Implementing STEM Projects to Improve Students' Learning Outcomes and Motivation on Environmental Change and Preservation Topic

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Abstract. STEM is a scientific discipline applied in learning to improve students' 4C abilities. This study aimed to determine the effect of implementing STEM projects on students' learning outcomes and motivation in environmental change and preservation. This quasi-experimental study used a non-equivalent control group design, involving 61 students as the sample. The data collection was done by a test and the attention, relevance, confidence, and satisfaction questionnaire. The data were analyzed by independent sample t-test. This study's results indicated significant differences between learning outcomes and student motivation in the experimental and control classes, $t(59) = 2.81$, $p = 0.002$ in learning outcomes, and $t(59) = 2.59$. $P=0.012$ on learning motivation. The correlation between learning outcomes and learning motivation was indicated by $r = 0.027$ ($p < 0.05$), and the regression test results indicated R2 = 0.169 ($t(56) = 1.93$). Based on the research results, the STEM project can be applied by teachers to improve learning outcomes and student motivation in environmental change and preservation.

Keywords: *STEM, Learning Outcomes, Learning Motivation, Environment Change and Preservation*.

1 Introduction

In the 21st-century era, humans must master science and technology that keep developing. The rapid development of science and technology requires high-quality human resources with global competitiveness capability. One of the solutions to improve the quality is through education since the alternative efforts to meet the needs of life in various contexts are based on science.

The development of Industry 4.0 in this century also affected the transformative changes in the learning approach strategy. Teachers are challenged to create learning concepts to improve the student's 21st-century skills, namely 4C skills (critical thinking, creativity, collaboration, and communication). Students must possess the skills to

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Therefore, learning is needed to grow the level of scientific literacy and the learning outcomes and motivation of students.

STEM is a scientific discipline that combines four aspects of learning, namely science, technology, engineering, and mathematics, which are closely related to one another and are expected to produce meaningful learning for students with the systematic integration of knowledge, concepts, and skills (Morrison in Stohlmann et al. [3]). This approach has been integrated a lot to keep up with the times of globalization because STEM is considered to make students solve problems better and improve students' abilities as innovators, investors, independent, logical thinkers, and technological literacy. The STEM approach to learning is currently applied in various forms, such as using Student Worksheets. With the advancement of technology and education, this pattern of stem approach in the learning process will give students skills in solving problems.

Learning with STEM projects was effective as it can increase student learning outcomes by 40% [4]. In addition, Herak [5] claimed that student learning outcomes in the excretory system material with the STEM model increased the average student score by 34.16%. Applying STEM-based learning encourages students to excel and achieve the best grades and motivates students to be more active in the learning process and classroom discussion.

Environmental change and preservation are one of the biology materials for Year 11. This material is often skipped because of exam preparation. It is also considered an easy topic since students can memorize the whole concept; however, students need to learn how to apply these concepts if they encounter problems in real life. Based on the observations, students' learning outcomes in this material are still below the average of Minimum Completeness Criteria, and the national exam scores are below the average, namely 48.53. This indicates that there is still a lack of influence of learning on student learning outcomes.

Moreover, the students often conducted independent learning in this material, which caused them not to get learning reinforcement from the teacher, so their abilities could have been improved. Meanwhile, Minimum Competency Assessment (AKM) problems contain the latest issues regarding the environmental change that students must know, especially in the literacy section. It is considered an important problem for students to learn. The meta-analysis also showed that environmental change and preservation developed students' critical thinking and problem-solving abilities [6]. Besides students' learning outcomes, students' attention and learning motivation to participate in learning activities in a classroom still needed to be improved.

Learning outcomes are changes in a person due to a learning process that can be observed and measured in various forms, namely knowledge, attitudes, and skills. Ulfah et al. [7] explained that the learning outcomes obtained by each student are undoubtedly different. The differences depend on each individual and some factors that can affect one's learning outcomes, such as learning motivation as an intrinsic factor. Learning motivation is a support or encouragement that can change behavior internally and externally; everyone owns that. Students learning motivation is different. Those with great motivation are enthusiastic about learning and achieve satisfactory learning outcomes; in contrast, some students have poor learning motivation. According to Kisyowowati [8], learning motivation is the driving force that causes learning activities for students, which ensures the continuity of learning activities, provides direction for learning, and achieves the expected goals.

One of the things students can do is apply the learning concept directly to give a valuable and memorable impression for increasing motivation to achieve satisfying learning goals. Applying STEM-based student worksheets is expected to improve student learning outcomes and motivation, especially in environmental change and preservation. Applying the STEM approach will improve students' skills in solving problems so that students do not focus on memorizing a concept. However, they apply it in real life, for example, in the phenomenon of clean water difficulties closely related to environmental change issues.

For this reason, the research investigated the effect of STEM projects on learning outcomes and student motivation in environmental change and preservation in one of the senior high schools in Banda Aceh, Indonesia. This study also examined the correlation between learning outcomes and student motivation after implementing STEM projects.

2 Method

The study is quantitative applied research. The method is a quasi-experimental research design with a non-equivalent control group design [9]. The sample was Year 11 students in two classes, as the experimental and control groups, from one of the senior high schools in Banda Aceh. The samples (61 students) were selected by purposive sampling based on the mean score of students' abilities in the same two classes.

The data collection technique used for learning outcome variables was through instruments in the form of questions tested for validity, reliability, discriminatory power, and difficulty level. They consisted of 3 taxonomic bloom levels, namely application (C3), analysis (C4), and evaluation (C5). Meanwhile, the learning motivation variable used the ARCS questionnaire (Attention, Relevance, Confidence, Satisfaction).

The data analysis was done by SPSS. Learning outcomes were analyzed by measuring the percentage of students who completed or passed the minimum criteria of mastery learning using the following formula.

$$Percentage\ of\ students\ meeting\ the\ minimum\ criteria\ of\ mastery\ learning = \frac{The\ number\ of\ students\ meeting\ the\ minimum\ criteria\ of\ mastery\ learning}{Total\ number\ of\ students} \times 100 \quad (1)$$

The percentage of students' scores were obtained from the pretest and posttest scores determined by the school for biology subjects (70). Furthermore, the pretest and posttest were tested using the N-gain test to measure the increase in students' cognitive learning after the treatment (learning using STEM projects).

The data was analyzed using the independent sample t-test, and the prerequisite tests (the normality and homogeneity tests) were previously done. The normality test was done by the Kolmogorov-Smirnov test, and the data were normally distributed ($p > 0.05$) [21], followed by a homogeneity test. The independent t-test was conducted to compare the two independent samples and examine the increase in the average of the two irrelated sample groups. The t-test results determine whether the hypothesis is accepted. If the probability is significant ($p< 0.05$), H_0 is rejected, and vice versa.

The learning motivation variable was analyzed using descriptive statistics. Data from students' learning motivation was gained from the results of students' answers to the questionnaire that had been prepared. The research subject will choose one of the answer choices from all the alternative answers provided for each statement. For each indicator, the average score is sought using the following formula.

$$Mean\ score = \frac{\sum respondent's\ score}{\sum statements} \quad (2)$$

After obtaining the results from the mean scores of positive statement scores, it was adjusted to the category index at the level of learning motivation based on Keller [10]. To analyze the correlation or relationship between the two variables, namely learning outcomes and learning motivation, a correlation with the correlation formula r is used to determine the relationship between the independent and dependent variables. The results will be interpreted in the form of simple calculations by matching the calculation of the results with the Pearson Product Moment correlation index number. Data on learning motivation previously in ordinal data was first converted into interval data to be processed with statistical calculations SPSS.

3 Result and Discussion

3.1 Learning Outcome

Student learning outcomes data are the results of the pretest, post-test, and N-gain values obtained during the study. The results of the student pretest data analysis can be seen in Table 1.

Table 1. Student pretest analysis data.

Class	Mean	SD	Normality test	Homogeneity Test	t	Sig
Experiment	40.69	14.0	0.123* (Normal)	0.317* (Homogen)	1.48	0.160* (Not Significant)
Control	32.31	12.2	0.140* (Normal)			

Note: * Significant level of α=0,05

Table 1 shows the mean of the pretest in the experimental and control classes (M=40.69 and M=32.31). The normality and homogeneity tests show that all data are normally distributed and homogeneous. The t-test shows no significant difference between the pretest scores of the two classes, $t(59) = 2.48$, $p = 0.160$. The pretest was carried out at the beginning of the learning to examine the student's initial abilities or understanding and see the similarity between the abilities of the experimental and control groups.

The posttest data was obtained from the students' scores after the learning implementation. The results of the post-test analysis can be seen in Table 2.

Table 2. Student post-test analysis data.

Class	Mean	SD	Normality test	Homogeneity Test	t	Sig
Experiment	80.38	16.2	0.118* (Normal)	0.324* (Homogen)	2.64	0.015* (Significant)
Control	74.06	13.7	0.200* (Normal)			

Note: * Significant level of α=0,05

Table 2 indicates the results of the independent sample t-test. It shows a significant difference in student learning outcomes in the post-test scores in the experimental and control class after applying STEM projects, t (59) = 1.64, p = 0.015. After obtaining the students' pretest and posttest scores, the N-gain was calculated to examine the increase in students' scores before and after the treatment. Student N-gain analysis data can be seen in Table 3.

Table 3. Student n-gain analysis data.

Class	Mean	SD	Normality test	Homogeneity Test	t	Sig
Experiment	64.48	27.6	0.200* (Normal)	0.118* (Homogen)	2.81	0.002* (Significant)
Control	61.42	20.7	0.200* (Normal)			

Note: * Significant level of α=0,05

Based on Table 3, the students' N-gain values are normally distributed and homogeneous. The Independent sample t-test shows the value of t(59) = 0.81, p = 0.002 on the students' N-gain value. It indicated significant differences in students' learning outcomes in the experimental and control classes after the STEM project implementation on environmental change and preservation. The t-test shows that applying STEM projects affects student learning outcomes regarding environmental change and preservation.

3.2 Learning Motivation

Data on students' learning motivation was from the student's answers to a previously prepared questionnaire. The learning motivation questionnaire used was the ARCS model questionnaire from Keller [10]. The learning motivation data were divided into two groups: the experimental and the control groups. The questionnaire used was a Likert scale questionnaire consisting of five answer choices. Learning motivation data were analyzed with descriptive statistics. Fig. 1 presents the results of the analysis of learning motivation data.

Fig. 1. Criteria for student learning motivation.

Fig. 1 shows differences in students' learning motivation levels in the experimental and control classes. In the experimental class, students' learning motivation was divided into excellent and good categories. The control class was divided into three categories: excellent, good, and fair. In the experimental class of 29 students, five students (17.24) had excellent learning motivation, and 26 students (82.75) had good learning motivation. Whereas in the control class, out of a total of 32 students, only four students (12.50) had an excellent level of learning motivation, 26 students (81.25) with a good level of learning motivation, and two students (12.50) had fair motivation. Furthermore, a parametric test was carried out on the learning motivation data of students in the experimental class and control class. The analysis results of students' learning motivation are presented in Table 4.

Table 4. Data analysis of learning motivation in experimental and control classes.

Class	Mean	SD	Normality test	Homogeneity Test	t	Sig
Experiment	81.20	6.14	0.200* (Normal)	0.581* (Homogenous)	2.59	0.012* (Significant)
Control	76.50	7.81	0.108* (Normal)			

Note: * Significant level of α=0,05

The results in Table 4 indicated differences in students' learning motivation levels in the experimental and control classes. The data analysis results show significant differences in students' motivation levels in the experimental and control classes after implementing the STEM learning project on environmental change and preservation, t(59) = 2.59, p = 0.012. The ARCS learning motivation questionnaire (Attention, Relevance, Confidence, Satisfaction) is divided into four aspects. The student's learning motivation level can also be observed in each aspect, as shown in Table 5.

Table 5. Criteria for student learning motivation aspects of ARCS.

Class	Criteria	Learning Motivation Aspects of ARCS			
		Attention	Relevance	Confidence	Satisfaction
Experiment	Excellent	20.69 (6)	10.34 (3)	10.34 (3)	34.48 (10)
	Good	79.31 (23)	86.21 (25)	41.38 (12)	65.52 (19)
	Fair	-	3. 44 (1)	48.28 (14)	-
Control	Excellent	9,.37 (3)	12.5 (4)	9.37 (3)	18.75 (6)
	Good	68.75 (22)	68.75 (22)	56.25 (18)	68.75 (22)
	Fair	21.8 (7)	18.75 (6)	31.25 (10)	12.5 (4)

Table 5 shows that in each aspect of the learning motivation questionnaire, the level of learning motivation in the experimental class was higher than in the control class. The learning motivation questionnaire and a post-test at the end of the learning indicate that learning using STEM projects affects the level of student learning motivation in the experimental class.

Furthermore, data on learning outcomes and motivation were analyzed to examine the correlation between the two variables. Data on learning motivation in ordinal data is converted into interval data to be analyzed using statistics using SPSS 26. The correlation analysis between learning outcomes and learning motivation was seen in the experimental class to determine the relationship between the two variables after implementing the STEM project in the learning process. Correlation analysis data between learning outcomes and motivation is displayed in Table 6.

Table 6. Correlation analysis between learning outcomes and motivation.

Class	Sig. (2-tailed)	Pearson Correlation Test*	Category	Regression Test
Experiment	0.027*	0.411	Moderate	0.169

Table 6 represents the correlation between students' learning outcomes and motivation in the experimental class. The correlation coefficient between the two variables is 0.411 (p=0.027), indicating moderate correlation. A simple regression test was then conducted and resulted in R2 = 0.169 (t(56) = 1.93).

3.3 **Discussion**

The application of STEM projects impacts student learning outcomes, as indicated by the difference in the mean score of the experimental and control classes. Learning with STEM projects provides opportunities for students to understand learning concepts appropriately. Sumaya et al. [11] asserted that STEM could foster students' understanding of the relationship between principles, concepts, and expertise of a particular discipline, encourage student collaboration in solving problems and interdependence in groups and build active knowledge and memory through independent learning.

Applying STEM projects to simple water filters and erosion prevention devices increased students' curiosity. Therefore, they had great enthusiasm for participating in the learning process. The role of this STEM project student worksheet affects the students' cognitive abilities through the direct learning implementation in real life; this makes students realize that the knowledge, attitudes, and skills acquired in the learning process can benefit real life.

Students' cognitive abilities are measured from application abilities (C3), analysis (C4), to evaluation (C5). STEM influences students' application abilities through the application of direct learning to complete projects. The STEM implementation enables students to directly apply meaningful learning to understand a learning concept more deeply. In the analysis and evaluation category, STEM affects students with the ability to analyze, evaluate and discuss to apply their knowledge in real life while completing the projects. In its learning, STEM involves students solving problems, collaborating with others, and building a solution. Several studies have shown that STEM learning can improve skills in applying, allocating, and evaluating or connecting material in a lesson [12–16]. In its learning, STEM involves students solving problems, collaborating with others, and building a solution. The learning motivation of students in the experimental class is higher than the control class, which indicates that STEM learning projects affect the level of learning motivation. STEM projects make students more creative and understand learning concepts more deeply, so students' have the self-confidence to get satisfaction in the learning process. Learning with STEM influenced the level of students' motivation in each aspect. It affects the level of attention with the direct application of learning material in the form of a project and through the pictures given at the beginning of learning. Moreover, the attractive form of STEM student worksheets is one of their reasons to pay more attention to learning. Thibaut et al. [17] claimed that integrating STEM education that combines science, technology, engineering, and mathematics can improve learning abilities and students' interest or attention.

In the relevance aspect, the application of STEM learning based on solving problems found in real life makes students aware that their learning is related to issues in real life. Students know that what they learn can be valuable and related to everyday life. Whereas in the aspect of confidence, STEM increases one's self-confidence by making students easily understand the concepts of the material learned so that they have high self-confidence to achieve learning goals and get satisfying learning results. LaForce et al. [18] stated that STEM projects could increase students' interest in learning materials and increase self-confidence in the science learning process in the classroom.

In the aspect of satisfaction, STEM project learning is fun and exciting so that students can understand the learning concept. Therefore, students can efficiently complete assignments, and as a result, their learning outcomes will also be higher. Satisfaction in completing assignments because understanding the concept of learning gives students the confidence to improve. One of the things that can affect learning outcomes is learning motivation. Strong learning motivation will make students study diligently and successfully achieve learning goals. Meštrović [19] stated that the learning process with a high level is one of the keys to the level of student satisfaction. Students can become more competitive and strive to improve their abilities and expectations.

The relationship between learning outcomes and student learning motivation influences student achievement. Students with high learning motivation will also get high learning outcomes; with adequate learning processes, students have the strength to learn optimally. Nurmaliza et al. [20] claimed that learning motivation is one of the solutions to increase the student's interest and attention in the classroom so that students can learn actively and work together and collaborate well in the learning process.

4 Conclusion

The results of the research and discussion showed significant differences in the learning outcomes of students in the experimental class and control classes. It indicates that there is an influence on the application of STEM projects on student learning outcomes in the material of change and environmental preservation as indicated by the N-gain value learners. In the experimental and control classes, there are also differences in the level of learning motivation; namely, the level of learning motivation in the experimental class is higher than in the control class. The level of learning motivation is divided into three categories: very good, good, and fair. In the experimental class, learning outcomes and motivation variables moderately correlate.

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