The influence of STEM project-based learning on students' motivation in heat transfer learning

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Abstract. Different types of skills are required to be able to remain competitive in 21st-century global developments, particularly in science, technology, engineering, and mathematics fields. The purpose of this study was to investigate the influence of STEM project-based learning on students' motivation in learning heat transfer. The pre-experimental method with one group pre-test post-test design was implemented. The sampling technique used in this study was convenience sampling. The samples of this study consist of 26 students who come from two different schools in 7th grade. Student's motivation is measured using the SMTSL questionnaire, and the data result analyzed using SPSS software. The result of this study showed that the implementation of STEM project-based learning gives an improvement in students' motivation significantly. Although N-gain values are 0.06, which categorized as low levels, the statistical test shows that there is a significant difference before and after the implementation of STEM project-based. According to this research, STEM project-based learning can be an alternative strategy to improve students' motivation towards science learning.

1. Introduction

The teaching and learning process intends to develop effective methods of learning and to develop curricula according to the challenges of the 21st century. Many reform efforts have influenced science, technology, engineering, and mathematics (STEM) in recent decades, teaching and learning processes [1]. Therefore, the combination of various pedagogical strategies such as project-based learning (PBL) with science, technology, engineering, and math are applied as a systematic component for solving real-world problems [2]. Physics is taught by learning in schools through a range of appropriate organizational activities that promote student learning processes. The understanding of students towards integrated science and any idea of science is complicated, boring, uninteresting, and abstract. Hence a learning strategy is required, which can help students boost their learning science motivation [3]. The latest learning models prioritize student-led, interdisciplinary, collaborative, and technology-based education strategies in the field of education, such as STEM project-based learning [4].

Motivation is one of the factors that influence an individual's activities. Learning motivation is a driving force within students to perform certain activities to accomplish a goal in a science study [5]. Tseng et al. revealed in a previous study that STEM-integrated project-based learning can improve the learning motivation of students, promote positive learning, help students solve the problem of daily life, and encourage their future careers [6]. Motivational values of students and self-regulatory activities were
described as being important in influencing student participation in the learning process. Students' motivation to study sciences is important because it plays a key role in the conceptual development, critical thinking, learning strategies, and scientific performance of the students [7]. Furthermore, STEM Project-Based Learning (PBL) motivated low-performing students in school to be more interested in studying hard in STEM fields and to reduce the achievement gap [8].

The current study has shown through the implementation of STEM project-based learning that it gives influence in many aspects. The previous study found that STEM project-based learning can foster students' problem-solving ability to achieve high achievement[1]; improving students' attitude to explore future career opportunities[9]; enhance science literacy, gain impressive experience and improve learning motivation and interest [10]; enhance students' imagination in project-based work[6]; and give a good impact on students creativity [11].

A study that focuses on measuring the learning motivation of students in science learning has not yet been found from a variety of studies that implement STEM project-based learning as their research area. This study, therefore, focused on the principle of heat transfer through building projects of a simple heat resistance device that implements five stages of STEM project-based learning. For further identification, this study will investigate students' motivation towards learning science using SMTSL (Students Motivation towards Science Learning Science) questionnaire, which consists of 35 statements, including six aspects of motivation. Based on an interview with the students, heat transfer is one of the physics subjects that is still considered as an abstract subject because students only get the explanation about the concept without the real-life application of heat transfer subject. Therefore, the purpose of this research is to analyze the influence of students' motivation through STEM project-based learning in learning heat transfer.

2. Methods

The method used for this research was a pre-experimental method with one group pretest-posttest design in which a single group is examined not only after being treated to some type of treatment but beforehand as well [12]. By using this method, only one group is involved in investigating the influence of STEM project-based learning towards the motivation of students in learning heat transfer. The research design of this study can be seen in Table 1.

![Table 1. One group pre-test and post-test design.](image)

| 01 | X | 02 |
|---|---|---|
| Pre-test | Treatment | Post-test |
| SMTSL Questionnaire | STEM Project-Based Learning | SMTSL Questionnaire |

The sample population in this research was seventh-grade students consisting of 26 students with 6 male and 20 female students with the average age is 12-13 years old, from two separate schools that implement the 2013 National Curriculum of Indonesia. The sample was taken using a convenience sampling technique in which a sample is a group of individuals available for this study [13]. Table 2 presents the population and sample of this study as convey.

![Table 2. Population and sample.](image)

| Population | Sample | Percentage (%) | Total (%) |
|-----------|--------|---------------|----------|
| 7th Grade Students | Male | 23 | 100 |
| | Female | 77 |

Before implementing the students' STEM project-based learning, the researchers give a pre-test at the beginning, conducting the treatment and post-test at the end of the learning. The SMTSL (Student Motivation Towards Science Learning) questioner developed by Tuan et al. [13] was used as a pre-test
and post-test in this study to learn the influence of the STEM project-based learning on student motivation to learn science learning. Thirty-five statements are consisting of five motivation scales, which are self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The questionnaire given was a questionnaire of a 5-point Likert scale in which five stands for "strongly agree," 4 stands for "agree," 3 stands for "no opinion," 2 stands for "disagree," and 1 stands for "strongly disagree." There are two kinds of statements here that comprise both positive and negative statements. 5-point is given for "strongly agree," while 1-point is given for "strongly disagree" in a positive statement. Whereas in a positive statement, 5-point is given for "strongly disagree," while 1-point is given for "strongly agree." The statement distribution number can be seen in Table 3.

| Scale                        | Statement and Number                        | Total |
|------------------------------|---------------------------------------------|-------|
| Self-efficacy                | Positive Statement: 1, 3                    | 7     |
|                              | Negative Statement: 2, 4, 5, 6, 7           |       |
| Active Learning Strategies   | Positive Statement: 8, 9, 10, 11, 12, 13, 14, 15 | 8     |
|                              | Negative Statement: -                       |       |
| Science Learning Value       | Positive Statement: 16, 17, 18, 19, 20      | 5     |
|                              | Negative Statement: -                       |       |
| Performance Goal             | Negative Statement: 21, 22, 23, 24          | 4     |
|                              | Positive Statement: 25, 26, 27, 28, 29      | 5     |
| Achievement Goal             | Negative Statement: -                       |       |
| Learning Environment Stimulation | Positive Statement: 30, 31, 32, 33, 34, 35 | 6     |
|                              | Negative Statement: -                       |       |
| Total                        |                                             | 35    |

Meanwhile, the treatment was carried out with the implementation of STEM project-based learning as a learning model using some steps introduced by Shi-Jer, Yung-Chieh Ru-Chu, and Chih-Chao [14]. The five stages of STEM project-based learning include preparation, implementation, presentation, evaluation, and correction. The STEM project-based learning activity can be represented in Table 4.

| Stage                | Activity                                      | Percentage (％) |
|----------------------|-----------------------------------------------|-----------------|
| Preparation          | Triggering students' prior knowledge          | 100             |
|                      | Grouping the students and let them divide the task |               |
|                      | Gathering materials                            |                 |
|                      | Creating the design project                   |                 |
| Implementation       | Creating a project based on their design      | 100             |
|                      | Conduct the test of the product               |                 |
|                      | Identifying problem                            |                 |
| Presentation         | Presenting design idea and product            | 100             |
|                      | Sharing problem and solution to resolve the problem |             |
| Evaluation           | Evaluating project                            | 100             |
| Correction           | Correcting the product based on the suggestions | 100           |

All the stages mentioned in Table 3 are carried out sequentially for students in implementing the PBL STEM. The teacher must be able to establish the duration of each stage carefully so that the goals of applying this model can be properly conveyed. Student activities in learning STEM PBL can be seen in Figure 1.
3. Result and Discussion
The questionnaire was given to the students as an instrument to see the motivation of the students before and after the teaching-learning process. The questionnaire used in this study was adopted from the Motivation of Students towards Science Learning (SMTSL) by Tuan et al. [13]. The students’ motivation data score from the questionnaire in the pre-test and post-test is shown in Table 5.

Table 5. Students’ motivation score for pre-test and post-test.

|            | n  | Minimum Score | Maximum Score | Average Score |
|------------|----|----------------|---------------|---------------|
| Pre-test   | 26 | 57.71          | 90.29         | 72.06         |
| Post-test  | 26 | 66.29          | 88.57         | 74.87         |

Out of a total of 26 participants, the minimum pre-test score compared to the post-test score is increased with a difference of about 8.58. Meanwhile, with a difference of about 1.72, the maximum pre-test score compared to the post-test is decreasing. On the other hand, the average student motivation score before learning activities using STEM project-based learning is 72.06, and the average student motivation score after STEM project-based learning is 74.87, with a difference of about 2.81. The data reasonably assume that there is an improvement in the motivation of students towards science learning after the class treatment. Figure 2 presented the increase in student motivation towards learning science based on the average score on each scale.
In addition, the motivation of students towards learning science is also analyzed using a parametric statistics test. The statistical test was performed in order to see the influence students' motivation before and after implementation of STEM project-based learning. The questionnaire used in this study is adopted from Tuan et al. that developing the questionnaire of Students Motivation towards Science Learning (SMTSL) [13]. The statistical test was executed using version 23 of SPSS to analyze the normality, homogeneity, and efficiency of students' motivation between pre-test and post-test after the treatment. Table 5 reflects the recapitulation of the statistical test of the whole data result.

Table 6. Normality test, homogeneity test, and N-gain test.

| Component          | Signification | Description          |
|--------------------|---------------|----------------------|
| Normality          |               |                      |
| Pre-test           | 0.700         | Normally distributed |
| Post-test          | 0.069         | Normally distributed |
| Homogeneity        | 0.523         | Homogeneous          |
| Hypothesis         | 0.016         | H<sub>1</sub> accepted, there is a significant difference |
| (Paired sample t-test) |             |                      |
| N-gain             | 0.06          | Low efficiency       |

Table 6 shows the N-gain score of the motivation of the students for each aspect that is also categorized on low efficiency because of the informed value < 0.3 according to the rule of Hake. Whether the effectiveness of each aspect is categorized in low, but these six motivation aspects still have a significant difference in the post-test compare to the pre-test before treatment. The outcome of N-Gain improved after treatment rather than before treatment, since six stages of STEM project-based learning were introduced in this study for the students and their motivation for studying science was increased [14]. The significant difference in the motivation of students will inspire students to actively participate in science learning. Since motivation will result in a much higher level of cognition; indeed, students who are more motivated by themselves will be more consistent and frequent in the conceptual learning process [15].
In this study, the efficiency of STEM project-based learning on students’ motivation in learning heat transfer is categorized as low. There are many factors affecting the conclusions drawn. In this case, groups of students were collected at various times when they were delivering STEM project-based learning treatment. During the pandemic, the researcher found it quite difficult to assemble all participants in one room and one time, until only one group of 4-5 students actually came together in one session. With the limited number of students who can participate in one session, it is considered to be less effective as the project creation is less interesting as students are unable to compare the products that they have made directly to other groups. So students feel that science, tiresome, boring, and abstract is difficult [3].

The medium and low level of motivation for the learning of students in physics is due to a lack of interest in studying physics by students. Nonetheless, the findings show that project-based research by STEM will empower students to learn heat transfer. It is compatible with Samsudin’s statement that the integration of the STEM approach with project-based learning has a positive impact on learning physics [1]. STEM Project-based learning can be used in Junior High Schools as an alternative model for learning [16]. In contrast to traditional learning, learning using STEM project-based learning have a positive effect that increases the self-efficacy of students in solving physics problems [17]. After conducting this analysis, the researcher maintains that the explanation behind the increase of students’ motivation is because students can recognize problems and propose the solutions they have directly so that not only the theory they obtain but also the implementation of what they have learned in classes. When implementing STEM project-based learning or any kind of learning prioritizing project-led orientation, it is therefore felt to be less successful if it only includes a few students. However, it is better to collaborate with other students to make them more interested and motivate in the learning sciences.

4. Conclusion

The use of STEM project-based learning is founded in data interpretation, which provides improvement to students. Although the n-gain value is defined as low level, the statistical test indicates that there is a significant difference between the motivation of the students before and after the STEM project-based learning implementation, which means the treatment could improve the students’ motivation towards science learning. It can be concluded that students are motivated by the implementation of the STEM project-based learning in heat transfer learning, including another six aspects of motivation such as self-efficacy, science learning value, active learning strategies, performance goal, achievement goal, and learning environment stimulation. In addition, the implementation of STEM project-based learning can be an alternative learning strategy to improve students’ motivation for science learning.

5. References

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