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The Effectiveness of Android-based Thermodynamics Digital Book Integrated with PhET Simulations to Improve Students' Graphical Representation Skills

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ABSTRACT
A digital book is one of the media that can support learning because has the easiest access and can be equipped with multimedia features such as simulations. This research aims to determine the effectiveness of an Android-based thermodynamics digital book integrated with PhET simulation to improve students' graphical representation skills. The independent variable in this research is an Android-based thermodynamics digital book integrated with PhET simulations. In contrast, the dependent variable in this research is the ability of graphical representation skills. This research type is pre-experimental using a one-group pretest-posttest research design. At State High School in Yogyakarta, 72 students in the 11th grade participated in the cluster random sampling technique. N-Gain and eta square values showed that the students' graphical representation skills were significantly enhanced by the android-based thermodynamics digital book integrated with PhET simulation. This points out that using electronic physics learning materials and integrating technology has a positive effect on improving graphical representation skills. The recommendations made based on this research include that observation sheets be added to future research to observe the students better as they engage in each learning activity.

INTRODUCTION

Education is the main focus of the industrial revolution 4.0 in the 21st-century. The world's focus on education in the 21st century requires students to have learning abilities and aspects of innovation. The learning abilities referred to in the demands of 21st century education consist of metacognition, communication, critical and creative thinking, problem-solving, collaboration, innovation, and innovative literacy [1] [2]. Problem-solving ability can be categorized as an important component in scientific thinking [3] [4]. But in fact, the problem-solving ability of students in Indonesia can be categorized as low [5]. Based on the results of the initial survey at the State Senior High School of

Yogyakarta City, the low problem-solving ability is due to the lack of representation skills possessed by students. More than 50% of students have low category representation skills, especially graphical representation skills. Graphical representation skills are an essential ability that needs to be improved to support the achievement of students' understanding of physics concepts.

Representation skills are key to learning physics. Physics concepts can be explained in a variety of different ways, including through descriptions, symbols, graphs, diagrams, and mathematics. These various forms of presentation are known as representation. This ability is important because it can (1) improve understanding of physics concepts, (2) minimize physics learning difficulties, (3) improve physics learning outcomes, and (4) improve critical thinking and problem-solving skills [6] [7] [8] [9]. But in fact, students' representation skills are still low in terms of integrating and connecting several new representations, such as graphs and equations, in terms of solving physics problems [10]. One of the physics materials that is closely related to graphical representation skills is thermodynamics. Thermodynamic concepts are often explained through graphs such as pressure-to-volume (P-V) graphs.

The use of complex graphical representations makes thermodynamics a topic that students find difficult. Students need a strong understanding of the interaction of variables in various thermodynamic processes. Therefore, a learning strategy is needed that can improve students' graphic representation skills in thermodynamics. The latest technology-based learning media makes a breakthrough in the implementation of more optimal education [11] [12]. However, the reality of physics learning implementation still uses monotonous media and approaches, learning methods that only focus on teacher [13] [14]. Overcoming this, students need to be facilitated with learning media that can trigger an increase in graphical representation skills on thermodynamic material.

One of the learning media that utilizes technology is digital books. Digital books are one of the media that can support learning because their use has the easiest access and is equipped with multimedia features such as audio, video, and animation [15] [16]. There are many benefits of using digital books, including 1) increasing student interest and motivation in learning, 2) increasing understanding of the material, 3) increasing interaction between students and teachers during the learning process, 4) improving 21st-century skills, including critical thinking skills, problem-solving, collaborative, creative, and communicative students, and 5) improving representation skills [17] [18]. Thus, digital books have the potential to be used as learning media that support the achievement of more optimal student representation skills.

Digital books can be integrated with virtual laboratories to support the achievement of more optimal student representation skills. Physics Education Technology (PhET) is a virtual laboratory platform that provides interactive simulations for various science concepts. With PhET simulations, users can explore various concepts through visualization and direct manipulation, which helps improve understanding and active learning. PhET Interactive Simulations are proven to improve physics graphical representation skills [19]. Graphics help students understand physics concepts better because they can visually see the relationships between variables [20] [21]. PhET simulation provides various interesting features in the simulation, such as the slider feature to set parameters [22]. PhET simulation provides immediate feedback visualization of the effects that occur when parameters are changed [23]. In addition, PhET simulation can be accessed from a smartphone offline or online.

Digital books integrated with PhET simulations can be packaged in the form of Android applications so that they can be accessed easily via smartphones with the Android operating system. In addition, smartphones can make a positive contribution to the thinking ability of students [24]. This is reflected in the increasing number of smartphone users; recorded in January 2024, smartphone users in Indonesia were 353.8 million units, while the population in Indonesia at that time was 276.4 million. With 74.3% using the Android operating system [25]. At this time, smartphones can not only be used as a medium of communication but can also be used as an educational medium [26]. Thus, android-

based digital books integrated with PhET simulations on thermodynamics are an opportunity to improve high school students' physics graphical representation skills.

Android-based digital books integrated with PhET simulations on thermodynamic material have several advantages in improving the ability to represent physics graphs of high school students, namely 1) PhET simulations offer dynamic visualization so that students can easily understand changes in temperature, pressure, or volume in the thermodynamic process, 2) PhET simulations can help students to represent the relationship between thermodynamic variables in the form of graphs, and 3) android-based digital books are easily accessible anytime and anywhere to provide students with the opportunity to learn and repeat material as needed [27] [28]. The combination of android-based digital books with PhET simulations can help students understand thermodynamic material through clear visualization. Based on the background description, this study aims to determine the level of effectiveness of an android-based thermodynamics digital book integrated with PhET simulation to improve students' graphical representation skills.

METHOD

This research type is a pre-experimental using a one group pretest-posttest research design. This study used one modeling class and one implementation class [29]. Table 1 shows the research design as follows.

Table 1. Experimental Design

Class	Pretest	Treatment	Posttest
Modeling	O_1	X	O_2
Implementation	O_1	X	O_2

Information:
O_1 : Pre-test of students' graphical representation skills
X : The use of an android-based thermodynamics digital book integrated with PhET simulations
O_2 : Posttest of students' graphical representation skills

Modeling and implementation classes used an android-based thermodynamics digital book integrated with PhET simulations. The modeling class was taught by the researcher, while the implementation class was taught by a physics teacher. Both classes used the guided discovery learning model. The sampling technique in this study was cluster random sampling involving 72 students of class XI of State High School in Yogyakarta. The independent variable in this research is an android-based thermodynamics digital book integrated with PhET simulations, while the dependent variable in this research is the ability of graphical representation skills. The data collection techniques used were tests and questionnaires. The data were analyzed using the N-Gain equation to compare the graphical representation skills of students before and after using an android-based thermodynamics digital book integrated with PhET simulations.

$$\mathrm{N-Gain} = \frac{\mathrm{S_{post}} - \mathrm{S_{pre}}}{\mathrm{S_{max}} - \mathrm{S_{pre}}} \quad (1)$$

Information:
S_{post} = Posttest mean score
S_{pre} = Pretest mean score
S_{max} = Maximal score

The results of the calculation of the gain score (N-Gain) can be categorized based on the criteria listed in Table 2.

Table 2. N-Gain Categorization

Normalized Gain Score	Interpretation
0,70 < N-Gain	High
0,30 ≤ N-Gain ≤ 0,70	Medium
N-Gain < 0,30	Low

RESULTS AND DISCUSSIONS

The implementation of an android-based thermodynamics digital book integrated with PhET simulation applied the guided discovery learning model. In both, modeling and implementation classes, the learning process is carried out by dividing students into several groups. Students were given a QR code containing a Google Drive link to the digital book application that can be installed on a smartphone with an Android operating system. Figure 1 shows the digital book application used in this research. Students were focused on understanding the graph of the relationship between pressure (P) and volume (V) through conducting a simple practicum using the PhET simulation. In addition, students are also assisted to drawing and interpreting graphs of the relationship between pressure (P) and volume (V) in processes in thermodynamics [30]. Figure 2 illustrates the PhET simulation used in this research. The test of graphical representation skills on thermodynamics material and student response questionnaire were tested for feasibility using expert judgment. The test results showed that the instrument could be used. The results of this study are divided into two categories, namely pretest-posttest results and improved graphical representation skills. The representation indicators used are constructing graphs, interpreting graphs, and processing information [21] [31].

Fig 1. *Visualization of using digital book applications*

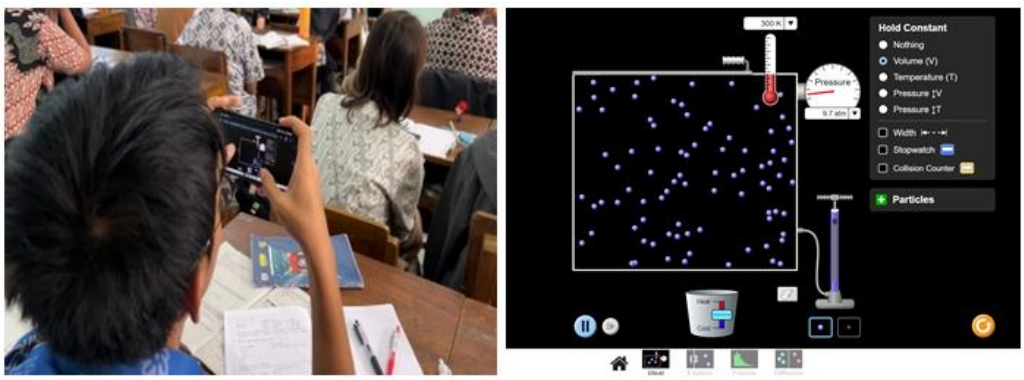

Fig 2. *Visualization of using PhET interactive simulation*

Pretest-Posttest Results

The data from pretest and posttest results of graphical representation skills in modeling class and implementation class have been tested for normality and homogeneity test. The results of the normality and homogeneity tests are presented in Table 3 and Table 4. The pretest and posttest scores have a significance value of more than 0.05. Thus, the pretest and posttest data can be said to be normally distributed and homogeneous so that the one-way ANOVA test can be carried out to determine the effectiveness of an android-based thermodynamics digital book integrated with PhET simulation to improve students' graphical representation skills.

Table 3. Normality Test Results

Class	Test	Shapiro-Wilk		
		Statistic	Df	Sig.
Modeling	Pretest	.965	36	.303
	Posttest	.961	36	.224
Implementation	Pretest	.962	36	.255
	Posttest	.966	36	.318

Table 4. Homogeneity Test Results

Class	Levene Statistic	df1	df2	Sig.
Modeling	.196	1	70	.659
Implementation	1.368	1	70	.246

The results of the pretest and posttest show significant changes as presented in Table 5. The pretest and posttest scores were analyzed with the N-Gain test to determine the improvement of graphical representation skills. The results of N-Gain analysis for the modeling and implementation classes are shown in Table 6. Both showed an average N-Gain value of more than 0.70. This shows that the improvement of students' graphical representation ability is in the high category in both the modeling class and the implementation class. The use of an android-based thermodynamics digital book integrated with PhET simulation is very practical and helps students improve their graphical representation skills.

Table 5. Pretest and Posttest Results

Result	Modelling Class		Implementation Class	
	Pretest	Posttest	Pretest	Posttest
The highest score	55	100	55	100
The lowest score	0	60	10	60
The average score	32	83	33	81
Increase in average score	50		48	

Table 6. The N-Gain Score Analysis

Class	The highest value	The lowest value	The average value
Modeling	1.00	0.50	0.75
Implementation	1.00	0.50	0.72

Based on the pretest results, students tend to have low graphical representation skills. This is because students have difficulty describing and interpreting the relationship between variables from a graph. However, based on the results analysis of the students' response questionnaire showed a positive response to the use of an android-based thermodynamics digital book integrated with PhET simulation. Students find it helpful with PhET simulations in the digital book application to learn thermodynamics concepts. The results showed that an andorid-based thermodynamics digital book integrated with PhET simulation improved high school students' graphical representation skills. This can be seen from the significant difference between pretest and posttest scores.

Improved graphical representation skills

The data that has met the normal and homogeneous requirements will be tested using a one-way ANOVA test and effect size test. One-way ANOVA test or F test to determine the comparison of the average pretest and posttest scores in the modeling class and implementation class, while the effect size test is used to determine the effect after the treatment is given. Based on the table, it is known that the experimental results show a difference between the pretest and posttest values in both the modeling class and the implementation class, which is indicated by the significance value in the significance column which is smaller than 0.05. It can be concluded that the android digital book is effective in improving students' graphic representation skills.

Table 7. The One-way ANOVA Test Results

Class	df	Mean Square	F	Sig.	Eta-squared
Modeling	1	45501.389	335.371	.000	.461
Implementation	1	41136.681	382.872	.000	.432

Table 7 also shows the partial eta value as a result of the ANOVA effect size analysis. The partial eta squared value can be used to determine the effect after the treatment is given to the modeling class and the implementation class. In the modeling class, the use of an android-based thermodynamics digital books integrated with PhET simulation significantly improved students' graphical representation skills by 46.1%, while in the implementation class by 43.2%. Based on this finding, it is known that the use of android-based thermodynamics digital book integrated with PhET simulation rather than implementation class can improve students' graphical representation skills. Thus, the implementation of the modeling class is more effective than the implementation class. Based on the results of interviews with physics teachers, he is still not used to using technology in the learning process. Thus, researchers expect the modeling class to provide direct teacher training on the use of an Android-based thermodynamics digital book integrated with PhET simulation.

The use of an Android-based thermodynamics digital book integrated with PhET simulation has been shown to significantly improve students' graphical representation skills. Graphical representation is one part of science process skills. Graphs explain the relationship between ideas and information by interpreting, organizing, and describing the results of conclusions and predictions [30]. This digital book offers interactive and accessible learning content, specifically designed to strengthen the understanding of thermodynamic concepts. Incorporating features that support active learning, such as PhET simulations, helps students better understand abstract concepts [27]. By engaging with dynamic simulations and immediate feedback, students are better equipped to draw accurate conclusions and develop a stronger foundation in thermodynamics. Therefore, an Android-based thermodynamics digital book integrated with PhET simulation allows students to visualize abstract concepts in physics more clearly and deeply.

PhET simulations play a key role in this process, as they allow students to explore various thermodynamic phenomena directly through manipulating variables and observing the resulting results. These simulations not only show how the graph is formed but also allow students to conduct virtual experiments that demonstrate how changes in system parameters affect the graph [19]. PhET simulations offer immediate visual feedback, which allows students to quickly understand the impact of their actions on the system and its graphical representation. This real-time interaction aids in reinforcing their understanding of cause-and-effect relationships in thermodynamics [32]. For example, by simulating changes in pressure and volume in a closed system, students can see how a thermodynamic graph is formed and how various factors affect the curves on the graph. This not only helps students understand the mathematical relationships between physics variables but also strengthens their skills in reading, analyzing, and drawing graphs.

The results of the students' response questionnaire showed a positive response to an andorid-based thermodynamics digital book integrated with PhET simulation. Implementation using the discovery learning model allows students to develop the ability to obtain information from various sources and

understand information in various forms of representation [33]. This can help students understand complex and abstract scientific concepts. In line with research by Karimah et al [34], the discovery learning model can improve representation skills. Discovery learning is a learning model where students discover knowledge independently from the information they get directly from the results of an investigation or an experiment with the teacher as a facilitator starting from simulation, problem identification, data collection, verification, and conclusion [35] [36]. The integration of discovery learning model with PhET simulation helps students to observe and consider information from several different representations [37] [38]. This can help students develop the ability to understand scientific concepts from several different perspectives.

The integration of the Android-based digital thermodynamics book with the PhET simulation creates a rich and interactive learning environment that enhances students' graphical representation skills by providing an immersive interactive and visual learning experience, which enables students to understand thermodynamic concepts through graphical exploration [27] [28]. This approach not only makes the concepts of thermodynamics easier to understand but also helps students to apply their knowledge in a real context, which ultimately enhances the students' understanding of thermodynamics. Additionally, the digital format of the book ensures that students can access the learning materials anytime and anywhere, promoting continuous engagement and self-paced learning [17] [18]. This innovative method ultimately supports students in developing a deeper and more practical understanding of thermodynamics, enhancing their overall learning experience.

CONCLUSION AND SUGGESTION

The purpose of this research is to determine the level of effectiveness of an android-based thermodynamics digital book integrated with PhET simulation to improve students' graphical representation skills. The use of android-based digital books combined with interactive PhET simulations is effective in improving students' graphical representation skills. This can be seen from the N-Gain value and eta square value which shows a high category, both in the modeling class and the implementation class. Recommendations made based on this research include that student activity assessment sheets be added in future studies to observe student activities in each learning activity following with the syntax of the learning model used. In addition, similar research can be developed on other materials.

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