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.

| 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.

| 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.

| Class          | Effect              | Sig.  |
|----------------|---------------------|-------|
|                | 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.

| 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.

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 interpret 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 H₀ is rejected and H₁ 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.

References

[1] D. Saregar, Antomi. Giyoto. Pawe, T I. Pricilia, A. and Astriawan 2019 How to Design Physics Posters Learning Media with Islamic Values in Developing Learning Motivation and Student Character? J. Phys. Conf. Ser.
[2] S. Priatmoko 2018 Memperkuat Eksistensi Pendidikan Islam di Era 4.0 Ta'lim. I 2 2
[3] R. Noor, A. Binti, R. Ali, and M. B. Ibrahim 2018 Preparation of Politechnic Sultan Mizan Zainal Abidin (PSMZA) Lecturers in Facing The Industrial Revolution Flow 4.0 Persediaan Tenaga Pengajar Politeknik Sultan Mizan Zainal Abidin (PSMZA) di dalam Mengharungi Arus Revolusi Indusri. 6 181–190
[4] Iswan and Herwina 2018 Penguatan Pendidikan Karakteristik Perspektif Islam Dalam Era Milenial IR.4.0. 1 1 22
[5] A. Hidayah and Yuberti 2018 Pengaruh model pembelajaran POE (Predict- observe- Explain) terhadap keterampilan proses belajar fisika siswa pokok bahasan suhu dan kalor. I 1 21–27
[6] L. Siew, N. M., Amir, N., & Chong 2019 Persepsi Pre-Service Dan Guru In-Service Mengenai Pemecatan STEM Berbasis Proyek Untuk Ilmu Pengetahuan Melayu. 3 1 21–27
[7] I. A. P. F. Wu 2018 Penguatan Pendidikan Karakteristik Perspektif Islam Dalam Era Milenial IR.4.0. 1 1 22
[8] M. Dewi and R. A. Fitria 2019 Kebutuhan Pengembangan Modul Bimbingan Teknologi Informasi Dan Komunikasi (Tik) Terintegrasi Literasi Baru Era Revolusi Industri 4.0 Muharika J. Pendidik. Teknol. Inf. 6 1 80–86
[9] A. Muhamin and H. Soeprianto 2015 Pengembangan Media Kapasitor Dan Pengaruhnya Development Of Capacitor Media And Effect On Students ‘ Understanding Of Concept And Scientific Attitude. 11 I 59–72
[10] A. Restanti, Indri; Sudarti; Haarijanto 2015 Pengaruh Model Pembelajaran ROPES Dengan Teknik Talking Stick Terhadap Hasil Belajar Dan Keterampilan Proses Sains Siswa SMA Di Bondowoso J. Pendidik. 4 1 93–97
[11] Antomi Maharani, L. Rahayu, D I. Amaliah, E. Rahayu, R. and Saregar 2019 Diagnostic Test with Four-Tier in Physics Learning: Case of Misconception in Newton’s Law Material J. Phys. Conf. Ser.
[12] H. Sa and M. Kusasi 2017 Menggunakan Model Pembelajaran Inkuiri Terbimbing (Guided Inquiry) Pada Materi Kesetimbangan Kimia Increasing Scientific Attitude and Concept Understanding Using Guided Inquiry Model in Chemical Equilibrium. 8 1 79
[13] A. Harjono, A. W. Jufri, K. Arizona, and U. Mataram 2015 Implementasi Media Tiga Dimensi Kemagnetan Berbasis Sikap Ilmiah Siswa. 1 I
[14] A. Riyadi, J. Ardhuha 2015 Pengaruh Penerapan Model Pembelajaran Kontekstual Berbantuan Media Flash Terhadap. I 2
[15] K. A. Astiti 2018 Pengaruh Penggunaan Bahan Ajar Berbasis Konsep Fisika Siswa Materi Suhu Dan Kalor. 3 3 185–192
[16] Y. Wikrama, N. Riastini, and I made suarjana 2017 Pengaruh model pembelajaran inkuiri
terhadap minat baca dan pemahaman konsep ipa siswa kelas V sd. 5 2 1–11, 2017. [17] R. Hikamh 2017 Penerapan Model Advance Organizer untuk Meningkatkan Kemampuan Pemahaman Siswa J. SAP. 1 3 271–280 [18] A. Wibowo, K. Baru, and K. Selatan 2017 Pengaruh Pendekatan Pembelajaran Matematika Realistik dan Saintifik terhadap Prestasi Belajar, Kemampuan Penalaran Matematis dan Minat Belajar The Effect of Teaching Realistic and Scientific Mathematics Approach on Students Learning Achievement, Mathematical Reasoning Ability, and Interest. 4 1–10 [19] A. Saregar 2016 Pembelajaran Pengantar Fisika Kuantum Dengan Memanfaatkan Media Phet Simulation dan LKM Melalui Pendekatan Saintifik: Dampak Pada Minat Dan Penguasaan Konsep Mahasiswa J. Ilm. Pendidik. Fis. Al-Biruni. 5 53–60 [20] A. Saregar 2017 The Effectiveness Of The Arias Learning Model In Terms Of Scientific Attitudes : The Impact On J. Ilm. Pendidik. Fis. Al-BiRuNi. 6 2 255–263 [21] N. Faridah and A. N. Aeni 2016 Pendekatan Open-Ended Untuk Meningkatkan Kemampuan Berpikir Kreatif Matematis dan Kepercayaan Diri Siswa J. Pena Ilm. 1 1 [22] A. ; dkk Saregar, Antomi & Thahir 2019 The Effectiveness of STEM-Based on Gender Differences: The Impact of Physics Concept Understanding Eur. J. Educ. Res. 8 3 753–761 [23] D. Agustina 2017 Penerapan Pembelajaran Berbasis STEM (Science, Technology, Engineering And Mathematics) Untuk Meningkatkan Kemampuan Control Of Variable Siswa Smp Pada Hukum Pascal. 6 35–40 [24] T. N. Utami and A. Jatmiko 2018 Pengembangan Modul Matematika dengan Pendekatan Science, Technology, Engineering, and Mathematics (STEM) pada Materi Segiempat. 1 2 165–172 [25] H. P. Rivai and L. Yuliati 2018 Penguasaan Konsep dengan Pembelajaran STEM Berbasis Masalah Materi Fluida Dinamis pada Siswa SMA J. Pendidik. 3 1080–1088 [26] S. A. Toip and G. Hamdu 2018 Pedaddidaktika: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar Pengembangan Multimedia Interaktif Pelaksanaan Pembelajaran Outdoor Tema Daerah Tempat Tingga Berbasis STEM di SD. 5 4 111–120 [27] diyah ayu budi Lestari, B. Astuti, and T. Darsono 2018 Implementasi Iks dengan pendekatan STEM (science, technology,engineering,and mathematics) untuk meningkatkan kemampuan berpikir kritis siswa. 4 2 205 [28] S. Lou 2017 A Study of Creativity in CàC2 Steamship-derived STEM Project-based Learning. 8223 6 2387–2404 [29] T. Education, E. Wiebe, A. Unfried, and M. Faber 2018 The Relationship of STEM Attitudes and Career Interest 2 1. 14 10. [30] S. Reinhold, D. Holzberger, and T. Seidel 2018 Encouraging a career in science : a research review of secondary schools ‘ effects on students’ STEM orientation secondary schools’ effects on students’ STEM orientation Stud. Sci. Educ. 7267 1–35 [31] R. Farwati, A. Permanasari, H. Firman, and T. Suhery 2017 Integrasi Problem Based Learning dalam STEM Education Berorientasi pada Aktualisasi Literasi Lingkungan dan Kreativitas dalam Prosiding Seminar Nasional Pendidikan IPA. 198–206. [32] Y. Safitri, T. Mayasari, and J. Handhika 2018 Interdiciplinary Stem Module Of Guitar Based Scientific Literacy: Modul Stem Pada Gitar Berbasis Literasi Sains Semin. Nas. UNIPMA. 109 [33] I. Ismail, A. Permanasari, and W. Setiawan 2016 Efektivitas Virtual Lab Berbasis STEM dalam Meningkatkan Literasi Sains Siswa dengan Perbedaan Gender STEM-Based Virtual Lab Effectiveness in Improving the Scientific Literacy of Students with Gender Differences J. Inov. Pendidik. 2 2 2. [34] J. Afriana, A. Permanasari, and A. Fitriani 2016 Penerapan Project Based Learning Terintegrasi STEM untuk Meningkatkan Literasi Sains Siswa Ditinjau dari Gender J. Inov. Pendidik. IPA. 2 2 2. [35] M. Syukri, H. Lilia, and M. M. T. Subahan 2013 Pendidikan STEM dalam Entrepreneurial
Science Thinking ‘ESciT’: Satu Perkongsian Pengalaman dari UKM untuk Aceh Aceh Dev. Int. Conf. 105–112

[36] F. . Ekosari 2018 The Effect Of STEM-PBL On Critical Thinking And Cognitive Outcome’s E-Journal Pendidik. IPA. 7 5 239–244

[37] A. Ismayani 2016 Pengaruh Penerapan STEM Project- Based Learning Terhadap Kreativitas,” J. Math. Educ. 3 264–272, 2016.

[38] J. Siswanto, 2018 Keefektifan Pembelajaran Fisika dengan Pendekatan STEM untuk Meningkatkan Kreativitas Mahasiswa J. Penelit. Pembelajaran Fis. 9 2 133–137.

[39] Sugiyono 2015 Metode Penelitian Pendidikan Pendekatan Kuantitatif, kualitatif dan R&D. (Bandung: Alfabeta)

[40] R. W. Bybee 2011 Scientific and Engineering Practices in K-12 Classrooms Understanding A Framework for K-12 Science Education NSTA’s journals. 1–7

[41] A. Permanasari 2016 STEM Education: Inovasi dalam Pembelajaran Sains,” in Prosiding Seminar Nasional Pendidikan Sains, 23-34.