The Effectiveness of STEM Learning

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The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding

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Abstract. This study aims to see the effectiveness of the learning approaches toward scientific attitudes and conceptual understanding. The research method used was quasi-experimental research with a pretest-posttest control design. The scientific attitude data was obtained using a questionnaire while the conceptual understanding data was obtained through a test instrument in the form of a description item. The results of the study are (1) there are differences in scientific attitudes and students' conceptual understanding taught using STEM learning approach and conventional learning, (2) there is a difference in conceptual understanding between students who were taught using the STEM learning approach and conventional learning, and (3) there are significant differences in scientific attitudes between students who were taught using the STEM learning approach and students who were taught using conventional learning.

Keyword: STEM Approach; Scientific attitude; Understanding of the Concept of

1. Introduction

The current industrial revolution era we are facing is the industrial era 4.0 where technology has become the basis in human life [1]. An era that impacts all aspects of human life, such as education [1–3]. Education itself is one of the activities and efforts to create potential and qualified human resources [5]. The education system in the world is currently facing global competition and is undergoing a transformation that requires learning experiences which are in accordance with the times [6]. The rapid development of education has an impact on the use of technology in the learning process, including science learning [6,7].

Science learning emphasizes students in providing learning experiences that are directed through scientific development and attitudes. Science learning is directed to find out the answers to problems so that it can help students gain a deeper understanding of the nature [5]. One part of science learning in senior high school is physics [9]. Sinaga and Simarmata state that physics learning is often seen as an abstract science that is theoretical, less interesting, seems difficult, and it is also difficult to understand and master [10].

The learning process is an activity carried out by the teacher to provide direction to students to have a correct understanding [11]. if the physics learning learned by only receiving information from the teacher in one direction, it will cause students to become passive and tend to get bored quickly. Teacher-centered learning can inhibit the development of students' scientific attitudes. Teachers in-class learning activities should be able to foster students' scientific attitudes and help them develop

scientific attitudes [12,13]. Scientific attitude is an attitude that must exist in a scientist or an academic when facing scientific problems and is one of the factors that influence learning outcomes [12, 14]. Teacher-centered learning can also lead to a poor understanding of the mastery of physics conceptual [10]. Students cannot develop their reasoning abilities if they are not yet familiar with the material being studied. Therefore, teachers need to check student understanding before continuing the material because the material in mathematics is interrelated between one another[17].

The explanation above explains that in learning, not only scientific attitudes are developed, but students' concept understanding also needs to be developed so that the students can define and generate ideas, facts, mastering conceptual, and theories [18]. Physics learning is not only emphasized on the knowledge of facts and memorization of formulas but also needs to be supplemented by understanding basic conceptual [17,18].

The results of a teacher interview at one of the senior high schools at Muara Enim regency showed that students were still less active in the learning process. The teacher said that the lack of active students was due to a lack of conceptual understanding and scientific attitudes. Also, the teacher emphasized on difficulties experienced by the teacher in controlling students. Besides the teachers, the researchers also conducted interviews with the students. This was done because the researchers feel the need to get information from different points of view. The results of interviews from several students showed that the physics learning process was still monotonous. The students had difficulty understanding the material and the source of the material was unvaried.

After seeing the description of the problems at the school, the researchers tried to overcome them by using the right approach in learning. A learning approach that can make students actively participate in learning and can construct their knowledge. To achieve scientific attitudes and students' conceptual understanding, an appropriate learning approach is needed. There are many learning approaches, including Scientific [18], Open-Ended [21], and STEM (Science, Technology, Engineering and Mathematics) [22], etc.

The researcher decided to implement the STEM approach to overcome problems related to scientific attitudes and students' conceptual understanding. The STEM learning approach is an integration of science, technology, engineering, and mathematics that are suggested to obtain success and skills. STEM learning can create human resources who think critically, logically, systematically and increase students' interest in learning [22- 29].

The use of the STEM approach in learning will encourage students to design, develop, and utilize technology, as well as to be able to hone their cognitive, manipulative, and affective knowledge [27-28]. It can also help the students to analyze and solve problems that occur in real life so that they are ready to carry out the learning process [29-30].

Based on previous research, STEM can train the students to think critically [31,32] and think creatively [33-34]. Although there exists a lot of research on the use of the STEM approach, the difference between this research and the previous one is in the dependent variable, namely scientific attitudes, conceptual understanding, and the application of the STEM approach on the momentum and impulses material. The researchers consider it is necessary to see the effectiveness of the use of the STEM (Science Technology, Engineering, and Mathematics) approach toward the students' scientific attitude and conceptual understanding.

2. Method

The method used was quasi-experimental research with a pretest-posttest control group design [39]. The population in this study was the tenth-grade students of SMA Negeri 1 Semende Darat Laut, Muara Enim, South Sumatra. The sample consisted of two classes selected by cluster random sampling. Class XI Science 1, as the experimental class, was given a treatment of STEM learning approach and Class XI Science 2, as the control class, was given a treatment of conventional learning. Data collection techniques used were tested to get the data on conceptual understanding and questionnaires to get the data on scientific attitude.

Multivariate Analysis of Variance (MANOVA) was used at the hypothetical testing stage. The data on scientific attitude and concept understanding was obtained after the samples were given treatment. Statistical tests were performed at a significance level of 5% using the SPSS 20.00 program. Before the data was used for hypothesis testing, the data must meet the prerequisite tests of the Multivariate Analysis of Variance (MANOVA). MANOVA requires that the data must be normally distributed and homogeneous.

3. Results and Discussion

3.1 The Results of the Research

The data obtained from the test and questionnaires regarding the use of the STEM learning approach and conventional learning. The average score in the study can be seen in table 1.

Table 1. Data Distribution of the Research Result

Statistics	Scientific Attitude		Conceptual Understanding	
	Experimental	Control	Experimental	Control
Mean	74	85	65	72
Median	80.00	67.34	84.44	66.67
Standard Deviation	6.83457	10.72469	7.13305	9.06029
Variance	46.11	115.019	18.665	25.412
Max Score.	89.00	80.67	95.56	75.56
Min score.	67.00	45.00	77.78	57.78

Table 1 shows that the average score of students' scientific attitudes using the STEM approach is higher than the average scores of students' scientific attitudes using conventional learning. Similarly, the average score of students' conceptual understanding using the STEM approach is higher than the average score of student learning outcomes using conventional learning. Before testing the hypothesis, the prerequisite tests were performed which include the normality of data distribution and the homogeneity of variance. The prerequisite tests have fulfilled the requirements for hypothesis testing.

To test the first hypothesis, the Between-subjects Effects Test was used which results are shown as in table 2.

Table 2. The Result of Between-Subjects Effects Tests

Source	**Dependent Variable**	**Sig.**
Class	Scientific Attitudes	.000
	Understanding	.003

It can be seen in table 2 that the scientific attitude of students who were taught using the STEM learning approach produces significance less than 0.05. This means that the H_0 is rejected and the H_1 is accepted. It proves that there is a significant difference in scientific attitudes between the STEM learning approach and conventional learning. To test the second hypothesis, the Between-subjects Effects test was also used. The results of the analysis are presented in Table 2. It can be seen that the significance of students' conceptual understanding taught using the STEM learning approach is less

than 0.05. This means that H_0 is rejected. The hypothesis H_1 indicates a significant difference in students' concept understanding taught using the STEM learning approach compared to conventional learning. To test the third hypothesis, the Multivariate test was used. The results of the analysis are presented in Table 3.

Table 3. The Summary of Multivariate Test Results

Effect		Sig.
class	Pillai's Trace	0.000
	Wilks 'Lambda	0.000
	Hotelling's Trace	0.000
	Roy's Largest Root	0.000

Table 3 summarizes the Multivariate test results. It is known that the values of the Pillai's Trace, Wilks' lambda, Hotelling's Trace, and Roy's Largest Root are smaller than 0.05. Thus, it can be concluded that there are significant differences in scientific attitudes and students' conceptual understanding. Based on the results of the MANOVA test analysis, the scientific attitude and learning outcomes of students who were taught using the STEM learning approach are better than the conventional learning model.

The STEM learning approach is said to be effective if after using this approach, there is an increase in scientific attitudes and students' conceptual understanding. To know the effectiveness of the STEM learning approach toward scientific attitudes and students' conceptual understanding, the effect size formula was used. Effect size indicates the extent to which a variable affects other variables in a study or shows how effectively a variable affects other variables [5]. The results of the analysis are presented in table 4.

Table 4. Results of the Effect Size Analysis

Class	Average Gain	Standard Deviation	Effect Size	Description
Experimental	0,5638	10,88	>0,8	High
Control	0,2166	8,711		

After obtaining the effect size from the data, then the step next was to compare the value of the effect size with the table to find out how much STEM learning approach influenced the scientific attitudes and conceptual understanding. The STEM learning approach was implemented in the experimental class and conventional learning was implemented in the control class. It can be seen that the average value of the experimental class was higher than the control class. The distribution of the mean values of pretest and posttest the experimental class and the control class are respectively shown in Table 2 and Table 4.

3.2 Discussion

Based on the results of the data analysis, it is found that there are differences in the STEM learning approach towards scientific attitudes and conceptual understanding. From the analysis of the first hypothesis, there are differences in scientific attitudes and conceptual understanding of those who were taught using STEM approach and conventional learning. The data proves that this learning can

develop scientific attitudes and students' conceptual understanding. The steps for the STEM approach in the Inquiry model are presented in chart 1[40].

Figure 1. Steps of the STEM Approach in the Inquiry Model

Figure 1 shows the steps of the STEM learning approach in the Inquiry model used in the experimental class. These steps encourage students to make an observation of various phenomena or contents and then construct questions from such phenomena. The students are motivated to be able to solve existing problems and try to communicate them.

Figure 2. Presents a Problem

In the second stage after making an observation and obtaining information about various phenomena related to science, the students developed and used the models or examples. In this step, the students were asked to see through models and simulations to help them develop the observed information.

Figure 3. Students are Given the Opportunity to Solve Problems

In the third stage, the students were asked to plan and carry out scientific investigations to obtain data. For the innovations obtained to be more meaningful, the researcher asked the students to generate new ideas that are worthy to be applied in social life. Then, in the fourth stage, after the students conducted scientific investigations and obtained data, the data obtained was then analyzed and then interpreted.

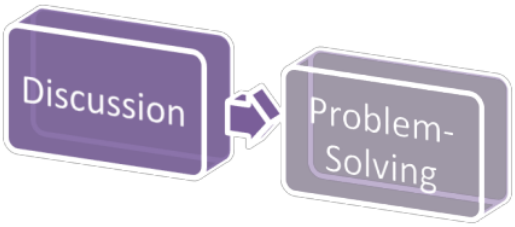

Figure 4. How to iterpret data

In the fifth stage, the students used mathematical thinking and computational thinking to build simulations and analyze the data. In the sixth stage, the students were able to construct explanations related to learning activities and able to design new solutions to problems found in learning. In the seventh stage, the students engaged in an argument to clarify the concept of learning and the best solution to a problem and then reinforced them with strong data evidence to maintain a conclusion. In the last stage, the students obtained information from the learning activities and then evaluate and communicated the results of the findings to conclude.

The second hypothesis regarding the effectiveness of STEM learning toward the concept of understanding based on data analysis shows the results of the Between-subjects Effects test are 0.003 <0.05. It can be concluded that H_0 is rejected and H_1 is accepted.

The results of previous studies are in line with research conducted by the researchers where the STEM learning approach provides an increase in scientific attitudes and students' conceptual understanding. This happens because STEM learning requires students to be able to integrate the four aspects of the STEM approach in learning. Four aspects of the STEM approach can encourage students to hone their thinking skills Besides, the application of the STEM approach in learning can encourage students to understand and manipulate natural phenomena, utilize technology, design or arrange, and interpret solutions from data and calculation results.

4. Conclusion

Based on the results of research and data analysis, the researchers concluded that there are differences in the effectiveness of learning physics using STEM learning in improving scientific attitudes and students' conceptual understanding. The STEM learning approach is more effective than conventional learning in improving scientific attitudes and students' conceptual understanding. It can be concluded that the differences in student learning outcomes can be used to determine the increase of conceptual understanding between STEM learning and conventional learning.

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