The impact of STEM PjBL on students’ engineering practice, scientific practice, and scientific attitude

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Abstract. The study aimed to analyze the effect of Science Technology Engineering and Mathematics (STEM) Project-based Learning (PjBL) on students’ engineering practice, scientific practice, and scientific attitude. Scientific and engineering practice in this research focused on the planning and carrying out investigations (PCOI) aspect and obtaining, evaluating, and communicating information (OECI) aspect. This study employed the pretest-posttest control group design of experimental research. In this study, 70 of 8th-grade junior high school students in Yogyakarta were determined by a simple random sampling technique to become subjects. Data were obtained through (1) a multiple-choice test to measure the planning investigation and obtaining, evaluating, and communicating information as cognitive domains, (2) an observation sheet to observe the carrying out investigation as a psychomotor domain, (3) a questionnaire to obtain students’ scientific attitude of this study. The test instrument, the observation sheet, and the questionnaire had been developed and validated. Data from this study were analyzed by MANOVA in SPSS 16. The result of this study showed that STEM PjBL effected students’ scientific practice, engineering practice, and scientific attitude.

1. Introduction
STEM education is a solution to the global economic problem and a pivotal program which gives positive impacts on students’ success in the future. It provides an opportunity to increase students’ experience in hands-on practice and allows them to incorporate and apply related knowledge in the condition of learning by practicing and accomplishing understanding from errors [1]. It has become an international agenda to face the 21st-century demands of information and productive technology that stimulate changes in politic, demographic, and economic fields [2], and workforce needs which predict the shortage of STEM educators and prepared workers globally [3]. It is believed not only can enhance students’ motivation for STEM careers but also can enhance their attentiveness and accomplishment in science and mathematics [4]. However, many barriers are found to implement integrated STEM education. Students detach from the study of STEM beyond compulsory schooling [5], the lack of consensus about instructional practices [6], and the limit information about the benefits of integrative approaches to teachers in STEM fields [7] are some obstacles of STEM education practice. Hence, research on STEM education should be conducted to analyze the benefits and minimize the constraints.

The appropriate learning model should be used to implement STEM education in the class. To promote students’ learning, project-based learning can be integrated into STEM education [3]. It is focused on establishing real-world projects which facilitate pupils to administer their knowledges of diverse concepts [8]. Besides, STEM PjBL (Project-based Learning) uses not only a project with two...
up to four STEM subjects but teaching orientation of constructionism and constructivism also [9]. Thus, the PjBL model can be used in the STEM education class by integrating two or more STEM subject areas, constructivism, and constructionism teaching orientation.

One of the aspects that can be used as a consideration of integrating PjBL in STEM education is its advantages. Engaging project-based learning in STEM course gives a huge positive impact because it affects (1) student perceptions of STEM skills, the usefulness of joining in STEM courses, and STEM careers [10], (2) students’ skills and professional understanding, (3) students’ experience with contextual and professional realities, (4) students’ capabilities to work either in groups or independently [11], (5) students’ STEM literacies [12], (6) the decreasing of the achievement gap in the class [13], (7) effectiveness and meaningful learning [14], and (8) students’ critical thinking skill [15]. Moreover, the challenge, imagination, adventurousness, and curiosity can be enhanced by STEM PjBL [1]. In conclusion, engaging project-based learning in STEM courses has the potential to give an effect on students’ learning achievement.

STEM education which uses contextual problems in the learning activities tends to enhance various learning outcomes. Moreover, The traditional barriers among Engineering, Science, Mathematics, and Technology be able to be removed by STEM education which focuses on using contemporary technologies and tools in the designing solutions of contextual and complex situations [3]. Contextual learning strategies may lead to developing students’ conceptual mastery, process skill, problem-solving skills, scientific attitude, and critical thinking skills [16]. One of the learning outcomes that should be assessed and evaluated is the scientific attitude. It should be a major concern of science teachers because its measurement might enable a science teacher to identify the inclination of science learners towards different endeavors in science [17]. Besides, scientific attitudes have a pivotal role in improving scientific literacy [18]. For those reasons, students’ scientific attitudes should be analyzed as STEM PjBL learning outcome.

In this era, not only students’ scientific attitudes but students’ knowledge and practices in science also should be mastered. To support students’ understanding and practicing about science in the 21st century, three-dimensional teaching approach standards namely, science and engineering practices, crosscutting concepts, and disciplinary core ideas were enlightened since in 2013 a fundamental change in teacher practice was called for by the NGSS [19]. The science and engineering practices aspect is an important aspect among them which can be evaluated in the STEM PjBL class because of its characters. Based on NGSS, science and engineering practices are technique of obtaining the reasoning and applying primary ideas in science [20] which consist of 8 aspects [21]. However, this study only concerns on the contribution of STEM PjBL on planning and carrying out investigations (PCOI) aspect and obtaining, evaluating, and communicating information (OECI) aspect.

Depend on the domains of learning, PCOI in this research was divided into two domains that are planning investigation as a cognitive domain and carrying out investigations as a psychomotor domain. PCOI aspect defined as conducting an cooperative investigation to generate data which are served as base evidence and used equitable tests by controlled variables and the number of considered trials [21]. This practice links with inconsistent evidence [22]. Furthermore, obtaining, evaluating, and communicating information aspect is a pivotal constituent in science and engineering. A major practice of science and one of the engineers’ abilities to produce or develop technologies is sharing ideas and results of the inquiry by oral or written communication [21]. This aspect was analyzed as the cognitive domain of learning in this study.

Based on the previous explanation, this study aimed is to analyze the impact of STEM PjBL on students’ engineering practice, scientific practice, and scientific attitude. Hence, the impact of STEM PjBL on them will be clear to answer the following research questions.

a. Is there a significant impact of STEM PjBL to learners’ scientific attitude skills?

b. Is there a significant impact of STEM PjBL to learners’ carrying out investigation skills?

c. Is there a significant impact of STEM PjBL to learners’ planning investigation and OECI skills?

d. Is there a significant impact of STEM PjBL to learners’ planning investigation and OECI skills, carrying out investigation skills, and scientific attitude?
The constructivism learning theory will be used in this research to discuss the impact of STEM PjBL on students’ learning outcomes. In this theory, experience is used by learners to develop their understanding about world surrounding them by electing and reconstruct previous information and existing knowledge and experience into new personal understanding and knowledge [23]. The discrepancy between the new knowledge and the current schema encourages the learner to assess and adjust their schema and knowledge [24]. Eliciting prior knowledge, creating cognitive dissonance, applying new knowledge with feedback, and reflecting on learning are four fundamental principles to identify and assess constructivism [25].

2. Research Method
A pretest-posttest control group design of experimental research was used in this quantitative study. STEM PjBL was implemented in the three learning activities of the pressure concept that was focused in maritime technology as a theme. The topics of three learning activities were (1) the correlation between the hull’s area and the pressure, (2) the correlation between ship’s weight and the pressure, and (3) the upward buoyant force in the ship.

Seventy of 8th-grade junior high school students in Yogyakarta from two public schools were selected randomly subjects in this research. To analyze the effect of STEM PjBL on students’ scientific practice, engineering practice, and scientific attitude, data were collected through the multiple-choice test, an observation sheet, and a questionnaire before and after this study. Scientific practice and engineering practice in this research were concerned about PCOI and OECI. A multiple-choice test was used to measure the planning investigation and OECI as a cognitive domain. An observation sheet was used to observe carrying out investigation as a psychomotor domain in the PCOI while the questionnaire was disseminated to obtain data of students’ scientific attitude. Data from this study were analyzed by MANOVA in SPSS 16.

3. Result and Discussion
The result of STEM PjBL on learners’ scientific practice, engineering practice, and scientific attitude could be seen from the result of a statistical analysis based on the data of the pretest dan posttest. Multivariate normality test, Box’s M test, and Levene’s test were used to analyze the assumptions before the MANOVA test in SPSS 16. The results of multivariate normality tests from controlled and experimental classes were shown in Figure 2 and Figure 3. Moreover, the coefficient correlation of Mahalanobis distance and qi was served in Table 1. Box’s M tes was employed to describe the matrix covariance of both groups and the result could be seen in Table 2. The result of Levene’s test was provided in Table 3. The effect of a STEM PjBL on three dependent variables could be found in Table 4 as the result of the multivariate test and the effect of STEM PjBL on each dependent variable was shown in Table 5 as the result of tests of between-subjects effects.

3.1 Multivariate Normality Test
The results of multivariate normality from the controlled class and experimental (STEM PjBL) class were shown in Figure 2 and Figure 3.
Based on the graphs, the populations in this study were multivariate normal distributions because each graph was shown a linear line. Moreover, coefficient correlation of Mahalanobis distance and qi based on the gain scores of controlled class and experimental class could be found in Table 1.

Table 1. Coefficient Correlation of Mahalanobis distance and qi (gain score)

| Class                        | Coefficient Correlation |
|------------------------------|-------------------------|
| Experimental (STEM PjBL) Class | 0.875                   |
| Controlled Class             | 0.956                   |

The coefficient correlation scores of Mahalanobis distance and qi in the table indicated that the populations were multivariate normal distributions with high coefficient correlation scores.

3.2 Box’s M Test

The matrix covariance of both groups in this study was analyzed by Box’s M test and the result was provided in Table 2.

Table 2. The Result of Box’s M Test

| Test     | Result |
|----------|--------|
| Box’s M  | 6.080  |
| F        | 0.965  |
| Sig.     | 0.447  |

The result had shown that the matrix covariance of both groups was homogenous because the significant score was higher than α (0.05).

3.3 Levene’s Test

Levene’s test was employed to identify the variances of each variable in this research and the result could be seen in Table 3.

Table 3. The Result of Levene’s Test

| Aspect                        | F       | Sig.   |
|-------------------------------|---------|--------|
| Planning investigation and OEI | 0.009   | 0.924  |
| Scientific Attitude           | 1.435   | 0.235  |
| Carrying out investigation    | 3.229   | 0.077  |

Levene’s test result indicated that the variances of each variable equal across the groups. Based on the results of multivariate normality test, Box’s M test, and Levene’s test, the MANOVA test could be done.
3.4 Multivariate Test
The result of the MANOVA test which was used to analyze the effect of STEM PjBL on the dependent variables was shown in Table 4.

Table 4. The Result of Multivariate Test

| Effect                | Value | $F$    | Sig. |
|-----------------------|-------|--------|------|
| Class Pillai's Trace  | 0.544 | 26.296 | 0.000|
| Wilks' Lambda         | 0.456 | 26.29a | 0.000|
| Hotelling's Trace     | 1.195 | 26.29a | 0.000|
| Roy's Largest Root    | 1.195 | 26.29a | 0.000|

The result had shown that STEM PjBL gives a significant impact on students’ planning investigation and OECI skills, carrying out investigation skills, and scientific attitude. Thus, STEM PjBL had effected significantly on students’ scientific practice, engineering practice, and scientific attitude.

3.5 Tests of Between-Subjects Effects
Based on p-value of Tests of Between-Subjects Effects, the effectivity of STEM PjBL on each variable could be identified in Table 5.

Table 5. The Result of Tests of Between-Subjects Effects

| Aspect                          | F   | Sig.  |
|--------------------------------|-----|-------|
| Planning investigation and OECI | 55.272 | 0.000 |
| Scientific Attitude            | 12.340 | 0.001 |
| Carrying out investigation      | 8.424  | 0.005 |

Because the significant numbers of them were lower than $\alpha$ (0.05), those could be concluded that STEM PjBL gives a significant impact on each variable base on domains of learning namely students’ planning investigation and OECI skills (cognitive domain), carrying out investigation skill (psychomotor domain), and scientific attitude (affective domain).

Based on constructivism theory, STEM PjBL gives a significant impact on students’ planning investigation and OECI skills, carrying out investigation skill, and scientific attitude because STEM PjBL in this study accommodates the activities such as eliciting prior knowledge, creating cognitive dissonance, applying knowledge with feedback, and reflecting on learning. Learning activities which elicited prior knowledge in the STEM PjBL class with maritime technology topic were demonstration, problems, and discussions. The teacher showed videos about the effect of hull shapes on their pressure, a tragedy of sinking ship due to overload, and the phenomenon of ships at sea. Moreover, the teacher demonstrated how to measure the area of ship’ hull models, the weight of the ship models, and Archimedes’ law. Based on the problems, demonstration, and STEM PjBL practices, students discussed with their classmates and teacher. Creating cognitive dissonance was facilitated in the STEM PjBL activities by uncovering misconceptions, discussing missing information when students did their projects, comparing lists of data based on their experiments, and asking students' understanding. Assessing based on the STEM PjBL activities in three domains of learning, designing the ship models, manipulating the variables, and testing the hypothesis about the effect of ship’ hull area on the pressure, the weight of ship on the pressure, and the upward buoyant force in the ship model were conducted to apply knowledge with feedback. Further, the data were analyzed, explained in the graph, and communicated in writing. The teacher gave feedback to the students based on STEM PjBL learning practices and students’ assignments. The STEM PjBL learning activities were done in three topics and completed by students' worksheets in every topic. Students reflected their new knowledge through students’ worksheets which provided assignments to explain variables, processes, and conclusions from evidence-based on their experiment. The steps on STEM PjBL were repeated in different topics.
4. Conclusion
The results and discussion in the study have shown that STEM PjBL gives a significant impact not only on students’ planning investigation skills, OECI skill, and carrying out investigation skills which are components of science and engineering practices but scientific attitude also. According to the constructivism theory, this result can be obtained since STEM PjBL accommodates the activities such as eliciting prior knowledge, creating cognitive dissonance, applying knowledge with feedback, and reflecting on learning. This study provides information about the benefits of STEM PjBL implementation which can be used to encourage school administrators, teachers, and policy makers to use STEM PjBL in learning activities. Moreover, the impact of STEM PjBL on students’ achievement can be used as a consideration of learning activity and assessment with a specific purpose.

5. Acknowledgments
The authors are grateful to the SEA-STEM 2020 committee for providing the opportunity to publish my article.

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