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[Research Article]

Maximizing Problem-Solving Abilities Through Hybrid Problem-Based Learning With Formative Assessment

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ABSTRACT

Problem-solving is one of the abilities students must master when learning physics. Teachers must try to find solutions to improve their students' problem-solving abilities. This research aims to explore students' problem-solving abilities regarding work and energy concepts and determine improvements and differences in students' problem-solving abilities regarding work and energy material by applying the Hybrid Problem-Based Learning model with formative assessments. This research method uses a mixed-method approach with an embedded experimental design. The research sample consisted of 35 high school students. Qualitative and quantitative data were analyzed simultaneously. Qualitative data was analyzed using open coding and generalization, while quantitative data was analyzed using the n-gain score test. The results of the quantitative analysis show that students' problem-solving abilities increased from an average of 38.74 to 80.65. Calculating the n-gain value obtained a score of 0.68, which indicates that hybrid problem-based learning with formative assessment effectively improves students' problem-solving abilities regarding the concepts of work and energy. The results of the qualitative analysis revealed students' difficulties in solving problems. Some of the challenges found include 1) students needing help translating test items into graphic representation, 2) students needing help determining the specific application of physics, and 3) some students still needing help carrying out mathematical procedures. Teachers can use the findings of this research as a basis for designing and planning learning in the classroom to improve student's problem-solving abilities.

Keywords: problem-solving, hybrid problem-based learning, formative assessment

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1. INTRODUCTION

Problem-solving abilities are still a topic that is often discussed and is one of the focuses of science education research (Zhang & Shen, 2015). Problem-solving is an essential ability for students to learn physics (Pradugawati et al., 2016). Problem-solving activities can help students construct new knowledge and facilitate physics learning (Mukhopadhyay, 2013). Students' problem-solving abilities can be developed in science learning, one of which is through learning physics (Siringoringo et al., 2018). This ability can help students connect one phenomenon with another phenomenon (Wu et al., 2021). They can think thoroughly and comprehensively about a scientific phenomenon at hand.

Research findings reveal many problems faced by students in solving problems in physics learning, and in general, students' problem-solving abilities are in a low category (Azizah et al., 2016). Students need help to test problem solutions or evaluate solutions to the problems given (Ansori, 2013). Some reasons students find it challenging to solve physics problems are not understanding the question, lack of ability to identify problems, and lack of understanding of concepts. One concept that is difficult for students to solve is the concept of work and energy. They need help solving a problem that can be solved with the concept of work and energy (Yazid & Suprapto, 2018). Even though this concept has an important role and often intersects with everyday life.

Teachers and educational researchers have made various works to help students improve their problem-solving abilities. One of them is the application of problem-based learning in the classroom. This learning model has positively impacted problem-solving skills (Klegeris & Hurren, 2011). Problem-based learning can improve long-term knowledge, problem-solving skills, and student competence (Carrió et al., 2016). In further developments, one alternative model that is considered capable of training students' problem-solving abilities is the problem-based hybrid learning model (Sujanem et al., 2018), namely problem-based learning using face-to-face classes and online classes (Kharay et al., 2018). Hybrid learning helps increase student learning independence and knowledge (Shams, 2013), improves high order thinking and information and communication technology skills (Jufriadi et al., 2022, 2023), and facilitates student access to learning (Andayani et al., 2020). The hybrid problem-based learning approach is based on constructivism, which postulates that students' attitudes, behavior, and total learning are based on their previous knowledge (Kassem, 2018).

However, there has yet to be much research that reveals solving problems related to work and energy through the application of hybrid problem-based learning (HPBL) with formative assessments. This research aims to investigate students' problem-solving abilities regarding work and energy concepts through applying a hybrid problem-based learning model accompanied by formative assessment.

2. METHOD

The research design uses a mixed-method approach with an embedded experimental design (Creswell & Clark, 2007). The research involved 35 high school students selected using simple random sampling techniques. The research stages consist of four stages: collecting qualitative data before the learning intervention, collecting quantitative and qualitative data during learning, collecting qualitative data after learning, and analyzing and interpreting data. The research stages are presented in Figure 1 in detail.

Qualitative data collection through interviews was conducted with a forum group discussion (FGD) before the intervention. The first stage of this research was conducted to determine the initial understanding of the concept of work and energy. The inventory of initial understanding was analysed with pre-test data which was carried out at the beginning of the intervention simultaneously.

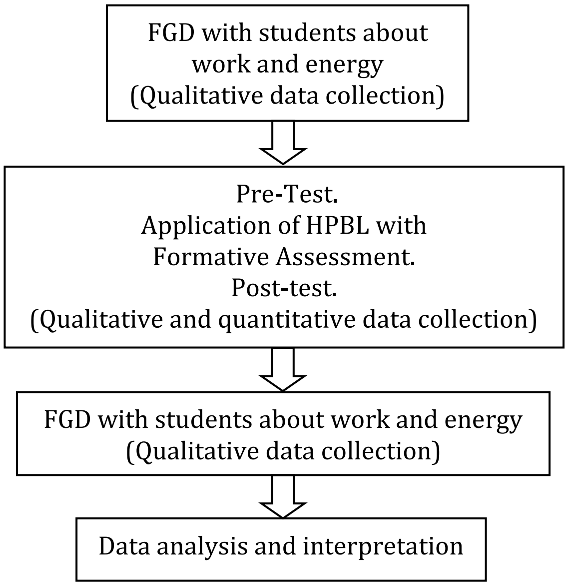
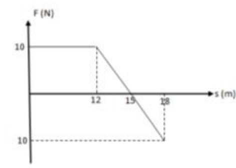


Figure 1. The research stages

This analysis will produce a general conclusion of the initial understanding of the concepts of work and energy. The second stage is the implementation of a hybrid problem-based learning model with formative assessment. This stage is the intervention stage of the research to collect qualitative and quantitative data. Qualitative data were collected through pre-test and post-test, while qualitative data were obtained from discussion notes with students, and between students. Some of the concept mastery tests used are shown in Table 1.

Quantitative data analysis was carried out through the calculation of the n-gain score (Hake, 1998). The n-gain score was used to determine the effectiveness of the intervention. Effectiveness is based on indicators of problem-solving ability, namely: useful description, physics approach, *specific application of physics, and mathematical procedures* (Docktor & Heller, 2009). The score is divided into 3 criteria, namely: low (if the score is smaller than 0.3), fair (if the score is in the range of 0.3 to 0.7), and high (if the score is greater than 0.7) (Hake, 2002). Qualitative data was analyzed by coding (Uwe, 2009) the reasoning presented by students during discussions at each stage of the study. Various kinds of students' thoughts and reasons for solving the problem were inventoried and grouped. After that, students' general understanding was concluded based on the grouping of students' thoughts and reasons.

Table 1. Concept mastery test

Indicator	Test item
Analyzing the work graph	Sebuah benda bermassa 20 kg di dorong dengan gaya yang berubah-ubah terhadap posisi seperti gambar dibawah. Tentukan usaha yang dilakukan oleh gaya F 
Apply the concept of the law of conservation of energy	Sebuah benda mempunyai massa 2 kg berada pada ketinggian 20 meter dari tanah. Benda yang semula dalam keadaan diam dijatuhkan sehingga mencapai tanah. Jika grafitasi bumi di tempat itu 10 m/s2 maka energi kinetik benda saat ketinggian 5 meter dari tanah adalah ...
Comparing kinetic and potential energy	Seekor elang terbang pada ketinggian 8 m dengan kecepatan 2 m/s. Perbandingan energi potensial dan energi kinetik elang adalah ...

3. RESULT AND DISCUSSION

The application of H-PBL with *formative* assessment *has a* positive impact on students' problem-solving skills, especially on the concept of work and energy. This impact is reflected in the statistical description shown in Table 2.

Table 2. General description of research statistics

Statistics	Pre-test	Post-test
N	35	35
Min	20	70
Max	58	92
Mean	44.57	85.64
N-gain	-	0.74

The n-gain calculation resulted in a high score of 0.74. The n-gain score shows that HPBL with formative assessment is effective in improving students' problem-solving skills. The problem-solving phase allows students to improve their problem-solving skills. They can generate and propose the right solution to answer the problem at hand (Edens, 2000). Problem-solving skills have an impact on improving concept understanding, and student competence (Carrió et al., 2016). These abilities can construct new knowledge and support learning (Sujarwanto et al., 2014). So in general, problem-solving ability is an important component in the learning process (Siringoringo et al., 2018).

Students' problem-solving ability was assessed from four indicators including useful description, physical approach, specific application of physics, and mathematical procedures. Students' scores based on problem-solving ability indicators are shown in Table 3.

Table 3. Problem-solving ability n-gain scores

Indicator	Pre-test	Post-test	n-gain	Category
Useful description	64,7	98,0	0,94	High
Physics approach	51,4	96,4	0,93	High
Specific application of physics	26,7	84,7	0,79	High
Mathematical procedures	12,3	72,6	0,69	Fair

Score n-gain indicator useful description, physic approach, and specific application of physics showed high category. Students can re-describe the physics problems presented. Students can choose a physics approach and apply it to solve the problems presented in the test. HPBL with formative assessment has a high impact on these three indicators. While the ability of mathematical procedures shows a medium category. The difference in the n-gain score of the problem-solving indicators before and after the intervention indicates the difference in students' problem-solving ability before and after the application of HPBL with formative assessment.

Students' problem-solving ability can be seen in the test scores of each indicator. In the case of the concept of work and energy, students' problem-solving ability is shown in Table 4.

Table 4. Students' initial problem-solving ability

Test indicator		Problem-solving ability indicators			
		ud	pa	sa	mp
Analyzing the work graph	Pre	71,43	68,57	34,29	14,29
	post	98	98	74,29	72,43
Apply the concept of the law of conservation of energy	Pre	62,86	40	28,71	14,29
	post	98	94,29	91,43	74,86
Comparing kinetic and potential energy	Pre	60	45,71	17,14	8,57
	post	98	97,14	88,57	70,57

ud: useful description, pa: physics approach, sa: specific application of physics, mp: mathematical procedures

In general, students' initial problem-solving ability was very low to complete the mastery test of the concepts of work and energy, starting from analyzing work graphs, applying the concept of the law of conservation of energy, and comparing kinetic energy and potential energy. After the application of HPBL with formative assessment, students' problem-solving skills experienced a high increase. This shows that HPBL with formative assessment is very effective in improving students' problem-solving skills. Active participation of students during the learning process, especially at the stage of independent investigation, presentation of student work, and evaluation of problem-solving can lead students to achieve the desired results. (JaleniauskienĿ, 2016; Kassem, 2018). HPBL stages are more effective with the support of *formative assessment*. Assessment during the learning process that produces feedback from teachers or peers strengthens and ensures students' correct understanding.

Some of the students' difficulties in solving the problems presented in the concept understanding test are understanding the test items in graphical representation, not being able to determine the *specific application of physics* and difficulties in mathematical procedures. This was reflected in students' statements during the FGD.

Some of the students' statements in the FGDs are presented in the following scripts.

Researcher : "Who wants to explain what is known and asked from the test about the work graph?"
Student A : "Me mum"
Researcher : "Okay... go ahead
Student A : "The graph shows that the mass is pushed with a force of 10 N, that's the beginning ma'am, until the point of 12 meters. Then from 12 to 18, the object is just launched on the inclined plane on the graph mum, so no force is needed."
Researcher :"What do you mean by launching on an inclined plane?"
Student A :"It means that the object is pushed from point 0 to point 12, it's like on a table, then the object is lowered by launching it down without force."
Researcher :"Mmm...okay, for the other test items. Are there any difficulties in solving the problem?"
Student B :"Mum..." (raises hand)
Researcher :"Go ahead"
Student B :"Actually, to solve the problem, mum...we are confused about which formula to use, and...maybe we also have difficulty doing the maths, mum...don't you think mate? Hehe
Students :"Yes mum...right (almost in unison)

From the expression of student A, it can be seen that students consider graphs to be real objects represented in the form of pictures and graphs. Students have equated the shape of the graph with real shapes in everyday life, in the case above such as the shape of a table. They are not able to read that the graph shows the relationship between force and displacement of an object. Students think the graph is a real picture of the object. In addition, students also revealed that their difficulty was determining the *specific application of physics* and completing mathematical procedures appropriately and correctly. This is also found in other studies, that one of the difficulties of students is performing mathematical procedures and understanding physics concepts mathematically. (Carli et al., 2020).

4. CONCLUSION

Hybrid Problem-Based Learning can improve students' problem-solving skills. In addition, the support of formative assessment at the learning stage has been able to support students' maximum achievement and ensure students' understanding is correct and by expert understanding. Some other important findings are students' difficulties in solving the presented problems are misunderstanding the test items in graphical representations, students are unable to determine the specific application of physics, and students are not skilled in performing mathematical procedures.

The findings of this study can be used by teachers as a consideration for using HPBL to improve students' problem-solving skills, especially on the concept of work and energy. However, it is recommended to conduct other studies using HPBL on other physics concepts.

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