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Building Cognitive and Affective Learning Outcomes on the Concept of Linear Motion through Ticker Timer Experiment Using Problem Based Learning

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Abstract

This study is aimed to determine the impact of the ticker timer experiment using Problem Based Learning (PBL) model on students' cognitive and affective learning outcomes in Physics. The research used a quasi-experimental method which is conducted in one of the senior high schools in Semarang, Indonesia. The research subject for both experimental and control classes was chosen randomly from the population. The experimental class carried out the learning using the PBL model-based experiment and the control class implemented the Direct Instruction model. The cognitive and affective learning outcomes were collected through the test and the observation sheets. The data analysis used the t-test statistical method. The results showed that there were differences in cognitive learning outcomes between the control class and the experiment class (t_{count} = 1.993> t_{table} = 1.667). Based on the results of the observations also found differences in students' affective learning outcomes with the average value of the experimental class was 25 which is in the very good category and 23.21 for the control class which is in the good category. Based on the results of the discussion, it can be concluded that the PBL model-based experiment has a significant impact on students' cognitive and affective learning outcomes

Keywords: Problem Based Learning, Cognitive and Affective Learning Outcomes, Experiment

INTRODUCTION

Learning Physics in high school emphasizes the importance of using a scientific approach because physics is a lesson that requires a lot of understanding instead of memorizing; therefore, it needs the procedures to accomplish a comprehensive and proper understanding of physics concepts (Sunal et al., 2016; Lutasari et al., 2019; Sarjono et al. 2018). The learning procedures of the scientific approach include: (a) observing; (b) questioning; (c) trying; (d) reasoning; (e) presenting (Ministry of Education and Culture, 2013). Science, particularly physics, is related to the way of finding the knowledge about nature, which is not only a collection of knowledge in the form of facts, principles, and concepts, but also a process of activity in discovery activities (Moosvi, et al., 2019; Hajian et al., 2019; Maknun, 2020; Husnaini et al., 2019). This scientific approach is expected to make students more active in finding knowledge, spiritual attitudes, gaining skills and social attitudes. Based on the Core Competencies of the 2013 Curriculum, one of the learning purposes of Physics in Senior High School is that students can master the concepts and principles of physics, have the skills to develop knowledge and a confident attitude as a provision to continue education towards a higher level and develop knowledge. Knowledge and technology (Kemendikbud, 2013). Through physics subjects, it is expected to foster students' thinking skills which are useful for solving problems in everyday life. Problem-solving skill is one of the important demands provided to students. Problem-solving skills can be trained in various subjects, one of which is physics, because physics lessons teach the thinking concept (Ince, 2018; Nordin, 2018). Therefore, it becomes important to equip the problem-solving skills through learning physics. Several studies conducted a research by involving the Direct Instruction model in the science classroom which is effective for teaching students; however, it reveals that this model only support the cognitive aspects (Wenno, 2014; Ilik & Sari, 2016).

Therefore, the efforts that teachers can make to overcome the low of students’ participation on the direct learning so that students do not feel bored is to find the learning methods that stimulate a better of students’ participation. One of the models that is thought to be able to increase students’ participation during the learning process is the Problem Based Learning (PBL) model. PBL model is a learning model with problem-based. Problems can stimulate students to learn a problem based on the knowledge and learning experience; therefore, it will ease for students to form new knowledge and experience that can affect student learning outcomes (Baran et al., 2018; Santyasa et al., 2020; Bancong et al., 2020). These studies suggest to not only focus on one particular learning outcome; therefore, it needs to investigate how others learning outcomes will be affected. The practicum-based PBL model has an effect of 49.98% on student learning outcomes (Fatimah, 2016). However, this study did not explicitly reveal which kind of learning outcomes that has been affected. Another relevant research is that the learning outcomes of students who implemented PBL practicum-based is that 80% of students' scores achieve the KKM (minimum completeness criteria) (Sulastini, 2014). This study only focuses on the learning outcome for cognitive aspect, whereas it is possible to take into account others learning outcome such as the affective aspect.

The physics learning can be executed through the experimental activities to increase students' participation or activity during the learning process because in the practicum process students are involved in activities to obtain the data (Snetinová et al., 2018; Ogodo, 2019;). These studies particularly focus on the data collection; however, it is crucial for the teachers to pay more attention on the learning outcomes related to the cognitive and affective aspects. Experiment is one way of learning by conducting laboratory activities, observing the process so that students know and understand the things through the practice they carry out (Roestiyah, 1991; Rajapaksha et al., 2017; Snetinová et al 2018). Nevertheless, it is essential to consider affective aspect on the students' learning outcome which is not only focus on how the students know and understand the knowledge. In many studies, the PBL model is more often used for research related to mastery of physics concepts (Massolt et al., 2020; Abushkin et al., 2018; Argaw et al., 2017). In fact, the students do not only need that cognitive aspect. Therefore, it is an essential approach to conduct a research with PBL that also consider other aspect of learning outcome such as the affective aspect. The implementation of PBL model that begins with the delivery of problems in physics learning is more on conceptual problems. So that the next stage is students will determine the answers to the problems given by the teacher through the stage of reading a reference and discussing the obtained understanding until obtaining the problems' answer. Since, the PBL model is frequent used for research related to conceptual understanding, so that students' problem-solving skills is in a good category (Yuberti et al., 2019; Tursucu, 2020; Iwuanyanwu et al., 2019; Apriyani et al., 2019. Kurniawan et al., 2019). Eventhough, the conceptual understanding holds an important role for measuring the cognitive learning outcome, but during the learning process teachers also need to consider how students affective will be affected. Physics learning will be more meaningful if it is carried out through an inquiry process that is oriented towards problem-solving skills in the field of science. (Zainuddin et al., 2020; Duda et al., 2019; 2018; Ogunleye et al., 2018; Aydogdu, 2015). Nevertheless, it is crucial for the teachers for promoting the learning process not only focus on the cognitive aspect; therefore, other aspect related to the students' affective is also important to be considered. Providing problem-solving skills to students is very strategic for the students to have good skills in solving problems in the daily life. Physics experiment activities are essentially also looking for answers to problems (unknown concepts), to find answers through experiment activities. Based on these conditions, a study was conducted to determine the impact of the ticker timer experiment using Problem Based Learning (PBL) model on students' cognitive and affective learning outcomes in Physics.

METHOD

The quasi-experimental method was used in this study with a pre-test-post-test control group design with two groups, each of them were chosen randomly (R). The first group was given treatment (X) and the other group was not (Sugiyono, 2010). The research was conducted at one of the Senior High Schools in Semarang City, Indonesia. The students' characteristics in this school which is heterogeneous economically and socially could illustrate the very heterogeneous representation of all students in Semarang. Therefore, the students' learning outcomes in this study are strongly suspected to be affected by a PBL model based experiment and not due to other factors such as economic or social. The research was conducted in the 2019/2020 school year. The subject in this study involved 72 students which was divided into an experimental class and a control class.

Table 1 Research Design

Groups	Pre-Test	Treat-ment	Post-Test
Experiment (R)	T_1	X	T_2
Control (R)	T_1	Y	T_2

The research design in Table 1 is the provision of a T1 pre-test before being given each treatment. Then, the experimental class was given learning treatment using PBL model based experiment (X), while the control class used the Direct Instruction (DI) model (Y). In the end, both the experimental class and the control class were given the T2 post-test after being given treatment using the PBL based experiment and the DI model. The independent variable in the study is the PBL model based experiment. While the dependent variable in this study is the cognitive and affective learning outcomes of students in control class or experimental class on the linear motion topic. The data collection techniques in this study were test and observation techniques. Observation techniques are observational activities to obtain data related to behaviour, work processes, natural symptoms and if the observed respondents are not too large (Sugiyono, 2010). In terms of the instrumentation used, the observations are made in the form of structured observations to obtain data on learning outcomes in affective aspects which include: receive opinions, respond to, assess, manage and live the role during practical activities. Test techniques are used to retrieve data in the cognitive domain.

The observation sheets after being compiled was tested to obtain a good research instrument that was valid and reliable. There are four experts from two experienced physics teachers and two university physics lecturers which obtain the average validity of the instrument is 0.8222. Since its validity is ≥ 0.75 based on the Mardapi (2007); therefore, the instrument is valid. Meanwhile the reliability values which is showed by the value of Krippendorff's Alpha (k_{alpha}) is 0.76 ≥ 0.667; therefore, the instrument is reliable (Krippendorff, 2004).

For the questions used to measure cognitive learning outcomes, the discrimination power test, and the difficulty level of the questions were also carried out. The validity (0.334), reliability (0.738), power and difficulty level (0.629) of the questions were tested by using the t-test and product-moment correlation. The obtained data in this research was preceded by the normality and homogeneity test before the statistical test was carried out. The normality test aims to generalize the finding in the population. Meanwhile, the homogeneity is carried out to determine the type of statistical test.

RESULTS AND DISCUSSION

The preliminary activity in this study was interviews with nine students from the sample on August 12, 2019, who were randomly selected. From the interview, information obtained that they learned direct instruction, explanations by the teacher while doing the exercises. The nine students agreed that they had difficulty understanding the concept of physics, and they found that learning physics was very boring. This condition has an impact on students' cognitive and affective learning outcomes. The results from the preliminary test showed that the cognitive aspect which is represented by the physic test score is 66 which is under 76 the minimum criteria. This situation was assumed that the learning method which cause the low of students' participation and bored during the lesson.

The learning material that was taught during the research was linear and regular motion. In this study, the measured aspects are the cognitive and affective learning outcomes that describe the mastery of the concept of motion post-tests and observation sheets. To obtain a valid and reliable research data, the validity and reliability tests were carried out on the instruments used. The test results obtained a valid and reliable instruments so that it is suitable for implementing in the next research process.

The normality test is used to determine the condition of the initial data of research subjects. The pre-test results show that the abilities of the two classes are normally distributed. Both classes can be given further treatment. In this study, the normality test was carried out during the pre-test or initial normality test. The normality test used the Liliefors test, at a significant level of 5%.

Tabel 2. Normality test of *pre-test*

Group	Pre/Post	N	L_O	L_{table}	Information
Experiment	Pre-test	36	0.121	0.143	Normal Distributed
Control		36	0.134	0.143	Normal Distributed

Table 2 illustrates that the results of the pre-test with a significant level of 5% with $N_{experiment}$ = 36 and $N_{control}$ = 36 are normally distributed. A homogeneity test or similarity test between two variances is used to determine the similarity of the two samples by using the Bartlett test. The test results are shown in Table 3.

Table 3 Homogeneity test of *pre-test*

Group	N	D_f	$\chi2_{table}$	$\chi2_{count}$	Information
Pre-test Score	72	1	3.81	0.47	Homogeneous

Table 3 shows that with $d_f = 1$ in the pre-test group, it was obtained $\chi2_{count}$ = 0.47 and $\chi2_{table}$ = 3.81. For the test criteria, Ha has accepted if χ2count < 2 tables. The results of the calculation obtained $\chi2_{count}= 0.470519 < \chi2_{table} = 3.81$; therefore, it can be concluded that the samples from the population are homogeneous or have the same variance. This means that the further data can be analysed by using discrimination tests.

Research Implementation Stage

At the beginning of the study, the initial data collection was carried out on the sample. The initial data or before being given different treatment between the experimental class and the control class are the same. The next stage is to provide different treatment between the experimental and control classes, namely the experiment class used the ticker timer through PBL model based experiment and the control class used the DI model. After being treated with different learning models, they showed different results. The sample of the experimental class and control were 36 students for each group. Figure 1 is a comparison of the pre-test and post-test mean scores.

Figure 1 shows the changing of cognitive learning outcome from the pre and post-test's result of both groups. It is clear that the post-test results, the score after receiving treatment as stated in the previous explanation, the mean score for the control class is 58.07, while for the experimental class the average score obtained is 64.71. From this data, there are different results in the two samples after being given treatment, the experimental class has a better result than the control class. This shows that the ticker timer by using PBL model based experiment is more effective and having an important role in the learning process and also affect to the students' learning outcomes (Santyasa et al., 2020; Susbiyanto et al., 2019; Ali, 2019; Prayekti, 2016).

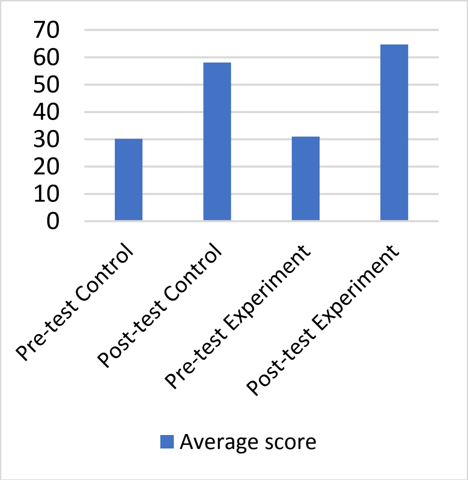

Figure 1. Diagram of changing of cognitive learning outcome between experiment dan control class.

The average post-test score of the control class was smaller than the experimental class, the control class was 58.07 and the experimental class was 64.71. In statistical hypothesis testing, the researcher tested the two-sample t-test to determine students' cognitive learning outcomes between the experimental class and the control class. The purpose is that to find the difference in the post-test of the experimental group and the control group.

Table 4. Results of the two-samples t-test of the post-test

Correlation	D_f	t_{count}	t_{table}
experiment & control	72	1.992898	1.667

The difference between scores in the control class and the experimental class was analyzed through their overall mean. The results of the post-test scores in the experimental class are higher than the post-test results in the control class. However, both the experimental class and the control class experienced an increase in cognitive learning outcomes, it means that the cognitive learning outcomes of both groups are increased. To test whether there are differences in the post-test results for the cognitive learning outcomes of the experimental class and the control class, the t-test is carried out.

From table 4 it shows that the t-count = 1.992898 and t-table = 1.667. The score with a significance level of 5% (meaning that Ho is rejected and Ha is accepted). Therefore, there is a difference in the post-test results between the experimental class using ticker timer learning using the PBL model based experiment and the control class by using the DI model. It can be said that the cognitive learning outcomes after conducted learning in the experimental class of a ticker timer learning using the PBL model based experiment are higher than the cognitive learning outcomes in the control class using the DI model.

To determine the increasing of the students' cognitive learning outcomes from the results of the pre-test and post-test, a gain test. The results of the gain test for improving learning outcomes are obtained from the difference between the mean score of the pre-test and post-test. The following is a table of the results of the study gain test results from the control class and the experimental class.

Table 5 Results of the gain test

Group	N	The average		Gain (g)	Information
		Pre-test	*Post-test*		
Control	36	30.16	58.08	0.40	medium
Experiment	36	31.00	64.71	0.49	medium

Based on the criteria of gain test result, from the table 5 shows that the value of the gain test is ranged on the medium category which is $0.3 \leq g \leq 0.7$ (Meltzer, 2001). Although the results of both gain score are classified as medium criteria, the obtaining gain score in the experimental class that used ticker timer learning using the PBL model based experiment is higher than the control class that used the DI model. This data informs that there is an impact on using the PBL model based experiment. These findings relevant to previous studies which found that the application of different learning models has an impact on different learning outcomes (Khoiri, 2020; Zu et al., 2019)

The information about students' cognitive learning outcomes is carried out through the tests with 10 questions representing four aspects of cognitive learning outcomes indicators. The indicators sheet of cognitive learning outcome is used to measure how much the cognitive learning outcome indicators are achieved. The results of the achievement indicators of cognitive learning outcomes in the control and experimental classes are shown in table 6.

Table 6 The results analysis of achievement indicators cognitive learning outcome

Indicators of Cognitive Learning Outcome	Control	Experiment
Knowing	67.63%	85.78%
Understanding	58.28%	65.92%
Applying	57.58%	66.09%
Analyzing	32.89%	51.05%

Table 6 shows the four observed indicators, each of which has increased the percentage between the control class and the experimental class. In the indicator of knowing, the difference between the percentage of the control class and the experimental group was very significant, that is 18.15%. This condition occurs because experiment activities require good initial knowledge, there are demands for students to be able to carry out practical activities properly requiring good initial knowledge of the concepts that will be carried out by experiment (Caleon et al., 2018; Close et al., 2016; Wilcox et al., 2016). The problems that arise in the experimental class are very real because students will have difficulty doing experiment if they lack of understanding. For indicators of understanding, the difference between the percentage of the control class and the experimental group is not large that is 7.64%. This condition is presumably because the level of students' understanding of motion is not much different. After all, the experimental and control groups are in a homogeneous condition. For the indicator of applying, the difference between the percentage of the control class and the experimental group was slightly larger than the level of understanding, which was 8.51%. Experiment activities make the activity of communicating the understanding is more visible. Then for the indicator which has the biggest difference was the analyzing activity that is 18.16%. This condition occurs because the analytical activities in the experimental activities are more real. There are stages of activities to discuss the obtaining data during the experimental activities. In the control class, the conceptual analysis activity is not as facilitated as the experimental class, which obtain the data, then performs data analysis. So that experimental activities have facilitated analysis activities to solve problems that are obtained at the beginning of the experimental activity.

Overall score, the experimental class was better than the control class. This condition is thought to be caused by a PBL model that has stimulated students to obtain basic information about the material being discussed. Experimental activities with PBL make students prepare themselves to learn. Without sufficient knowledge, students will experience difficulties in carrying out experimental activities and analyzing the results (Blais, 2020; Andersson et al., 2017; Nixon et al., 2017), since the number of knowledges in mastering the linear motion will be seen when students do the ticker timer experiment.

The results of student observations

To strengthen information on learning outcomes in the cognitive aspects, observations were also made during the learning process which aims to determine students' affective learning outcomes. The good of students' understanding of the concepts will affect their activities during experiment activities (Quan, 2018; Cobbinah et al., 2017). The assessment for each indicator of the affective aspect is carried out through student observation sheets. The results of the student observation test were seen from the score of each observed aspect and compared between the experimental class and the control class. From the five indicators studied, each indicator was developed into one or two aspects. The number of aspects developed from the five indicators and then examined as many as eight aspects. The following is a diagram of the results of student observation tests to measure the affective aspect in the experimental and control classes.

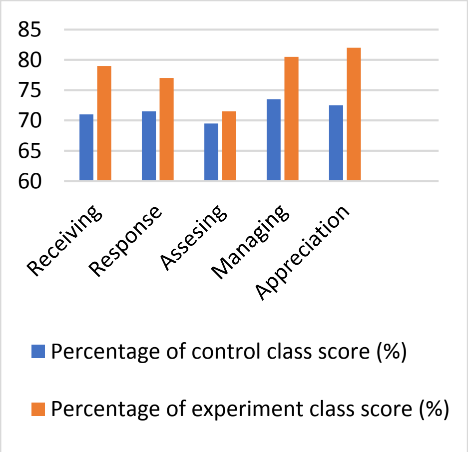

Figure 2. Diagram of increasing of percentage of the affective indicators on the experiment and control class

From the figure 2, there are five observed affective indicators, each of them increased the percentage between the control group and the experimental group. On the receiving indicator, the difference between the percentage of the control class and the experimental class is 8.5%. For response indicators, the difference between the percentage of the control class and the experimental class is 5.04%. For the indicators of assessing, the difference between the percentage of the control class and the experimental class is 2%. The managing indicator is 6.56 and the indicators of appreciation, the difference percentage between the control group and the experimental group is 9%. The indicator that has the highest percentage difference between both classes is the appreciation indicator, which is 9%. The high aspect of this appreciation illustrates that the mastery of the concept of linear motion by students has become better. The meaning of the high difference in aspects of appreciation is that the ticker timer practicum activity with the PBL model has had a significant impact on the students' mastery of the concept of linear motion. While the lowest percentage between the control class and the experimental class on this affective indicator is found in the assessing indicator. The results of the experimental group in the indicator analysis were higher than the control class indicator analysis. These results can be explained that PBL model based experiment is thought to make all students actively involved in the learning process and the aspects that are in the student observation sheets that have been made have been adjusted or lead to the attitudes of students during learning.

Based on the discussion of the cognitive and affective learning outcomes, it was found that the application of the ticker timer experimental activity with the PBL model had a significant impact on student learning outcomes. The application of the ticker timer experimental activity with the PBL method also informs that experimental activities with problem-solving methods have a real impact on students' understanding of the concepts. Through practicum activities with PBL model has made students well-prepare themselves related to understanding of the concept. Students have become more independent to solve their problems. The smooth practicum activities, discussion, and analysis in a good and smooth practice report illustrate that students have been able to solve problems given at the beginning of the learning.

CONCLUSION

Based on the discussion that has been done, it can be concluded that the ticker timer experiment using problem based learning has had a significant impact on students' cognitive and affective learning outcomes

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