Application of Project-Based Learning (PjBL) Models with STEM Approaches in Dynamic Electricity Material Learning

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Abstract

This research aims to determine the effect of the Project Based Learning (PjBL) model with the STEM approach to improving learning outcomes in dynamic electricity material in class XII MIPA students of SMAK Abdi Wacana. The research used designed one group pre-experimental pretest-posttest. Design using the measurement of data collection techniques on tests conducted before and after treatment. Analysis of data was undertaken with the normality, homogeneity, Wilcoxon test, and analysis effect size. The results showed that (1) Before and after the Project-Based Learning (PjBL) model with a STEM approach was implemented, learning results for dynamic electricity material were different (P-value 0.05), (2) Application of the PjBL models with STEM approaches in dynamic electrical material learning is effective in improving student cognitive learning outcomes in class XII MIPA SMAK Abdi Wacana. An average pre-test score of 31.22, a post-test score of 61.83, a standard deviation value of 20.22, and an effect size (ES) value of 1.5136 belong to the high category. The results of this study are expected to be considered by teachers in choosing effective learning models and approaches to improve student cognitive learning outcomes.

Keywords: Cognitive learning Outcomes; Dynamic Electricity; Project-Based Learning; STEM Approach

INTRODUCTION

Information and communication technology has permeated all parts of life in the twenty-first century age of the industrial revolution 4.0. One of them works in the educational field. As a result, the younger generation must be equipped with the necessary skills and abilities. In terms of the three components of these talents, (1) learning and innovation skills, which comprise ways of thinking and doing; (2) work-related information, media, and technology; and (3) life and career skills. Skills in thinking and doing are the most important (Sukmana, 2018).

In addition to these abilities, students must possess four competencies: communication, collaboration, critical thinking and creativity. These four skills are called 4C talents (Prihadi, 2017). Providing these skills and abilities could increase the quality of our country's human resources (HR).

The Indonesian government has made various efforts to improve the quality of education in order to educate the next generation of the 21st century. The 2013 curriculum was created taking into account the competencies of the 21st century. This research was conducted using the 2013 curriculum, emphasizing a student-centred learning approach (Student Centered Learning). Learner-centred learning allows students to have a more active role in constructing and developing cognitive structures and skills using common concepts and events.

Physics is one of the sciences that analyzes natural phenomena in life. Because students are asked to verify a theory or notion in physics, they must be active participants in the learning process (Badriyah, 2017). Physics classes are designed to help students comprehend concepts and principles that can be used to explain a variety of natural events. Students must comprehend mathematical and theoretical principles that may affect the degree of study results to answer physics challenges.

According to the observations, Abdi Wacana Christian High School's mid-semester average (PTS) for physics classes for the 2019/2020 academic year was 53.67, with the best score of 69.20 and the lowest score of 28.00. From the average physics value, the minimum completeness of 70.00 still needs to be met. Students struggle to solve dynamic electrical problems, particularly those involving direct current (DC) electric circuits. According to the teacher, only 25-40% of kids were able to think critically, creatively, and collaboratively.

In addition to observations, interviews with physics subject teachers at SMAK Abdi Wacana (18 February 2021) revealed that online learning delivers content and learning videos and that when teachers ask questions, some students frequently do not respond. Students rarely ask and answer questions from the teacher. As a result, teachers are less likely to hold discussions or question-and-answer sessions with pupils.

It was also revealed that understanding mathematical ideas relating to physics principles, particularly dynamic electricity, still needs to be improved. The lack of student interaction during the learning process, the teacher merely presenting material due to limited conditions, students not being directed to form groups in problem-solving, and the policy of not using face-to-face learning all contribute to inefficient learning. Another factor that may contribute to a lack of knowledge of mathematical ideas connected to physics is that models and techniques are not appropriate for dynamic electrical materials.

The findings of the preceding observations and interviews indicate that improvements are needed to improve student learning outcomes. Teachers must balance and improve cognitive ability, collaboration, creative thinking skills, and problem-solving inventiveness.

The Project Based Learning (PjBL) approach is another option for dealing with this issue. PjBL is an approach to project-based learning that encourages students to solve problems and work independently to gather knowledge (Viana et al., 2019). Students use the PjBL paradigm to create their own knowledge based on what they already know. Participants become engaged learners due to this (Santyasa et al., 2020). Other research also reported that project-based learning could improve students' understanding of concepts in science, mathematics, engineering, and technology (Branch, 2015).

Project-based learning can be integrated with learning that helps students to understand a topic quickly, solve issues, and think creatively, notably the Science, Technology, Engineering, and Mathematics approach, to instil character in kids. STEM in education is to satisfy the demands of students in the twenty-first century, specifically, that they gain scientific and technology literacy through reading,

writing, observing, and performing science. They can apply the skills they currently have to solve issues. STEM science-related issues arise in everyday life (Bybee, 2013).

The Project-Based Learning model with the Science, Technology, Engineering, and Maths approaches used a blend that is very suitable to complement each other with its advantages and disadvantages so that students can understand the concepts of product making with the help of the PjBL learning model and the design process (Engineering design process) in order to produce appropriate product results (Han et al., 2015).

Science, Technology, Engineering, and Mathematics approach is an approach that refers to the four components of science, namely knowledge, technology, engineering, and mathematics (Permanasari, 2016). According to his research, applying STEM can help develop knowledge, help answer questions based on investigation, and help students create new knowledge".

In line with this explanation, "Students who study STEM are taught and trained to use critical thinking, investigation, problem solving, collaboration, and engineering as design thinking" (Task Force STEM, 2014). STEM provides systematic reasons for the material or problem being discussed.

Several research has been undertaken using the STEM approach to apply the PjBL model. Students' scientific literacy has been shown to improve when STEM-integrated PjBL is used on the topic of air pollution (Afriana et al., 2016). Furthermore, further research suggests that using PjBL-STEM learning can help students develop their creative thinking skills (Ismayani, 2016). Experimental tests of the PjBL-STEM paradigm have shown that it can increase students' cognitive and creative learning results (Meita et al., 2018).

PjBL with an integrated STEM approach can increase student motivation, create meaningful learning, help students solve problems of daily life, and support future careers (Tseng et al., 2013). In addition, STEM in PjBL also challenges and motivates students because it trains them to think critically and analytically and improve higher-order thinking skills (Corlu et al., 2014).

As a result, PjBL learning using the STEM approach used in this study has the potential to provide meaningful learning in understanding concepts through household electrical installation project activities related to dynamic electricity materials, which are expected to be able to apply mathematical concepts and physically through project activities, allowing students to participate actively in the learning process. Things that encourage pupils to think critically, creatively, and analytically are beneficial (Furi et al., 2018). Mastery of concepts, critical thinking, creativity and problem-solving skills, and the ability to collaborate can all be improved with the STEM method.

According to the description above, the study using the PjBL models with STEM approaches to improving cognitive learning outcomes in the dynamic electricity matter was felt to be quite rationally carried out on students at SMAK Abdi Wacana.

METHOD

This study used a one-group pretest-posttest design with a pre-experimental approach; there was only one experimental class and no control group. (Sugiyono, 2017). The experiment design in this study is listed in Table 1.

Table 1 Experiment Design

Pre-test	*Treatment*	*Post-test*
O_1	X	O_2

Description :
O_1: Pretest
X : Treatment
O_2: Posttest

This research was conducted from 10 November to 10 December 2021. It lasted four weeks (1 month), with an allotted

time of 2 hours of lessons for the pre-test, 2 hours of lessons for treatment, and 2 hours of lessons for the post-test. On November 10 2021, a pre-test will be held. The test aims to assess students' first ability to solve dynamic electricity problems. On November 16 2021 the first treatment will be carried out for one hour of study. On December 10, 2021, 1 hour of a second treatment lesson and 2 hours of study for the post-test will be given.

The participants in this study were SMAK Kristen Abdi Wacana, 18th-grade students who had never studied dynamic electricity before. All 18 students in class XII IPA SMAK Abdi Wacana were used in this study. The sampling technique used in this investigation was complete sampling. Measurement-based data collection approaches were used to collect test findings before and after therapy. Individuals or groups own the property (Arikunto, 2010).

The test attempts to describe students' cognitive learning outcomes by writing down the steps for completing the material contained in dynamic electrical material. Data analysis was complete with normality, homogeneity tests, Wilcoxon tests using the SPSS application version 23.0 windows, and effect size analysis.

RESULT AND DISCUSSION

This study used a quantitative research approach using a pre-experimental method with a one-group pretest-posttest design. The data collection technique used is the learning achievement test technique in the cognitive domain. Learning outcomes in the cognitive domain use tests designed with the characteristics of STEM questions, which can develop thought processes from the results of applying project-based learning models with the STEM approach in dynamic electricity material.

Before learning was carried out using a project-based learning model with a STEM approach to dynamic electricity material in power generation projects in the form of miniature household electrical installation products. In this study, the authors compiled a Learning Implementation Plan integrated with STEM.

As for its relation to learning dynamic electricity material with the STEM approach in the form of products with the topic of miniature energy-saving electrical installations in households, which has an analysis of STEM indicators is the following.

Science: Knowledge acquired by students consists of concepts by discussing the factual knowledge that is learned is that a lamp will turn on if it is connected to a current source, conceptual knowledgable which includes the same current strength, the voltage in a series circuit will be divided into several lamps while in a parallel circuit the voltage on each electric load is the same as the source, procedural knowledge that can be learned is how to assemble series-parallel electrical circuits as well as metacognitive abilities, namely about how to save electricity consumption by designing energy-efficient homes.

Technology: The technology that is trained on students is related to making miniature houses (passive) in which there is an electrical installation using series-parallel electrical circuits; then, to create a scheme, students are trained to use the form of the Livewire software application as a supporting technology.

Engineering: engineering in this lesson trains students to design miniature houses that are energy efficient and electrical installations in miniature households, evaluate the results of their work and redesign if necessary based on the results of the evaluation.

Mathematics: mathematics in this study is used to scale miniature houses, calculate the height of buildings, calculate the area of open and closed rooms (bedrooms, bathrooms, living rooms, and family rooms), determine the diagonal of the field for lamp positions, calculate the number of lamps, calculate the number

lamp used and calculate the switch used. From the research that has been done, the pretest-posttest score data on cognitive learning outcomes can be seen in Figure 1.
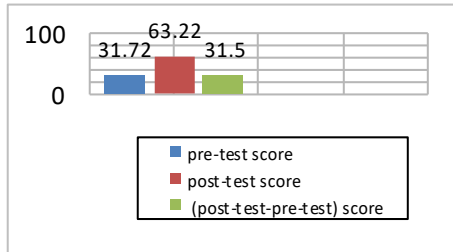

Figure 1 Graph of Study Results *Pretest-Posttest*

The average pre-test score was 31.72, according to data analysis. The post-test score increased by 63.82, with an average score difference of 31.50 after using the

PjBL model with STEM approaches. To determine the influence of the PjBL model with a STEM approach to improving cognitive learning outcomes in learning dynamic electrical material for class XII MIPA SMAK Abdi Wacana students. This study can be reviewed from two aspects, analyzing variation in cognitive learning outcomes and how effectively applying the Project Based Learning (PjBL) model with a STEM approach is.

First, data analysis was carried out. Before and after employing statistical testing, there was a difference in student cognitive learning outcomes. It was determined whether the data were normally distributed using the Shapiro-Wilk normality test. The data is shown in Table 2 based on the normalcy test.

Table 2 Normality Test Pre-test and post-test data

	Class	Kolmogorv-Smirnov[a]			Shapiro-wilk		
		statistic	Df	Sig.	Statistic	df	Sig.
Study							
Result	Pre-test	0.252	18	0.004	0.80	18	0.002
	Post-test	0.183	18	0.113	0.91	18	0.112

The results of the Shapiro-Wilk normality test are shown in Table 2. The significance value for the pre-test is 0.02 (0.05), and the significance value for the post-test is 0.112 > (0.05). The normality test may reveal that the data are not normally distributed; as a result, the study can be finished using a non-parametric statistical test called Wilcoxon.

Second, the homogeneity of variance test was used to evaluate whether or not the data had a homogeneous variance. Table 3 shows the results of the tests.

Table 3 Variance Homogeneity Test

Variance Homogeneity Test Pre-test Learning Outcomes			
Levene Statistic	df1	df2	Sig.
5.710	9	19	0.001

From the test results, it can be concluded that the data does not have the same variance because the value of sig < 0.05 (0.001 < 0.05), so it must be continued on non-parametric testing, namely the Wilcoxon test.

Third, after performing the normality and variance homogeneity test, the Wil-Coxon test was used to examine the differences in pre-test and post-test learning outcomes after using the project-based learning (PjBL) models with STEM approaches. Table 4 shows the test results.

Table 4 *Wilcoxon Test Pretest-Posttest*

	Posttest-Pretest
Z	-3.734[b]
Aysmp. Sig (2-tailed)	0.000

Table 4 shows that there are variances in student learning outcomes before and after the introduction of the Project-Based Learning (PjBL) model with the STEM approach on dynamic electricity content. As a result, this study was deemed effective because substantial changes were found and impacted improving student learning outcomes.

According to the observational data, there is a significant increase in the post-test average score, which now stands at 63.22. However, it failed to meet the

requirements or standards set for the minimum level of learning mastery, namely 70. This is owing to students' need for more comprehension of mathematical ideas and less-than-ideal delivery of sub-materials on Kirchhoff's I law due to time constraints and application to small goods. Not all dynamic electrical topics included in the test questions are relevant for households' miniature electrical installations.

However, it may be deduced that student learning outcomes differ before and after the STEM approaches incorporating the Project-Based Learning (PjBL) paradigm.

According to these studies, combining the PjBL model with the STEM approach positively influences student cognitive learning outcomes since the learning activities focus on active participation in critical, creative and able-thinking skills. Collaborate. Arends' point of view backs this up (Arends, 2015) PjBL is developed to help pupils improve their thinking, problem-solving, and intellectual abilities. Project-based learning (PjBL) models with a STEM approach are used in its execution, utilizing experimental approaches such as projects, demonstrations, conversations, and questions and answers.

Project-based learning in Science, technology, engineering, and mathematics (STEM-PjBL) is a teaching and learning paradigm integrated with PjBL curriculum design and based on the STEM approach to learning (Lou et al., 2017). Students will be able to practice the modules learned throughout the educational process as a result of the educational model employed. It is impossible to deny the influence of learning before and after introducing the project-based learning (PjBL) model with the STEM approach on improved student learning outcomes.

Although project-based learning using the STEM approach may be effectively maximized even with a restricted face-to-face system, it has been demonstrated that the efficacy of employing Glass's Effect size formula is obtained by an ES value of 1.5718, which falls into the high category. The data is presented in Table 5.

Table 5 Recapitulation of Effect Size Calculation Results

	pre-test score	Post-test score	(Post-Test) – (Pre-Test) Score
Average Standard Deviation	31.72 20.04	63.22	31.5
ES		1.5718	

Combining PjBL models with STEM approaches can encourage students to improve their cognitive abilities.

This learning model focuses not only on what people do but also on what they think while doing it, based on the concept of a PjBL model with STEM approach. The results of this study support the previous (Hamidah, 2019), which found that the PjBL learning model with the STEM approach improves students' creative problem-solving abilities and metacognitive capabilities while they study physics.

The cognitive learning outcomes in this study are the results of a learning process that was carried out with the direct application, namely the creation of a project/finished product, namely the implementation of a tiny domestic electrical installation. The researcher's tests are completed at the end of the learning procedure. According to (Sudjana, 2016) perspective, learning outcomes are abilities that students possess after obtaining their learning experiences. In other words, cognitive learning outcomes are determined by how students conduct themselves during the learning process. The learning outcomes are also beneficial when a student maximizes his learning process.

CONCLUSION

Based on the findings, it can be concluded that the Project-Based Learning (PjBL) model combined with a STEM approach in dynamic electricity learning has a high-category influence on increasing student learning outcomes in class XII MIPA SMAK Abdi discussion. Based on the results of data analysis and discussion, in particular, it was concluded that there were differences in cognitive learning outcomes before and after the application of the Project-Based Learning (PjBL) models with STEM approaches in dynamic electricity learning (P-value <0.05). Furthermore, the Project-Based Learning (PjBL) model combined with STEM approaches can effectively improve student learning outcomes on dynamic electricity material. The average pre-test score is 31.22, and the average post-test score is 61.83, with an effect size (ES) value of 1.5136, which is included in the high category.

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