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Project-Based Learning Based on the Internet of Things to Improve Students' Science Process Skills

Tita Dewi Larashati [1,2], Indarini Dwi Pursitasari[1*], Didit Ardianto[1]

[1] Master of Science Education, Pakuan University, Bogor, West Java, Indonesia.
[2] State Senior High School 9 Bogor City, West Java, Indonesia.

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Corresponding Author:
Indarini Dwi Pursitasari
indarini.dp@unpak.ac.id

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Abstract: This study aims to analyze the application of Project Based Learning to improve science process skills (SPS) using IoT-based learning media. The method is qualitative and quantitative with a quasi-experimental type namely a pre-test-post-test control group. The population is students of class XII MIPA in one of the State Senior High Schools in Bogor City, totaling 214 students. Sampel for experimental and control classes were selected purposively, each with 35 students. Data were obtained through written tests, product assessments, observations, and questionnaires. Data analysis is included descriptive, validity test, reliability test, and t-tests. The results showed in the control, the SPS pre-test was not good and the post-test was good with a fairly large n-gain value. In the experimental class, the SPS pre-test was not good and the post-test was very good. The N-gain of the experimental class is higher than the control class. The SPS value of each indicator increased both in the control and experimental classes. PjBL is able to improve SPS and the t-test shows the application of PjBL of PjBL with IoT on unidirectional electrical physics material.

Keywords: IoT; N-gain; Project Based Learning; Science Process Skills

Introduction

The industrial revolution 4.0 opens opportunities for the maximum utilization of IoT to support Project Based Learning (PjBL) in improving science process skills (SPS). The internet of things (IoT) is crucial in the PjBL model in the education era 4.0 because internet technology can improve traditional PjBL by offering new resources, tools, and services sourced from the internet. Utilization of IoT resources, tools, and services is expected to improve student inquiry processes in the learning process.

Preliminary studies at one of the Bogor City Public High Schools show that the implementation of PjBL is still not optimal and has not made much use of IoT. The achievement of the value of science process skills is also not in accordance with the expected conditions, which is still in the sufficient category. SPS achievement needs to be improved to be good or very good. The problems in learning that are faced require teachers to be able to find appropriate learning methods so as to be able to increase students' SPS scores. The flexibility of the teacher to choose various learning models and teaching tools so that learning can be adapted to the learning needs and interests of students is supported by changes to the current curriculum. In this curriculum, SPS is one of the competencies that must be achieved. It is hoped that the changes made to the curriculum will improve the quality of education and meet the needs of the community (Ananda et al., 2021). One learning approach that can maximize online learning is PjBL because this learning allows students to study concepts in depth while also improving their learning outcomes (Abidin et al., 2020). The same thing was stated by Guo (2012)stating that PjBL refers to a constructivist framework that makes the learning and teaching process active, and meaningful inquiry and builds knowledge through learning.

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Based on the description above, the purpose of this research is to evaluate and analyze the application of PjBL model learning in improving science process skills in students using Internet of Things-based learning media.

Method

This study used qualitative and quantitative methods with a quasi-experimental research type, namely the pre-test-post-test control group. This research was conducted on class XII MIPA students at one of Bogor City Public High Schools for the 2020-2021 academic year with a total population of 214 students. The sample of students was selected using a purposive sampling technique, namely 35 students each. In the two groups, the pretest was carried out together before learning began. The research variables used consisted of independent variables, namely the Implementation of PjBL using IoT media and bound, namely the students' SPS.

The instruments used were in the form of SPS multiple choice test questions and SPS questionnaires as well as student response scales for PjBL using IoT media in Physics learning with unidirectional electricity. Data collection was carried out through written tests, product assessments, observation and questionnaires. The instruments used were written tests, scoring rubrics, observation formats and questionnaires.

The SPS assessment is obtained through indicators in the form of (1) Observing, (2) Predicting/predicting, (3) Planning an experiment, (4) Using tools/materials, (5) Applying concepts, and (6) Communicating (Septantiningtyas et al., 2020). Calibration of the SPS Instrument Calibration is carried out with expert judgment (Expert Judgment). For the SPS assessment, students are given an assessment in the form of a written test in the form of multiple-choice questions of 20 questions. The value given is 1-100. The criteria for answer scores were categorized with reference to Arikunto (2013) namely ≥ 85 (very good), 70-85 (good), 55-70 (enough), 40-55 (poor) and ≥40 (very poor). The final value obtained is averaged, the standard deviation is calculated, and the value of n-gain is calculated.

PjBL in the form of students are assigned to design a one-way electric circuit in the form of a prototype of a series of lights commonly used in homes that can be controlled using an application in the form of the Arduino IDE software, as the microcontroller and the blink and IFTTT applications to control the electrical circuit. PjBL product evaluation is carried out by observing the activities carried out using an observation sheet on process/product skills in PjBL activities. Aspects observed include conformity of the product with the concept (theory), creativity, experimental skills, and novelty (Hamidah et al., 2020).

The analysis carried out in this study included descriptive analysis, validity test, reliability test, and t-test for the pre-test and post-test groups. Descriptive analysis is used to describe the research variable data, namely in the form of percentages, averages, histogram graphs, and standard deviations. The validity test was carried out on the student response questionnaire instrument with the Pearson product-moment correlation technique. The validity of the instrument items is determined by the calculated Product Moment Coefficient where $F_{count} > r_{table}$ at $\alpha = 0.05$. The reliability test of the questionnaire instrument was carried out using the Alpha Cronbach technique, with good reliability criteria ($\alpha > 0.9$), good ($0.7 < \alpha < 0.9$), acceptable ($0.6 < \alpha < 0.7$), bad ($0.5 < \alpha < 0.6$), and unacceptable ($\alpha < 0.5$) (Bhatnagar et al., 2014).

The assessment of student response instruments to PjBL is using a questionnaire in the form of a Likert Scale with 5 alternative answers, namely Strongly Agree (SA) = 5; Agree (A) = 4; Undecided (U) = 3; Disagree (D) = 2; and Strongly Disagree (SD) = 1. Score interpretation refers to Arikunto (2013) namely 0–19.99 (Strongly disagree), 20–39.9 (Disagree); 40–59.9 (Enough), 60 –79.9 (Agree); and 80–100 (Strongly agree).

The t-test was carried out on the pre-test and post-test students' SPS scores so that the effect of PjBL learning with IoT was known. Testing was carried out using SPSS software.

Result and Discussion

Learning is carried out offline in each class, namely through practicum using the guided inquiry method for the control class, and PjBL for making one-way electric circuit prototypes using IoT for the experimental class. Based on the results of observations, the entire learning process has been covered in accordance with the lesson plans that have been prepared.

Student projects in the form of prototypes of one-way electric circuits using IoT are made in groups, taking into account examples of the use of IoT in one-way circuits that are commonly used in everyday life that were previously presented by the teacher in video form. The project is collected in a time allocation of 4 (four) weeks. During the work process, students can ask questions and consult with the teacher. All groups can complete the project according to the circuit design they made. At the time of testing the tool, all electrical circuits connected to the internet used Arduino software as a microcontroller. At the end of the project, students report the results of projects that have been made in the form of reports and present the results of projects that have been done. SPS assessment was carried out in both groups, namely SPS based on teacher observations using an assessment rubric and SPS using tests.

SPS Based on Observation

The results of the observational SPS assessment and n-gain can be seen in Table 1.

Table 1. Observational SPS Assessment Results

SPS	Mean	SD	Value	
			Max	Min
Control	79.86	9.89	95	65
Experiment	90.14	6.24	100	80

The SPS value of the experimental class was better than the control. The mean SPS value for the control class was in the good category (79.86) while the mean for the experimental class was included in the very good category (90.14). Assessment according to indicators shows that there is no difference in observing indicators, this can be because each class has the same ability to observe electrical measuring instruments. In the indicator of applying the concept, both classes have the same ability to apply the concept of one-way electric circuits. The striking difference is in the indicators of planning the experiment.

The results also showed that the mean value of the control group (79.86) was lower than that of the experiment (90.14). This shows an increase in the overall observed SPS value of the experimental class compared to the control.

Comparison between the observed SPS values and post-test SPS control and experimental classes (data not shown), shows the same average value, which is in the good category. This shows that there is no bias in teacher observation of their students' SPS scores, indicating that teachers have a good understanding of their students' academic abilities. In teaching and learning activities, teachers are the central point in efforts to reform learning and they are the key to the success of any effort to improve the quality of education (Sudrajat, 2011). In addition to the method that needs attention, a teacher is also required to understand the passion of his students. Passion is excitement, awareness or energy that arises from within a person when doing something. This good understanding will determine what method is best applied to students (Suwardi et al., 2018).

SPS Based Test

The SPS score based on the test was carried out using an assessment rubric and the results are shown in Table 2.

Table 2. Results of the SPS Test for the Control and Experimental Classes

Class	Mean		N-gain (%)
	Pre-test	Post-test	
Control	46.52	80.42	63.70
Experiment	46.57	88.14	76.28

The mean pre-test values of the controls and experiments were not much different, namely 46.52 and 46.57, while the post-test scores of the experimental class (88.14) were higher than those of the controls (80.42). Based on the n-gain value, it appears that learning through the guided inquiry method in the control class is quite effective (63.70%) and the PjBL method is effective (76.28%) to increase the SPS value in one-way electricity material in the experimental class.

The results showed that there were differences in the pre-test SPS values and post-test values in the control class as shown in the n-gain value. The acquisition of n-gain (63.70%) on average is quite large indicating that on average the provision of one-way electricity material is quite effective in increasing students' SPS. Several indicators show quite high n-gain values such as indicators of planning experiments, using tools and materials and communicating. Observing indicators obtain a relatively small n-gain, indicating that just giving material does not make students have the ability to observe.

The results of the Mann Whitney test (asymp. sig. 2-tailed = 0.000), showed a significant difference between the SPS pre-test and SPS post-test in the control class, meaning that giving one-way electrical material was able to increase students' SPS scores. The teacher's ability to provide material to students is very important in the teaching and learning process because when the SPS shows a low score, the teacher can make the best effort to increase the student's SPS score. The N-gain SPS values for the pre-test and post-test for the experimental class are shown in Table 3.

Table 3. SPS Pre-test and Post-test Experimental Class

SPS	Experiment		
	Pre-test	Post-test	N-gain (%)
Observe	52.34	83.03	64.39
Foresee	41.14	72.57	53.39
Planning Experiments	56.94	95.80	90.25
Using tools and materials	45.71	100.00	100.00
Applying Concepts	68.57	92.00	74.55
Communicate	63.91	100.00	100.00
Average	55.00	91.57	80.55

The results above show that all indicators show an increase in the SPS value. The average change for each indicator is 80.55 which means good, showing PjBL with IoT on direct electricity material effectively increases the

SPS of experimental class students. In assessing each indicator, the predictive indicator (53.39%) shows the smallest n-gain (less effective).

The value of n-gain for other indicators is observing (64.39%) and applying the concept (74.55%) which are quite effective. The value of n-gain indicator is planning an experiment (90.25%), using tools and materials (100%) and communicating (100%) is effective. The results of the normality test showed that the pre-test SPS sig value was 0.323 > 0.05 so that it can be said that the pre-test SPS data was normally distributed. For the SPS post test, the significance value is 0.159 > 0.05 so that it can be said that the data is normally distributed. The results of the paired t test show the value of Sig. (2-tailed) of 0.000, namely the p value < 0.05 which indicates a significant difference between the pre-test SPS and post-test SPS in the experimental class.

These results show that all indicators show an increase in SPS values, meaning that PjBL with IoT is able to increase SPS scores for experimental class students. In observing and predicting indicators, PjBL with IoT shows that the acquisition of n-gain is less effective. However, on the indicators of observing, predicting and applying concepts, PjBL has not been effective in increasing students' SPS. On the indicators of planning experiments, using tools and materials and communicating, PjBL is effective in increasing students' SPS.

The results of the t test showed a significant difference in SPS values between the pre test and post test experimental class. This means that the application of PjBL with IoT on direct electric materials can significantly increase the SPS value of the experimental group. The results of this study are consistent with the findings of Umara et al. (2018), namely the application of a project-based learning model to the concept of pollution and environmental damage can improve students' science process skills.

Whether there is a difference in the implementation of PjBL with IoT can be seen based on the difference in n-gain between the control and the experiment. The results of the analysis are shown in Table 4.

The n-gain value for each indicator for the experimental class has a higher value than the control class, except for planning an experiment. In the control, the indicator using the tool shows the highest n-gain (69.44%) and in the experimental class communicating has the highest n-gain value, namely 82.86, meaning that this indicator is effective with the PjBL method. When compared to the control, the average value of n-gain in the experimental class is higher than that of the control class. This shows that giving projects can increase the value of SPS compared to giving conventional materials. This condition is in line with Natty et al. (2019) which states that PjBL is able to improve students' ability to process information; improve the ability to solve existing problems, develop creative thinking in the form of products; and increase motivation, self-confidence, tolerance, cooperation and also students' understanding of the material.

Table 4. N-gain Control and Experimental Class According to Indicators

Indicator	N-gain	
	Control	Experimental
Observe	46.81	50.15
Foresee	37.36	41.48
Planning an experiment	61.11	60.00
Using tools	69.44	71.43
Implement the concept	52.77	58.48
Communicate	68.15	82.86

SPS themselves involve cognitive or intellectual, manual, and social skills (Ulmiah et al., 2016). Providing science projects will directly impact these skills because students can directly apply theory into a project whose product is assessed thereby increasing cognitive and manual abilities (Dias et al., 2017). Social skills also increase because projects are usually carried out in groups (Sa-ngiamjit, 2016), so that students have the opportunity to share information and create a different social atmosphere compared to the control class.

Increase in Student SPS scores

The results showed an increase in the value of each SPS indicator between the control and experimental classes. This means that the project given in the physics subject of unidirectional electricity is able to increase students' SPS. This increase in SPS scores is generally accompanied by an increase in students' academic scores. The results of this study are in accordance with Derilo (2019) who found that there is a real correlation value between basic SPS scores and academic achievement and there is a very positive correlation between all SPS and scientific achievement scores.

Theoretically, the increase in student SPS through PjBL learning is understandable because students use real-world problems as their learning media. Problems given to students in the form of projects will be able to arouse students' understanding of problems, awareness of gaps, knowledge, goals of wanting to solve problems, and the perception that they are able to solve these problems. The problems presented at the beginning of learning are authentic and meaningful problems. Each student or group must solve these problems independently (Dewi et al., 2018). By trying to solve problems independently, students are expected to be able to gain knowledge more meaningfully. PjBL model learning is more effective than conventional learning in improving science process skills (Chasanah et al., 2016). The project-based learning model provides opportunities for all students to be active in the learning process (Wulandari et al., 2018), moreover to complete the projects provided in the learning process by conducting experiments and discussions so that students can prove themselves by carrying out the experimental process themselves to prove and conduct discussions to resolve the problems that have been provided.

Student Response to PjBL

Students' responses to the implementation of PjBL with IoT on unidirectional electrical physics material were analyzed using statement items which were assessed using a Likert scale. The results of data analysis show that all statement items are declared valid. The SPSS output results show a Cronbach's alpha value of 0.846 so that it can be said that all items are reliable. The average percentage of student responses to the PjBL method was 78.11%, meaning that on average students gave an agreeable response to the implementation of PjBL with IoT on unidirectional electrical physics material. The highest response was on the aspect of PjBL's influence on concept mastery.

These results show that by using PjBL it is easier for students to connect the concept of unidirectional electric circuits with events or the application of the use of electric circuits in everyday life. The results of this study are in line with Kamba (2018) who found that although students' SPS was still low, there was a positive relationship between SPS and attitudes towards physics or there was a positive response from students towards learning using PjBL. In general, the application of project-based learning has a positive impact on the teaching and learning process (Nugraheni, 2018). A good response from these students is important because it will determine their interest and passion for learning which will ultimately result in higher academic achievement.

Conclusion

Based on the results of observations, the entire learning process was covered in accordance with the lesson plans that had been prepared and all students were able to complete projects on time. Comparison between observational SPS scores and post-test SPS in control and experimental classes (data not shown), shows the same average score, which is in the good category, which means that there is no bias in teacher observation of students' SPS scores, indicating that teachers have a good understanding of students' academic abilities. The application of PjBL with IoT on direct electricity material was able to significantly increase the SPS value of the experimental group. When compared to the control class, the n-gain value of the experimental class is higher than that of the control class, indicating that giving projects can increase SPS values compared to conventional giving of material. The results showed an increase in the value of each SPS indicator between the control and experimental classes. This means that the project given in the physics subject of unidirectional electricity is able to increase students' SPS. Students gave a good response (agreed) to the application of PjBL with IoT on unidirectional electrical physics material.

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