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Development of PhET-assisted Problem Based Learning Physics E-Book to Improve High School Learners' Concept Understanding

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Abstract

The 21st century is an era where technology is increasingly advanced. Integrating technology in learning, especially physics, can increase student interaction in learning. 21st century skills cannot be achieved without concept understanding. It was found that 70% of students still did not fulfil the appropriate concept understanding ability. This research aims to develop a PhET-based problem-based learing e-book that can improve students' concept understanding. The research method used is the research and development method. The development model carried out in this study is the ADDIE model. Furthermore, the research was conducted with a research design in the form of pre-experimental design. The research technique was carried out using the pretest posttest control group design technique. The research subjects were determined by cluster random sampling technique. The results showed that the PhET-based problem-based learning e-book was feasible to use from the aspects of content feasibility, language and images, presentation, graphics, and additional content by obtaining an ideal standard score of 0.5 which was included in the very good category. In addition, the developed e-book is also effective in improving students' concept understanding by obtaining an N-Gain value of 0.76 in the modelling class with a high category and 0, 57 in the implementation class with a medium category.

Keywords: *Conceptual Understanding; Physics; PhET; E-Book; Problem Based Learning*

Introduction

The life of every individual is inseparable from education. Education is a bridge in improving the abilities of every human being (Hartini et al., 2018). Education not only has a major role in human life in terms of mastering knowledge and practical skills, but education also develops the potential of everyone in terms of character such as spiritual strength of diversity, self-control, and noble character (Rahman et al., 2022). Education in Indonesia faces great challenges in improving the quality and relevance of learning, especially in the current digital era. Physics subjects are in the spotlight because they are often considered difficult by most students (Istiyono, 2018; Mardiana & Kuswanto, 2017; Sejati et al., 2021).

The 21st century is an era where technology is increasingly advanced. The use of technology also influences the learning process, especially physics learning (Raja & Nagasubramani, 2018). Integrating technology in learning, especially physics, can increase student interaction in learning (Bogusevschi et al.,

2020). In addition, the resulting learning can be more interactive so that it attracts the attention of students (Asrizal et al., 2022).

21st century skills cannot be achieved without concept understanding. Concept understanding requires students to absorb the meaning of a given material or concept (Mufit et al., 2019). Students' concept understanding still needs to be improved. Based on research by Hidayati (2019) found that 70% of students still did not fulfil the appropriate concept understanding ability. In the next study, it was also found that there were still many students who did not understand the concept and 11.0% of students who experienced misconceptions (Puspitasari et al., 2022). One way to improve the concept of the material provided by the teacher is by using an e-book (Kusumawati et al., 2020). E-books are electronic books that contain text, images, and even videos. With the use of e-books, students can be more interested in the learning that will be carried out, especially physics learning (Andani et al., 2022). In addition to the use of e-books, the use of virtual laboratories can also improve students' concept understanding (Erkacmaz et al., 2023). The problem-based learning model can also help improve students' concept understanding. The problem-based learning model places learners in real situations that are relevant to the material being studied, so that learners can see how concepts are applied in a practical context so that it can improve learners' concept understanding (Bili et al., 2022). In problem-based learning, learners are encouraged to analyse problems, identify necessary information, and evaluate various possible solutions. This strengthens learners' thinking skills. Therefore, research was conducted in the form of e-book product development research using the Problem Based Learning learning model based on the PhET virtual laboratory. This research aims to develop a PhET-based problem-based learing e-book that can improve students' concept understanding.

Method

This study uses the research and development method. The research and development method aims to produce a product and test the effectiveness of the product produced. The development model carried out in this study is the ADDIE model. The ADDIE model consists of the analyse stage, which is the needs analysis stage in the importance of product development. This stage aims to find out an overview of physics learning in schools so that problems and appropriate solutions can be found to overcome existing problems. The design stage, which is a systematic stage in designing the concept and content of a product. The development stage, which is the stage of realisation of making products that have been designed previously. The implementation stage, which is the stage of applying the product in learning to obtain feedback from students. And the last is the evaluation stage. The evaluation stage is the stage of product revision from the feedback that has been given. Furthermore, the research was conducted with a research design in the form of a pre-experimental design. Pre-experimental design is a research design that includes one group or class that is given a pre and post-test. In this study there was no control class. The research technique was carried out using the pretest post-test control group design technique. The research subjects were determined using cluster random sampling technique.

Instrument validity is done by calculating Aiken's V value. The V Aiken value is calculated using the following formula.

$$V = \frac{\Sigma s}{n(c-1)} = \frac{\Sigma(r - l_0)}{n(c-1)}$$

V = content validity coefficient

l_0 = lowest validity assessment number

c = highest validity rating number

r = the number given by the validator

n = number of validators

The validity assessment criteria based on the V Aiken scale are in the table below.

Aiken's V Scale	Criteria
$V \leq 0{,}4$	Low
$0{,}4 \leq V \leq 0{,}8$	Medium
$V \geq 0{,}8$	High

As for product validity, namely PhET-based problem-based learning e-books using ideal standard. The analysis step is carried out by calculating the average total score calculated by the equation:

$$\bar{X} = \frac{\Sigma X}{n}$$

$\bar{X}$ = average score obtained

ΣX = number of scores obtained

n = number of assessment items

The interpretation of the ideal standardised score can be seen in the table below.

Score Range	Category
$\bar{X} \geq Xi + 1{,}8Sbi$	Very good
$Xi + 0{,}6\ Sbi < \bar{X} \leq Xi + 1{,}8Sbi$	Good
$Xi - 0{,}6\ Sbi < \bar{X} \leq Xi + 0{,}6Sbi$	Medium
$Xi - 1{,}8\ Sbi < \bar{X} \leq Xi + 0{,}6Sbi$	Less
$\bar{X} \geq Xi - 1{,}8Sbi$	Very less

The improvement of concept understanding ability was analysed using standard gain. Analysis was carried out on the results of the pretest and post-test of students.

$$g = \frac{post\ score - pre\ score}{maximum\ score - pre\ score}$$

The N-Gain score criteria are interpreted into the following table.

Value (g)	Criteria
$g < 0{,}3$	Low
$0{,}3 \leq g \leq 0{,}7$	Medium
$g > 0{,}7$	High

This research aims to produce a product in the form of physics teaching materials, especially on thermodynamic material. The subjects of this research are students of class XI IPA in a high school in Yogyakarta. The class used in this study consisted of 2 study group of class XI IPA. Both classes were divided into implementation and modelling classes. The implementation and modelling classes were given the same treatment, namely learning by using PhET-based problem-based e-books. However, the experimenters of the implementation and modelling classes were different. In the implementation class, the perpetrator of the experiment was the physics subject teacher at the school. While the experimenters of the modelling class are researcher. The trial design is presented in the following table.

Class	Pretest	Treatment	Posttest
Implementation	O_1	X_1	O_2
Modelling	O_1	X_2	O_2

O_1 = giving pretest questions to measure students' concept understanding

O_2 = giving posttest questions to measure students' concept understanding

X_1 = use of the product in learning by teachers

X_2 = use of the product in learning by researcher

Results and Discussion

Product Description

Product development begins with learner analysis, curriculum and concept analysis. Learner analysis is done by observing the learning process of students in the classroom. Based on the results of observations, students still need to cultivate the ability to understand concepts. Curriculum analysis was conducted on the independent curriculum, followed by analysing the concept of thermodynamics. The results of the analysis show that physics learning, especially on thermodynamic material, requires the development of teaching materials that can improve students' concept understanding abilities. Therefore, the development of a PhET-based Problem Based Learning e-book on thermodynamic material was carried out. The developed e-book consists of cover, preface, table of contents, description, instructions for use, learning objectives, learning activities, material consolidation, sample questions, and bibliography.

Figure 1. E-Book's cover

Figure 1 shows the cover of the developed product. The e-book cover consists of a logo, author's name, e-book name, and illustrations. The developed product can be accessed online through the website. By integrating the e-book into the website, it makes it easier for students to access the e-book anywhere and anytime.

Figure 2. E-Book's home page

Figure 2 shows the e-book home page which contains a preface, table of contents, and instructions for using the e-book. The e-book home page aims to make it easier for students to understand the flow of learning the e-book and facilitate the navigation of students to other parts of the e-book. Figure 3 shows the content of the problem-based learning e-book. The e-book contains the learning stages of the problem-based learning model. The stages consist of problem orientation, organising students to learn, guiding investigations, developing and presenting results, and analysing and evaluating the problem-solving process.

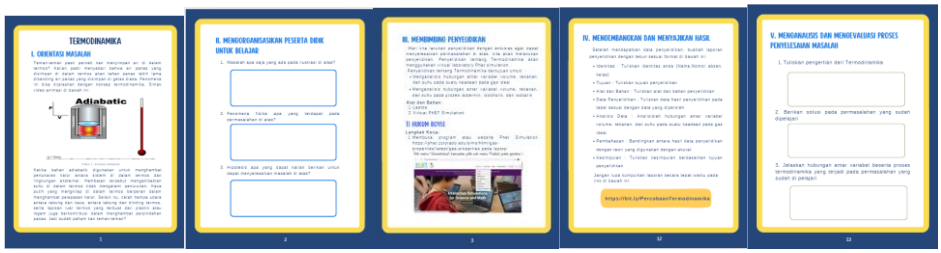

Figure 3. Problem based learning stage

In the problem-based learning stage, it contains a triggering question for students in the problem orientation section. At the stage of communicating students, students are directed to do discussion related to the problems given. Furthermore, at the stage of guiding the investigation, students will conduct experiments using the PhET virtual laboratory related to the laws of ideal gas. At the stage of developing and presenting results, students are directed to make a practicum report. Finally, at the stage of analysing and evaluating the completion process requires students to conclude the experiments that have been carried out.

Figure 4. Material consolidation

Figure 4 shows the material consolidation contained in the e-book. The material consolidation consists of material descriptions related to kinetic gas theory, ideal gas equation, pressure and energy according to gas kinetic theory, and thermodynamic processes. In the kinetic gas theory material, the definition of ideal gas and the characteristics of ideal gas are discussed. Furthermore, in the ideal gas equation section, the ideal gas laws and equations are discussed. Finally, the thermodynamic process discusses adiabatic, isochoric, isobaric, and isothermal processes.

Product Validity

The feasibility of the product was calculated using an e-book feasibility sheet that has 10 criteria items grouped into 5 assessment aspects. The assessment sheet was analysed using the ideal standard (SBI). The validation results of the PhET-based problem-based learning e-book product are shown in the table below.

Aspect	SBI Average	Category
Content appropriateness	0,5	Very good
Language and images	0,5	Very good
Presentation	0,5	Very good
Graphics	0,5	Very good
Additional Content	0,5	Very good
Total average	**0,5**	**Very good**

The validity results above show that the PhET-based problem-based learning e-book teaching materials are valid. The validity of PhET-based problem-based learning e-book teaching materials is reviewed from the aspects of content feasibility, language and images, presentation, graphics, and additional content. Therefore, it can be concluded that the PhET-based problem-based learning e-book product is suitable for use.

Instrument Validity

The pretest and post-test instruments were analysed using an instrument validation sheet. The instrument validation sheet consists of 11 items of assessment criteria which are grouped into 3 aspects of assessment. The assessment aspects measured include construction, language, and content. The results of the instrument validation are presented in the table below.

Aspect	Aiken's V Average	Category
Construction	0,8	High
Language	0,8	High
Content	0,8	High
Total Average	**0,8**	**High**

The results of Aiken's V analysis showed a value of 0.8. This means that the pretest and post-test question instruments fall into the high category. So, it can be concluded that the pretest and post-test question instruments developed are feasible to use to measure concept understanding ability.

Ability Improvement Results

The treatment was conducted in modelling and implementation classes. In the modelling class, face-to-face learning played by the researcher was carried out to measure the concept understanding ability of students. While in the implementation class, face-to-face learning is carried out by the subject teacher. The results of improving students' concept understanding ability were calculated by calculating the N-Gain value. Measurement of ability improvement aims to see the effectiveness of PhET-based problem-based learning e-book products developed. The results of ability improvement are shown in the following table.

Class	N-Gain	Category
Modeling	0,76	High
Implementation	0,57	Medium

The results above show that the increase in concept understanding ability in the modelling class is 0.76. The value of 0.76 is in the high N-Gain value category. While in the implementation class, the increase in concept understanding ability is 0.57. The results of increasing the ability to understand concepts in the implementation class are included in the medium category. Based on the results of measuring the increase in N-Gain, it can be concluded that the PhET-based problem-based learning e-book is effective in improving students' concept understanding ability. This is in line with research conducted by Asrizal et al. (2024) that the use of e-modules in physics learning can improve students' concept understanding. In addition, the use of virtual laboratories is also proven to improve students' concept understanding (Papalazarou et al., 2024). Many previous studies have also proven a significant increase in the use of virtual e-books on students' concept understanding (Aisyah & Sucahyo, 2022; Harjono et al., 2020; Rahmayani et al., 2024).

Conclusion

Based on the results of the product feasibility test using the ideal standard, a result of 0.5 can be obtained with a very good category in terms of content feasibility, language and images, presentation, graphics, and additional content. This shows that the PhET-based problem-based learning e-book is suitable for use. In the results of the recapitulation of the improvement of students' abilities in concept understanding, the N-Gain value was obtained 0.76 in the modelling class with a high category and 0, 57 in the implementation class with a medium category. So, it can be concluded that the PhET-based problem-based learning e-book is effective in improving students' concept understanding ability.

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