

The Effectiveness of the STEM Project Based Learning Approach in Physics Learning to Improve Scientific Work Skills of High School Students

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Abstract

This study aims to improve students' scientific work skills by using a STEM-integrated Project Based Learning approach with simple water wheel props on energy and work in class X high school physics learning. The method used is classroom action research. The research was carried out in two cycles in class X SMA Negeri 1 Koto XI Tarusan on the material of work and energy by making a water wheel project. Aspects of students' scientific work skills observed were skills in asking questions, planning experiments, making observations, using tools/materials, analyzing experimental results, making conclusions, compiling experimental reports, and presentation skills. In the first cycle, students' work scientific skills were 64.35%, while in the second cycle, they were 78.5%. In addition to scientific work skills, students' conceptual knowledge also increased by 9.15%. The conclusion from this study is that the application of the STEM-integrated Project Based Learning approach with the waterwheel props can improve students' scientific skills. The STEM-integrated Project Based Learning approach with effective waterwheel teaching aids to improve students' scientific skills on energy and work materials in physics learning.

Keywords: *Scientific Work Skills, Physics, Project Based Learning, STEM*

INTRODUCTION

The development of science and technology which developed rapidly in the 20th century 21, requires teachers to follow these developments. According to the National Science Foundation, in the next 10 years 80% of jobs will require competency in science, technology, engineering and mathematics. Besides that, teachers need to prepare students to have 21st century skills including high order thinking that are in accordance with the demands of the curriculum (Gradini, 2019).

Efforts to improve higher-order thinking skills in senior high schools can be carried out with meaningful and context-appropriate learning contained in the competencies in the 2013 curriculum and the independent curriculum. In physics learning, this context can trigger students' scientific work skills (Fajri, 2017). In learning carried out in senior high schools, scientific work ability is one of the basic concepts that must be given to students. In this ability, in the process of learning physics, students are trained in ways of thinking and reasoning in drawing conclusions through investigative, exploratory, experimental activities, showing similarities and differences, consistent and inconsistent (Kusumaningrum, 2012: 752).

One approach that can be used to improve students' scientific work skills is using the Science, Technology, Engineering and Mathematics (STEM) approach (Beers, 2011). STEM is an issue that is often discussed in today's 21st century learning. Inadequate education in mathematics and science has resulted in a shortage of qualified workforce, causing inequality in the global industrial sector (Cooney & Bottoms, 2003). STEM education does not mean only

strengthening educational praxis in separate STEM fields, but rather developing an educational approach that integrates science, technology, engineering and mathematics, by focusing the educational process on solving real problems in everyday life and professional life (National STEM Education Center, 2014). Yildirim, 2018 also suggests that improving the quality of education in the 21st century with the application of STEM has a positive effect on increasing students' critical thinking skills. Furthermore, the application of *STEM* with project based learning (PjBL) will support each other in implementing the learning process. PjBL learning with a STEM approach is project-based learning by integrating STEM fields and can improve the scientific work abilities of students and students (Susanti, 2020; Sugiarto, 2020; Wijayanti, 2018).

The application of the project-based learning in physics learning in high school can build students' learning experiences through the products produced in the learning process, so that students have competence in three dimensions, namely attitudes, knowledge and skills. Capraro et al (2013) revealed that STEM-integrated PjBL can provide challenges and motivate students because it trains critical, analytical thinking and attitudes, and improves student skills. PjBL learning with the STEM approach can provide knowledge to teachers to become facilitators and motivators who do not provide direct knowledge like conventional learning (Susanti, 2020). The STEM-integrated PjBL approach can improve high school students' scientific work skills, which include skills in asking questions, planning experiments, making observations, using tools/materials, analyzing experimental results, making conclusions, compiling experimental reports, and presentation skills of experimental results (Sugiarto, 2020)

The problem so far is that teachers experience problems in integrating several disciplines, both science, technology, engineering and mathematics in classroom learning. Learning with conventional methods is still often used, even though some conventional methods are no longer relevant to be applied in the current era of digital technology. Improving students' mathematical thinking skills is considered too difficult for students, even though this increased ability is contained in the learning outcomes in the independent curriculum currently used. Therefore, the application of STEM project based learning to high school students is a demand for 21st century learning. With this approach, it is hoped that it can improve the scientific work skills of both high school students and teachers later. The components of scientific work skills with the STEM project based learning in this study were identified in 5 components, including; reflection, research, discovery, application and communication

STEM stands for Science, Technology, Engineering and Mathematics is a learning method that is currently being developed in Indonesia. In recent years STEM has become a major topic of discussion and learning planning in the United States because the United States believes that the country's competitiveness depends on strong educational programs in preparing innovative scientists and engineers who will provide important innovations in economic development in the current technological era.

STEM is an integration between four disciplines namely science, technology, engineering, and mathematics in an interdisciplinary approach and is applied based on real-world contexts and problem-based learning. STEM learning includes critical and creative thinking processes, in which students integrate processes and concepts in real-world contexts from science, technology, engineering and mathematics that encourage the development of skills and competencies for study, career and life.

Pfeiffer, Ignatov, and Poelmans (2013) stated that in STEM learning skills and knowledge are learned simultaneously by students. Things that are different from the STEM aspect will require a connecting line that allows the four disciplines to be studied and applied simultaneously in learning.

Project Based Learning (PjBL) is a learning method that uses projects/activities as media. Students carry out exploration, assessment, interpretation, synthesis and information to produce various forms of learning outcomes.

Project based learning is a student-centered learning model to conduct an in-depth investigation of a topic. Students constructively deepen learning with a research-based approach.

Steps for making project based learning:

- a. Opening lessons with a challenging question (start with big questions/essential questions)
- b. Planning a project (design a plan for the project)
- c. Arranging an activity schedule (create a schedule)
- d. Supervising the project (monitor the students and the progress of the project)
- e. Assessment of the resulting product (assess the outcome)
- f. Evaluation (evaluate the experience)

STEM Integrated PjBL

Learning STEM integrated PjBL in physics learning is PjBL learning model with the STEM approach, while the learning syntax used is in the table 1.

Table 1. STEM Integrated PjBL Learning

No.	PjBL Learning	STEM Stage
1.	Fundamental Questions	Reflection
2.	Designing	Research
3.	Arranging Schedules for	Discovery
4.	Monitoring Activeness and Development of	Application
5.	Testing	Communication
6.	Evaluation experience man Learning	Evaluation

Sugiarto, 2020 from the results of his research it is known that the STEM-integrated

PjBL model can improve aspects of high school students' scientific work skills. Skills Scientific work skills are a process carried out by students through a scientific method to get answers to a problem (Saputra et. al, 2012). According to Rustaman (2007), scientific work skills are considered as an extension of the scientific method and are interpreted as scientific inquiry applied in learning science and life. Scientific inquiry is very important to develop because it allows students to use higher order thinking in problem solving and develop critical thinking that is embedded in various scientific processes. Working scientifically integrates science into learning activities that provide students with direct experience. Scientific work skills include intellectual intelligence and emotional intelligence. According to Rustaman (2003), intellectual intelligence in scientific work skills includes: (1) asking questions, (2) planning experiments/investigations, (3) making observations, (4) using tools/materials, (5) analyzing experimental results, (6) making conclusions, (7) compiling experimental reports, and (8) presentation skills. This aspect of scientific work skills is used as an indicator of skills in this study.

RESEARCH METHODS

This study used the Kemmis-Mc.Taggart Classroom Action Research model. The model is a device consisting of three components, namely: planning, observation, and reflection which aims to improve and improve the quality of learning. The three components in the form of strands are seen as one cycle. The three components are carried out in stages and systematically. This model is used to increase students' understanding. The procedures of this

study are: 1) The preparation stage, the activities at this stage are adjusting the lesson plans, making pretest and posttest questions, and making observation sheets. 2) The implementation phase, namely: a) giving a pretest to determine students' initial learning abilities, b) Carrying out learning using the STEM integrated PjBL model with a simple water wheel prop, c) During the learning process, observations are made on student activities in integrated PjBL learning STEM in making a simple water wheel. d) Make a summary of learning materials, e) give a posttest. 3) Reflection Phase, namely examining all test documents and observation sheets and identifying problems that occurred in cycle I which caused less than optimal results in cycle I based on the results of observations and tests. Then arrange the steps of cycle II based on input from the reflection of cycle I. The subjects in this study were 29 class X students of SMA Negeri 1 Koto XI Tarusan for the 2022/2023 academic year on energy and business.

RESULT AND DISCUSSION

The results of cycle I obtained from the learning process with the STEM-integrated PjBL model with a simple water wheel are expected to improve students' scientific work skills on work and energy material in physics learning. Cycle I was carried out in three meetings with the learning steps in table 2.

Table 2. Student Activities

No.	Stage	Activity
1.	Reflection	Reflecting on previous material
2.	Research	Gathering information that supports a simple windmill project
3.	Discovery	Making a windmill design and presenting it
4.	Application	windmill and using it as a project
5.	Communication	Presenting the results of the windmill project and compiling a report

Based on the stages of scientific work reflecting, research, discovery, application and communication above. Students are considered to have good scientific work skills if they get scores above 70.

Table 3. Percentage of scientific work completion

No.	Aspects	Completely	Not Completed
1.	Asking questions	76.23	23.77
2.	Planning experiments	85.15	14.85
3.	Making observations	93.35	6.65
4.	Using tools/materials	100	0
5.	Analyzing experimental results	80.65	19.35
6.	Compiling experimental reports	90.35	9.65
7.	Making conclusions	80.25	19.75
8.	Presentation skills	81.25	18.75

To find out students' understanding of the concept of work and energy, a pre-test is carried out before learning begins and after learning is carried out a post test. Measurement of student learning outcomes with scores above 75 is as follows:

Table 4. Analysis of Student Learning Outcomes

No.	Aspect Score	Pretest	Posttest
1.	Average score	65.25	77.15
2.	Completed Percentage	17.35	68.95
3.	Percentageincomplete	82.65	31.05

From the analysis of student learning outcomes, there is an increase in learning outcomes from the pretest scores compared to the posttest results. This means that the use of the PjBL STEM approach is effective in learning high school physics.

Discussion

This research was carried out on the material of energy and work with a simple water wheel as a visual aid. The research was carried out in two cycles. Cycle I was carried out with four meetings and continued improvement in cycle II with two meetings. STEM-integrated PjBL model learning through the Reflection stage, namely students reflecting on material previously obtained with what will be learned; Research, namely students collect information that supports the water wheel experiment that will be made; Discovery, namely students looking for discoveries about waterwheels, compiling waterwheel designs, presenting waterwheel designs. If it is feasible then the water wheel design is ready to be made into a product, if it is not feasible the students redesign it according to the results of the presentation; Application, namely students make waterwheel products that have been designed followed by trials. Students observe energy changes in the water wheel; Communication, namely students presenting the results of observations and then proceed with compiling experimental reports. This study aims to improve students' scientific work skills through the application of the STEM-integrated PjBL model with a water wheel teaching aid. In accordance with the learning steps with this model it is proven to be effective in improving students' scientific work skills. The results of this study are in accordance with the results of research by Lani et al. (2018) and Capraro et al. (2013) who reported that the application of the STEM-integrated PjBL model in learning can improve student skills. All students after the first cycle of action had obtained very skilled results in using experimental tools/materials.

Tools and materials used: ice cream sticks, cups, bottle caps, hot glue, G glue, cutter, scissors, straws, paper clips, rulers, pencils and markers. The experimental steps include:

1. Prepare some ice cream sticks and glue.
2. Arrange the ice cream sticks into 4 rectangular/square shapes.
3. Then unite them to form a box-like shape, then cover and glue the top with ice cream sticks as well.
4. Give a connection from the cup holder boxcup to the pinwheel holder using an ice cream stick that has been perforated at the end, don't forget to glue it.
5. Prepare the bottle caps and then glue using g glue or glue gun to unite and after putting everything together it is ready to be used as a waterwheel propeller

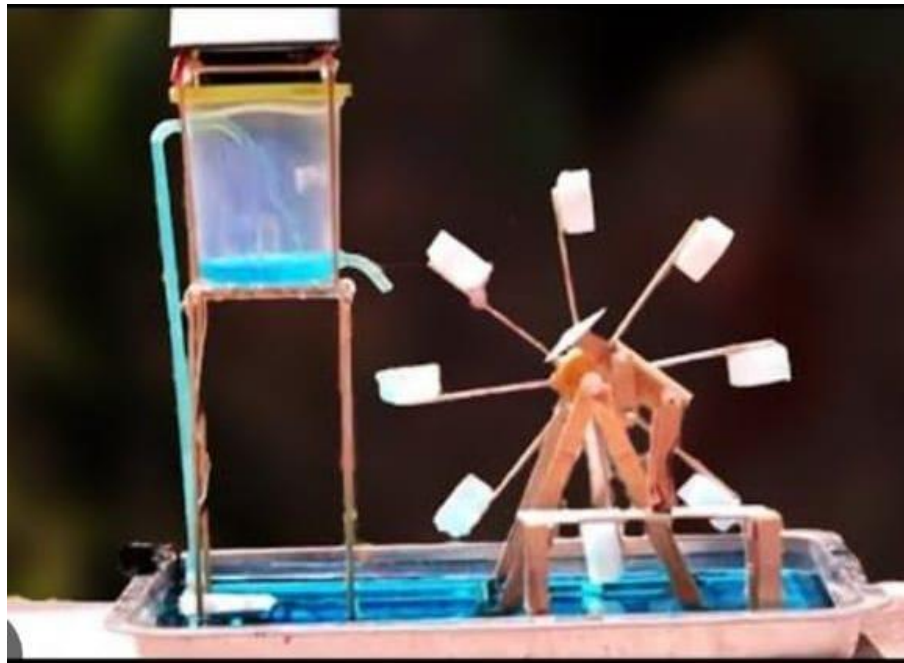


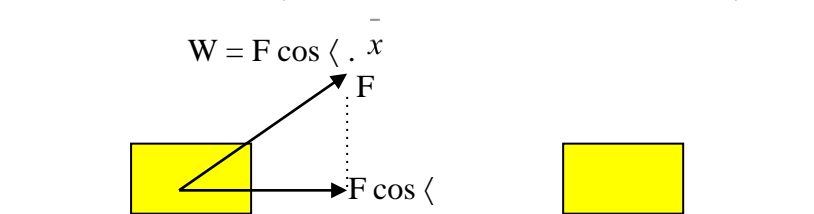
Figure 1. A Simple Water Wheel

The workings of a water wheel by utilizing wooden planks or ice cream sticks that are put together (support box) as a place to direct water to the waterwheel in the box is likened to water flowing in a river, to keep the water flowing in the glass Our cup needs to remove/flow water from above continuously. In accordance with the concept of hydrostatic pressure, the farther in the depths the greater the pressure so that the velocity of the water that comes out is also greater. Water and the wheel as a medium for transferring energy, if the current strength of the water in the cup is very large then the water wheel will move fast, and vice versa if the current strength of the water is slow the water wheel will move slowly too.

The concept of physics in this water wheel is that there is a law of conservation of energy which states that energy can only be changed from one form of energy to another form of energy, and the transfer of energy is accompanied by work, one example is the law of conservation of mechanical energy that carries out business processes, with the waterwheel by transferring the energy it has to other objects. In addition, in a simple water wheel, there is the application of hydrostatic pressure, where the farther in the depths, the greater the pressure.

Based on the experiments above, it can be concluded that work is the product of the component of the force in the direction of displacement with the displacement. If a force F

causes a displacement of a distance x , then the force F does a work of W , ie



Description: W = effort; F = force ; x = displacement , θ = angle between force and displacement

A system is said to have energy, if the system has the ability to do work. The amount of energy of a system is equal to the amount of work that can be generated by the system.

Therefore, the units of energy are the same as the units of work and energy is also a scalar quantity. In physics, energy can be classified into several types, including: Mechanical energy (kinetic energy + potential energy), heat energy, electrical energy, chemical energy, nuclear energy, light energy, sound energy, and so on.

Energy cannot be created and cannot be destroyed, what only happens is the transformation/change from one form of energy to another, for example, from mechanical energy to electrical energy in a waterwheel. Kinetic energy is the energy possessed by any moving object. The kinetic energy of an object is directly proportional to the mass of the object and the square of its speed.

$$E_k = \frac{1}{2} mv^2$$

Description: E_k = Kinetic Energy ; m = object mass; v = velocity of the object

Business is a change in kinetic energy symbolized $W = \otimes E_k = E_{k2} - E_{k1}$

In the STEM integrated PjBL model learning at the Discovery stage, students redesign a simple waterwheel again if it turns out that it is not suitable or fails after being tested in its use. This makes students very skilled in using experimental tools/materials because they are done repeatedly. In terms of skills in planning experiments, in cycle I only 64.35% of students were skilled while those who were still unskilled were 35.35%. This is because students are not used to doing something new, so they are still afraid and hesitant to do it. After the action was taken in cycle II, all students were skilled in planning experiments. Learning the STEM-integrated PjBL model with a simple waterwheel teaching aid can also improve students' mastery of concepts on work and energy material. After following learning with this model, students' mastery of concepts increased by 9.15%. These results are in accordance with Saputra's research (2012), that students' conceptual knowledge will increase optimally along with the increase in students' scientific work skills. The results of this study are also consistent with the results of Jaka and Ani's research (2016) which applied the STEM-integrated PjBL model to increase student knowledge. Learning with the STEM-integrated PjBL model with a simple waterwheel demonstration requires cooperation, communication between students, problem-solving skills, and self-management. In addition, students are also required to work collaboratively, be involved in solving problems, designing investigations and assessing them, and making inquiry and reflection activities. Students can develop meaningful learning experiences, so as to increase students' conceptual knowledge.

CONCLUSION

The STEM-integrated PjBL approach with waterwheel teaching aids on work and energy material in physics learning can be used to improve students' scientific work skills. To improve students' skills in planning experiments, teachers need to pay more attention to the Discovery stage, namely when students make a simple waterwheel design.

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