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Development of Physics E-Learning Based on Discovery Learning to Improve Students' Conceptual Understanding and Learning Interest

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Abstract
Thermodynamics material is abstract material that causes misconceptions. Misconceptions are caused by several things, one of which is the use of learning media that has not been maximized. The procedure for developing physics e-learning based on discovery learning uses the ADDIE type Instructional Design and only reaches the practicality test stage. The developed e-learning contains attendance, discussion forums, e-modules that guide students to improve their understanding of concepts, learning videos, power points, student worksheets, quizzes, summative assessments, glossaries and references to other relevant reading sources with a validity value of 0.92 with a very valid category, a teacher's practicality value of 95.00 and a student's practicality value of 90.25 with a very practical category. Based on the results of validity and practicality, it can be concluded that physics e-learning based on discovery learning is feasible to use in physics learning.

Keywords: e-learning, discovery learning, conceptual understanding

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INTRODUCTION

The era of globalization has a fairly broad impact on various aspects of life, including demands in the implementation of education, where education is required to produce human resources who have complete competencies, known as 21st century competencies (Roshid & Haider, 2024; Saleem et al., 2024) . Entering the 21st century, science and technology are developing very rapidly and of course increasingly sophisticated (Timothy, 2021) . Students in facing 21st century competencies are required to solve problems through the knowledge they have acquired and be able to make decisions based on evidence from the scientific process in solving everyday life problems and have mastery of technology (Kurniawan, 2024) .

21st century competencies in a country can be identified through the results of a survey conducted by PISA. Based on research conducted by *the Program for International Student Assessment* (PISA), a survey conducted on 15-year-old students involving 81 countries and carried out every three years, it states that the majority of Indonesian students are still at the LOTS level. Based on the results of research conducted in 2022, information was obtained that Indonesia was ranked 11th from the bottom with a score of 366 in mathematics, 383 in science, and 359 in reading, where this score decreased compared to the results of the previous survey in 2018. The decrease in the survey results was 13 points for mathematics and science, 12 points for reading (Golla & Reyes, 2022) .

The low PISA score of Indonesia underlies the change of the 2013 curriculum to the independent curriculum with the aim of improving Indonesia's PISA score through optimal learning (Sobri et al., 2023) . The independent curriculum is an improvement in the education system implemented through the driving school program to advance the quality of learning in schools (Nafi'ah et al., 2023) . The independent curriculum is characterized by constructivist learning theory. Constructivism means being constructive and is one of the schools that originates from cognitive learning theory (Ariandini & Hidayati, 2023) . Constructivism is closely related to discovery learning methods *and* meaningful learning (Sufraini et al., 2024). *Discovery learning* is a process where students can learn and experiment as if they were solving problems through reflective thinking (Kindsvatter & Ishler, 1996) . The *discovery learning model* is a learning model that involves students to be active in the process of discovering knowledge through experimental activities.

The independent curriculum has three characteristics, one of which is that the independent curriculum focuses on essential material so that there is a more meaningful and enjoyable deepening and development of competencies. Based on the results of the analysis carried out by the researcher, it was obtained that one of the essential materials is thermodynamics material, where 77.8% of students have difficulty learning thermodynamics material and this is in line with research conducted by Barokah in 2021, Connell in 2021 and Ma'ruf in 2023 (Barokah et al., 2021; Connell, 2019; Ruf Ma'ruf & Dhiqfaini Sultan, 2023) . Thermodynamics is a branch of physics that includes the basic concepts of thermodynamics, energy and the first law of thermodynamics, the properties of pure substances, ideal gases, and the second law of thermodynamics and the Carnot cycle (Eli Trisnowati et al., 2023) . According to research conducted by Barokah (Barokah et al., 2021), the level of difficulty experienced by students in understanding the concept of thermodynamics law material was 54.5% experiencing difficulties, 36.4% may experience difficulties and the remaining 9.1% did not experience difficulties. These difficulties occur because thermodynamics learning contains abstract concepts and requires the application of mathematical procedures to solve problems (Pals et al., 2023; Pandiangan, 2024). Failure to understand the relationship between abstract concepts and lack of necessary mathematical knowledge can lead to frustration and disappointment for teachers and students (Apriani & Sudiansyah, 2024).

Lack of understanding of this concept causes low student learning outcomes which are indicated by many students who get scores below the minimum completion criteria and also have an impact on low student interest in learning. Interest is a feeling of preference and attraction to something or an activity, without anyone telling you (Apriyani et al., 2022). Students who have a high interest in learning in learning materials are likely to have high learning outcomes, because students are able to manage their interests and emotions and also understand the subject matter being taught, the existence of good relationships and communication between teachers and students will affect their interest in learning, and if a student has an interest in learning, it will have an impact on increasing student learning outcomes, conversely if they have a low interest in learning, they are likely to get low learning outcomes on learning materials (Setiawan et al., 2022) .

Misconceptions are caused by several things, one of which is the use of learning media. Learning media as a means of learning thermodynamics is a very important component in the teaching and learning process. Learning media is generally used to help the learning process achieve its goals (Demir, 2024). Based on the analysis carried out, information was obtained that 100% of students stated that learning media influenced students' ability to understand the material and 94.4% of students stated that learning media influenced students' interest in learning. Based on the description of the problems above, researchers are interested in developing learning media by utilizing technology, because it is in accordance with 21st century competencies that guide students to be able to master technology. The media developed is *e-learning* physics based on *discovery learning* on thermodynamics material. With the development of *e-learning* physics based on *discovery learning* on thermodynamics material, it is hoped that it will be able to increase students' understanding of concepts and interest in thermodynamics material. Therefore, the topic "Development of *E-Learning" was studied* Physics Based on *Discovery Learning* to Improve Students' Understanding of Concepts and Learning Interest in Thermodynamics Material”. This research is expected to provide alternative choices of appropriate learning media for senior high school education units in improving students conceptual understanding and learning interest in physics materials, especially thermodynamics.

METHODS

Detailed procedure for developing e-learning physics based on discovery learning using ADDIE type Instructional Design is shown in Figure 1 below (Yulia et al., 2023):

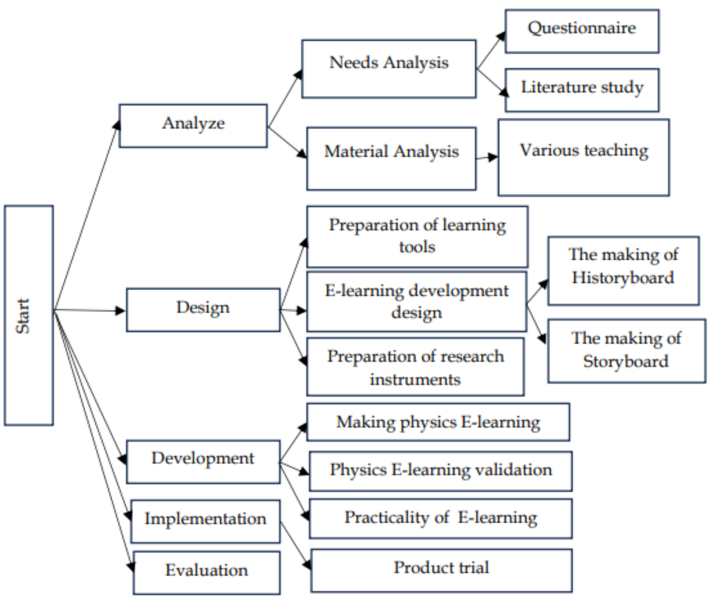

Figure 1. ADDIE type *Instructional Design*

This research was conducted only up to the practicality test stage. After *the discovery learning* -based physics *e-learning* was developed, a validity test and a practicality test were conducted on the *discovery learning*- based physics e-learning on thermodynamics material. The validity test aims to obtain a physics *e-learning* on thermodynamics material that is suitable for use in physics learning. The validity test was conducted by 3 experts using an assessment sheet consisting of pedagogical, material, and media aspects. The validation sheet as a data collection instrument was given to the experts (validators) consisting of 3 experts to determine the level of feasibility of each product developed. The validity assessment grid of the discovery learning-based physics e-learning on thermodynamics material can be seen in Table 1.

Table 1. Validity assessment grid for learning media

No	Aspect	Indicator	Number of Items
1	Pedagogy	Suitability of teaching materials in *e-learning* with *discovery learning*	6
		Suitability of *e-learning* with aspects of concept understanding.	3
2	Material	Suitability of Material to Curriculum	3
		Visual conformity to the material	7
		Clarity of material sequence	1
		Accuracy and precision of the material	3
3	Media	Legibility	4
		Visualization	4
		Compliance with target character	4
		Presentation support	2

Source: Adapted from Nisrina (Nisrina et al., 2022)

The data from the validity test *of e-learning* physics based on *discovery learning* were analyzed using equation 1, namely:

$$V = \frac{\text{number of scores obtained}}{maximum\ number\ of\ scores} \quad \ldots\ldots(1)$$

This value is then interpreted descriptively based on table 2.

Table 2. Validation Result Categories

No	Average Score Interval	Criteria
1	$0.80 < V \leq 1.00$	Very valid
2	$0.60 < V \leq 0.80$	Valid
3	$0.40 < V \leq 0.60$	Less valid
4	$0.20 < V \leq 0.40$	Invalid

Source: (Azwar, 2015)

Based on the table, a product is declared feasible or valid if all assessment indicators on the validity instrument have a validity coefficient value of $V > 0.6$. However, if the value of $V < 0.6$; then the product is declared unfit or invalid.
The practicality test aims to obtain a physics *e-learning based on discovery learning* that is practical to use in physics learning. The practicality test is carried out by the teacher using an assessment sheet consisting of aspects of ease of use, effectiveness, and benefits, as well as student responses using an assessment sheet consisting of aspects of ease and use. The practicality assessment grid can be seen in table 3 and table 4.

Table 3. Grid for assessing the practicality of learning media for teachers

No	Assessment Aspects	Number of Items
1	Ease of use	10
2	Time effectiveness	4
3	Benefit	6

Source: Adaptation by Fernando (Fernando & Sarkity, 2023)

Table 4. Grid table for assessing the practicality of learning media for students

No	Assessment Aspects	Number of Items
1	Ease of use	10
2	Uses of media	5

Source: Adapted from Fernando (Fernando & Sarkity, 2023)

The data from the practicality test *of e-learning* physics based on *discovery learning* were analyzed using equation 2, namely:

$$\text{Practicality} = \frac{\text{sum of scores}}{\text{maximum score}} \times 100 \quad (2)$$

Based on equation (2), the researcher obtained the practicality value of each product developed. This value was then interpreted descriptively based on Table 5.

Table 5. Practicality assessment criteria

No	Practicality Value (P)	Criteria
1	$80 < P \leq 100$	Very Practical
2	$60 < P \leq 80$	Practical
3	$40 < P \leq 60$	Less practical
4	$20 < P \leq 40$	Not Practical

Source: (Riduwan, 2011)

Based on the table, a product is declared practical and suitable for large-scale usage testing if all assessment indicators on the practicality instrument have $P > 60$. However, if the P value < 60, the product is declared impractical so that improvements or revisions are needed to the relevant assessment aspects.

RESULTS & DISCUSSION

E-learning is an information technology model applied in the field of education. The term e-learning is said to be an effort to make a change in digital teaching and learning activities bridged by technology (Laisa, 2019; Tianyi, 2024). E-learning is learning that uses electronic circuits to convey learning content, interaction, or guidance (Kumar, 2002) . E-learning is one of the innovations in the field of education (Chen, 2024). E-learning is a learning system that is carried out through electronic media, such as computers, tablets, or smartphones. (Carmi, 2024; Lim et al., 2023). E-learning platforms provide greater flexibility and accessibility for students to access learning materials anytime and anywhere (Mohammed Albanyan, 2024; O'Connor et al., 2023; Setiaji & Dinata, 2020). The use of E-Learning in learning has the advantages of learning independence, interactivity, and training the use of technological media (Setiaji & Dinata, 2020).

Results

E-learning in this study can be accessed using the LMS Edukati platform and is structured according to the discovery learning model. Discovery learning has 6 steps, namely stimulation, problem statement, data collection, data processing, verification, and generalization. This e-learning was developed to improve students' conceptual understanding and learning interest in thermodynamics material. The development of *e-learning* in this study only reached the practicality stage. The stages of *e-learning development* in this study are as follows:

1. Analysis Stage

The analysis stage explains the basic problems needed in developing *e-learning* physics based on *discovery learning,* namely conducting material analysis and student needs analysis.

a. Material analysis

   At the material analysis stage, several steps are taken, namely: determining learning outcomes; analyzing learning objectives and developing them; calculating the time allocation needed to implement the product in the independent curriculum. The thermodynamics material developed consists of four meetings. The first meeting discusses the topic of thermodynamic systems, the second meeting discusses the topic of thermodynamic processes, the third meeting discusses the topic of the zeroth law and the first law of thermodynamics, and the fourth meeting discusses the topic of the second law of thermodynamics.

b. Student needs analysis

   This research was conducted at SMA Negeri 12 Pekanbaru, Riau Province in the 2024/2025 academic year. This research was conducted on thermodynamics material, based on the results of the analysis carried out by researchers through interviews, observations and questionnaires, information was obtained that thermodynamics material is material that is difficult for students to understand, and learning in schools uses textbooks and power point as the main learning resources. In addition, 93% of students stated that they were interested in learning using *e-learning*. *The e-learning* that students want is interactive and interesting *e-learning* , there are PPTs, quizzes, and material reviews and guide students to carry out discovery learning.

2. Design Phase

After determining and analyzing the problem at the analysis stage. The next stage is to design learning media in the form of e-learning physics based on discovery learning. Preparation of learning devices, design of e-learning physics development, and preparation of research instruments.

a. Preparation of learning devices

The learning devices that are prepared are teaching modules. The teaching modules that are prepared consist of two types, namely the control class teaching module which is adjusted to the teaching module used by physics teachers of SMA Negeri 12 Pekanbaru. The experimental class teaching module contains the syntax of the discovery learning model listed in the core learning activities. In addition, the core learning activities also train students' conceptual understanding skills which consist of 3 indicators, namely translation, interpretation, and extrapolation.

b. E-learning development design

The physics e-learning design process consists of 2 steps, namely designing a historyboard and a storyboard. The historyboard includes the opening page, login, content and closing. The storyboard consists of scenes, displays, and descriptions. Scene contains the e-learning creation section which consists of 2 scenes, namely in education and the thermodynamics e-learning section. The display section contains the display images on e-learning in each section, and the description section contains an explanation of the images displayed in the display section.

c. Preparation of research instruments

The instruments used in this study consisted of validity assessment sheets, practicality assessment sheets for teachers and students, concept understanding tests, and student learning interest questionnaires.

3. Development Stage

At this stage, the development of *e-learning* physics based on *discovery learning is carried out* in accordance with *the flowchart* and *storyboard* that have been designed at the design stage, validity testing, and practicality testing.

a. Development of *e-learning* physics based on *discovery learning*

E-learning is developed using an educati-based Learning Management System. The appearance of the developed *e-learning is as shown in Figure 2.*

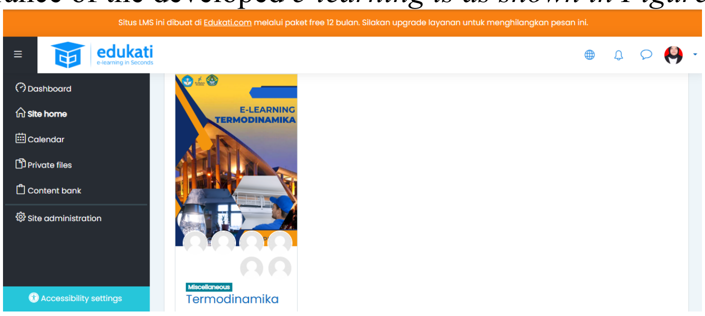

Figure 2. View of the home site *for e-learning* physics based on *discovery learning*

E-learning includes attendance, discussion forums, e-modules that guide students to improve their understanding of concepts, learning videos, power points, student worksheets, quizzes, summative assessments, glossaries and references to other relevant reading sources. The intended development results are:

1. Attendance
   Attendance in e-learning is available at every meeting. This attendance can be set for the duration of filling and can be given an attendance code to minimize student cheating in filling in attendance. Attendance cannot be filled in after the specified time.
2. E-module
   E-module in e-learning is available at every meeting, where the e-module developed using Canva is then uploaded to Hyzine to get a display like using a book. E-modules are arranged according to the discovery learning syntax and contain indicators of conceptual understanding ability.
3. PPT
   PPT in e-learning is available at every meeting. The PPT developed includes material and example questions that are arranged in such a way that they are interesting to use.
4. Video
   Video in e-learning is available at every meeting. The videos in this e-learning are adopted from YouTube videos that are relevant to the subject matter at each meeting.
5. LKPD
   LKPD in e-learning is available at every meeting, LKPD developed using Canva is then uploaded into a liveworksheet so that it can be filled in directly by students.
6. Discussion forum
   Discussion forum in e-learning is available at every meeting. Discussion forum is developed by utilizing the features available in e-learning. This discussion forum is used for joint discussions if there are difficulties or problems obtained by students or a forum to convey information.
7. Quiz
   Quiz in e-learning is available at every meeting. Quiz is arranged by utilizing the features available in e-learning. The quizzes developed have various forms, namely pairing, calculating, classifying.
   This content section is also equipped with a summative assessment consisting of 9 conceptual understanding questions consisting of three indicators and in the form of multiple choice, glossary and bibliography.

b. Validity test

Validity test on e-learning physics based on discovery learning consists of 3 experts using an assessment sheet consisting of pedagogical, material, and media aspects. Each validator is an expert lecturer from the Postgraduate Program in Physics Education and the Faculty of Mathematics and Natural Sciences, University of Riau. The validator then conducted an assessment twice on the media and pedagogical aspects and once on the material aspect of e-learning physics based on discovery learning on thermodynamics material based on the aspects available on the validity assessment sheet. Two validators in validity test 1 stated that there were several items in each aspect of the assessment that did not meet the criteria for being feasible, while one validator stated that each aspect of the assessment was already in the feasible category. Therefore, the researcher must make improvements according to the suggestions given by the validator. The final validity results obtained can be seen in Table 6.

Table 6. Validity results of e-learning physics based on discovery learning

Aspect	Validation Score
Material	0,91
Pedagogy	0,93
Media	0,92
Average	**0,92**

The validation score in table 6 is obtained by using equation 1. Based on the validity category in Table 2, the validation result criteria for the developed discovery learning-based physics e-learning are in the very valid category both in terms of material, pedagogy and media. So it can be stated that the physics e-learning thermodynamics material is suitable for use in physics learning. This is in line with research conducted by Nurcholif et al., (2021) which states that discovery learning-based e-learning is very valid for use in learning physics, especially thermodynamics material, to improve students' conceptual understanding and interest in learning. .

c. Practicality test

The practicality test aims to obtain a physics e-learning based on discovery learning that is practical to use in physics learning. The practicality test is carried out by teachers using an assessment sheet consisting of aspects of ease of use, effectiveness, and benefits, as well as student responses using an assessment sheet consisting of aspects of ease and use. The results of the teacher's practicality test can be seen in table 7 and the results of the student's practicality test can be seen in table 8.

Table 7. Results of the teacher's practicality test

No	Aspects	P	Criteria
1	Ease of use	94,00	Very practical
2	Efficiency	96,60	Very practical
3	Benefits	94,40	Very practical
	Average	**95,00**	**Very practical**

Table 8. Results of students' practicality test

No	Aspect	P	Criteria
1	Ease of use	89,30	Very practical
2	Benefit	91,20	Very practical
	Average	**90,25**	**Very practical**

Based on Table 3, the results of the practicality test of physics e-learning by 3 physics teachers obtained an average value of 95.00 with a very practical criterion. Not much different from Table 4.8, which states that the average value of the practicality of physics e-learning carried out by 20 students was 90.25 with a very practical criterion. Since the average practicality value is already in the very practical criterion and there are no suggestions from each teacher or student, overall physics e-learning is declared practical for use in the physics learning process.

Discussion

This study successfully developed a learning media in the form of e-learning physics based on discovery learning which was developed with the aim of improving students' understanding of concepts and learning interests and in accordance with 21st century competencies, namely technology-based learning. The e-learning developed consisted of 4 meetings with descriptions such as table 9.

Table 9. Results of Physics E-learning Development

No	Section	Description
1	Meeting 1	Discusses the topic of thermodynamic systems, which is equipped with attendance, e-modules, power points, learning videos, student worksheets, discussion forums, and quizzes.
2	Meeting 2	Discusses the topic of thermodynamic processes, which is equipped with attendance, e-modules, power points, learning videos, student worksheets, discussion forums, and quizzes.
3	Meeting 3	Discusses the topic of the Zeroth Law and the First Law of Thermodynamics, which is equipped with attendance, e-modules, power points, learning videos, student worksheets, discussion forums, and quizzes.
4	Meeting 4	Discusses the topic of the Second Law of Thermodynamics, which is equipped with attendance, e-modules, power points, learning videos, student worksheets, discussion forums, and quizzes.
5	Summative assessment	Consists of 9 multiple choice questions containing indicators of conceptual understanding.
6	Glossary	Consists of a list of terms related to thermodynamics material.
7	Bibliography	Contains a list of references relevant to thermodynamics material.

After the physics e-learning was successfully created, the next step was to ensure the feasibility of the product through a feasibility test. The feasibility test process involved media, material, and pedagogical experts. The validation results showed that the feasibility of the material reached 0.91, the feasibility of the pedagogy reached 0.93, and the media reached 0.92. Based on these three values, the developed physics e-learning was declared feasible as a learning medium. Furthermore, a physics e-learning trial was conducted involving teachers and students to measure their responses. The results showed that teachers gave a positive response of 95.00, and students gave a response of 90.25. This shows that the developed physics e-learning is considered feasible as a learning medium. The developed discovery learning-based physics e-learning can be accessed via the link https://termodinamikaasik.edukati.com/. This material can be accessed not only during guided learning sessions with the presence of teachers, but also independently, which serves as a source of reflection for students to review the learning material they have learned. The availability of various types of teaching materials such as e-modules, power points, videos, worksheets, and quizzes can provide convenience for students in exploring the material being studied. In addition, the discussion feature presented in e-learning makes it easier for students to have discussions with friends or teachers.

CONCLUSION

The developed e-learning contains attendance, discussion forums, e-modules that guide students to improve their understanding of concepts, learning videos, power points, student worksheets, quizzes, summative assessments, glossaries and references to other reading sources that are relevant to thermodynamics material with a validity value of 0.916 with a very valid category, a teacher's practicality value of 95.00 and a student's practicality value of 90.25 with a very practical category. Based on the results of validity and practicality, it can be concluded that discovery learning-based physics e-learning is feasible to be used to improve students' understanding of concepts and learning interests in physics learning.

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