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Crafting Briquettes for Learning: The Role of Project-Based Learning in Enhancing High School Students' Scientific Reasoning Skills in Physics Education

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Abstract

Physics learning in senior high school faces challenges in developing students' scientific reasoning ability. This study aims to examine students' scientific reasoning ability through project-based learning of briquette making and its effect on improving students' critical thinking ability, especially in SMA Negeri 1 Jatiroto, to improve a more effective understanding of physics. The research was conducted at SMA Negeri 1 Jatiroto, Lumajang Regency, in semester one of the 2024/2025 scholastic year. The population of the research sample was class X students, which was determined using homogeneity test and random sampling technique or purposive sampling. The research design used Quasi Experimental with pre-test and post-test. Data collection was done through tests, observations, interviews, and documentation. The pre-test and post-test results showed a significant increase in the experimental class, with a higher mean post-test result (84) than the control class (50). Data analysis displayed a significant difference between the two groups, indicating that the project-based learning model had a beneficial effect on enhancing performance students' scientific reasoning skills. Thus, project-based learning in briquette making is proven to be able to encourage increased understanding of physics concepts while developing students' critical thinking skills more effectively.

Keywords: project-based learning, briquette-making, scientific reasoning skills

INTRODUCTION

Physics learning plays an important role to help understand physics concepts, develop knowledge, scientific skills, and abilities in the student science process (Zaidah & Wijaya, 2021). Strengthened by research Murdani's (2020) states that physics learning can be learned through a scientific approach by developing skills on phenomena in the form of experiments. Thus, physics learning is able to develop skills in students.

Skill development that includes cognitive, social, and emotional skills is emphasized in the 21st century to improve student skills in the independent curriculum (Lubis et al., 2*023)*. Supported by research Sari et al., (2021) that in the 21st century, 6C skills (critical thinking, creative skills, communication skills, collaborative skills, computation skills, compassion) are important for students to be able to be skilled in facing global challenges. Therefore, students need to be equipped with 6C skills in order to achieve optimal potential in developing thinking skills.

Scientific reasoning skills are adopted from the Lawson Classroom Test of Scientific Reasoning (LCTSR) as well as 6 dimensions including conservation reasoning, proportional, variable control, probabilistic, correlation, and deductive hypotheses (Hanson, 2016). Research by Pascaeka et al., (2023) states that scientific reasoning skills are important to equip students in scientific understanding so as to improve thinking and reasoning skills to support student learning, especially in physics learning. Supported by research Zimmerman & Klahr (2018) states that scientific thinking involves the principles of scientific inquiry that can be applied by exploring problems, proposing hypotheses, designing experiments, carrying out experiments, argumentation, and drawing conclusions.

Scientific reasoning is considered among the important skills tested by the Program for International Student Assessment (PISA) so it becomes an urgency in this study (OECD, 2023). The outcome of the PISA test in 2022 showed that Indonesian students experienced a decline in science literacy, numeracy, and science even though their ranking rose in positions 5-6 (Schleicher, 2023). This has an impact on the ability to reason, argument, confidence in answers, and weak conceptual understanding in solving physics problems (Erlina et al., 2018). In line with the outcomes of research by Anjani et al., (2020) showed that students' scientific reasoning skills were still unsatisfactory. Supported by the results of preliminary observations at SMAN 1 Jatiroto, teachers rarely train scientific reasoning skills specifically so students still show low thinking skills in physics learning. This is evidenced by students' difficulties in explaining scientific arguments in answering questions on a problem.

The problems found in Karmila research et al., (2019) stated that students still have difficulties in the inquiry learning stage. However, the results of interviews with physics teachers at SMAN 1 Jatiroto show that teachers still implement inquiry learning models and rarely use project-based learning. This results in less variety so that project-based learning could be an efficient solution to the existing problems.

Afifin research et al., (2021) indicates that project-based learning could actively motivate thinking skills through student learning activities. The application of the project-based learning model as a constructivism method effectively involves students in solving problems by constructing learning independently and producing realistic products. The advantages of implementing a project-based learning model can focus on students, enhancing creativity, and have a pleasant of learning atmosphere even though it takes longer (Firdaus et al., 2020). In accordance with the results of research by Miezah & Whajah (2023) stated that the project-based learning model is able to encourage students' scientific reasoning skills. The outcomes of research by Karmila's (2024) also show that students' skills could be developed through the implementation of project-based learning based on local wisdom.

The local values in Indonesia can be utilized if it can be managed properly, in fact, Indonesia is still experiencing crucial energy problems. Indonesian still relies on limited fossil energy so that renewable energy plays a crucial role in human life to be considered for its availability (Lubna et al., 2021; Sarante, 2024). Presidential Regulation No. 22 of 2017 concerning the National Energy General Plan (RUEN) is one of the Indonesian government's policies in assessing the total primary energy supply (TPES) in a sustainable manner (Rahman et al., 2021). Research by Subagya & Eskak (2021) stated that the availability of coconut waste in Indonesia is very abundant, but has not been optimally utilized. Biomass waste in Indonesia can be made into charcoal briquettes that have potential as solid fuel (Murni et al., 2021). Gebeyehu et al., (2023) mentioned that briquettes are a renewable energy source and can improve biomass waste management practices.

Based on the description above, research on scientific reasoning skills in the topic of renewable energy sources using the project-based learning model for briquette making needs to be conducted to assess high school students' scientific reasoning skills. The findings of Meizah et al., (2023) also suggest that other researchers should focus on the project-based learning model to more quickly develop students thinking and reasoning skills. It is hoped that project-based learning will have an impact on high school students' scientific reasoning skills in physics education.

METHOD

The research location was held at SMA Negeri 1 Jatiroto, Lumajang Regency. The participants in this study is the entire class X students of SMA Negeri 1 Jatiroto. In determining the sample using homogeneity test with ANOVA (Analysis of Variance) based on physics daily test scores. This research uses experiments with the type of quasi eksperimental design.

The design used was nonequivalent control group by giving pre-test and post-test to experimental and control class. The experimental class applicated project-based learning and the control class used inquiry. The design of the study can be see in table 1 (Sugiyono, 2018:116).

Table 1. Research Design

Sample	Class	*Pre-test*	Treatment	*Post-test*
R	experiment	O_1	X	O_2
R	control	O_1		O_2

Description:

X : Treatment of project- based learning for making briquettes
R : Randomization
O_1 : Pre-test
O_2 : Post-test

The techniques for gathering data in this research are using tests, observations, interviews and documentation. The data collected can be analyzed with descriptive techniques using the calculation of the average student achievement in each aspect with formula 1 as follows:

$$\bar{x} = \frac{\sum X}{N} \quad (1)$$

Description:
$\sum X$: The sum of all students' scores on one aspect
N : Total number of students

Measuring student scores on each aspect of scientific reasoning skills with formula 2 as follows:

$$SD = \sqrt{\frac{\sum(X-\bar{x})^2}{N-1}} \quad (2)$$

Description:
X : The sum of all students' scores on one aspect
x̄ : Mean of aspect scores
N : Total number of students

The value of students' scientific reasoning skills is obtained by analyzing quantitative data. The assessment technique in this study used the scientific reasoning skills test assessment rubric proposed by Hanson (2016). The formula proposed by Arikunto (2019) to find out the percentage value of the scientific reasoning skills equation 3 is written as follows:

$$\text{Proportion Of value range} = \frac{\text{Sum of student scores}}{\text{Student's maximum score}} \times 100$$

The percentage of the above equation can be categorized in Table 2 as follows (Arikunto, 2018).

Table 2. Proportion of value range scientific reasoning skills

Proportion of value range	Kategori
$0 \leq P \leq 20$	Scientific reasoning skills are lack
$20 \leq P \leq 40$	Scientific reasoning skills very poor
$40 \leq P \leq 60$	Scientific reasoning skills sufficient
$60 \leq P \leq 80$	Scientific reasoning skills are good
$80 \leq P \leq 100$	Scientific reasoning skills very good

RESULT AND DISCUSSION

This study was implemented at SMA Negeri 1 Jatiroto Lumajang Regency using quasi-experimental research. The research sample consisted of two classes, namely class X-2 as the experimental class and class X-1 as the control class. The implementation of learning was carried out 4 times face-to-face in the experimental and control classes. At the first meeting, a pre-test of scientific reasoning skills was conducted followed by providing learning materials about renewable energy assisted by worksheet in experimental and control classes. In the experimental class, students were taught using a project-based learning model of making briquettes, although the control class used the learning model often implemented in SMA Negeri 1 Jatiroto, namely the inquiry learning model. Furthermore, on the 4th meeting, it ended with the scientific reasoning skills post-test and questionnaire filling. Data on students' scientific reasoning skills were obtained from the results of the scientific reasoning skills pre-test and post-test. Experimental and control class students worked on pre-test and post-test questions, each of which was 6 multi-level multiple choice questions with essay-shaped reasoning. The outcomes of the pre-test are used as a basis for measuring students' initial abilities before intervention, while the post-test results are employed to assess changes or development of abilities after treatment is given. the comparison between the outcomes of the pre-test and post-test in both classes (experimental and control) provides an overview of the effectiveness of the treatment applied to the experimental class in improving studensts' scientific reasoning skills. the pre-test and post-test questions granted to students included 6 indicators of scientific reasoning skills, as shown in following table 3.

Table 3. Average score for each aspect of scientific reasoning skills

Indicator scientific *reasoning skills*	**Average score Experimental class**	**Average score Control Class**
Conservation reasoning	1,8	0,8
Proportional reasoning	1,8	1,1
Control of variables	1,2	0,4
Probabilistic reasoning	1,9	1,3
Correlational reasoning	1,8	1,4
Hypotetical-deductive reasoning	1,4	1,5
Average score	1,7	1,1

The data obtained is based on the correct and incorrect aspects of each multiple choice question with essay-shaped reasoning. The data as a whole comes from the pre-test and post-test scores of students' scientific reasoning skills. If the answer and reason are accurate then the score is 2. If only the chosen answer is accurate, whereas the reasoning is flawed then the score is only 1. Furthermore, if the reason is correct the answer is wrong then get a score of 0. However, if both are wrong then the score will also be 0. From these data calculations, the mean score in the experimental class and control class was obtained.

The experimental class displayed three indicators that scored 1.8. This proves that students answer more questions and reasons correctly because the average maximum score is 2. The indicators in question are conservation, proportional, and correlation reasoning. In these three indicators, the average student is only less strong in presenting arguments. This is considered reasonable because some students are less serious in working on the project. However, most students have been taught conservation, proportional, and correlation reasoning in the LKPD project so that they are able to do the post-test with satisfactory results.

On variable control reasoning and hypothesis-deductive reasoning, the average student tends to lack mastery of this reasoning because students answer questions with wrong answers and illogical reasons. In working on projects, students do not consider things that can affect the quality of the products produced. Then students are also still confused in solving problems when facing an obstacle in making projects. As a result, their ability to critically evaluate and improve their work is limited, hindering their progress in project-based learning.

Finally, in the probabilistic reasoning indicator, almost all students mastered it. This is because on average students answer multiple choices correctly and with the right reasons. In addition, in this probabilistic reasoning, students have tried to plan and predict things that might happen during the project so that overall students can understand this reasoning easily. This suggests that students are able to apply probabilistic reasoning skills compared to other types of reasoning. Students' power to predict and handle difficulties makes the project-based learning experience more effective.

In the control class, it is clear that in each indicator of scientific reasoning skills, many students find it hard to working on problems to get the right answer and the right reason. In conservation reasoning and controlling variables, the average student obtained the lowest score among other indicators. It is evident that students did not work on the problem seriously. Many answers and reasons are not correct in working on the problem. However, in proportional reasoning, probabilistic reasoning, and correlation reasoning, students get an average score above it even though the score obtained is still lacking. On the other hand, in hypothesis-deductive reasoning, students get a higher average score even above the mean score of hypothesis-deductive reasoning in the experimental class.

Based on the explanation above, each indicator of scientific reasoning skills of most students in the experimental class gets a greater mean score than the control class. This proves that after being given intervention in the form of a project-based learning model for making briquettes, students have a ability to answer multiple choice questions correctly and for scientific reasons. However, in the control class students still lack scientific thinking in answering multiple choice questions along with logical reasons because there is no treatment in the class. After knowing the mean score of students' scientific reasoning skills, the average value on each aspect of students' could be found in table 4 below.

Table 4. Average score for each aspect of scientific reasoning skills

Indicator scientific reasoning skills	Pre-test		Post-test	
	Average score eksperimental class	Average score control class	Average score eksperimental class	Average score control class
Conservation reasoning	33	29	88	46
Proportional reasoning	83	70	93	56
Control of variables	19	14	63	23
Probabilistic reasoning	64	49	96	70
Correlational reasoning	51	43	93	68
Hypotetical-deductive reasoning	24	33	73	37
Average	46	40	84	51
Standard deviation	19,471	17,011	8,570	14,355
Category	Simply	Less	Very good	Simply

According to the table, the mean pre-test and post-test scores of students' scientific reasoning skills show that the experimental class has a biger mean result than the control class. The assessment was done by calculating the number of correct answers divided by the total questions multiplied by one hundred, which revealed an increase in both classes. However, the improvement in the experimental class was more significant due to the project-based learning model that linked each indicator of scientific reasoning skills.

The category in each class was determined based on the score range proportion table. The control class got a sufficient category because it applied an inquiry model without the introduction of scientific reasoning skills, while the experimental class displayed a big improvement after the application of the project-based learning model that was directly connected to these indicators. Although the standard deviation value is quite large, this indicates a wide variation in the data. However, as long as the standard deviation is smaller than the mean score, the gain is still considered logical.

In the experimental and control classes, learning has been running in accordance with the research flow. The experimental class applied project-based learning with briquette making, although the control class used the inquiry model. Learning went smoothly according to the syntax of each model, with the experimental class linking each indicator of scientific reasoning skills through worksheets.

In the conservation reasoning indicator, experimental class students can answer the questions correctly even though there are some arguments that are less rational. For proportional reasoning, some students have not been able to fully compare the proportion of briquette making, but most can implement it when testing the product. Variable control reasoning showed unsatisfactory results because many students were not serious in designing the product. On probabilistic and correlation reasoning, students could answer the questions well and showed a good understanding of project planning and product testing.

On hypothesis-deductive reasoning, the results were lower as students struggled to formulate fundamental questions relating to cause and effect. Control class students only showed a slight improvement and remained in the sufficient category, because the inquiry model did not involve students directly in the manufacture and testing of briquette products.

Comparison with previous research shows that project-based learning shows greater efficient in developing students' scientific reasoning skills, in line with the findings that project-based learning can improve scientific reasoning skills, as proven by Miezah & Whajah (2023) and Putri et al. (2020). Thus, project-based learning is expected to be applied more often to develop students' competence in physics, especially in renewable energy materials.

CONCLUSION

Considering the outcames of the analysis and discussion, it can be inferred that increase in the scientific reasoning skills of high school students in physics learning. The average value of each indicator of students' scientific reasoning skills obtained a very good category. All indicators show the final results of students' scientific reasoning according to the project experience. In addition, the correlation between scientific reasoning skills and project-based learning, it can be said that students with good scientific reasoning skills are more likely to make the right decision. Project-based learning on briquette making is proven to have a significant outcome on scientific reasoning skills of high school students in physics learning. This is according to the results of the analysis which obtained an Asymp sig (2-tailed) value of 0.000 or smaller than 0.05, which means that there is a significant difference between the average value of scientific reasoning skills of students in the experimental and control classes. So that the problem formulation can be answered in this study.

Suggestions that can be proposed are: First, for teachers, the project-based learning model should be used to train students' scientific reasoning skills in physics. Second, for students, it is expected to be more active and focused when following the project, so that scientific reasoning skills can develop optimally. Third, for other researchers, the project-based learning model in briquette making could be further developed to evaluate students' scientific reasoning skills in physics.

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