



## The Development of a Problem-based Learning Physics Module to Facilitate the Critical Thinking Skills of SHS Learners for the Material of Work and Energy

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### ABSTRAK

This research aims to develop a physics module based on problem-based learning to improve high school students' critical thinking skills in work and energy. The research also aims to evaluate the quality of the module and obtain student responses to its use. This research uses a 4D model, namely define, design, develop, and disseminate. The development stage only includes the development stage with extensive testing. There were 10 students randomly selected from classes XI Math and Science 2 and 4 for the limited trial phase, while 35 students from class XI Math and Science 3 for the extensive trial. The research instrument consists of a validation sheet, assessment sheet, and response questionnaire sheet. Module evaluation and student responses are presented in checklist form. The results of this research are: (1) producing a physics module based on a problem-based learning model to facilitate high school students critical thinking skills on the subject of work and energy, (2) the quality of the module that has been developed according to material experts, media experts and physics teachers is Very Good with the respective mean scores being 3.46, 3.58 and 3.74, and (3) the student's response to the module being developed was Agree with the mean score on the limited trial being 0.97 and on the extensive trial being 0.90. Thus, the development of a physics module based on problem-based learning to facilitate high school students' critical thinking skills on the subject of work and energy is suitable for use in physics learning.

### INTISARI

Penelitian ini bertujuan mengembangkan modul fisika berbasis problem based learning untuk meningkatkan kemampuan berpikir kritis siswa SMA dalam usaha dan energi. Penelitian juga bertujuan mengevaluasi kualitas modul tersebut dan mendapatkan tanggapan siswa terhadap penggunaannya. Penelitian ini menggunakan model 4D, yaitu define, design, develop, dan disseminate. Tahap pengembangan hanya mencakup tahap develop dengan uji coba luas. Terdapat 10 peserta didik yang dipilih secara acak dari kelas XI MIPA 2 dan 4 untuk tahap uji coba terbatas, sedangkan 35 peserta didik dari kelas XI MIPA 3 untuk uji coba luas. Instrumen penelitian terdiri dari lembar validasi, lembar

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penilaian, dan lembar angket respon. Evaluasi modul dan tanggapan peserta didik disajikan dalam bentuk checklist. Hasil penelitian ini adalah: (1) menghasilkan modul fisika berbasis model problem based learning untuk memfasilitasi kemampuan berpikir kritis peserta didik SMA pada pokok bahasan usaha dan energi, (2) kualitas modul yang telah dikembangkan menurut ahli materi, ahli media dan guru fisika adalah Sangat Baik (SB) dengan rerata skor masing-masing adalah 3.46, 3.58 dan 3.74, dan (3) respon peserta didik terhadap modul yang dikembangkan adalah Setuju (S) dengan rerata skor pada uji coba terbatas 0.97 dan pada uji coba luas adalah 0.90. Dengan demikian, pengembangan modul fisika berbasis problem based learning untuk memfasilitasi kemampuan berpikir kritis peserta didik SMA pada pokok bahasan usaha dan energi layak digunakan untuk pembelajaran fisika.

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## A. Introduction

Energy and work are the physics materials for tenth grade as mandated by the revised 2003 curriculum. Energy and work are basic materials for the learners to master [1]. The materials are the parts of classic mechanic materials that review an object's motion from the starting until the stop points, and the causes of the object to move. Work and forces become the foundation for the subsequent materials, such as momentum, impulse, and harmonic motion. The understanding of work and energy is important because these materials are complex physical concepts. An excellent understanding of a material is important to solve problems properly [2]. This matter is observable in each correlated concept. In the interview results with the learners at Public SHS 3 Cilacap, the concepts of energy and work are complicated for the learners. The difficulties in learning the materials include the difficulties of different work and forces, understanding the work by the gravitational force, and determining the indications of the work of an object. The other difficulty is understanding the work of an object that makes the object move away [3].

The characteristics of work and energy materials are observable in daily life concepts. Many problems are useful as reference and guidance in learning so the learners can motivate their learning independently. The materials of work and energy do not only need an accurate learning model but also a teaching material to make the learners master the concepts and applications of the materials in daily life.

A preliminary observation at Public SHS 3 Cilacap found the teachers applied dictate and worksheets as the teaching materials. The applied strategy was teacher-centered learning. Many learners could not focus on the given materials because they were talking to each other, sleepy, and passive. They only noted the materials given by the teachers without any responses. The learners even did not share any argument and did not do the work. This matter made the learning interaction minimal and passive. Therefore, teachers should have been active in providing explanations while the learners should have been more active in constructing excellent understanding.

Before the facilitation to develop the critical thinking skills, the researchers found problems. Therefore, the learners required Problem-based Learning for physics learning. The module could facilitate the learners to be active in solving physics problems so the learners would not only learn physics concepts but also develop their critical thinking, communication, and problem-solving skills. The implementation of teaching material is interesting to improve the effectiveness of the PBL model.

Teaching materials refer to any applicable materials to help teachers or instructors in promoting the teaching-learning activity. The design of the teaching material could encourage learners to understand and find the concept so the learning would be more meaningful. One of the teaching Types of materials is a module. This module is a self-directed learning model with some steps of planned and designed learning systematically to facilitate learners in achieving learning objectives. The module is also applicable independently at any time and anywhere so that the module will not be hindered. The role of the teachers in using the module is not to dominate the learning but to focus the learners on learning [4]. The roles of the teachers as moderators facilitate learners to construct cognition actively. Besides that, the relevance of the addressed curriculum on the model is based on the objectives and the attempts to achieve the objectives, to make the learners correlate with learning, and with processing the results [5]. The efforts of teaching material and learning model could improve the critical thinking skills of the learners and arrange teaching materials in the form of an integrated model with the PBL model. The physics module based on PBL makes the problems the context and motor for the learners to learn [6]. The PBL-based module could motivate learners to learn, construct comprehensive knowledge, improve cognitive skills, solve problems, collaborate, communicate, and think critically [7].

Based on the explanation, the researchers developed the teaching material in the form of a printed module for the materials of work and energy. The researchers expect the developed module could meet the learners' necessities as an independent learning source. The implementation of the PBL model could facilitate the critical thinking skills of the learners.

## **B. Method**

This research and development applies the 4D model: defining, designing, developing, and disseminating. The researchers developed the product until the developing stage specifically the massive trial run. The respondents during the trial run were 10 learners taken randomly by the physics teacher of XI Math and Science 2 and XI Math and Science 4. Then, during the trial run test, the research involved 35 learners of XI Math and Science 3. The applied instruments were validation, assessment, and learner questionnaire sheets. The assessment of the module quality applied the 4-scale Likert scale: 4 (extremely excellent), 3 (excellent), 2 (under average), and 1 (extremely under average). On the other hand, the questionnaire

response of the learners applied the 2-scale Guttman: agree and disagree. The researchers used a checklist to assess the module quality and response questionnaire.

## **C. Result and Discussion**

### **The Defining Stage**

This 4D research design consists of defining, designing, developing, and distributing. In this research, the researchers focused on the developmental stage with the product-trial run. The trial run lasted in two steps: the limited and massive trial run at Public SHS 3 Cilacap. The first step deals with defining the problem in the learning process to design the appropriate module. The learners encountered difficulties understanding the physics concept of work and energy and the solution [8]. The implementation of a physics module based on PBL could manage the difficulties and facilitate the learners to be active and improve their problem analysis [9]. After the analysis, the researchers could formulate the indicators of achieving the competencies based on the problems.

### **The Designing Step**

In this step, the developed module is based on the analysis of the learners' necessities that had no independent learning media. This module consisted of problems related to contextual matters. The module format is based on the ideal module criteria by the National Education Department. The determination of the applied basic competence becomes a reference to arrange the indicators of cognitive and psychomotor competence achievements. The arranged module refers to the revised 2003 curriculum at Public SHS 3 Cilacap.

Module I consists of opening, content, and closing. The opening consists of module information and competence, the content part with material and learning activity, and the closing with a glossary, reading list, and author's information. The opening part of the module begins with the front cover, consisting of general descriptions of physics module content based on problem-based learning about the materials of work and energy to facilitate the learners' critical thinking skills. The front cover presents 4 figures: tug of war, carrier man, rafting man, and cyclist. Besides that, the writing of "Work and Energy" on the upper part and the writing of "Based on Problem-based Learning" on the lower part could provide descriptions for the learners that the developed module is - the module of work and energy based on PBL.

After the front cover, the module has a preface, table of contents, and module manual. The content of the module could facilitate the learners to find the material pages and so do the module manual. These features provide information and facilitate learners to use the module. Then, in the introduction part, the module has module

identity, core competence, basic competence, competence achievement indicator, and module description.

The core parts of the module begin with a conceptual map of work and energy to provide an understanding of the material. Then, the introduction part elicits questions to facilitate learners gaining meaningful understanding. The module also has an explanation of the learning activity with specific objectives for each activity. The module consisted of three learning activities, such as the materials of work, energy, and the law of energy and power conversion.

In every learning activity, some columns provide the PBL stages such as the study case, let's think, activity, train your skill, and question. The learners encounter problems in their daily lives to solve in groups. They also promote investigation, development, and presentation of their works. This module refers to the Watson-Glaser critical thinking skill indicators. The indicators suggest learners assume, evaluate arguments, and draw conclusions. This core competence also covers the material summary, formative test, and reflection. The summary facilitates the learners to understand the materials quickly while the formative test measures their understanding levels.

The closing part has the key answers of the formative test and the tasks of each learning activity to allow learners to work on the questions in the module and determine the correctness of the answers. On the following page, the module has a glossary to facilitate learners in finding the definitions of the terms from the previous explanations. The developed module arrangement has relevant references to the physics material discussion. Therefore, the researchers put the reading lists at the end of the module.

### **The Development Stage**

The validation of the physics module based on PBL for the materials of work and energy is useful to determine the validity and relevance between the presentation and the module content. The researchers asked the assistance of material and media experts to validate by filling in the validation sheet. The validation sheet contains a validation table with some remarks such as valid without revision, valid with revision, and invalid. Besides that, the pages are useful for the experts to provide suggestions and recommendations for the developed module. Here are the revisions for the developed module based on the criticisms and suggestions of the material and media experts.

1. The Material Expert Validation
  - a. Expert 1 criticized the consistency of the multiplication operator, the dot ( $\cdot$ ), for each equation and the importance of considering the measurement types whether they are scalar or vector.

- b. Expert II suggested the researchers not to use the word 'mengetahui' or 'knowing.' The expert argued the word was not operational and could not be measured. The expert also criticized the remarks of the figures.
2. The Media Expert Validation
    - a. The expert I suggested the figures, on the front cover, be adjusted with the module content. The other suggestion deals with font size and tidiness.
    - b. The expert I suggests the researchers provide the indicators of competence achievements and learning objectives with some explanations on each point.
    - c. The expert I suggested the syntaxes of PBL to be visible, briefly, and tidily put on the module.
    - d. The expert I suggested the equation of power (P) was not correct.
    - e. The expert suggested using the term reading list instead of bibliography.

These revisions were useful to arrange module II. Then, the researchers involved the experts in media and material and the physics teachers to assess the revised module. The assessment involved two experts of material and media; and two physics teachers. The assessment step has qualitative data with the categorization based on each indicator: extremely excellent (SB), excellent (E), under average (UA), and extremely under average (EUA). The researchers converted the qualitative data with the Likert scale and obtained the quantitative data to determine the quality of module II. Besides that, the assessment of the module provided some suggestions as further consideration, for revision II. Here are the parts of the revised physics module based on the suggestions and recommendations of the experts.

1. The Material Expert's Assessment

The two material experts assessed the physics module based on material validity, PBL implementation, and critical thinking skills. The material validity aspect has two indicators to assess. The first indicator was the material relevance with the learning objectives and core and basic competencies. The second indicator dealt with the conceptual map, the concept of work and energy, and question examples. The combination of the materials uses many references such as books, journal articles, and Internet sources. The obtained score of the aspect assessment was 3.50 with the category of extremely excellent (EE).

The expert also assessed the steps of PBL of the module. The module had 5 PBL steps, such as problem orientation for the learners, learner organization for the learners, individual or collaborative investigations, development and presentation of the work, and analysis and evaluation of the problem-solving process. The mean score of the aspect is 3.67 with the category of extremely excellent (EE). The problem presentation of the module was interesting and relevant to the development of science.

The final aspect was - critical thinking skills. The researchers assessed three indicators: recognizing the assumption, evaluating the argument, and drawing a conclusion. The mean score of the aspect is 3.2 with the category of excellent, E. The

column "Mari Berpikir!" facilitated the learners to analyze information objectively and accurately based on the learners' arguments. Thus, overall, the developed module was excellent in terms of material, PBL implementation, and critical thinking skills. Here are the module parts to follow up based on the material experts' suggestions.

- a. For the assessor, I suggested the writing of the equation to be more consistent by using the symbol of dot (.) or not using it for both the materials and the question examples.
- b. The assessor suggested providing relevant examples and illustrations with the field facts.
- c. Assessor II suggested adding the indicators of energy-conversion law achievement as mandated by the Basic Competence.
- d. This assessor suggested correcting the writing of any incorrectly typed words.

## 2. The Media Expert's Assessment

Two media experts assessed the developed module from three aspects: content validity, linguistic validity, and graphic validity. The obtained mean of the material validity was 3.67 with the category of extremely excellent (EE); the linguistic aspect with 3.50 and the category of extremely excellent (EE), and the graphic aspect with 3.58 and the category of extremely excellent (EE). After obtaining the scores on aspects, the researchers summed up and divided the scores with the numbers of the aspects. The obtained mean was based on the expert media assessment. The obtained mean of each aspect is 3.58. Based on the criteria of the product assessment, the mean score is categorized as extremely excellent (EE). Here are the revised module parts based on the suggestions and recommendations of the media experts.

- a. The assessor II suggested the researchers always put full stops (.)
- b. The assessor suggested the researchers use an italic format for each English word.
- c. The assessor suggested enlarging and making all figures clear.
- d. The assessor suggested changing the colors of the back cover since it was dark and pixelated.

## 3. The Assessment by Physics Teachers

The teachers assessed the content, presentation, problem-based learning implementation, and critical thinking skills. The material validity was based on the material relevance with the indicators and learning objectives such as the comprehensiveness of the material based on the learners' developments and the material relevances with the physics concepts. The mean of the aspect was 3.70 with the category of extremely excellent. The aspect of presentation deals with the presentation technique, material-figure relevance, font size, font combination, and punctuation. The mean of the aspect was 3.75 with the category of extremely excellent.

The aspect of the PBL model consisted of 5 PBL steps. The mean of the aspect was 3.70 with the category of extremely excellent. The critical thinking skill dealt with three indicators of critical thinking skills: recognizing the assumption, evaluating the argument, and drawing a conclusion. The mean of the aspect was 3.8 with the category of extremely excellent. Based on the analysis, the mean of all assessed aspects of the physics teachers was 3.74 with the category of extremely excellent. The result shows the developed module was valid to use as teaching material.

Here are the revised module parts based on the teachers' recommendations and suggestions.

- a. The physics teacher I suggested explaining the concept of work from the basics and providing illustrations.
- b. The teacher suggested adding more references from books such as Tipler, Giancoli, etc.
- c. The teacher also suggested the researchers provide the term definitions, use understandable language, and use correct concepts.
- d. The physics teacher II suggested the questions parts of the second learning activity be added with questions about potential energy, mechanic energy, and kinetic energy.
- e. Physic teacher II suggested improving the incorrectly-typed sentences.

After revising the module, the following step was - promoting limited tests and massive trial runs to determine the learners' responses. The limited test involved 10 learners of XI Mathematic and Science class of Public SHS 3 Cilacap, selected by the physics teachers. The researchers collected the data face-to-face at the school. The researchers explained to the learners and asked them to fill in the response sheet. The sheet consisted of positive and negative statements to answer: disagree or agree. The learners answered based on their arguments. The obtained responses were 25 statements grouped into 4 aspects: the presentation, PBL model implementation, critical thinking skill, and material validity. After promoting the limited test, the researchers found the four aspects had a mean score higher than 0.50. The results showed the learners' responses were mostly agree. Besides sharing the responses, the learners also criticized and shared suggestions. The suggestions dealt with incorrect writings and unclear figures on the module's cover. Then, the researchers used the criticisms and suggestions to revise.

After promoting the limited test, the researchers did a massive trial run for the XI Math and Science 3 learners at the school. The test involved 35 learners. Then, the researchers explained the module parts from the introduction until the closing. The learners had 30 minutes to fill in the responses, consisting of 35 statements with 4 aspects: presentation, PBL implementation, critical thinking skill, and material validity. Based on the data, most learners agreed with the aspects on the response sheet. The mean scores of the presentation, PBL implementation, critical thinking,



and material validity were 0.90, 0.92, 0.89, and 0.89 with the categories of agree. The learners also shared their suggestions for the developed module. The mean score of the module was 0.90 with the category of agree. The developed module could be a learning reference to facilitate the learners' critical thinking skills. Critical thinking skills allow learners to learn systematic problems and manage the challenges in an organized manner; formulate innovative questions; and design original solutions.

Many previous research support this research. Fauziah [10] also found similar research results: the material aspect mean score of 356 with the category of extremely excellent; the presentation aspect mean score of 3.79 with the category of extremely excellent; and the graphic aspect with the mean of 4.00. The results are similar to current research, especially about the applied PBL syntaxes and the problem of the material, the daily life. Besides that, the researchers found the differences with the previous research such as the developed physics module. The previous module did not clearly explain the PBL syntaxes, lack of materials, and lack of illustrations or figures. On the other hand, the currently developed module shows the PBL syntaxes for each learning activity with detailed material explanations and clear illustrations or figures.

Sari [11] and Himawan [12] also found the implementation of the module could improve the learners' critical thinking skills. This matter happens because the module presents various components to encourage the learners to think critically about the concepts of work and energy [11]. Sari [13] and Himawan [14] also developed a physics module with the content of daily life.

The previous research also supported the implementation of a physics module based on PBL. The collaboration between the problem-based learning approach and the independent teaching materials could provide innovative education products. The developed module could guide the learners in solving the problems gradually. Jayanti [15] explained that the module based on PBL excellently influenced the analytical skills of learners. Therefore, based on the learners' responses on the limited test and massive trial run, the developed module based on PBL was valid to use in physics learning.

Generally, the developed module has some strong points such as the colorful figures. The problem in the module deals with the daily activities encountered by the learners; the presentation of formative tests for each learning activity to evaluate the learning, and the content of the module with the implementation of PBL to facilitate the learners in thinking critically and solve problems. These matters facilitate the learners to monitor their cognitive progress. On the other side, this module has some drawbacks such as a lack of question variation; limited daily life content for the formative test questions; the A4 size module; and a lack of flexibility.

## D. Conclusion

The developed physics module based on PBL was for the materials of work and energy as the learning source. The quality of the developed module for the materials of work and energy could facilitate the learners' critical thinking skills. The experts of materials and media shared a mean score of 3.59, indicating an extremely excellent category. Thus, the developed module is applicable as a learning source. The learners' responses toward the developed module for the materials of work and energy were positive. They found the module could facilitate critical thinking skills. The learners agreed with the module and obtained a mean score of 0.97 in the limited test and 0.90 in the massive trial run.

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