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DEVELOPING PHET-AIDED PROBLEM-BASED LEARNING DEVICES FOR VIBRATION AND WAVES TO ESCALATE STUDENT THINKING SKILL

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ABSTRACT

This development research used the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. It resulted in valid, practical, and effective PhET-aided problem-based learning devices to learn vibration and wave materials. The research area was one of the junior high schools in Gorontalo District in 2021/2022. According to expert validation, lesson plan, student worksheet, learning material, and critical thinking test components were very valid at a mean score percentage of > 90%. The mean posttest score of the critical thinking skill of students increased at N-Gain (0.64) in the medium category for Tryout 1 and (0.73) in the high category for Tryout 2. The increase in the normalized mean gain was due to a better implementation of the PhET-aided PBL syntax, excellent student activities, and excellent student responses after the tryouts. In other words, the PhET-aided PBL model could effectively improve the critical thinking skills of students in vibration and wave materials.

KEYWORDS: Problem-Based Learning Device, PhET, ADDIE, Critical Thinking Skill

INTRODUCTION

Physics, biology, chemistry, geography, and space are part of science as a subject delivered at junior high school levels in an integrated fashion (Kemendiknas, 2006). Science is closely related to finding nature-related information systematically. In other words, science is not solely a group of scientific knowledge, such as facts, concepts, principles, theories, laws, generalizations, and models referred to as products. It also covers the finding process and scientific attitudes (Rutherford & Ahlgren, 1990; NRC, 1996). Science products are structured knowledge acquired through inductive activities and an active, dynamic, and explorative process (Carin, 1997).

Vibration and waves are delivered as science learning materials at junior high school levels. Vibration is defined as a regular, back-and-forth motion through an equilibrium, while waves are vibration (energy) sinusoidally propagating (Tipler & Mosca, 2008; Giancoli, 2014; Halliday, Resnick, & Walk, 2007). Vibration and waves, as parts of scientific knowledge, play an important role in daily life. The role is apparent through the implementation of modern technology, such as communication through radio streaming and televisions, listening to music, measuring the depth of an object (fish location) under the sea surface, monitoring the condition of sea water waves, ultrasonography (USG), ultrasonic therapy and cleaning, and the like.

Vibration and waves as knowledge, as well as their concepts, are mostly invisible. Fortunately, many applications have been available for learning media development, allowing the invisible concepts to be concretely presented. Additionally, the applications enable teachers to be more creative and innovative. Arsyad (2007) argues that teaching methods and learning media are indispensable to the teaching-learning process. An interplay between them involves teachers, students, and the learning environment to attain learning objectives. Using media in learning will enable effective message or material content delivery (Arsyad, 2007). Learning media will also evoke student learning motivation and interest and help students heighten their understanding of the delivered material. Learning media effectively support the learning process (Mahnun, 2012).

Our observation of a science teacher at one of the schools in Gorontalo District showed that students did not show critical thinking skills, interactive learning media were inadequately available, and students suggested a low interest in learning science, especially vibration and wave materials. Our interviews with students attested that vibration and wave materials were invisible, difficult to understand, and delivered using conventional learning models, monotonous lecturing methods, and monotonous learning media, e.g., unattractive modules. Learning media used in the learning process were still limited to pictures and PowerPoint. Additionally, teachers acted as the only learning and information sources.

One of the solutions to these problems is using a PhET simulation media-aided problem-based learning model. Using learning media in the class has a more significant influence compared to providing motivation and learning site conditions (Wahyudi, 2017). Learning media contribute to an effective learning process (Umar, 2014). In other words, using appropriate media can draw student interest and curiosity in learning. Criteria to select appropriate media should comply with the learning objectives to achieve.

Using learning media can improve conceptual understanding and critical thinking skills (Sumarni, 2013). Implementing critical thinking skills in the right context will make students understand how to think critically and solve daily problems using a smart, balanced, and responsible approach (Lambertus, 2009).

This research focuses on using a PBL or problem-based learning model in the learning process. One of the model characteristics is students as the learning center. Using the PBL model will minimize student dependence on teachers. The features of problem-based learning models will make students get accustomed to specific learning procedures (Gusniar & Juliani, 2019). They will be oriented to problems (formulating and making a prediction/hypothesis), group learning, investigations, result presentation, analysis, and evaluation of the problem-solving process.

Learning using PBL, through which real-life problems act as an initial learning context, will be more effective if collaborated with the PhET (Physics Education and Technology) simulation media. The collaboration is expected to increase students' critical thinking skills, allowing them to solve real-life problems. This research describes our attempt to promote students' critical thinking skills of vibration and wave materials using PhET simulation-aided problem-based learning devices.

METHOD

This research and development aimed to create PhET-aided problem-based learning devices to scale up the critical thinking skills of students. The developed devices were lesson plans, student worksheets, learning materials, and critical thinking skill tests. The subjects comprised two try-out classes, each containing 30 students. The number was determined using a cluster random sampling technique applied to the eighth-grader population at a school in Gorontalo District.

The PhET-aided PBL devices were developed using Borg and Gall's (2010) perspectives that research and development aimed to develop and validate an educational product. These PhET-aided PBL device development phases complied with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model, adopted from Dick & Carry (2001) and Prihatiningtyas et al. (2013), exhibited in Table 1.

Table 1 Development Phases Based on the ADDIE Model

No.	Development Phases	Activity
1.	Analysis	Analyzing the paramount importance of developing PhET-aided PBL devices by carrying out the analyses of the need, curriculum, material, learning outcome, critical thinking skills, and characteristics of students.
2.	Design	Designing PhET-aided PBL devices by determining learning objectives and lesson plans, learning scenarios, learning materials, student worksheets, and critical thinking skill test instruments.
3.	Development	Developing the conceptual framework of PhET-aided PBL devices into valid products ready to be implemented in learning after expert validation and revisions.
4.	Implementation	Implementing the PhET-aided PBL device products having been validated and revised. The implementation embarked upon a pretest activity and treatment using observation sheets concerning the PhET-aided PBL implementedness.

5.	Evaluation	Giving a posttest and distributing questionnaires.

The learning process to test the devices was performed using a pretest-posttest group design (Cohen & Manion, 1994; Sugiyono, 2014). The pretest activity was intended to describe the initial critical thinking skills of students. The posttest was given after the PhET-aided PBL devices were implemented. A posttest was given to analyze the increase in the critical thinking skills of students. Questionnaire distribution aimed to describe student responses to the implementation of PhET-aided PBL devices.

Pretest and posttest results were tested using the average normalized gain <g> and Hake's (1998) equation. The average normalized gain <g> was categorized (Nirmalasari, 2016) as indicated in Table 2.

Table 2. Category of the Average Normalized Gain

Hake's Equation	No.	Category
$<g> = \frac{<X_f> - <X_i>}{100 - <X_i>}$	1.	$<g> \geq 0.7$ = High
	2.	$0.3 \leq <g> < 0.7$ = Medium
	3.	$<g> < 0.3$ = Low

X_f = Mean score of the posttest, and X_i = Mean score of the pretest

The successful PhET-aided PBL process was determined by comparing the average normalized gain between Class Tryouts 1 and 2. A t-test at a 0.05 significance level was undertaken using SPSS version 12.0 for Windows to examine if critical thinking skills for vibration and wave materials differed between students.

RESULT AND DISCUSSION

The mean scores of experts/validators' validation in percent regarding the developed PhET-aided problem-based learning devices, comprising lesson plans, student worksheets, teaching materials, and critical thinking skill tests are pointed out in Figure 1.

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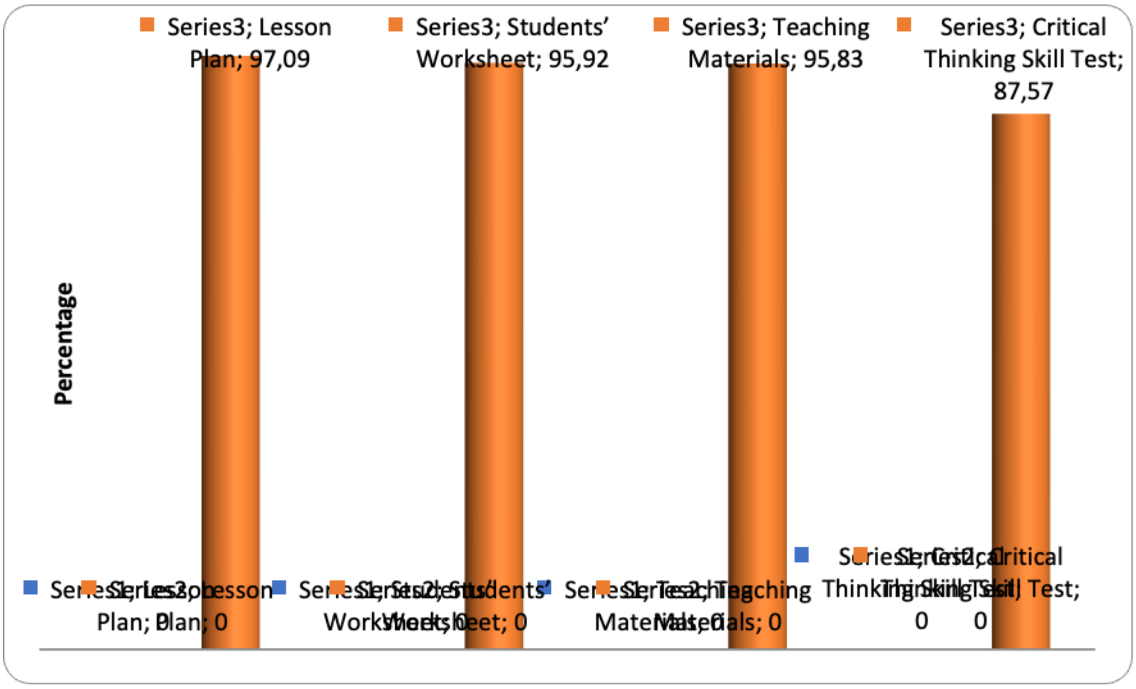

Figure 1. Mean Scores of the Expert Validation of PhET-Aided PBL Devices in Percent

Figure 1 demonstrates the percentage of the scores given by experts to the PhET-aided problem-based learning devices. The scores were considered very valid, suggesting that the devices were reliable to use in learning to augment the critical thinking skills of students. Data from pretests and posttests after Tryouts 1 and 2 on the PhET-aided problem-based learning devices are exhibited in Figure 2.

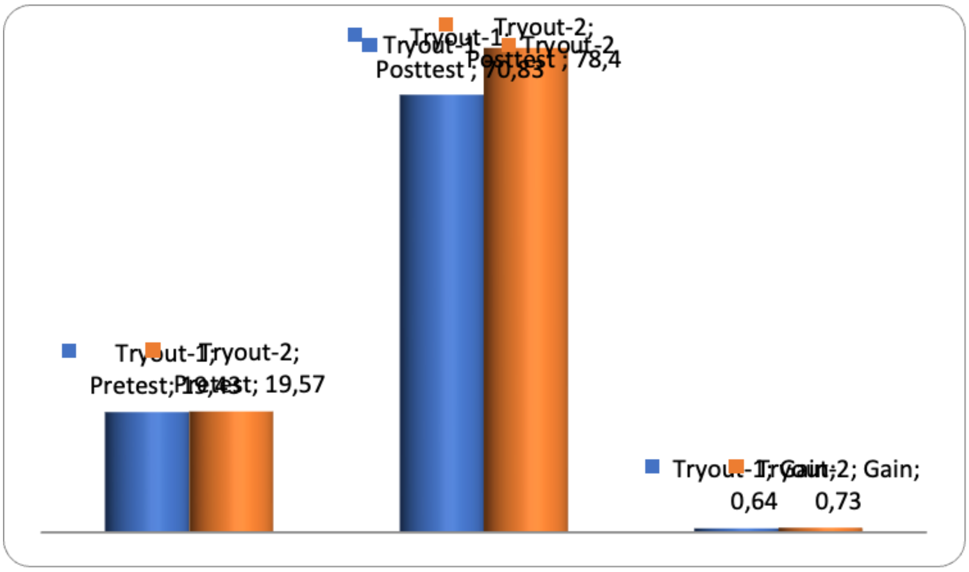

Figure 2. Comparison of the Mean Scores of Pretests and Posttests and Normalized Gain

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As indicated in Figure 2, the mean scores of pretests in Class Tryouts 1 and 2 were the same. It pointed out no difference in the initial critical thinking skills of students as regards vibration and wave materials. After the implementation of PhET-aided PBL devices, there was a difference in the mean scores of posttests in Class Tryouts 1 and 2. The difference in the mean scores of posttests was supported by the means of normalized gain <g> = 0.64 (medium) in Class Tryout 1 and <g> = 0.73 (high) in Class Tryout 2. Class Tryout 1 (N = 30) achieved a score of 70.83 at a standard deviation of 3.95 and variance of 15.59. Class Tryout-2 (N = 30) achieved a score of 78.40 at a standard deviation of 3.08 and variance of 9.49. Based on the t-test, the t-count (8.276) was higher than the t-table (1.670) at a 0.05 significance level and the degree of freedom of 58. Accordingly, critical thinking skills of students in Tryout-2 elevated. The PhET-aided PBL model effectively enhanced critical thinking skills of students for vibration and wave materials. It was commensurate with Dwi et al. (2013) stating an increase in problem-solving concepts and skills using Information and Communication Technology (ICT)-aided PBL strategies, Yassin et al. (2010) and Fong Ma et al. (2008) suggesting successful learning using ICT-based PBL strategies, Mulyono (2011) finding that real-life experience provision could stimulate students to learn using ICT-based PBL strategies, and Mursalin (2013) stressing remediation and minimizing student misconceptions of electricity circuit topics using the PhET simulation model.

The increase in critical thinking skills of students was in tandem with an increase in the PhET-aided PBL syntax implementedness quality in Tryout-1 and 2, as demonstrated in Figure 3.

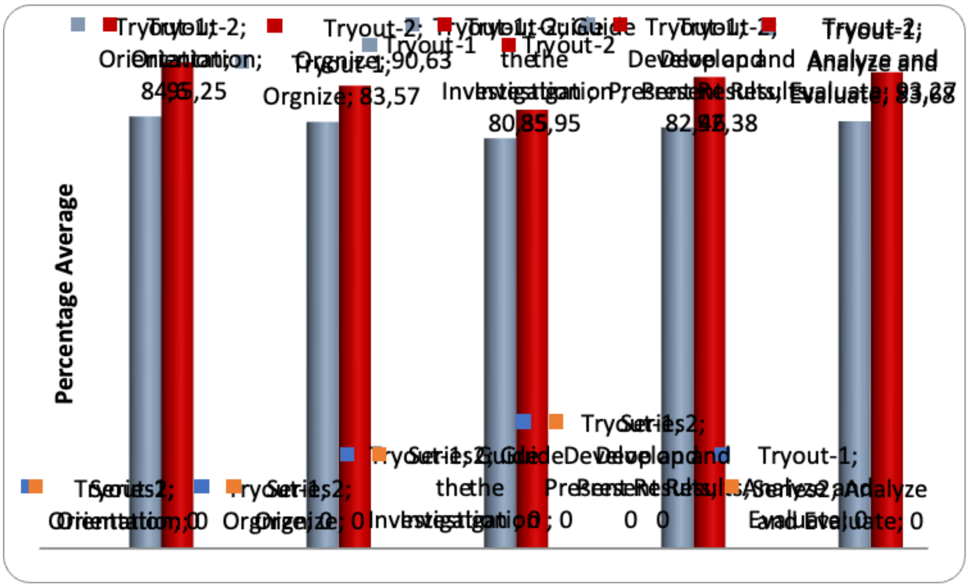

Figure 3. Percentage of the Mean Scores of PhET-Aided PBL Syntax Implementedness

Figure 3 indicates that the quality of PhET-aided PBL syntax implementedness in Tryout-2 was better than that in Tryout-1. In Tryout-2, the highest implementedness score was in the stage of student orientation to the problem, followed by the analysis and evaluation of the problem-solving process, the development and presentation of the work, student organization to learn, and guidance for individual/group investigation. Implementing PhET-aided PBL made teachers customized to implementing the PhET-aided PBL syntax. Additionally, transforming Class Tryout-1 and Tryout-2 into a conducive and democratic virtual laboratory conferred opportunities for students to express arguments. Scaffolding was given when students carried out experiments, observation, data analysis, and conclusion drawing.

From the questionnaire addressing the implementation of the PhET-aided PBL model in learning vibration and wave materials, as indicated in Table 3, students regarded the model as new. All students argued that this model could enhance interest and motivation to learn physic materials and elevate skills of understanding physic concepts and principles. Most students conveyed that this PhET-aided PBL model could heighten curiosity, problem-identifying and formulating skills, and solution planning and finding. They also stated an increase in the skills of explaining, communicating the relationship between a concept and another, conducting experiments and observation using PhET, analyzing data, and drawing conclusions.

Table 3. Student Responses to the Implementation of the PhET-Aided PBL Model

No.	Statement in the Questionnaire	Agree (%)
1.	The PhET-aided PBL model is new.	100
2.	Using the PhET-aided model, I am more interested and motivated to learn physic materials.	100
3.	Using the PhET-aided model, my curiosity adds up.	97
4.	Using the PhET-aided PBL model, my skills in identifying and formulating problems and planning and finding a solution to a learning topic improved.	97
5.	Through the observation activity required in the implementation of the PhET-aided PBL model, my skills in understanding physic concepts and principles increased.	100
6.	Through the observation activity required in the implementation of the PhET-aided PBL model, my skills in explaining and communicating the relationship between a concept and another scaled up.	90
7.	Through the scaffolding activity required in the implementation of the PhET-aided PBL model, my skills in conducting experiments and observation using PhET, analyzing data, and drawing conclusions escalated.	90

CONCLUSION

The results indicated that our development of the PhET-aided Problem-Based Learning model to learn vibration and wave materials was valid, practical, and effective. The PhET-aided Problem-Based Learning model could promote the critical thinking skills of students when learning vibration and wave materials. The results could be implemented in science learning to enhance the understanding and critical thinking skills of students. Future researchers can perform further research on another topic to

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test the consistency level of the results of this research and previous research to escalate the quality of learning processes and outcomes.

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