	30				
	10	5	4	5	5	5	5	29				
	11	5	4	5	4	5	4	27				

The development of TPACK-based Physics Magazine as teaching materials in high school education reflects a significant advancement in educational technology and pedagogical methods. This discussion section integrates findings from the current research with insights from previous studies.

This research aligns with the growing emphasis on integrating technology into education, as exemplified by studies like those of Maryati et al. [26] and Baihaqi [27], who demonstrated the effectiveness of TPACK-based educational tools in physics. The necessity for such innovative teaching approaches is further underscored by Walan [6] and Syukri et al. [7], who highlighted the role of digital technology in enhancing student motivation and facilitating teacher assessments. Moreover, the findings of Susila et al. [14] and Ilmi and Sunarno [15] emphasize the potential of digital platforms to foster higher-order thinking skills and scientific attitudes among students.

The developed TPACK-based magazine received high validation scores and positive student responses, indicating its effectiveness in physics education. These outcomes resonate with the findings of Popilaya [28] and Susanti and Mukminin [16], who also reported the successful integration of TPACK in teaching materials. Additionally, this research extends the work of Wijaya [29] and Silva et al. [30], who emphasized the importance of teacher preparation in implementing TPACK in educational settings.

The results align with the findings of Rosenblatt and Zich [17] and Schubatzky et al. [18], who stressed the importance of initial solid knowledge of pedagogy and content for the effective use of digital media in teaching. The study also addresses the

gaps identified by Ekawati and Prastyo [19] and Puspitasari et al. [20] in assessing TPACK capabilities in educational settings. The high approval ratings and student engagement suggest that the TPACK-based materials effectively conveyed complex physics concepts. This finding is in line with the research of Masrifah et al. [21], who found that multimodal TPACK-based materials enhanced teacher ICT literacy. However, as noted by Akuma and Callaghan [22], the implementation of such innovative teaching approaches can be challenging, particularly in resource-limited settings.

The positive reception of the TPACK-based magazine indicates readiness among students and educators for interactive learning materials. This finding is supported by the work of Wahyuni et al. [23] and Syukri et al. [31], who developed validated TPACK measurement tools for educators. Further, the study contributes to the ongoing discourse on digital competencies in science education, as explored by Thoms et al. [32] and Bakri and Sunardi [33]. The need for continuous professional development in utilizing such materials, as suggested by Efwinda and Mannan [34] and Septiandari [35], is also highlighted.

D. Conclusion

The study successfully developed a TPACK-based physics teaching magazine for rotational dynamics and equilibrium of rigid bodies, primarily aimed at SMAN 1 Lembah Seulawah Aceh Besar students, using a Research and Development approach with the 4-D model. The magazine, validated by material and media experts, demonstrated high feasibility (94% and 87.9%, respectively) and was well-received by students, indicating its effectiveness as a learning medium. This underscores the growing readiness for interactive, technology-integrated learning in science education, aligning with the ongoing discourse on digital competencies. The study's limitations include its limited scope and small sample size, potentially impacting the generalizability of findings. Future research should expand the scope, have larger sample sizes, and explore the integration of various technological tools to enhance interactive learning. This study contributes to the field by highlighting the importance of innovative materials and continuous professional development in science education.

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The Development of Electronic-based Student Worksheets to Facilitate the Critical Thinking Skills of Tenth Graders

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ABSTRACT

Smartphones become something familiar to learners. Most learners have smartphones. Learners require guidance to use smartphones for learning. This matter becomes the principle of developing an electronic-based worksheet. Based on the encountered problems especially the materials about renewable energy and critical thinking, the learners needed the development of an electronic-based worksheet to facilitate their cognitive skills within the material of renewable energy. This research and development, R&D, applied the 4D design, starting from defining, designing, developing, and disseminating. However, this research only lasted until the development stage specifically the limited test. The result showed the category of extremely excellent from the learners. On the other hand, the implementation of the whole aspect was done excellently.

INTISARI

Smartphone bukanlah hal yang asing bagi peserta didik. Setiap peserta didik tentu memilikinya. Sebagai seorang pelajar, penggunaan *smartphone* perlu diarahkan agar menjadi bermanfaat dalam pembelajaran. Hal tersebut mendasari pengembangan bahan ajar LKPD berbasis elektronik. Berdasarkan kendala pada pembelajaran, terutama pada materi energi terbarukan dan kemampuan berpikirkritis. Maka, LKPD berbasis elektronik dikembangkan dengan tujuan memfasilitasi kemampuan berpikir kritis pada materi energi terbarukan. Penelitian ini merupakan penelitian *Research and Development (RnD)* dengan model pengembangan 4D (*Four-D*) yang terdiri dari *Define, Design, Develop, and Disseminate.* penelitian ini dibatasi sampai *Develop* (Pengembangan) pada uji coba terbatas. Hasil respon peserta didik yaitu Sangat Baik (SB). Sedangkan hasil keterlaksanaan seluruh aspek dapat terlaksana dengan baik.

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A. Introduction

The technological development in Indonesia is significant, such as the Internet development. Sasmita [1] argues that the increased numbers of Internet users lead to increased benefits of the Internet. Montanesa [2] explain that adolescents and the Internet are strongly associated. On the other hand, the Internet brings both positive and negative impacts to the Internet for the users, to realize excellent Internet implementation. Gunawan [3] explain that survey about Internet addiction in 204. The results found that 41.7% of learners aged between 12 and 25 years old had Internet addiction. Dewi [4] explain that Internet addiction in adolescents worsens daily life matters, starting from inter-individual interaction, learning concentration, and poor sleeping quality. Dewi [4] found that eleventh graders of Senior High School with smartphone addiction and those without smartphone addiction were also balanced, 50.16% and 49.84%. On the other hand, the longest duration of using a smartphone by the learners was 5 hours. The technological implementation skills of adolescents require appreciation and direction, especially in terms of the educational field.

Husamah [5] explain that education refers to the interactive process between learners and educators to realize educational objectives. Therefore, the efforts to achieve the objectives require other educational factors and basic values. The educational factor may include the infrastructure, the delivered material, the media, and the applied methods. Learning media could create an effective learning process, accelerate learning, and improve the learning quality [6]. Learning media that uses technological and smartphone developments is called mobile learning. The implementation is flexible to be anywhere and anytime [7]. Mobile learning refers to a suitable learning media because this media is installable on a smartphone. Moreover, the smartphone has a proportional size and is portable to bring anywhere compared to a laptop computer. If learners had excellent skills in using smartphones, the media would have easy implementation. For example, mobile learning at schools could be electronic books, e-modules, and e-worksheets.

Worksheet refers to media that learners use. The media contains procedures of activities for the learners to promote base don the targeted learning objectives [8]. Arianto [9] define worksheets as teaching materials to facilitate learners in improving their understanding and the concept of scientific nature. Firdaus [10] explain that a worksheet refers to an activity sheet for learners to find concepts and train their critical thinking skills. Critical thinking is an important skill for this 21st century. The era demands that learners have excellent thinking skills [11].

Critical thinking becomes one of the science educational objectives, providing positive impacts on daily life and creating readily attitude of the learners with various science disciplines [12]. Samsudi explains an important educational objective is critical thinking skills [12]. The skill refers to inductive-deductive thinking by expressing ideas. Critical thinking realization of the learners occurs when the learners

encounter new matters to solve by associating the obtained information [11]. Critical thinking skill realizes excellent learning because of the active participation and curiosity of the learners. In this learning, teachers act as facilitators, moderators, and motivators [13]. Besides that, critical thinking also prepares the learners to rationally and logically think; and solve problems [14]. The Merdeka curriculum demands learners to have critical thinking skills.

Based on the interviews with the teachers, the researchers found that the implementation of smartphones was not maximum although the learners were habituated to using it while in online learning. Therefore, the learners still used printed books. The encountered problems by the learners were observable when they worked on the questions, such as analyzing and elaborating on the problems. The teachers thought the learners had difficulties while learning about renewable energy. The researchers held a forum of group discussion with 36 learners. Before discussing, the learners filled out the questionnaire about their learning style. Based on the questionnaire, 33 learners seemed to have a visual learning style while the others had a kinesthetic learning style. The first forum of group discussion dealt with physics learning with a lecturing strategy to make the learners understand. However, when the learners worked on the questions, they were confused to use the equation. The learners attempted to prevent the situation by actively asking and working on the questions. The second FGD dealt with the assumption of difficult materials. The researchers found many learners thought the materials difficult because they were confused to use the equation, especially the direction and displacement. The difficult materials included the planetary and parabolic patterns and the renewable energy materials. Learners argued that the material of renewable energy was difficult because the material was correlated to the surrounding environment. However, when the learners worked on the questions, they encountered difficulties in working and analyzing the renewable energy from the surrounding environment.

The focus of the following discussion dealt with the activeness of the learners in comprehending, working on the question, and finding other sources. Most learners were not trained to work on the questions independently at home. However, based on the interview, learners realized the importance of learning sources to comprehend the material. This action was important because the textbook provided limited questions for exercising. The fourth discussion focus dealt with the power and energy of the renewable energy chapter. The obtained answers from the learners indicated that they understood the materials because they had similar materials at Junior High Schools. However, while studying at senior high schools, the learners found the materials tended to be something related to renewable energy. The material became something new for the learners to study. The encountered difficulties by the learners were: confusion while using the equation; difficulty related to motion, direction, and displacement; question difficulty compared to the junior high school levels; incomplete comprehension while learning about power in physics; and incomplete

understanding of the correlation between the renewable energy and the environment such as the positive and negative impacts and the potency of the renewable energy.

The focus of the fifth discussion deals with critical thinking. The learners could not understand the essence of critical thinking. Then, the sixth discussion deals with the implementation of gadgets for learning. The learners preferred smartphones to learning with laptop computers. The reason was - the learners had excellent smartphones with high specifications to support their learning. They also found that smartphones were more practical than laptop computers for learning so they could leave the use of paper. The focus of the last discussion deals with the expected physics learning by the learners. The learners expected that the learning would be convenient; have many question exercises; provide practices; and use technology for learning such as gadgets or the Internet. Based on the interview results, the researchers found that the electronic-based worksheet could facilitate the critical thinking of the learners about the material of renewable energy.

B. Method

This research is an R&D (Research and Development). The applied research model is 4D, consisting of defining, designing, developing, and disseminating [15]. However, this research only took the development stage with limited tests. In this stage, the researchers involved the tenth graders, 15 learners. The product of this research was the electronic-based worksheet to facilitate the critical thinking skills of the tenth graders about renewable energy.

C. Results and Discussion

In this research, the researchers validated the electronic-based worksheet. The validation of the expert material obtained a score of 3.7, extremely excellent; and the media expert validation obtained a score of 3.6, extremely excellent. The researchers also assessed the product by the material expert, media expert, and teacher. The obtained results are consecutively 4, 3.6, and 3.7.

Then, the researchers promoted a limited test for 15 individuals in the tenth grade. The responses show that the learners agreed with the product. The obtained mean is 0.93. The responses cover the content, critical thinking skills, language, display, figure and video, and application language.

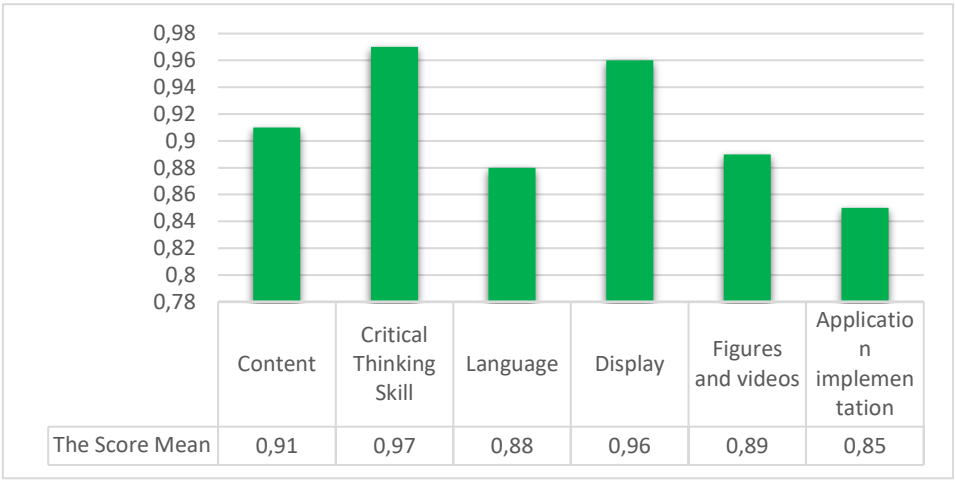

Figure 3.1. The Graphics of the Learner Response Mean toward Each Aspect

The researchers promoted the test to examine the developed teaching material implementation in the learning process. The participants remained the same, the tenth graders consisting of 15 individuals. In this process, the researchers directed the learners to use the electronic-based worksheet named "*Energi Terbarukan,"* or "Renewable Energy." In this stage, the researchers directed the learners step-by-step so all learners could install the application. Then, the researchers explained the worksheet implementation. Eventually, the learners worked on the worksheet with three worksheets in groups while the other one was with individual working. After the learning process, the learners filled in the sheet of implementation.

On the other hand, the learners had to fill out a sheet about convenience, interest, content, and critical thinking skills. The first aspect deals with convenience. This aspect obtains a score of 0.8. This matter indicates that the learners feel convenient while using the electronic-based worksheet. They also found the installation was easy. They also effortlessly used the electronic-based worksheet. The aspect of interest had an excellent realization. The obtained mean is 0.9. This matter shows that the learners are interested in the display of the worksheet, the color composition, the size, and the font type. For the aspect of content, the obtained score of this aspect is 0.8. This matter indicates that the learners could understand the read articles, answer the question while having learning activity, and find the developed worksheet useful to comprehend the material about renewable energy.

The developed worksheet could facilitate critical thinking skills. Thus, the aspect of implementation also had the aspect of critical thinking skills on each worksheet indicator. The first indicator is interpretation. Dealing with this indicator, the researchers found 4 learners who could not identify the problems from the read articles in the first worksheet. However, the other eleven learners could identify the

problems from the article excellently. On the other hand, all learners with the first, third, and fourth worksheets found the learning activities assisted them in understanding and interpreting the problems. Learners could answer the questions by observing, analyzing, and expressing the problems from the articles they read. Thus, the aspect of critical thinking, based on the indicator of interpretation of the learning activity, ran excellently.

The second indicator is analysis. In this indicator, the learners learned and practiced to train their analytical skills. The first worksheet implementation showed excellent implementation. The result shows that the learners could answer the questions while the learning activity was based on the indicator of analysis. One of the learners during the implementation of the worksheet found he could answer and explain the question about energy dynamics. In the second worksheet, the questions about indicators of analysis consisted of two items. For each item, fourteen learners agreed with the capability of the questions to facilitate the learners' analytical skills. However, the researchers found a learners could not perform this skill. Based on the data, the learners with difficulty with this indicator also could not interpret as found in the interpretative indicator. In the third worksheet, the researchers found one learner who could not analyze problems. However, in this third worksheet, the learners did not encounter any difficulty in the indicator of interpreting. Thus, the researchers concluded that the directive questions toward the indicator of analysis were not excellent. On the other hand, fourteen learners could answer the questions related to the indicator of analysis. Eventually, in the fourth worksheet, fourteen learners found the learning activity and practice could facilitate the learners to analyze. However, a learner assumed something different. Overall, based on the obtained data from the sheet of implementation, the learners had excellent critical thinking skills based on the analytical indicator. This matter indicates that the electronic-based worksheet could facilitate the critical thinking skills of the learners based on the analytical indicator. The interview results found that learners had difficulties while analyzing problems.

The third indicator is evaluation. In this indicator, the first worksheet had an excellent promotion, proven by the responses of thirteen learners. They agreed with the indicator. On the other hand, two learners encountered difficulties while elaborating on the problems. In the second worksheet, fourteen learners found that learning could facilitate the learners in explaining the problems. On the other hand, one learner did not find so. Previously, the learners also had difficulties with the interpreting indicator. Then, in the third worksheet, the researchers found the same results as the previous worksheet. The researchers found one learner who could not elaborate on the problems. The same problem was observable in the learners in the second worksheet. On the other hand, in the third and fourth worksheets specifically in the analytical indicator, the learners also found the difficult to analyze the problems.

The learners explained the difficulties because the learners did not maximally understand the problems. They also found the questions were long and provided them with multiple interpretations. However, in the fourth worksheet especially the evaluation indicator, the learners could answer the questions. All learners agreed with the fourth worksheet that provided the indicator of evaluation. They could evaluate excellently. Based on the answers, the learners could demonstrate excellent evaluation. This matter indicates that the learning and the practice could facilitate the critical thinking skills of the learners based on the indicator of evaluation. The final indicator is the conclusion. All learners could answer and conclude the learning activity. This matter shows that the indicator has excellent implementation in learning. Thus, the indicator of conclusion could facilitate the critical thinking skills of the learners in the learning.

Based on the sheet of the implementation, the researchers concluded that the aspects, starting from the convenience, interest, content, and critical thinking of the worksheet had excellent implementations.

D. Conclusion

The electronic-based worksheet could facilitate critical thinking skills about renewable energy. The trial test found most learners agreed and the obtained score was 0.93. Most learners also agreed with the critical thinking skill. The obtained mean is 1. The developed worksheet could facilitate the realization of the aspects of convenience, interest, content, and critical thinking. Based on the learning activity and practice, the worksheet could facilitate critical thinking skills, especially the analytical and evaluation indicators.

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Computational Analysis for Free Fall Cases with Air Friction

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ABSTRACT

Free fall motion without initial velocity is a mechanical concept that can be analyzed using analytical, experimental, and computational methods. Free fall motion is difficult to analyze analytically if air friction is not neglected. The aim of this research is to explain computational free fall motion analysis procedures with air friction. Air friction disturbance in free fall motion is represented by the coefficient *C* which states the drag coefficient is time dependent. In this scientific study, the application used for computational analysis is *IDE Spyder* with various library support. With the help of this application, a significant difference in the output v_{max} and t_{max} is obtained between the two cases of free fall based on the interpretation of the graph that appears.

INTISARI

Gerak jatuh bebas tanpa kecepatan awal merupakan konsep mekanika yang dapat dianalisis menggunakan metode analitik, eksperimen, maupun komputasi. Gerak jatuh bebas sulit untuk dianalisis secara analitik apabila gesekan udara tidak diabaikan. Tujuan dari penelitian ini adalah menjelaskan prosedur analisis gerak jatuh bebas dengan gesekan udara secara komputasi. Gangguan gesekan udara pada gerak jatuh bebas diwakili oleh koefisien *C* yang menyatakan koefisien drag bergantung pada waktu. Dalam kajian ilmiah ini, aplikasi yang digunakan untuk analisis secara komputasi adalah *IDE Spyder* dengan berbagai dukungan *library*. Dengan bantuan aplikasi ini, didapatkan perbedaan output v_{max} dan t_{max} yang berbeda secara signifikan antara kedua kasus gerak jatuh bebas berdasarkan interpretasi grafik yang muncul.

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A. Introduction

Free fall is the movement of a particle caused by disturbances in the Earth's gravitational force which is considered constant. This condition causes particles moving in a straight line to experience a uniform change in the vertical *y* coordinate. This motion occurs assuming the distance traveled is not too far, external forces are ignored, and the initial speed is zero. The free fall motion variable is denoted by *h* as the distance traveled, *g* is the gravity acceleration, *v* indicates the speed of the object after traveling a distance of *h*, and *t* is the travel time, so the following equation applies:

$$v = \sqrt{2gh} \quad (1)$$

$$h = \frac{1}{2}gt^2 \quad (2)$$

The geometric shape of the earth occupied by humans is not perfectly round, and there is a large difference in the earth's radius at the equator and the radius at the poles of $\pm 21.10^3$ meters [1]. This difference makes variations in the height of places on the face of the earth affect the value of gravitational acceleration inversely[2]. Several theories state that the value of the constant $\boldsymbol{g}$ is influenced by the height of the object [3], where this is caused by the influence of the centrifugal force at the equator which is greater, thus influencing the value of the speed of the free-falling object.

The increasing development of science has an impact on the development of technology which produces various kinds of devices that help in carrying out analysis [4], including numerical and computational analysis for physical phenomena [5]. Several devices have been developed, such as using free fall motion video-based trackers and obtaining an average value of gravitational acceleration of (9.63 ± 0.33) m/s^2 [6], [7]. To make it easier to understand the subject of free fall motion, a set of experimental tools was created with two different cases with the help of Audacity as a time sensor. The processing results obtained provide a value of 9.78 m/s^2 with an accuracy of observation and numerical results of 92% [8], [9].

In accordance with increasing precision and measuring tools, demands for the correctness of physical concepts and analysis are increasingly receiving attention and are urgent to be achieved. Including the analysis of free fall motion which previously ignored some forces and is now considered [10]. Analysis of free-fall motion by considering external forces that might influence the state of motion is rarely carried out because the concept of free-fall motion that is taught uses the assumption that free-fall motion occurs in a vacuum [11], [12]. This review eliminates the influence of external forces in the form of air friction which occurs due to friction between falling objects and small air particles [13], [14].

Reviewing vertical free fall motion with air friction disturbances is a complex series of analyses because it involves variables of size and mass of objects. In addition, the parameters used empirically do not necessarily show real results because they

depend on the surrounding conditions [15], [16]. Air friction is modeled using a linear velocity variable and calculated assuming the object moves without initial speed, is influenced by the force of gravity, and the magnitude of the friction is proportional to the square of the velocity (v^2) in the opposite direction [17], [18].

Oxygen (O_2) is categorized as a fluid so that it influences the form of friction or air resistance, so the empirical properties of the fluid need to be considered. The magnitude of the air friction force is different from the standard friction model for solid objects because it depends on the relative speed experienced by the object due to its movement in the liquid [19], [20]. The speed aspect has high complexity and only certain cases can be explained analytically [16], [21]. Very low velocities occur in small-sized particles where the air resistance is proportional to the speed expressed in the following equation:

$$f = -bv \tag{3}$$

where the negative sign of the above equation implies that the friction force always has the opposite direction to the object's speed. For cases with larger objects and higher speeds, the force exerted on the air is proportional to the square of the relative speed of the object and the air [16], [22].

$$f = -\frac{1}{2}\rho AC v^2 \tag{4}$$

where ρ is the density of the object, A is the cross-sectional area of the object, and C is the numerical drag coefficient. Meanwhile, for spherical objects, the empirical coefficient C value is 0.47 [23].

Analysis with equations 3 and 4 can of course be carried out simply if the value of the dependent variable is known. Assume that friction occurs for a falling object with no initial speed, with the value of the friction force being proportional to the square of the acceleration (v^2) which has the opposite direction. So, the total vertical force acting is:

$$F = mg - kv^2 \tag{5}$$

$$F = m.a = m.\frac{dv}{dt} \text{ dan } v = \frac{dh}{dt}$$

where h is the vertical distance of the object from the falling position to the earth's surface, so we get:

$$\frac{dv}{dt} + \frac{k}{m}v^2 = g \tag{6}$$

However, sometimes this mathematical expression is only described numerically, giving the impression that there is no other method for analyzing free fall motion [24], [25].

Analysis in physics is generally divided into two, namely numerical and computational analysis. Physics analysis using computational methods using computer assistance with programming language input, such as *Java, Matlab* [26], *Phyton,* and etc [27], [28]. The use of this analysis is seen to facilitate mathematical calculations for cases with complicated variables where the user is only required to define the desired quantities and operations [29], [30]. This research aims to explain how to analyze the free fall motion of objects with air friction constraints using the *IDE Spyder*.

B. Method

The research method used is computational free fall motion analysis carried out using *IDE Spyder* software with a *Python*-based programming language. Use this software as a tool in carrying out computational-based analysis with *Numpy*, *Matplotlib*, and *Matplotlib.pyplot* libraries.

C. Result and Discussion

Computational physics case analysis this time uses *IDE Spyder* software in free fall cases by installing the application first on the computer. This application can be downloaded for free on several internet sites. *Spyder* is a *Python* language-based *interactive development environment* (*IDE*) that has a variety of advanced editing features, interactive testing, debugging analysis, evaluation, and numerical application space. *Spyder* can also be used as a library feature that provides widgets related to console settings support from *IPyton*, *NumPy*, *SciPy*, or *matplotlib* [27], [28]. This support allows users to integrate the debugging console into program designs directly. *Spyder's* capabilities can be expanded by integrating with a variety of plug-ins and instruments, such as *Pyflakes*, *Pylint*, and *Rope*.

The first step that needs to be taken is to download and install the *IDE Spyder* software. This is because this application is not the default software for Windows OS or Mac OS. Once installed, the user will enter the *Spyder* display as shown in the following figure:

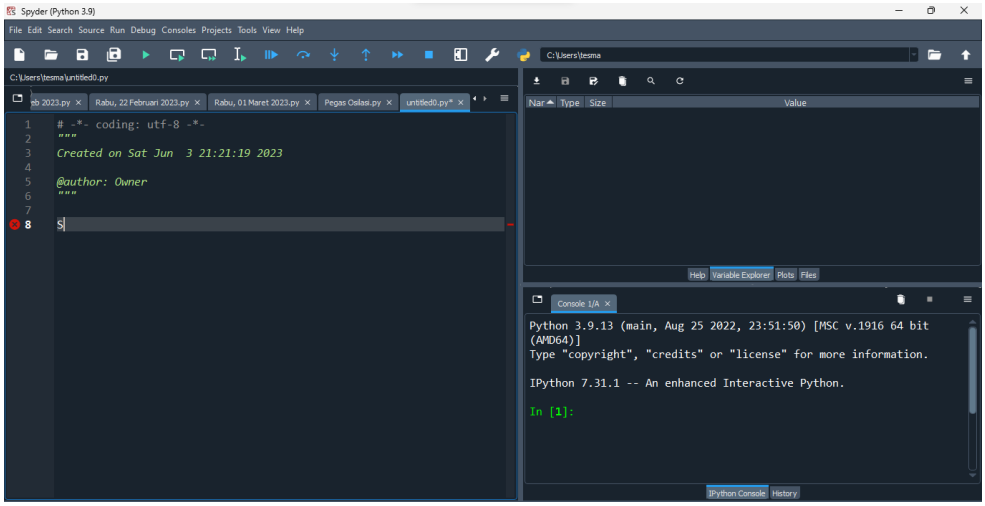

Figure 1. Interface of Spyder application

The initial appearance of Spyder is divided into 3 bars. The left bar is a worksheet for users where in this section the user can compile programming, analysis, or coding. The top right bar is a part of the library that displays the processes carried out, definitions of variables, or other important information. The bottom right bar is the view of an application of the program created [26].

The next step is to prepare the work environment on the worksheet by inserting a *library* as a program library so that the programming that has been created can be function as intended [30], [31], [32]. The *library* input is as follows:

```
5   @author: User
6   SS"""
7
8   #Persiapan Lingkungan Kerja
9   import numpy as np
10  import matplotlib as mpl
11  import matplotlib.pyplot as plt
12  from pylab import*
13
```

Figure 2. Work Environment Preparation

Input the *library* using the "*import*" command. Then continue with the command "*as*" to provide initials to make it easier to use later. *Numpy* contains a package of commands related to numbers to operate *scientific computing*, *matplotlib* contains visualizations related to mathematical operations and *matplotlib.pyplot* contains commands to provide additional information on visualizations from previous *library* [32]. This work environment preparation needs to be done before the coding is input so that it is a reference for the coding language in carrying out operations at the next stage.

The next step is to create parameters for the case to be resolved. This process is like the steps in mathematical representation, namely finding the value of the variable quantity contained in the problem [32], [33]. The specified parameters then become a reference in the operations carried out by *NumPy*. As for this physics case, the parameters are determined as follows:

```
14  #Menentukan Parameter
15  g=9.81
16  y0=9
17  v0=0
18  t0=0
19  dt=0.1
20  Cd=0.47
```

Figure 3. Phenomenon Parameter Determination

Referring to Equations 1 and 2, it is explained that the free fall motion of an object is influenced by several variables, namely *g* (gravitational acceleration), h/y_0 (height), v_0 (initial speed), and *t* (time). Meanwhile, for cases with air friction, according to Equation 4, there is an entity *C* (drag coefficient) which is a factor inhibiting movement [34]. Figure 3 shows the influencing variables along with the desired values. This value can be varied according to needs

Then, define the previously created parameters into the programming language by formulating *numpy library* (represented by *np*) with a data structure (*array*) for each parameter. This is necessary so that the previous parameters can be formulated using *scientific computing*.

```
22  #Membuat Variabel
23  v=np.array([v0])
24  y=np.array([y0])
25  t=np.array([t0])
26
27  #Inisiasi Gerak Mula mula
28  ketinggian=y0
29  waktu=t0
30  kecepatan=v0
```

Figure 4. Creating Variables on the Worksheet

It should be noted that the variables operated must match the parameters in Figure 4 because they are interconnected. Apart from that, variables are also created specifically for the parameters that change, in this case speed (v_0), height (y_0), and time (t_0). Then in the "*Inisiasi Gerak Mula mula*" section, there is a variable input bar

for the initial state of motion with a value that can be changed according to the desired initial condition. Free fall motion is motion without initial velocity vertically so that the initial input is the same as the parameters that have been created as in Figure 3.

The next process is to carry out mathematical operations using computational analysis. This stage is carried out to find the numerical integral of the free-fall motion.

```
#Loop untuk mencari integral numerik dari gerak jatuh bebas
while ketinggian >=0:
    kecepatan = kecepatan - ((g-Cd*kecepatan**2)*dt)
    v = np.append(v, kecepatan)
    ketinggian = ketinggian + kecepatan*dt
    y = np.append(y, ketinggian)
    waktu = waktu + dt
    t = np.append(t, waktu)
```

Figure 5. Finding the Numerical Integral of Free-Falling Motion

Figure 5 shows the numerical analysis by finding the integral of the free fall motion case. The operation uses *Numpy* formulation with *append* function so that variable values can be added to the final array. The operation of the variable *v* is influenced by the value of the time-dependent friction force, the operation of the variable *y* depends on the time-dependent fall speed at the current height, and the operation of the variable *t* changes by *dt*.

```
#Mencari perhitungan v max dan t max
print(v[-1])
print(t[1])
```

Figure 6. Calculations to Find the Maximum Value

The next stage is to find the maximum *v* and *t* values. The values of these two variables indicate the speed immediately before hitting the ground (y_0 = 0) and the duration of the object until it hits the ground [3]. Values in the form of numbers are displayed using the print function, a function to display the investigated output from the coding that has been created. This function is applied to the variables *v* and *t*.

```
#Menampilkan hasil perhitungan gerak jatuh bebas
fig, ax = plt.subplots(2,1,sharex = True)
fig.subplots_adjust(hspace=0.6)
```

Figure 7. Programming coding to display calculation results

To display the results graph, a previously imported *library* is used, namely *plt (matplotlib.pyplot)*. Before you can display the results as required, it is necessary to first create a graphic framework that will be used to display the output of the previous

operation. Two graphic frames have been created with a vertical downward arrangement with 2 (vertical) × 1 (horizontal) configuration with coding ***fig, ax = plt.subplots(2,1,sharex = True)***. Then create a separation distance with the coding ***fig.subplots_adjust(hspace=0.6)***. The *hspace* value states the desired distance between two graph frames, the smaller the value entered, the closer the graph frames will be.

```
49  ax[0].plot(t,y)
50  ax[0].set_xlabel("Waktu, t(s)")
51  ax[0].set_ylabel("Ketinggian, y(m)")
52  ax[0].set_title("Ketinggian")
53  ax[0].set_ylim(0.0,11.0)
54
55  ax[1].plot(t,v)
56  ax[1].set_xlabel("Waktu, t(s)")
57  ax[1].set_ylabel("Kecepatan, v(m/s)")
58  ax[1].set_title("Kecepatan Jatuh Bebas")
59  show()
60  plt.savefig(r'D:\User')
```

Figure 8. Determination of the Coordinate Axis on the Output Graph

After the graphic framework is created, the next step is to create an identity for each framework. The first graph is symbolized by ***ax[0]*** with an explanation regarding the coding entered as follows:

```
ax[0].plot(t,y)                          → Create an axis plot
ax[0].set_xlabel(“Waktu, t(s)”)          → X axis identity
ax[0].set_ylabel(“Ketinggian, y(m)”)           → Y axis identity
ax[0].set_title(“Ketinggian”)                  → Graphic Title
ax[0].set_ylim(0.0,11.0)                 → Create a length limit for the
y-axis
```

The second graph is symbolized by ***ax[1]*** with the following coding input

```
ax[1].plot(t,v)                          → Create an axis plot
ax[1].set_xlabel(“Waktu, t(s)”)          → x axis identity
ax[1].set_ylabel(“Kecepatan, v(m/s)”)          → y axis identity
ax[1].set_title(“Kecepatan Jatuh Bebas”) → Graphic Title
ax[1].set_ylim(0.0,11.0)                 → Create a length limit for the
y-axis
```

Then, issue a graphical output command with the following coding

```
show()                              → Output functions
plt.savefig(r’D:\User’)                   → Output storage directory
```

The thing to note is that the *User* name must match *@author* in Figure 2. The next step is to run the coding program by selecting the *Run* option (►) or pressing F5 (*for Windows devices*) until the numerical analysis output appears on application display bar as in Figure 9

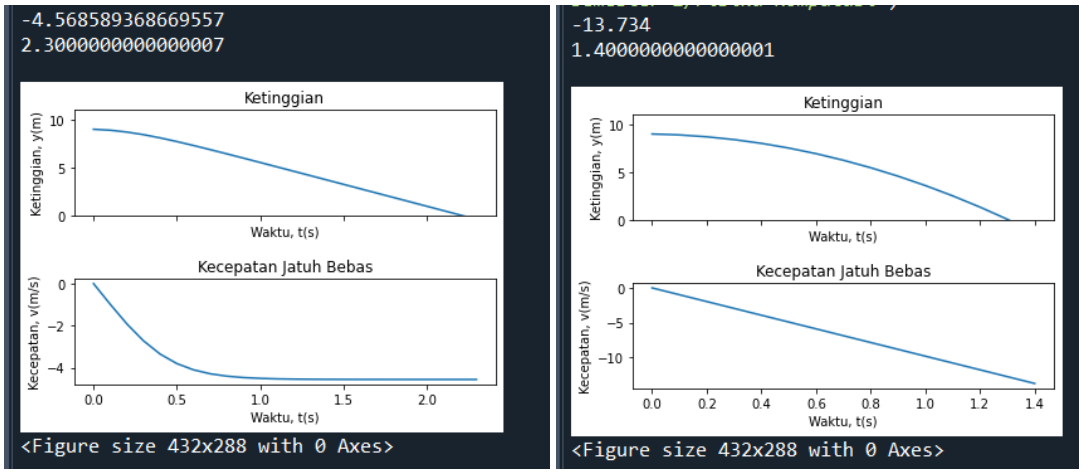

Figure 9. Numerical Output and Graph of Free Fall Motion with Air Friction

The use of the negative sign (-) in the free fall speed value is used to indicate that the direction of the object's fall is towards the center of gravity. Apart from that, a graph of the falling motion on the negative *y-axis* was also made to show that the object's motion was downward [35]. This action was carried out as a form of conformity to the interpretation of physics in this computational analysis which refers to the Cartesian coordinate system (*x, y, z*). This was created to minimize misunderstandings among the public, especially for those who are studying physics.

The results of computational analysis for numerical integrals in free fall motion with air friction produce v_{max} = -4.56858. . . m/s and t_{max}= 2.3 s and the speed graph shows a gradient with extreme slope values. This output shows that there is an influence of air friction on the speed of the free fall motion so that it does not include an *uniformly accelerated rectilinear motion* (GLBB). The image on the right side shows a computational analysis for free fall motion without the influence of air friction, resulting in v_{max} = -13.734 m/s and t_{max} = 1.4 s which is to the results of the analytical method. The gradient on the speed graph is also constant and this shows that the motion is an *uniformly accelerated rectilinear motion* (GLBB)[36], [37].

The graph and results in Figure 9 show that there are quite significant differences in the two free fall motion calculation results. The first simulation uses air resistance as a function of disturbance causing the falling speed of the object to be far apart, namely 4.5 m/s compared to 13.7 m/s from a height of 10 meters. The interpretation that can be taken is that air resistance behaves as "*something that collides and resists the departure*" of something that passes through it [38], [39]. This behavior is caused by the dense concentration of molecules that make up air (N, O, C, and so on) in the path the falling object takes. The absence of a number of these molecules smoothes the path of falling objects so that the transformation of the object's potential energy into kinetic energy can be maximized [40].

Figure 9 is the result obtained with an input value of ***h*** (height) of 10 m for objects with air friction constraints and without any constraints. Below we will also present several computational analysis results for different variations of ***h*** values:

Table 1. Comparison of the Results of Computational Analysis of Variables v and t

Height (m)	**Air friction constraints**		**Non-air friction constraints**	
	v	***t***	***v***	***t***
5	4,55	1,41	9,91	1,01
10	4,57	2,30	13,73	1,40
15	4,57	3,59	17,17	1,75
20	4,57	4,69	19,82	2,02
25	4,57	5,79	22,17	2,26
30	4,58	6,89	24,23	2,47

The differences in results for these two variables are illustrated in Figure 10.

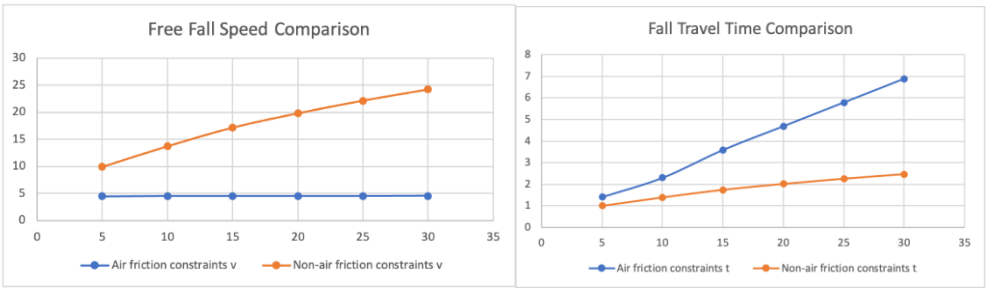

Figure 10. Comparison Graph of *v* and *t* Values

There is a significant difference in the speed graph, where the variable *v* on the blue line (with air friction) tends to be stagnant and flat, while on the orange line (without air friction) it produces a sloping line with a constant average gradient. Differences also occur in the duration of the fall to a height (*h*) = 0 m. The blue line shows the results in the form of a line with a large gradient when compared to the orange line which has a small slope. The large gradient value on the fall time graph shows that air friction ultimately also has an effect on the longer fall time based on the increased initial height value [2].

Computational calculation and analysis methods have been presented as an effort to minimize measurement errors in various cases, including cases of free fall motion. The use of this method has the effect of increasing the accuracy of the calculation results obtained [41]. Apart from that, this method also does not require a lot of resources to carry out experiments (in some cases it requires high costs to purchase an application license) because it is preloaded by the device used. The positive side of using computational methods is that they can be used to analyze cases that are difficult to realize in the real world, such as atomic collisions [42], and

molecule interactions, or to model physics cases that are full of mathematical equations (such as quantum mechanics and black body radiation)[43].

D. Conclusion

The phenomenon of free fall can be analyzed using various methods, one of which is computing with the help of Spyder. Analysis with this application is used because the analytical calculations for this case are quite complex and require a lot of time so this application can be used as a solution. The analysis begins with creating a work environment and then creating mathematical operations for the case. The results obtained show that there is an influence of air friction on the speed of free fall motion which causes a significant difference in tmax compared to tmax for free fall motion without air friction.

In this analysis, objects in free fall motion are assumed to be particles so their geometric shape is not taken into account. Further research can take analysis with different geometric shapes.

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The Educational Game Development of Physics Monopoly (Mofis) on the Materials of Momentum and Impulse for Learners at SHS/ISHS

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ABSTRACT

The use of learning media is one of the learning tools that can help in the learning process. One of them is the development of a physics monopoly educational game (Mofis) based on the needs of students. This study aims to 1) produce a Mofis on momentum and impulse material for SHS/ISHS students, 2) know the quality of Mofis for SHS/ISHS students, and 3) Knowing students' responses to the Mofis which was developed on momentum and impulse material.

This research is a Research and Development using 4D Thiagarajan models. This research was carried out up to the Develop step, namely extensive testing and implementation of Mofis. The instruments used were instrument and product validation sheets, Mofis quality assessment sheets, student response sheets, and implementation observation sheets. The product validation assessment in research uses Aiken's V scale with 3 scales. While assessing the quality of Mofis and student response sheets using a Likert scale with 4 scales.

The result of this research is a Mofis on momentum and impulse material for SHS/ISHS students. Mofis quality based on the assessment of material experts, media experts, and high school physics teachers obtained Very Good criteria with an average score for each assessment of 3.68; 3.53; and 3.83. Student responses to Mofis in the limited testing obtained the Agree criteria with a mean score of 3.24 and in the extensive testing obtained the Strongly Agree criteria with a mean score of 3.28. The results of Mofis implementation in extensive trials by observers obtained Very Good criteria with a mean score of 3.63.

INTISARI

Pemanfaatan media pembelajaran merupakan salah satu sarana pembelajaran yang dapat membantu dalam proses pembelajaran. Salah satunya ad|al|ah pengemb|ang|an educ|ation|al g|ame monopoli fisik|a y|ang did|as|ark|an kebutuh|an untuk pesert|a didik. Penelitian ini bertujuan untuk 1) Menghasilkan educational game Monopoli Fisika (Mofis) pada materi momentum dan impuls untuk peserta didik SMA/MA, 2) Mengetahui kualitas Mofis pada materi momentum dan impuls untuk peserta didik SMA/MA, dan 3) Mengetahui respon peserta didik terhadap Mofis yang dikembangkan pada materi momentum dan impuls.

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Penelitian ini merupakan penelitian Research and Development (R&D) dengan model pengembangan 4D Thi|ag|ar|aj|an y|ang terdiri d|ari t|ah|ap Define, Design, Develop, dan Dessiminate. Peneliti|an ini dil|akuk|an s|amp|ai p|ad|a t|ah|ap Develop y|aitu uji cob|a lu|as d|an keterl|aks|an|a|an Mofis. Instrumen y|ang digun|ak|an berup|a lemb|ar v|alid|asi instrumen d|an produk, lemb|ar penil|ai|an ku|alit|as Mofis, lemb|ar respon pesert|a didik, d|an lemb|ar observ|asi keterl|aks|an|a|an. Penil|ai|an v|alid|asi produk d|al|am peneliti|an menggun|ak|an sk|al|a |Aiken's V deng|an 3 sk|al|a. Sed|angk|an penil|ai|an ku|alit|as Mofis d|an lemb|ar respon pesert|a didik menggun|ak|an sk|al|a Likert deng|an 4 sk|al|a.

Hasil dari penelitian ini adalah educational game monopoli fisik|a (Mofis) p|ad|a m|ateri momentum d|an impuls untuk pesert|a didik SM|A/M|A deng|an kriteri|a s|ang|at b|aik (SB) berd|as|ark|an penil|ai|an |ahli m|ateri, ahli media, dan guru fisika SMA dengan rerata skor untuk tiap penilaian sebesar 3,68; 3,53; dan 3,83. Respon pesert|a didik terh|ad|ap Mofis p|ad|a uji cob|a terbatas memperoleh kriteria Setuju (S) dengan rerata skor 3,24 dan pada uji coba luas memperoleh kriteria Sangat Setuju (SS) dengan rerata skor 3,28. Hasil dari keterlaksanaan Mofis p|ad|a uji cob|a lu|as oleh observer memperoleh kriteri|a Sangat Baik (SB) dengan rerata skor 3,63.

A. Introduction

Relevant educational advancement with the educational changes undergoes innovation both theoretically and practically to realize excellent educational quality [1]. Education is strongly correlated to science, personal development, and personal character. Thus, education could help individuals with cognitive, affective, and behavioral achievements [2]. The learning process determines the educational quality because the learning process could realize reliable and independent individuals after joining the learning process (Prameswari et al., 2018). Learning refers to the promoted efforts by teachers to realize the targeted learning by directing the learners in learning activities. Therefore, learners must participate in the correct learning process with responsible teachers to create a learning process based on the learners' characters [3].

Classroom learning is inseparable from various influential components. Some crucial components of the learning process are teachers, learners, the relationships among teachers and learners, the applied teaching methods, and the applied learning media to influence the learners' learning outcomes [4] [5]. Learning process especially for physics learning requires conceptual understanding, scientific attitude, and implementation of equation to solve problems [6]. However, many lessons and learning are oriented on theoretical mastery and memorization. The lesson also does not apply various learning media so the learners cannot develop their skills maximally [7]. The teachers must prepare the physics learning attractively to realize joyful and meaningful learning for the learners. On the other hand, learners must fully realize and actively and enthusiastically participate in the learning to master the materials and gain positive impacts on the learning outcomes.

The applicable learning media could mediate the material delivery of the teachers [8]. Therefore, teachers must master various learning models and methods and use various relevant learning media based on the material characteristics to attract the attention and interest of the learners. These efforts are important to improve the learners' learning achievements [9]. Learning media refers to learning components with important roles in teaching-learning activity. Learning media for education is important in the teaching-learning process to facilitate information sharing and knowledge transfer for the learners. Learning media could be a solution to teacher-learning communication problems so that the teaching-learning process could be directed. Learning media is important to keep the focus of learners' senses during material sharing [10].

The implementation of the lecturing method in physics learning at schools is less effective for the learners. This method only allows one-way communication from the teacher to the learners. Thus, the learners become passive. The implementation of the lecturing method for the learners requires them to memorize the information without conceptual understanding. These matters make the learners bored and passive in learning [6]. Physics learning becomes joyful learning for the learners based on the efforts of the teachers to realize the classroom learning atmosphere. A joyful learning

activity should involve the learners to actively participate in the learning. The actively involved learners could improve their material understanding based on the given materials [6].

A lively and meaningful learning atmosphere realization may apply an educational game media [11]. Educational game refers to a game theme with educational value to amuse during the learning process and mediate the learning material [12]. An educational game for physics learning is useful as an alternative learning media and source to train the learners actively in learning.

The implementation of the educational game has positive impacts, such as joyful feelings of the learners during the learning process and evaluation, and improved motivation while learning physics. High interest or tendency of the learners to use various game products could be an innovation for physics learning [13]. Educational games are useful to invite learners to play the game wisely and appropriately. The learners do not only use the game as an amusement media to spend their time but also as a useful learning means.

The development of educational game learning media should have interesting designs to teach the learners to understand physics material with the assistance of learning-by-playing. These efforts could improve learning achievements. One of the educational games to develop as a learning means is Physics Monopoly (Mofis). The innovative learning media development, Mofis, could improve the learners' creativity in learning and make the learning atmosphere meaningful. Besides that, this learning media is familiar to learners so they could easily use the game.

Mofis is a gaming media adapted from a Monopoly game with some modifications based on physics learning media. The game consists of a board with various activities, dice, pion, and money toys to share only for learners with correct answers, and some question items based on the materials of the lesson [9]. A monopoly could be a medium to train the learners' memory and material mastery. The game could also encourage the learners' bravery to express their arguments, train conceptual mastery, and comprehend the learning material [14]. A monopoly game, such as physics learning media, could provide positive results such as improving the learning activities and learning achievements of the learners [15].

The teaching-learning process could run effectively and efficiently with the support of relevant learning media. Therefore, familiar physics learning media is important for learners. This research produces an educational game in the form of a physics monopoly, Mofis, to make the learners understand the physics material in the classroom. This product could attract learners and lower boredom while learning physics. Besides that, the researchers attempted to determine the quality and reliability of the developed game, Physics Monopoly (Mofis), under the materials of momentum and impulse for SHS/ISHS learners; and the learners' responses toward the implementation of the developed product as the physics learning media.

B. Method

In this research, the researchers applied the Research & Development model. This Research & Development attempts to produce certain useful products and examine the products to determine their effectiveness and reliability [16]. The product of the research is the educational game of physics monopoly, Mofis, for SHS and ISHS learners under the materials of momentum and impulse. The applied procedure is 4D as suggested by Thiagarajan [17]. This 4D model consists of defining, designing, developing, and disseminating stages. However, in this current research, the stage stops until the development stage.

The applied data collection methods were interviewing, observing, and distributing the questionnaire. The researchers interviewed the physics teachers to gain preliminary data about the development necessity from the research sites, the SHS and ISHS. From the interview, the researchers found the problems to investigate. The researchers observed to measure the aspects of learning, necessity, and skill attitudes from the learners. Then, the researchers shared the questionnaire to measure the validity of the developed media.

The applied data analysis technique to validate the instrument and the media was Aiken's V formula calculation. This formula is useful for calculating the content-validity coefficient based on the evaluations of the n-experts toward a certain item [18]. Here is the applied formula.

$$V = \frac{\Sigma s}{[n_1(c-1)]} \tag{1}$$

with

$$s = \mathrm{r} - I_0 \tag{2}$$

Remarks:

n_1 : the numbers of the raters (assessment)
s : the rater scales
c : the categories of the assessed criteria
r : the first-assessed criterion
I_0 : the lowest category

The applied data analysis technique was useful in calculating the product quality evaluations based on the material and media experts, teachers, and learners' response calculations toward the media as suggested by Sudjana (2009:131).

$$X = \frac{\Sigma x}{N.n} \tag{3}$$

Remarks:

X : Mean score
ΣX : Score total

N : The raters

n : The question items

C. Result and Discussion

The experts evaluated the developed learning media, the physics monopoly game (Mofis). The researchers expected the developed product to be applicable for SHS learning under the materials of momentum and impulse. In this research, the researchers applied a 4D model to produce the physics monopoly game (Mofis). Here are the results of each R&D stage.

The Defining Stage

The defining stage determines and defines the instructional conditions and necessities of the learning process. This stage leads to the learning objectives and learning material scopes. This stage is also useful to analyze the learners' necessities, materials, and objective formulations. The applied analyses found the absence of media implementation in school learning. Most learning relied on the lecturing method that made one-way communication from teachers to the learners. Thus, the learners were passive in the learning. The learners also had no interest in learning physics and tended to play games while the classroom was learning. The researchers expected the developed educational game of Physics Monopoly could solve the existing problems.

The Designing Stage

The analysis results, based on the defining stage, were useful in designing the learning media product, the physics monopoly (Mofis). In this stage, the researchers arranged the research instruments, selected the media and the format, and created a preliminary design and prototype. The researchers validated, revised, and assessed the physics monopoly base don the defining stage in the subsequent process. Here is the design of the physics monopoly learning media (Mofis).

Figure 1. The Physics Monopoly Game Board

The Development Stage

This stage produced the educational game learning, the first draft of Mofis, to validate. This stage has two activities: expert appraisal to validate the product reliability; and developmental testing or product trial run. The stage begins by validating the first draft of Mofis. The experts then shared the suggestions for further revisions. The validations of the expert materials are useful to obtain the content material adjustment within the Mofis before being assessed qualitatively. Based on the analyses, the developed physics monopoly, Mofis, has high validity based on the result of material experts with a score of 0.88.

The Mofis validation by the media experts is useful to find out the relevance of Mofis with the visual and implementation aspects. The analysis results found that Mofis had high validity based on the media experts with a mean score of 0.90. The validators also suggested and stated that the developed Mofis was valid with minor revisions.

Based on the validation and the first revision, the researchers revised the first draft of Mofis into the second draft. Then, the researchers evaluated the quality of the developed learning media by involving two material experts, two media experts, and a physics teacher at SHS. This procedure was useful to determine the developed learning media, Mofis. The experts also shared their evaluation, suggestions, and recommendations for further Mofis revisions. This assessment process applied a previously validated instrument.

Table 1. The Evaluation Results of the Material Experts

The Evaluation Aspect	The Score Mean	The Criteria
The Aspect of Material Validity	3.67	Extremely Excellent
The Language Aspect	3.75	Extremely Excellent
The Aspect of Question Item Display	3.63	Extremely Excellent
Mean	3.68	Extremely Excellent

The quality assessment by the material experts consisted of three aspects. They were the material, language, and question item display validity. The researchers had the experts score the product based on a 4-sore Likert scale. The obtained score from the material expert is 3.68, categorized as extremely excellent. The result shows that Mofis, based on the material aspect, has extremely excellent quality. The assessment result of the material expert found the language aspect had the highest score mean, 3.75 with extremely excellent criterion. The results show that the language is communicative and understandable to share the materials. The applied sentences are relevant to the General Guideline of Indonesian Language Spelling, PUEBI. The material validity aspect has two indicators: the material relevance and the correctness of the learning material. This aspect obtains a mean score of 3.67 with the criterion of extremely excellent. The results show that the materials of Mofis are relevant to the

core competencies, basic competencies, indicators, and learning objectives of the revised 2013 curriculum.

Table 2. The Results of the Media Expert Evaluation

The Evaluation Aspect	The Score Mean	The Criteria
The Visual Aspect	3.72	Extremely Excellent
The Media Implementation Aspect	3.33	Extremely Excellent
Mean	3.53	Extremely Excellent

The evaluation results by the media experts are based on the visual and implementation aspects. The given score is based on the 4-score Likert scale. The obtained mean score of the media experts is 3.53 with the criterion of extremely excellent. These results show that the developed Mofis, based on the media aspect, has extremely excellent quality. The evaluation results of the media experts found the visual aspect had the highest score mean, 3.72, based on three indicators: textual readability, color selection, and design quality. The results show that the text display of the developed Mofis is clear and readable. Besides that, the color composition of Mofis is harmonious and attractive. Then, the color display is in contrast with the applied letter colors. Mofis has excellent design quality based on the figure display, figure-material relevance, tidiness, attractiveness of Mofis design, and the package. Therefore, the visualizations of Mofis are attractive and interesting for the learners.

Table 3. The Assessment Results of Physics Teachers at SHS

The Evaluation Aspect	The Score Mean	The Criteria
The Visual Aspect	4.00	Extremely Excellent
The Aspect of Material Validity	3.67	Extremely Excellent
The Language Aspect	4.00	Extremely Excellent
The Aspect of Question Item Display	3.50	Extremely Excellent
The Learning Implementation Aspect	4.00	Extremely Excellent
Mean	3.83	Extremely Excellent

The evaluation results from the teachers show that the visual, language, and learning implementation aspects have the criterion of extremely excellent with a mean score of 4.00. The visual aspect consists of some indicators, such as Mofis display based on the design, color composition, and textual display. The results show that the physics teachers agree with the developed Mofis based on the visual aspect. They found the developed product had an attractive and tidy design, harmonious color composition, relevant figure implementation based on the material, and clear and readable textual presentations. The obtained criteria show an extremely excellent category based on the language aspect. The applied language is excellent, communicative, and understandable. Besides that, the applied sentences have excellent order based on the General Guideline of Indonesian Language Spelling,

PUEBI. Then, from the learning implementation aspect, the result shows an extremely excellent criterion. Thus, the developed Mofis could motivate the learners to learn physics based on the necessities of the learners. Mofis could also improve the activity and participation of the learners in learning and create a new atmosphere of learning physics.

The evaluation of Mofis led to the third draft of Mofis. This draft was useful for the subsequent trial run. The researchers tried the product in the second stage, the limited trial run. This stage involved nine learners of SHS. Then, the large-scale trial run involved 22 learners of SHS. The trial run process with the third draft of Mofis received some revision processes based on the assessment.

Table 4. The result of the Limited Trial Run

The Evaluation Aspect	The Score Mean	The Criteria
Display	3.22	Agree (A)
Material	3.22	Agree (A)
The Implementation	3.06	Agree (A)
Learning	3.33	Extremely Agree (EA)
Mean	3.24	Agree (A)

Table 5. The result of the Large-Scale Trial Run

The Evaluation Aspect	The Score Mean	The Criteria
Display	3.31	Extremely Agree (EA)
Material	3.21	Agree (A)
The Implementation	3.30	Extremely Agree (EA)
Learning	3.34	Extremely Agree (EA)
Mean	3.24	Agree (A)

In general, the obtained scores from the limited trial run and the large-scale trial run are 3.24 with the criterion of agree and 3.28 with the criterion of extremely agree. This matter shows the learners agree with the attractive Mofis display, the material-conceptual relevance, the ease of Mofis implementation, and the attractive Mofis implementation in the learning. Thus, the developed educational game, Mofis, could be accepted properly by learners for learning process purposes and as the learning media. The developed media could create a joyful learning atmosphere and make the learners interested. Hidayati et al (2022) found that physics monopoly learning media could be an alternative to realize relaxing and joyful learning. The learners could learn and solve problems based on the given cards and apply the prior knowledge and material from the books and the Internet. Learners would be interested to join and listen to the learning because they found the learning challenging. They could also explore their knowledge to answer the questions based on the cards.

D. Conclusion

This research produces an educational game in the form of a physics monopoly, Mofis, with the materials of momentum and impulse to apply in the learning process. The results show the physics monopoly, Mofis, based on the experts of material and media and the physics teachers of the SHS, with scores of 3.68; 3.53; and 3.83. All scores indicate extremely excellent (EE). Based on the learners' responses toward the developed media, during the limited trial run, the obtained mean score is 3.24 with the criterion of agree (A). On the other hand, the large-scale test obtained a mean score of 3.28 with the criterion of extremely agree (EE).

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