Project-based learning on water filtration experiment in high school chemistry subject

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Abstract. Project-based learning (PjBL) has been conducted in high schools around the provincial capital city. The PjBL students’ worksheet, which was not available in the topic of water filtering materials, had been developed with R&D (ADDIE model). The worksheet was considered valid by validators and feasible to apply in real teaching. Thirty (30) high school students participated and they were divided into six groups. Each group consisting of five students conducted their own projects guided by PjBL worksheet. Students were given problems on how to design and test an effective water filter for muddy water. Their cognitive score tests increased significantly after employing the PjBL class. Students’ skills were generally high as well as their work performance during and after conducting the projects. The majority of students and all teachers responded positively to the PjBL implementation and the model was recommended by teachers to apply to other classes and schools.

1. Introduction
Studies on active learnings, which have the main agenda to stimulate students to do scientific works, have been intensively conducted for years [1,2]. Some studies involve the active learning models such as the subjects under the discipline of science, technology, engineering and mathematics (STEM); science, technology, and society (STS), and the entrepreneurial-contextual-learning which is considered to effectively stimulate students not only to perform scientific works but also to demonstrate their creativity and innovation [3,4]. However, the implementation of active learning will have more challenges in rural areas [5].

Another interesting active-learning model that is currently being recommended in the Indonesian Nasional Education framework is project-based learning (PjBL), especially for chemistry subjects. Project-Based Learning (PjBL) is one of the learning models with the engagement of project structures as a learning tool [6]. Project-based learning is an effective approach in the teaching and learning process as the learning approach is facilitated by teachers [7,8]. However, based on our observations and interviews at a senior high school in Banda Aceh, the teachers had not carried out any scientific project for students in the Chemistry course. Student’s worksheet that guides students to perform project-based learning has not been easily accessed in literature.

The PjBL method has been successfully used in some developed countries to improve students’ achievement and also to prepare them to face daily life [9,10]. Project-based learning offers the opportunity to apply theoretical and practical knowledge as well as to develop group work and collaborative skills [11,12]. One of the advantages of PjBL is that students can determine their own
projects and also choose projects according to their own interests [13,14]. At the same time, it can improve professional skills such as teamwork and communication [15].

2. Method
Students' worksheet of PjBL was developed by following research and development (R&D) methods with the model of analysis, design, development, implementation, and evaluation; or for short known as ADDIE. After being validated, the worksheet was applied in a Chemistry course during the teaching-learning phase. The research subjects were 30 high school students that were randomly sampled with nearly similar academic achievement. So that it can be claimed that the students’ ability is homogeneous. The samples were then divided into six groups, they all did a project in theme, which is the filtration of muddy water. Each pair (two groups) had a similar project but they worked in separated groups. The data collection process is as follows. Each students’ worksheet contains some images of absorbent materials but none of the groups has the experimental procedures. They were just given a problem to be solved by designing and conducting simple research. The problems guide them to run the project were first, what are the effective absorbents? And what is the best sequence absorbent layers? Second, what is the optimum particle size of absorbents? and last, how is the thickness of the absorbents’ layer that effectively filtered the muddy water? After they finished conducting the experiment and filled out the worksheet, the teachers reviewed and scored using valid rubrics based on student capacity on the experimental procedure, data observation, result and discussion, and conclusion. The student comprehension of Water Purification methods and other related theories were also compared before (in pre-test) and after (in post-test) the learning process. Finally, students’ and teachers’ responses on this PjBL pilot learning were collected and analyzed.

3. Results and Discussion
The series of teaching and learning process that has been carried out by students aimed at providing the values of the students’ worksheet. The evaluation was done by analyzing the students’ learning outcomes, assessing the water purification products, and collecting the responses from the learners and teachers in regard to the student worksheets.

This study was initiated by designing PjBL students’ worksheets, which was not available especially for the topic of Water Filtration. The PjBL students’ worksheet was considered valid by three validators in terms of content, the systematic layout, the language, the comprehensiveness, and the scientific content with the main score of 88%. This finding was considered very valid and feasible for practical criteria [16]. An example and partial cropping of PjBL student worksheets and students’ work are displayed in Figure 1.

3.1. Cognitive assessment
Assessment scores of students’ comprehension of Water Filtration material and the related theories were compared based on pre- and post-test. The highest pre-test score was 80.4 and the lowest was 13.4. Whereas for the post-test, the highest was 93.8 and the lowest was 40.2. The mean score of the pre-test was 45 which is very low and the average score was 80, which showed excellent improvement. The score improvement might have a correlation with the implementation of the PjBL students’ worksheet. The worksheet guided learners not only to solve the given problem but also to stimulate the students’ science skills, which is deemed crucial for their life [17].

3.2 Assessment of students’ science skill guided by PjBL worksheet
All students in each group worked enthusiastically in running their projects and, for sure, they followed the PjBL worksheets systematically. Later, the worksheets that they have filled in were reviewed and scored by using rubrics by their teacher. The mean scores of students were displayed in Figure 2.
Group I has the highest score in almost all components (experimental procedure, data collected, discussion elaborated, and conclusion stated). Generally, the students have a very high score in ‘collecting data’ but they were rather weak in ‘formulating the conclusion’, except for group 6. Their skill on ‘elaborating the discussion’ section was surely needed to be improved. This finding confirms the previous report that students are usually good in data observation compared to other science skill component.

Translation of the text

Problem statement: In remote villages, muddy water is often used as the source of drinking water. Please discuss in your group to design a water filter by using absorbent from the materials available in your surroundings and from which displayed in this worksheet;

(a) Propose the experimental procedure.
(a) Conduct a research project to prove the effect of particle size on absorbent capacity.

Figure 1. The partial part of PjBL students’ worksheet and students’ work recorded.

3.3. Assessment of students ‘work performance

Students’ work performance was assessed during the process. This means that as they were conducting and reporting the project, the teacher assessed their work by using a valid rubric. The cumulative students’ score was tabulated in Table 1 and some representative photographs of students’ activities are presented in Figure 3.

All students were highly skillful in ‘observing data’ and they had enough skill in assembling tools and equipment, but they should practice more on presenting their works. This is in accordance with the characteristics of PBL presented in the worksheet that is valid and practical. The application was also characterized by conformity with the curriculum, item constructs, and perfect language spelling of the content. Consequently, it can spark more of students’ interest in doing the exercises [18].

In addition, the performance products fabricated by the student in this PjBL studied were considered to fulfill the expectation with score 83.33.
Table 1. Assessment of Average Product Scores.

| Project performance indicators                                      | Accumulative mean scores (%) |
|---------------------------------------------------------------------|------------------------------|
| Tool assembling skills                                              | 83.33 ± 18.6                 |
| Skill in reporting observed data                                   | 100.00 ± 0.0                 |
| Skill in oral presenting report                                    | 79.16 ± 9.31                 |
| Comprehension of project planning, conducting and concluding       | 79.16 ± 11.8                 |
| Output of project (product) performance                            | 83.33 ± 11.8                 |

3.4 Students’ and teachers’ responses

Questionnaires were distributed to teachers and students to find out their response to the implementation of PjBL, especially in concern of the new worksheet application. They were instructed to answer ten questions using Guttman scale with a choice of “Yes” or “No” and given blank spaces for comment. It is understood that all teachers (100%) gave positive responses and recommended to apply PjBL to other classes and courses. Meanwhile, students responded 95.39% of positive feedback and only 4.66% had a negative comment. The students’ responded positively because they enjoyed learning by doing the procedures scientifically; they feel themselves like a scientist invented something new [19]. In such a way, they experienced the process interestingly instead of memorizing facts and concepts alone, which they frequently had done in their learning process. In addition, their communication skills also enhanced as they learned to communicate during group discussions. This all generates learning motivation and interest in science, which should have a good impact on the learning outcomes later on.
Figure 3. Student’s learning activities of PjBL in high school chemistry

4. Conclusion
The generated PjBL students’ worksheet has been proven valid and effective to guide the student to conduct their learning projects. Moreover, there is a significant improvement in students’ cognitive score test after PjBL implementation. The scores of the students’ scientific skills were generally high, except for the ‘formulating conclusion’ section. Their work performance was considered very good as they were definitely skillful in conducting the project. All teachers and the majority of the students gave positive responses to the implementation of PjBL worksheet. The PjBL model and the worksheet are recommended by teachers to apply to other classes and courses as well as to other schools.

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