The use of STEM project-based learning toward students’ concept mastery in learning light and optics

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Abstract. Learning process in some school is still in the form of direct transfer from teacher to students, whereas students will learn better if the learning process is meaningful. The aim of this study is to investigate the effect of STEM Project-Based Learning on students’ Concept Mastery in learning light and optics. The method that is used in this study is a weak experiment with one group pre-test and post-test design. The population of this study is 8th-grade students in Junior Secondary School “X” that is located in Bandung, Indonesia. The sample is chosen by purposive sampling technique consist of 25 students. The result of this study shows that students concept mastery improves from pre-test and post-test. The improvement of concept mastery is obtained as much as 0.53 that categorized as a medium improvement. Based on the result STEM Project-Based Learning give a better effect on students’ concept mastery, so it can be considered as an alternative teaching model that can be implemented in Junior Secondary Schools.

1. Introduction
Science, Technology, Engineering and Mathematics (STEM) education becomes an international trend in education that encourages students' and teachers' interest in the STEM field. The STEM education is an alternative approach that was developed to improve the quality of education, this teaching and learning method will integrate the contents and skills in science, technology, engineering, and mathematics. STEM learning gives an opportunity for students to understand real-world problems based on those interdisciplinary subjects. Interdisciplinary STEM aims to emphasize the importance of 21-century skill development such as adaptation skill, social skill, communication skill, problem-solving skill, and self-development [1].

Some studies proved the needs of STEM field in education. Previous studies have been measuring the interest of pre-service science teachers in STEM career field by interest survey [2]; the attitude of pre-service science teacher towards STEM [3]; Problem-solving skill and creativity on girls’ interest in STEM subject area [4]; and science process skills, science concept and science content knowledge for gifted elementary students in the STEM intervention [5]. STEM education can be integrated with the learning model, such as problem-based learning, team-based learning, and project-based learning. One way to satisfy the need for STEM education with meaningful activity can be done by implementing STEM project-based learning. STEM project-based learning is a learning model based on the STEM education approach and integrated with the project-based learning curriculum design [6]. The unique things that make STEM project-based learning difference are the design process and interdisciplinary
instruction. The design process of STEM project-based learning is starting with well-defined of the project outcome planning and giving an ill-defined task that leads students to express ideas from the complex problem in different solution [7]. STEM project-based learning has been implemented in some countries because it can create the skills that needed in facing global competition. STEM project-based learning can give the interesting, enjoyable, and exciting approach that can increase the motivation of students to learn the concept, while for teacher STEM project-based learning can give the creative teaching ways of conveying the science content and motivate teachers to strengthen their teaching [8]. Students made the conceptual understanding by their-self with own word in STEM project-based learning [9]. The integration of knowledge through STEM project-based learning has a chance to develop students’ concept mastery. The reason is students should relate the appropriate skills to the application in real life through the relevant concept mastery. When the students have a good concept of mastery, students will think and find out the metaphors or the analogy of the concept.

Through STEM project-based learning, current studies have proved that it gives influences in some aspects. The previous study has been found that STEM project-based learning can give the positive influence in the development of creativity, including the aspects of adventurousness, curiosity, imagination and challenge [6]. In other studies, STEM project-based learning was measured students’ learning attitude through multi-function electric vehicle [10]; Students’ science achievement through the implementation of latent growth modeling [11]; Students’ imagination and STEM knowledge development of female high school students [12]; Academic achievement for high, middle, and low achievers [13]; and perception of pre-service and in-service teachers regarding the implementation of STEM project-based learning in science class [8].

One requirement in Junior Secondary Schools that should be fulfilled is the topic of light and optics topic. Based on teacher interview, students were never conducted the light and optic topic with project-based activity. However, there still no research that has been investigate students’ concept mastery through STEM project-based learning in the topic of light and optics. Therefore, this study engaged the concept of image formation by making the simple projector as the project. Students are trained to show their skill in designing the projector and relating the projector with the concept of image formation with the STEM approach. There are five stages of STEM project-based learning that can be adopted by the researcher, which are the stages of preparation, implementation, presentation, evaluation, and correction [6]. The aim of this study is to investigate the effect of STEM Project-Based Learning on students' Concept Mastery in learning light and optics.

2. Methods

The method that is used in this study is a weak experiment with one group pre-test and post-test design. One group pre-test and post-test design observe a single group before and after treatment [14]. The consideration using one group as the experiment class is because this study focuses on the effect of STEM project-based learning by comparing pre-test and the post-test result of students' concept mastery in light and optics topic. The design of the study can be shown in Table 1.

|       | O | X | O |
|-------|---|---|---|
| Pre-test |   | STEM Project-Based Learning |   |
|       |   | Post-test                     |   |

The research was done in six meetings. The first meeting was for the pre-test. The second, until the fifth meeting was for implementing STEM project-based learning, which is the second meeting was for preparation stage, the third meeting was for implementation stage, fourth meeting was for presentation and evaluation stage, and five meeting was for correction stage. The six meeting researcher conducted a post-test. The group was given the light and optic topic. The concept that student should achieved are light characteristic, the image formation in lens, the characteristic of image, and optic device.

This study is conducted in Junior Secondary School "X" that is located in Bandung, Indonesia. The curriculum that implemented in this school is "Kurikulum 2013". The population is 8th-grade students with ages ranged between 14 to 16 years old. The sample consist of 25 students consists of 13 males
and 12 females that selected by purposive sampling. In purposive sampling, the researcher uses personal judgment and believe to choose the samples [14]. Based on the interview with the science teacher, 8th-grade students are categorized as the high, medium and low achievement. Thus, the researcher chose the samples who have medium achievement as the consideration. Population and sample of this study are expressed in Table 2.

Table 2. Population and sample

| Population          | Sample | Gender | n  | Percentage (%) | Total (%) |
|---------------------|--------|--------|----|----------------|-----------|
| 8th Grade Students  | Male   | 13     | 52 |                | 100       |
|                     | Female | 12     | 48 |                |           |

There are five stages of STEM project-based learning that used in this study, which are the stages of preparation, implementation, presentation, evaluation, and correction [6]. To fulfil all stages of STEM project-based learning, the study is finished in fourth meeting. The learning activity of STEM project-based learning can be as shown in Table 3.

Table 3. STEM project-based learning activity

| Meeting | Stage          | Activity                                      | Percentage |
|---------|----------------|-----------------------------------------------|------------|
| 1st     | Preparation Stage | Understand the theme scope and limitation resources | 100%       |
|         |                 | Seek information from the internet to find out the basic concept and the way to make the project | 100%       |
|         |                 | Determine the tools and materials              | 100%       |
|         |                 | Produces design drawing                        | 100%       |
| 2nd     | Implementation Stage | Make the project based on design               | 100%       |
|         |                 | Conduct the actual test of the product         | 100%       |
| 3rd     | Presentation Stage | Group by group presented their design idea and product | 100%       |
|         | Evaluation Stage | Expert evaluation                              | 100%       |
|         |                 | Peer Evaluation                                | 100%       |
| 4th     | Correction Stage | Make correction according to suggestion and feedback | 100%       |

Table 3 gives information that STEM project-based learning has been implemented 100%. Regarding the percentage, it can be concluded that all activities in conducting STEM project-based learning is done well. Even though the activities were running well, but there are some obstacles that was faced when implementing STEM project-based learning in this study. Teachers need longer time to finish the topic because students not only get the information about the concept but they also experienced in creating product based on the concept. In conducting project-based activity, each group should have a good team management. In this study, there is one group that was fight each other, so they can’t produce the product optimally. From this case, teacher should pay much attention for each group, so students can work optimally with their group. The students’ activity regarding STEM project-based learning can be shown in Figure 1.
Figure 1. Students’ activity of STEM project-based learning

STEM project-based learning cannot be separated from the field of science, technology, engineering and mathematics (STEM) in making the projector of project activities. The field of science (S) refers to the concept of image formation in the lens. Students should understand the characteristic of the image that is formed in the convex lens and concave lens, so they can decide the most suitable lens that used in making a projector. Furthermore, they should determine the correct length or room to produces the real and enlarged image. The field of technology (T) can be observed in the preparation stage when students use the internet in finding the information and select the proper tools and materials. Otherwise, it also can be seen in the implementation stage when students conducting the actual test. The field of engineering (E) can be observed in the preparation stage when students make their own design drawing. This design draws should appropriate to the concept of image formation in the lens. However, students put the focal length and distance of the object in their design drawing in order to make them easier in constructing projector. The field of mathematics (M) can be observed when the student finds the magnification of the image that produces in a projector. The field of the STEM in this study can be presented in Table 4.

Table 4. The field of STEM

| Science (S)          | Technology (T)         | Engineering (E)   | Mathematics (M)                        |
|----------------------|------------------------|-------------------|----------------------------------------|
| The concepts of image formation in the lens | Using the internet to seek information, selecting tools and materials, conducting the actual test. | Design drawing | Calculation of magnification |

3. Result and Discussion
Students’ concept mastery data was collected by conducting pre-test and post-test that consist of 20 multiple choice questions. This study used three cognitive dimension based on Bloom taxonomy revision, which are C4 (Analysing), C5 (Evaluating), and C6 (Creating). Actually, this study only used three from six cognitive dimension. The consideration is the minimal ability based on “Kurikulum 2013” in Junior Secondary School level is analyzing. So, this study only focused with the minimal ability that students should achieved, which are C4 (Analysing), C5 (Evaluating), and C6 (Creating).

Students’ concept mastery can be concluded with the analysis parametric statistic. The paired t-test is used to test the hypothesis whether there is the difference between students' concept mastery in learning light and optics after implementing STEM project-based learning. The requirements for using paired t-test are the data should be normally distributed and homogenous. The recapitulation hypothesis test of students’ concept mastery is shown in Table 5.
Table 5. Recapitulation hypothesis test of students’ concept mastery

| Normality Test | Homogeneity Test | Paired t-Test |
|----------------|-----------------|---------------|
| Signification (sig. $\alpha = 0.05$) | Conclusion | Signification (sig. $\alpha = 0.05$) | Conclusion | Signification (sig. $\alpha = 0.05$) | Conclusion |
| Pre-test | 0.172 | Normally Distributed | 0.376 | Homogenous | 0.00 | $H_0$ = rejected, $H_1$ = accepted |
| Post-test | 0.053 | Normally Distributed | | | |

From the statistical calculation that was found in Table 5, the significant value of the normality test is obtained as much as 0.798 > 0.05 in the pre-test and 0.053 > 0.05 in post-test. It can be concluded that data obtained from both pre-test and post-test is normally distributed. Meanwhile, that significant value of homogeneity test in this study obtained for about 0.376, so it can be concluded that the data is homogenous. One way to test whether the hypothesis is rejected or accepted is by using a paired t-test. From the statistical calculation, significant value (2-tails) is obtained for about 0.00 < 0.05. Thus, the decision taken is $H_0$ = rejected and $H_1$ = accepted. It can be concluded that there is a significant difference in students’ concept mastery before and after implementing STEM project-based learning in learning light and optics.

Pre-test data gives the initial description of students’ competencies before giving the treatment by implementing STEM project-based learning in learning light and optics. On the other hands, post-test data become the final result that describes students’ competencies after implementing STEM project-based learning. The recapitulation of the average score from pre-test and post-test can be shown in Figure 2.

![Figure 2. Students’ concept mastery from pre-test to post-test](image)

Based on Figure 2, the average score of pre-test is obtained from 34.6, while the average score of post-test has been increased which is obtained about 69.4. The improvement of students’ concept mastery can be determined by using the calculation of normalized gain, while the gain value is obtained based on the score difference of pre-test and post-test for each student. The recapitulation of gain value and N-gain can be shown in Table 6.

Table 6. Gain value and N-gain from pre-test to post-test

| Gain | Normalized Gain (N-gain) | Category |
|------|--------------------------|----------|
| 34.8 | 0.53                     | Medium   |
Based on data in Table 6, the average gain value in this study is reached for about 34.8. In other words, the improvement of students’ concept mastery obtained as much as 0.53 that is categorized as the medium improvement. There are three different levels of the cognitive dimension based on Bloom’s Taxonomy revision that used in this study, which are C4 (Analyzing), C5 (Evaluating) and C6 (Creating). The result of the cognitive dimension that was taken from the student's score in pre-test and post-test can be presented in Table 7.

| C4 (Analyzing) | C5 (Evaluating) | C6 (Creating) |
|----------------|-----------------|---------------|
| Gain | N-gain | Category | Gain | N-gain | Category | Gain | N-gain | Category |
| 35 | 0.56 | Medium | 37.69 | 0.54 | Medium | 30.4 | 0.47 | Medium |

In regard to Table 7, it can be found that all cognitive dimension in this study has medium improvement. The highest improvement obtained by the C4 dimension with N-gain 0.56 and followed by the C5 dimension with N-gain 0.54. Meanwhile, C6 dimension becomes the lowest improvement which is obtained by 0.47 as the N-gain. In other words, the higher the level of the cognitive dimension, the lower N-gain that is obtained. For the conclusion, STEM project-based learning has influenced to improve students' cognitive dimension in learning light and optics.

The implementation of STEM project-based learning showed the improvement regarding students’ concept mastery between pre-test and post-test. The N-gain value that was obtained by all students is 0.53 which is categorized as a medium improvement [15]. Thus, the implementation of STEM project-based learning improves students’ concept mastery in learning light and optics. This study is in line with the previous study which stated that STEM project-based learning is improved students' concept mastery in creating Photon Multimedia PBL in the New England Board of Higher Education [16]. The design element in STEM project-based learning approach can help to motivate students and enhance their understanding of science concept in long-term memory [8]. Therefore, based on some study that already conducted by some researcher, it proves that STEM project-based learning can develop a cognitive skill that will improve students' concept mastery.

The improvement of students' concept mastery of pre-test to post-test is caused by some activities that conducted by students during the STEM project-based learning. Students should strengthen their knowledge and chose a suitable concept that relates to the project. In the preparation stage, students directly choose the proper lens that can be used. In other words, students should find the image that is formed in both convex and concave lens as their basic concept. Furthermore, students should determine the correct length or room to produces the real and enlarged image. From this concept, students can decide the proper lens that will be chosen.

Other than that, in preparation stages also students are actively finding some information and sources that needed. Students are given the discretion to seek information on the internet without references restriction, so students train to comprehend and make a solution in solving problems. Then, students made a design drawing of product that can improve their understanding of science concept. The design process in STEM project-based learning is the ill-defined task that requires students to higher order thinking [7]. In the implementation stages, students should make their product based on their design drawing. In other words, students conducted a project-based learning activity which requires them to mastery concept and also related the project with the concept. Therefore, students' who are involved in project-based learning activity can improve their concept mastery. This study is in line with the previous study which stated project-based learning gives positive outcomes for low achiever students in Greece [17].

The data can be explored by arranging based on Bloom’s Taxonomy revision, which contains six cognitive dimensions. This study used three cognitive dimensions which are C4 (Analyzing), C5 (Evaluating), and C6 (Creating). Based on the result, all of the cognitive dimensions categorized as a medium improvement. Thus, students' ability to analyze, evaluate and create is improving after treatment. N-gain that obtained for each cognitive dimension are: C4 (Analyzing) obtained 0.56, C5
(Evaluating) obtained 0.54 and C6 (Creating) obtained 0.47. The result is found that the higher the level of the cognitive dimension, the lower N-gain that is obtained. The situation happened was caused by the complexity of the test item in the C6 dimension. The result of this study is in line with Bloom's Taxonomy revision that stated the higher the level of the cognitive dimension, the more difficult ability to think [18]. For the conclusion, the higher the level of cognitive dimension, the more complex of objective test.

4. Conclusion
STEM project-based learning in light and optics topic has been implemented successfully. STEM project-based learning can give the improvement from pre-test and post-test. The improvement of concept mastery is categorized as the medium improvement. STEM Project-based learning has a significant effect on students' concept mastery, so STEM project-based learning can be considered as an alternative teaching model that can be implemented in Junior Secondary Schools.

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