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Application of the scientific approach to improve the mastery of concepts and science process skills of high school students on work and energy

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Abstract. Mastery of concepts is one of important things to measure achievement of the learning objectives. In mastering the concept of physics, process skills are required. The research used pre-experimental design with one group of pretest-posttest design which aimed to get an overview of improvement of mastery of concepts and science process skills on work and energy after the application of scientific approach in learning. The research instrument consisted of 19 items of concept mastery test shaped the essay, referring to revised Bloom's taxonomy with a reability of 0.64 and student worksheet to measure the students' science process skills referring to the worksheet developed by Rezba. The instrument is applied to 32 nature students of grade 11 in one of the senior high schools in Bandung which is selected by purposive sampling. The measured concept mastery aspects are related to cognitive aspects based on Bloom's Taxonomy which consists of the aspects of understanding (C2), applying (C3), and analyzing (C4). The measured science process skills aspects consisted of identifying variables, predicting, constructing hypotheses, and experimenting. The results showed that there were an increase in concept mastery with a normalized gain value of 0.48 and science process skills from a fair to excellent level.

1. Introduction

Physics is one of the lessons that require process skills to master its concepts. Mastery of concept is an important thing to measure the achievement of learning objectives. Mastery of concept is the ability of students in understanding the scientific meaning both theory and its application in daily life [1]. In the implementation of learning, broadly there are two most important educational goals of retention and transfer. Mayer and Wittrock explain that retention is the ability of students to remember what is learned up to a certain time, while transferring is the ability of students to understand and use what has been learned in order to solve new problems, answer new questions, or facilitate in accepting the new lessons [2]. In other words, one of the goals of education is to master the concepts learned. Mastery of concepts can be reviewed from the dimensions of cognitive processes proposed by Bloom. Where the dimensions of the cognitive process are remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) [3]. Based on understanding the above concept, the aspects of cognitive process dimension used in this research are understanding (C2), applying (C3), and analyzing (C4).

As one of science, physics is a combination of processes and products that are both interrelated. The process is a series of activities undertaken to achieve a specific goal or product while the process of science is a series of interrelated activities undertaken by everyone exploring the universe [4]. Kale

et al stated that physics learning process not only understands physics concepts, but also teaches students how to constructively think through physics as a science process skill so that students' understanding becomes intact to physics, both as a process and as a product [5]. Therefore, students must be active in the learning process in order to build their own knowledge of the concepts studied. In building that knowledge, students need skills called science process skills (SPS). Semiawan explained that the skills of the process of science relate to the fundamental skills to discover or develop knowledge [6]. SPS is important for students as a means to use scientific methods in developing science, acquiring new knowledge, and developing the knowledge it possesses [4].

The Indonesian curriculum as stipulated in Law No. 22 of 2013 on the Basic and Secondary Education Process Standards states that the learning process is organized interactively, inspiration, fun, challenging, motivates students to participate actively, and provides adequate space for initiative, creativity, and independence according to students' interests, talents, and physical and psychological development [7]. This curriculum demands learning in schools using a scientific approach in learning activities. Findings in schools showed that teachers were not optimal in using a scientific approach. For example, when teachers asked questions related to observations, students had not been able to answer questions correctly so that teachers explained concepts and theories using conventional methods. Physical learning with the transfer of lessons without any active interaction from students causes the learned concepts to be easily lost [8]. This can hinder the improvement of students' thinking skills so that students only accept the concepts given without mastering the concept [9]. Students can build concepts by conducting an inquiry process so that students have a habit of thinking to build the concept [10]. The activities of PDEODE * E (predict, discuss, explain, observe, discuss, explore, and explain) can improve understanding of students' physics concepts [11]. This study found the result of concept mastering test given to the students is still not optimal. From 15 questions given, less than 30% of students can answer the questions correctly. Lessons that do not apply SPS will affect the mastery of student concepts. Usmeldi revealed that the low mastery of students' concepts in physics is caused by the low skill required by students in learning activities [12]

This research applies a scientific approach to improve the mastery of the concepts and SPS of students. In applying a scientific approach, teachers present SPS in the learning process. Aktamis and Ergin revealed that learning by involving science process skills can improve academic achievement of cognitive and creativity aspects in science learning. [9] Abungu et al also stated that involving science process skills in learning activities has a significant influence on achievement students [13].

2. Research Method

The objective of the research is to get an overview of the students' mastery of concepts and SPS on work and energy after the application of the scientific approach in the learning process. Based on the objective, the pre-experimental design was used as one group pretest-posttest design [14]. The sample of this study were 32 students selected from 260 nature students of 11 grade in one of high schools in Bandung. According to Harry King's nomogram in Sugiyono, the sample has represented the population [15]. The sampling technique used purposive sampling based on observation result of students' concept mastery [14]. The test instrument is a concept master test consists of 19 items of essay-shaped reference to the revised Bloom Taxonomy. The measured concept mastery include aspects of understanding (C2), applying (C3), and analyzing (C4). While SPS uses a student worksheet instrument that refers to the SPS worksheet developed by Rezba. The measured SPS aspects consist of identifying variables, predicting, constructing hyphotheses, and experimenting [16]. Research stages consist of pretest of mastery of concept, treatment that is application of scientific approach and posttest mastery of concept. Treatment is done for three meetings. At each meeting the students worked on the PPP worksheet on business and energy. Then, posttest of mastery of concept. Improvement of students' concept mastery is determined through normalized gain values and students' SPS Improvement seen from the increase of the level of SPS obtained by students during the three meetings. The obtained gain score is categorized into three categories as shown by table 1 [17], while the students' science process skill levels refers to table 2 below [14].

Table 1. The normalized gain categories

Categories	Gain Score ($< g >$)
High	$(< g >) > 0,7$
Medium	$0,7 > (< g >) > 0,3$
Low	$(< g >) < 0,3$

Table 2. Science process skills levels

Score SPS	Levels
81-100	excellent
71-80	good
61-70	fair
51-60	poor
0-50	very poor

3. Result and Discussion

3.1. Improvement of Students' Concept Mastery

An overview of the overall mastery of concepts is obtained based on the normalized gain average of the pretest and posttest scores. Table 3 shows the recapitulation of the n-gain average scores and the overall concept mastery categorization.

Table 3. Recapitulation of n-gain average scores

Test	X_{ideal}	$\overline{X}$	Average N-Gain Scores <g>	Category
Pretest	100	43,10	0,48	Medium
Posttest	100	70,30		

Table 3 shows that the mean score of the students' posttest after the application of a scientific approach in learning is greater than the average pretest score before applying the scientific approach to learning. The average pretest score of the students is lower than the posttest score because the students have not been optimal in answering the questions of analyzing aspects (C4). Students can not answer the aspect of analyzing (C4) correctly even most students do not answer this question. Some students have been able to answer C2 and C3, but most have not been able to answer about C4. Bloom explains that the aspect of understanding (C2), applying (C3), and analyzing is a hierarchy [3]. This means that the aspects of analysis are more difficult than the aspects of applying and understanding. Anderson and Krathwohl stated that educatively, analyzing (C4) is an extension of the understanding aspect (C2) [2].

In traning aspects of C4, the skills of predicting and constructing hypotheses related to the aspect of C4 [16]. Students should be able to predict what will happen with the dependent variable if the independent variable is intentionally changed. This statement requires students have to good predicting skills. Then, the students can construct a hypothesis to associate the independent variable with the dependent variable. In answering the questions of the analyzing aspect (C4), when a variable is changed then the student must be able to determine how it affects the other variables and then can determine what steps should be taken to solve the problem. Based on data on the results of the students' SPS improvement, the skills of predicting and constructing hypotheses at the first meeting are in fair and poor levels, respectively [18]. These results support the research findings that the concept mastery aspect of analyzing (C4) is still low on pretest. However, the skills of predicting and constructing hypotheses increase and the cognitive aspect of understanding (C4) also increases. Therefore, the stages of predicting and constructing hypotheses can train aspects of analyzing (C4).

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The following shows the test and the tendency of students' posttest answers on the aspects of analyzing (C4).

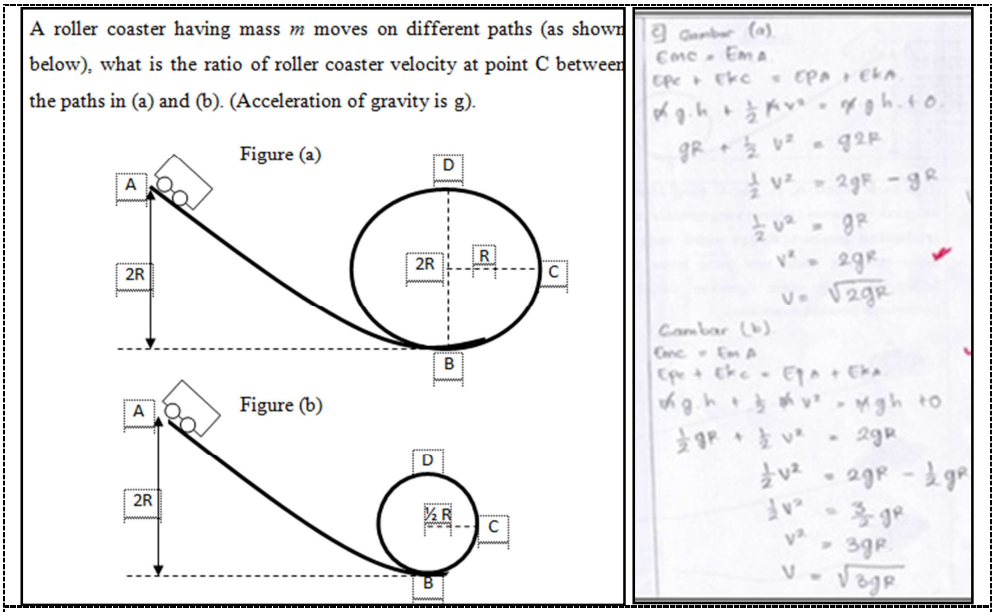

Figure 1. The example of the test and the tendency of students' posttest answers on the aspects of analyzing (C4)

3.2. Improvement of Students' Science Process Skills

Student's Science process skills are assessed by a student worksheet containing questions relating to aspects of SPS. SPS aspects measured include the skills of identifying variables, predicting, constructing hyphotheses, and experimenting. The recapitulation of the average students' SPS scores during the three meetings with the application of the scientific approach is listed in table 4.

Table 4. The recapitulation of the average students' SPS scores during the three meetings

SPS Aspects	Persentage of the students' SPS average scores		
	Meeting 1	Meeting 2	Meeting 3
Identifying variable	60,00	69,38	81,88
Predicting	59,39	63,13	79,38
Constructing hyphotheses	60,63	68,13	85,63
Experimenting	69,38	78,75	96,25
Average scores	64,38	70,50	84,38
Levels	Fair	Fair	Excellent

Based on table 4, there is an increase in the average score of student worksheets for three meetings. However, the first and second meetings have the same level. This is due to the predicting skills of students who have not increased significantly. Predicting skill starts from observation activities, make tentative conclusions from observations, then predict what will happen to conditions that have not happened yet. In the second meeting, the observations of the variables contained in the demonstrations displayed by the teacher were conducted qualitatively. These activities resulted in the students not having a definite number of observations made. Then, cause the students can not answer the full predicting aspect of the questions in the worksheet. The tendency of students' answers is simply to predict what happened without explaining the exact reason. Figure 2 below shows example of question and example of student answer on predicting aspects of the second meeting.

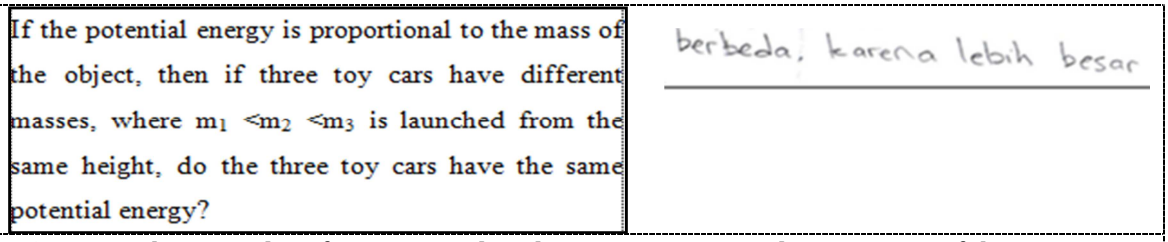

Figure 2. The examples of question and student's answer on predicting aspect of the meeting 2

In contrast to the first and second meetings, at the third meeting the percentage average score of the students' SPS increased more than the previous meeting and the students' SPS increased to excellent level. Skills that most influence the increasing percentage of students' average score of SPS is the skill of constructing hypotheses. Activities construct hypotheses starting from the students' ability to identify variables based on the demonstrations shown [16]. The skill of constructing hypotheses is trained through a series of activities, including observations to identify variables, then constructing hypotheses based on identified variables [16]. Students can not make the right hypothesis if they have not been able to determine the independent variables, dependent variables, and control variables. At the third meeting, students are able to identify the variables correctly. Figure 3 below shows an example of the question of constructing hypotheses aspect and the tendency of students' answers in answering the question of aspect of constructing hypotheses on the worksheet.

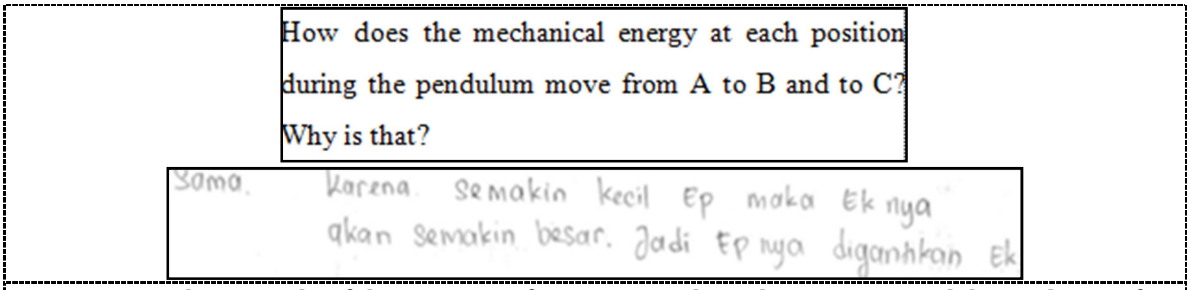

Figure 3. The example of the question of constructing hypotheses aspect and the tendency of student's answer on constructing hypotheses aspect

The results of this study are in line with research conducted by Hodson who reported that involving science process skills in learning can help students understand abstract concepts that are theoretical [19]. Doing practicum activities can help students improve the skills of the science process so that students' ability to understand scientific concepts also increases [19]. To build their own knowledge students need to study in the laboratory to familiarize their science process skills [20]. Learning activities that require students to be active in learning with active learning student sheets (ALSS) assisted by virtual media can improve the mastery of concepts, especially in describing the independent and dependent variable relationship graph which is an indicator of understanding aspect (C3) [21].

4. Conclusion

The results showed that the application of scientific approach can improve the mastery of concepts and science process skills of high school students on work and energy. However, research has not been able to improve the understanding (C2) aspect optimally. Required learning stages that better facilitate students in training this ability.

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