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Effect of STEM-Based Digital on Student's Learning Outcomes in Light Wave Material

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ABSTRACT

Low student learning outcomes are due to teacher-centered learning and lack of use of digital materials. One way to solve this problem is the use of digital educational resources for STEM (science, technology, engineering, and math) topics. This study's objective was to ascertain the impact of this STEM-based digital material for light waves on student learning outcomes in a physics class. This method of research is the scientific method, that is, experimental research. The study design used is a straightforward experimental strategy (post-test only control strategy). The XI sciences class served as the study's entire population, and the samples used were from the XI science 3 control class and the XI science 4 experimental class. Data collection means use end-of-learning tests or post-tests. Data processors were performed using the IBM SPSS program version 29.0 with normality tests, homogeneity tests, and hypothesis tests (t-tests). Based on the outcomes of our research, we discovered that the obtained data are normally distributed with a level of 0.182 ≥ 0.05 for the control class and 0.073 ≥ 0.05 for the experimental class. For the homogeneity test, the levels are 0.073 ≥ 0.05, so the classes are homogeneous. On the other hand, for hypothesis tests or t-tests, the obtained sig (two-tailed) post-test is <0.001. This value is less than 0.005 and is based on the rejection criteria for Ho. The result of the pre-test t-test analysis is 0.164, which means that this value is greater than 0.05, so Ho is accepted. From this, we can conclude that his STEM-based digital teaching materials on light waves have an impact on students' learning outcomes in physics.

Keywords :*Digital Teaching Materials; Learning Outcomes; STEM.*

I. INTRODUCTION

Education plays a crucial part in determining a person's moral character, quality of life, and level of humanity. Education is a means of producing quality human resources and is necessary for a nation to be competitive and competent [1]. Education is essentially an effort that can be made to provide an individual with specific knowledge, insights, skills and expertise, and to develop their talents and personality. The existence of education helps people evolve to cope with the many changes that come with technological advances.

Education as an activity and process of intentional activity is a symptom of society when it begins to realize the important of striving to shape, direct, and regulate human beings as society desires them to be [2]. It is hoped that society's awareness of the world of education will improve the quality of society in the future. Therefore, educational problems, which pose a wide variety of problems, both qualitative and quantitative, need to be given more attention and resolved.

Regarding the response to this problem, up to this point, the government has made a number of attempts to quality of education, such as improving the professional skills of teachers and improving the curriculum [3]. An increase in the professional ability of teachers and improvement of the curriculum is projected to raise educational standards, particularly in terms of student learning outcomes. Teachers are expected to be able to organize and carry out educational activities in a successful and creative manner. In teacher learning it is said to be successful if students have good learning outcomes [4]. As a learning manager, the teacher is one of the

components that has a big influence on the learning process. Teachers are required to have various abilities and efforts to improve the quality of education [5].

The 21st century's educational requirements both teachers and having skills in students in using technology, because the current state of education everything is related to technology, one example is the utilization of digital instructional resources. According to [6] teaching materials are an important tool when teachers provide material because teaching materials are intended as something that can be used to get a message in return from the sender to the recipient of the message. While packaged teaching resources are what digital teaching materials are in technology so that these teaching materials more then effective and efficient to use. Digital materials are interactive materials that help you understand concepts that cannot be visualized, so that they can support the learning process in class and as a means of independent learning by students [7]. Learning will be simpler to put into practice as a result of the availability of digital teaching materials since students will be more productive. Digital teaching resources can also be used whenever and whenever you choose.

21st century education also demands student-centered learning. One example of student-centered learning that will help students to learn more independently is learning using the STEM approach [8]. Learning using the STEM approach provides experience through project-based learning activities that aim to train real-life problem-solving skills in order to develop experience, life skills, and creativity for innovation and collaboration [9].

Based on the initial observations of researchers at senior high school, some information was obtained, namely that teachers still use conventional approaches when carrying out the teaching and learning process. Teachers still often use the lecture method or become a source of information for students. This tends to make the teacher the center of learning. So that students will become more passive in the learning process which causes students to not understand the material presented.

The use of digital teaching materials in learning physics in schools is also not optimal. Teachers still rarely use digital teaching materials because subject teachers are less able or less able to use technology and more often use books provided by schools. This causes students' understanding of related material to be low, resulting in low student learning outcomes. The average score obtained by students has not yet reached the Minimum Completeness Criteria set at senior high school. The Minimum Completeness Criteria set at senior high school Guguak is ≥ 70. Meanwhile, the average score obtained by each class has not reached the Minimum Completeness Criteria that has been set.

The solution that researchers consider appropriate to overcome these problems is to use digital teaching materials and learning approaches that provide direct learning experiences, involve student activities, and invite students to carry out experimental activities in the form of inventions that can help students understand physics concepts, and one of the learning approaches it is a STEM approach. By using STEM-based digital teaching materials, it is expected to be able to overcome these problems.

Digital teaching materials are an important component in achieving learning objectives [10]. The accessibility of content in digital teaching materials can effectively and efficiently support the learning process [11]. The existence of digital teaching materials is expected to assist students in their learning process and improve their learning outcomes. However, using digital materials without a learning approach to the learning process does not produce satisfactory results. The learning approach used in this learning process is the STEM approach. The STEM approach is one of the learning innovations that has developed in the 21st century. STEM stands for Science, Technology, Engineering and Mathematics [12]. According to [13]. The STEM approach to learning focuses on learning processes that actively place students in the context of exploring two or more disciplines and solving real-world problems. is outlined as instruction that combines The goal of learning using the STEM approach is to assist students gain the scientific and technical information that comes from their abilities to read, write, observe, and explore science, as well as the skills to use that knowledge to help solve problems that are important to society on a daily basis. To help develop it, whether it can be applied to the solution. STEM science area [13]

The STEM approach allows students to participate more directly and actively in learning activities, especially by conducting experiments to define concepts in the learning material. The use of the STEM approach in the instructional materials used has been proven to give good results in improving outcomes for student learning. This is evident from research conducted by [14] which states the utilization of STEM-based digital instructional materials work well in increasing student learning outcomes. That means STEM-based digital l,earning results for students are impacted by the teaching materials..

Through the products of a previous researcher namely Vaizatul Uzfa in 2022 STEM-based digital educational resources were created based on light wave materials, validated and included in a very valid category. The use of STEM-based materials is expected to improve student learning outcomes, especially at the cognitive level.

On the basis of description above, STEM-based Digital teaching resources should enhance students' academic performance. Therefore, the authors are interested in conducting a study entitled "The Influence of

STEM-based Digital Teaching Materials on Light Wave Material on Student Learning Outcomes in Physics Learning".

II. METHOD

Determination of the method that the author uses in this study is the scientific method, namely experimental research [15]. An experimental study is a study whose purpose is to determine whether or not to impose an outcome "something" on a subject. The study design used in this study is a simple experimental design (posttest-only control design). This study included him in two classes. For the experimental class he used STEM-based digital materials and for the control class he did not. The two classes then take a post-test (final test) to check their learning outcomes. According to [16] the research design can be seen in Table 1

Table 1. Research design

Group	*Treatment*	*Post-Test*
Eksperimen	X	T
Kontrol	-	T

Information:
X = The treatment given is using the STEM approach
T = Final test given for class

A research variable is something that can change in the research process. The research variable can be defined as an attribute of an object or activity chosen by the researcher to be examined, with findings made after drawing inferences from particular variants [16]. The two variables employed in this inquiry are the independent variable and the dependent variable [17].

The independent variable is a factor that affects or serves as the catalyst for the development or change in the dependent variable [16]. STEM-Based Digital Teaching Materials are both the independent and dependent variables are used in this investigation [16]. In this research, the dependent variable is student learning outcomes. Control variables, on the other hand, are variables that researchers deliberately control or keep constant in order to minimize the influence of non-independent variables that could impact the outcomes of the dependent variable [16]. In this research, the control variables were students' initial abilities, subject matter, teachers, time allocation, classes and data collection instruments.

The population is the complete subject of the study, whether it takes the shape of individuals, objects, events, values, or actual occurrences. On the basis of the aforementioned comprehension, the population might be seen as the entire topic or subject of a study. All 139 students were included in the study's sample in class XI sciences even semester at senior high school, which had 4 classes. The population under investigation includes the sample. Class XI science 4 served as the experimental class in this study, and class XI science 3 served as the control class. Purposive Sampling is the method of sampling used in this investigation. A sampling technique with specific considerations is the purposeful sample.

The research instrument is one of the devices used in finding an answer in a study The research [16]. Instruments are tools researchers use to acquire data in a systematic and easy way. This instrument is used to measure the variable under investigation. In this study, a post-test form of testing apparatus was used as the apparatus. The research instrument consisted of her five validated essay questions.

Data collection techniques are measuring tools needed in carrying out a study. In this study, data collecting methods were employed in the form of tests to help with comprehension of data collection techniques, and the type of data to be collected. According to [18] a test is a sequence of questions that are asked of pupils with the goal of obtaining responses that will serve as the foundation for calculating a numerical score. To determine the learning results of students who have used STEM-based digital teaching materials, this test is administered once as a post-test.

The findings of this study's suggested hypotheses, a review of research data was done. Evaluations of students' learning outcomes in the cognitive area make up the study's data. In this study, a number of data analysis methods were employed, including descriptive statistical analysis, normality and homogeneity tests, and hypothesis testing (t-test).

Statistical descriptive analysis is a method that can be used to summarize and give a summary of the variables' frequency distributions in a study. According to Ghozali (2016) statistical descriptive analysis aims to collect, process, and analyze data so that it can be presented in a better view. Statistical descriptive analysis is expected to provide a general explanation of the problem to be analyzed so that it is easier to understand.

To ascertain if the samples were drawn from a community with a regularly distributed population, a normality test was carried out. You can check for normalcy with the Lilliefors test. Prior to doing the prior

hypothesis test, a normality test should be performed. The evaluation criteria are as follows: If Lo<Lt, the sample is normally distributed; if Lo>Lt, the sample is not normally distributed. Prior to doing the prior hypothesis test, the normalcy test must be performed.

Homogeneity of Variance is to find out whether this sample is drawn from an identical population as the variance or not. With a homogeneous variance, estimating and testing activities can take place. Tests that will use the test Fisher at a significant level (0.05) The testing criteria are reject Ha if Fcount < $Ftabel$ or accept Ho if Fcount > $Ftabel$.

Test the study hypothesis, the authors used an inference analysis technique using t-tests. To evaluate whether Significant variations between post-test results means (means), the t-test is frequently utilized. Degrees of freedom (dk) = (n1 + n2- 2) were used in the test, and a significance threshold of 0.05 was used. Here, Sudjana's test condition states that Ho is ineligible if the t-count is more than the t-table [20]. There are two of when the data are in the form of two independent samples, his t-test formulas can be employed to test the comparison form of proportions or intervals.

III. RESULTS AND DISCUSSION

RESULTS

Statistical descriptive analysis is a method of describing and providing an overview of the frequency distribution of variables in a study. The data to be tested the information from the post-test control class and the post-test experiment class. Statistical descriptive analysis was performed using the IBM SPSS Statistics Versi 29.0 computer program. The dataset used was 36 students from the control class and 35 students from the experimental class. The SPSS output display after processing the descriptive analysis data is shown in Table 2.

Table 2. Lists the findings of the statistical descriptive analysis Posttest Control Group and Experiment Group

Descriptive Statistics

	N	Min	Max	Mean	Std. Dev
Posttest control	36	30	70	47.50	12.277
Posttest Experimen	35	50	100	72.29	15.163
Valid (listwise)	35				

According to Table 2, the control class has a value ranging from 30 to 70. Therefore, the standard deviation is 12.277 and the mean is 47.50. 50 is the lowest value and 100 is the maximum value for the experimental class. This yields a 72.29 mean (average) and a 15.163 standard deviation.

The purpose of A normality test is used to determine whether the data are normally distributed. The post-test experimental class and post-test control group result data are the ones that were employed. The two-class normality a test was run on the computer program IBM SPSS Statistics Version 29.0, and it was applied to the entire data of 36 students in the control class and 35 students in the experimental class. The Kolmogrov-Smirnov test was used to do it.

The normalcy test's significance can be assessed using a significance rate of 5% (= 0.05). The following are the decision criteria: The data are regularly distributed if the significance (sig) is 0.05 or less; otherwise, it is greater than 0.05. The data are not normally distributed at the threshold of 0.05. The results are displayed in Table 3 following the computer program's processing of the normalcy test data.

Table 3. Normality Test Results*Posttest* Control Group and Experiment Group

Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Stat	df	Sig.	Stat	Df	Sig.
Results study	Posttest control	.123	36	.182	.940	36	.050
	Posttest Experiment	.142	35	.073	.941	35	.061

a. Lilliefors Significance Correction

On the basis of the output from the normality test software in Table 3 above, it is possible to see that the significant value for the control class in the column Kolmograf Smirnov is 0.182, indicating that the data in the control class are normally distributed since 0.182 ≥ 0.05. While 0.073 is the experimental class's significant value, because 0.073 ≥ 0.05, the experimental class's data are also normally distributed. The class data are clearly normally distributed, according to the aforementioned facts.

To ascertain whether the sample is drawn from a homogeneous population or not, a homogeneity test is used. The F test or levene statistic is used in this homogeneity test, which is carried out with the use of a computer program, using posttest data from the control class and the experimental class. It is version 29.0 of IBM SPSS Statistics. One Way Anova's Test of Homogeneity of Variances is used to conduct homogeneity tests. Using a significant rate of 5% (α = 0.05), the homogeneity test's significance can be evaluated using the following judgment criteria: The data are homogeneous if significance (sig) ≥ 0.05, and non-homogeneous if significance (sig) < 0.05. Table 4 displays the outcomes of the computer program's analysis of the normalcy test data.

Table 4. Homogeneity Test Results of Control Group and Experimental Group

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Results Study Student	Based on Mean	3.303	1	69	.073
	Based on Median	2.933	1	69	.091
	Based on Median and with adjusted df	2.933	1	67.377	.091
	Based on trimmed mean	3.269	1	69	.075

Based on Table 4, the results of the homogeneity test can be seen in the section based on mean. The significance value is 0.073, which is greater than 0.05 and indicates that the value satisfies the criteria that the data is homogeneous or has the same variance.

With the aid of IBM SPSS Statistics Version 29.0, the t test was examined. When doing the test paired sample t-test, the basic rule of thumb is that if the significant value (2-tailes) > 0.05, Ho is rejected and Ha is accepted. While this is going on, if the significance value (2-tailed) > 0.05, Ho is accepted and Ha is denied. Table 5 displays the t test analysis' findings.

Table 5. Hypothesis Test Results (t-test)

	Actions	N	Mean	Std. Deviation	Std. Error Mean
Results Study	Using STEM Teaching Materials	35	72.29	15.163	2.563
	Not Using STEM Teaching Materials	36	47.50	12.277	2.046

It is evident from Table 5 above that there is a difference in the average value (mean) when STEM-based teaching materials are used versus when they are not. Whereas when using STEM-based teaching tools, the average is higher than when not using them. This indicates that there is a relationship between the outcomes of student learning and STEM-based digital teaching resources, as evidenced by the data on the results of hypothesis testing (t-test) in the experimental class and control class. Table 6 also contains a t test analysis of the outcomes from the posttest.

Table6. Results analysis t test on the results *posttest*

Independent Samples Test						
		F	Sig.	T	Df	Sig. (2-tailed)
Results Study	Homogeneous	3.303	.073	7.580	69	<,001
	Inhomogeneous			7.558	65.359	<,001

Based on Table 6 above, because the data used is homogeneous data, what is seen is the data in the homogeneous section. The significance value achieved in these data is < 0.001, which can be shown. According to the paired sample t-test's significance value of < 0.05, which was used as the foundation for decision-making,

Ho is rejected while Ha is approved. Table 7 is the next place to look to examine the outcomes of the t test analysis on the findings of the pretest.

Table 7. Results of the study of the t test on the results of the pretest

Independent Samples Test

		F	Sig.	T	Df	Sig. (2-tailed)
Results Study	Homogeneous	7.037	.010	1.407	69	.164
	Inhomogeneous			1.414	62.432	.162

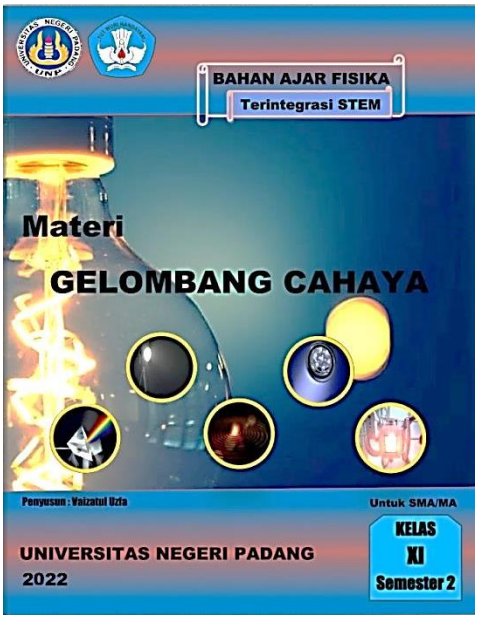
Based on Table 7 above, because the data used is homogeneous data, what is seen is the data in the homogeneous section. In these it is evident from the data that the significance value was < 0.164. According to the criteria used to make the decision in the test paired sample t-test, it was determined that the significance value was > 0.05, indicating that Ho was accepted and Ha was refused.

The initial settings for the experimental class, the control class, and the student learning results are nearly identical. After using STEM-based digital teaching materials, compared to the control class, the experimental class had different student learning outcomes. This variation demonstrates how digital teaching materials with a STEM focus have an impact on the learning results of students. It may be said that light wave-related STEM-based digital teaching resources have a big impact on how well students learn.

DISCUSSION

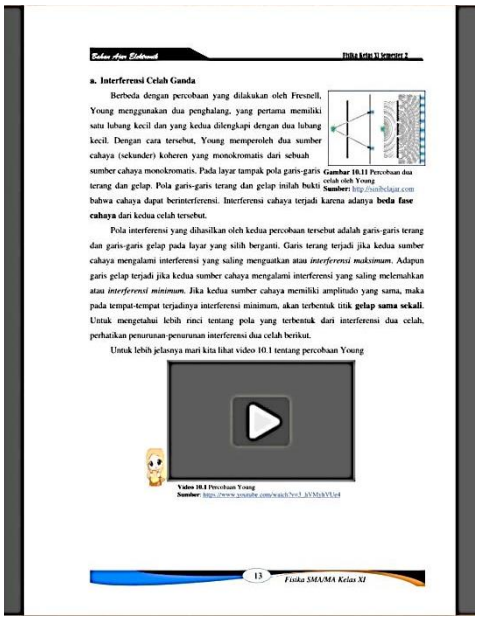
The results obtained are the application of STEM-based digital teaching materials to student learning outcomes. The resources used by instructors and students in the educational process are systematically structured materials or learning content [21]. The term "digital teaching materials" refers to instructional resources that utilize computers. [22]. Digital teaching resources may be accessed anywhere and its use is more effective and efficient than the use of printed teaching materials since it can be accessed at any time as long as there is an internet connection.

Based on research, with the existence of digital teaching resources, learning becomes more flexible. This is in accordance with the opinion of [6] the use of digital teaching materials will make the learning process more flexible because these teaching materials can be accessed via Handphones/computers as long as the cellphones/computers are still connected to an internet connection. In addition, digital teaching materials have an attractive appearance. Like the picture below:



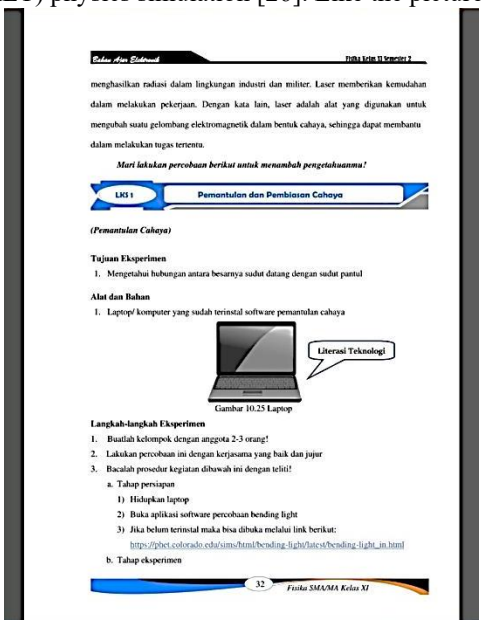
STEM-based digital teaching materials have a very attractive appearance so students will be more interested in reading and understanding the subject matter. In this teaching material there are animated pictures and videos related to the material presented. With this animated video, it will be easier for students to

comprehend the subject being studied and related to the four STEM components (science, technology, engineering, and math) [23]. The animated videos contained in these digital teaching materials will really help students to understand STEM components, especially the Technology and Engineering components. Like the picture below:

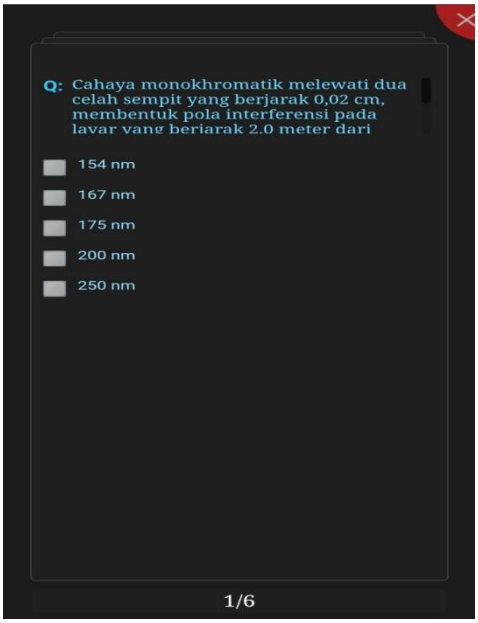


STEM-based digital teaching materials are also equipped with instructions and experimental activities that will serve as a manual for students to follow when performing experiments. The experiments carried out were experiments using virtual laboratories such as Phet Simulation which is a support for conducting practicums online [24]. The development of computer technology as a type of interactive multimedia product to imitate laboratory experiments on a computer is known as a virtual laboratory [25]. The virtual laboratory consists of animations, video images and tools used to carry out practicums.

In addition, virtual trials can also be opened via a link. With the link, it will be easier for students to access the virtual experiment, provided they have an internet connection. This virtual experiment is more efficient because the experiment will be faster than using a real laboratory experiment. Virtual laboratories using applied simulations of physics concepts can be used for the continuation of interesting physics learning, for example, Physics Educational Technology (PhET) physics simulation [26]. Like the picture below:



STEM-based digital teaching materials are also equipped with evaluations. Evaluation of teaching materials is an evaluation that can be done directly by students and obtain a score from the evaluation. Evaluation can help students improve their abilities and will be a benchmark for how well the achievements are obtained during the learning process [27]. Like the picture below:



Based on the results of the investigations, it was discovered that the control class' mean values were lower than those obtained from the experimental class. This is because the experimental class receives different treatment than the control class does. The presence of STEM-based digital teaching resources has an impact on or has the potential to enhance student learning outcomes. In addition to having animated images and videos, this educational resource also has a virtual lab that helps improve students' comprehension of the content being covered. Students will learn more effectively with animated images and videos since they can more easily understand the explanation in this animated video. This matter in accordance with [3] which says that digital-based teaching materials can increase student understanding through pictures and videos.

The existence of a virtual laboratory in STEM-based digital teaching materials can also increase student understanding so that it can improve student learning outcomes. This is consistent with the viewpoint of [28] she asserts that the use of virtual laboratory simulations has an impact on students' conceptual understanding. The difference between the means of the control and experimental classes, with the experimental classes' means being higher, serves as proof for this.. In addition, the existence of a virtual laboratory carried out in the experimental class can also increase creativity, especially in the engineering process, this is evident when students carry out these experimental activities.

Based on the elaboration that has been conveyed that using light wave-related STEM-based digital teaching resources has an effect on student learning outcomes in physics learning at senior high school. Therefore, researchers recommend STEM-based digital teaching materials for in the academic process, teachers and students serve as learning resources.

There were many restrictions and limitations during the implementation of the research. The researcher's flaws are the root of this restriction. It is hoped that the limitations that occurred during the research can be corrected in the future. The limitations faced by researchers are:

The first limitation is that the material contained in STEM-based digital teaching materials is limited to light wave material. The solution to this limitation is for digital teaching materials to be made based on all material contained in class XI so that they are able to produce more complete STEM-based digital teaching materials.

The second limitation is the integration of STEM into digital resources for educators. This digital teaching material is still limited to a few examples of integration consisting of light reflection, light refraction and interference in multiple slits. The solution to this limitation is that in the future examples of integrating STEM into teaching materials can be added to make it better

The third limitation is when it comes to conducting virtual laboratory experiments. At the time of conducting the experiment there were still many students who did not have an internet quota so that the virtual experiment could not run smoothly. The solution to this limitation is that in the future the school should facilitate students such as free WIFI so that when using digital teaching materials it can run smoothly

IV. CONCLUSION

On the basis of the findings from the analysis and discussion of the research data, it can be said that STEM-based digital teaching materials on light waves have an impact on students' learning outcomes in physics

learning. This is clear from the outcomes of the hypothesis test or t test that was performed on student learning outcomes, specifically from the analysis results produced, which are the sig (2-tailed) posttest value of < 0.001. Based on the criterion, Ho is disqualified if this value is less than 0.005. The t-test analysis for the pretest yielded a result of 0.164, and indicates that this value is higher than 0.05 and that Ho is therefore accepted. This indicates that, when compared to the control class, which did not use STEM-based digital teaching materials, the results of the posttest t test in the experimental class demonstrate that STEM-based digital teaching materials had an impact on student learning outcomes at senior high school.

V. SUGGESTIONS

The researchers offer the following recommendations in light of their research:

1. In order to prevent students from becoming disinterested, to keep them constantly motivated, and to engage them in their learning, teachers must use learning models that differ depending on the kind of information to be taught.
2. For students, it is necessary to improve learning outcomes by studying alone or discussing with friends and being more active in learning activities.
3. There is a need for further research on STEM-based digital teaching materials on different topics and materials.
4. STEM integration in this study there are three examples of STEM integration. Other research can add better examples of STEM integration.

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