



The Effectiveness of PBL (Problem-Based Learning) Sound Wave Electronic Student Worksheets to Improve Critical Thinking Skills of High School Students

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Abstract. Digital teaching resources are an alternative to traditional textbooks in the “digitalization 4.0” era. The student worksheet is one of the digital instructional resources that can be generated. Along with using digital teaching tools, the selection and implementation of learning models are equally important in promoting learning in schools. One of the learning methods that can be used is the problem-based learning (PBL) model. This study assesses how successfully PBL-based sound wave electronic worksheets improve high school students critical thinking skills. This type of research is categorized as research and development (R&D) when it follows the ADDIE approach (analysis, design, development, implementation, and evaluation). The test subjects were class XI MIPA PC (Prima Cendekia) SMA Negeri 3 Mataram students. Data collection techniques included validation sheets to determine validity and reliability, critical thinking skills test instruments in the form of a pretest and posttest to measure effectiveness, and observation sheets by teachers and students to determine practicality. The resulting data were examined qualitatively and quantitatively using quantitative descriptive statistics. The study’s findings are restricted to the viability of the created electronic LKPD. Based on the N-Gain value of critical thinking abilities, product efficacy falls under the high category. These results imply that PBL-based sound wave electronic student worksheets effectively foster critical thinking skills in high school pupils.

Keywords: critical thinking skills · electronic student worksheets · PBL · sound waves

1 Introduction

The 21st century, also known as the “era of globalization,” is one of accessibility characterized by the advancement of science and technology [1]. The 21st-century learning paradigm requires students to be technologically literate and skilled in various things that

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are useful for their lives [2, 3]. According to the National Education Association (2012), students who want to compete in the global era must possess the so-called 4C abilities of communication, collaboration, critical thinking, and creativity [4]. Students must receive the most training and development possible to acquire all the skills necessary for success in dealing with life's difficulties, which are becoming more complicated and uncertain [5]. Someone does not have these skills from birth; they are obtained through practice, learning, or experience [6]. If pursued through education, the development of human resources with 21st-century capabilities will be successful. The 2013 curriculum has integrated 21st-century skills into its content, procedural, and assessment standards [7]. Students' critical thinking ability is one of the most crucial abilities [8, 9]. The ability to make numerous analyses, assessments, evaluations, reconstructions, and decisions that result in logical and rational behaviors is known as critical thinking [10]. Critical thinking skills are essential in 21st-century society [11]. Critical thinking is a skill that students must possess to face the demands of the 21st century [12].

A study by Trilling and Fadel [13] found that postsecondary students, high school graduates, and diploma holders still lacked proficiency in the following areas: oral and written communication; critical thinking and problem-solving; professionalism; work ethics; working in teams and collaborating; working in different groups; using technology; and project management and leadership. It is undoubtedly a challenge for all parties, particularly the educational community, to be able to increase students' competency so that it is applicable to their daily life. As a fundamental building block for joining the workforce, the middle school must be able to give children the skills and mental maturity they need.

According to records, the Indonesian government announced that beginning in March 2020, students would be able to complete their coursework from home [14–16]. Nearly tens of millions of Indonesian students, from elementary to tertiary levels, can now not attend class as normal due to this policy [17, 18]. This situation surely drives the government and education officials to work hard in order to ensure that Indonesians continue to receive a high-quality education and are not left behind by other nations. Online teaching materials using media that are appealing and easily accessible to students are one of the things that are required in the process of adjusting to new learning habits after the pandemic occurs [19, 20]. It is required to create digital teaching resources packed in online learning media in the form of digitally based student worksheets (electronic student worksheets) to realize engaging learning. One of the instructional tools that can be used to support the teaching and learning process is the student worksheet [21]. A student worksheet is typically thought of as teaching material in printed form. Still, as technology has developed, student worksheets can now be presented electronically and come with videos and eye-catching images to help students better understand the presented material [22, 23].

Learning about conceptual physics requires using appropriate media, digital teaching resources, and learning models adapted to students' needs. Problem-based learning, or PBL, is an alternative learning strategy that can be applied. PBL is a method of learning where students apply their knowledge of the subject matter to real-world problems as a backdrop for learning about different ways of thinking and solving them [24–26]. The usage of the PBL model is anticipated to meet the demands of the students better

and make it simpler for them to comprehend the key ideas in learning physics. Both educators and researchers now frequently employ the PBL paradigm to help students develop their critical thinking abilities. According to research by Astuti et al. [27], the PBL paradigm can help students develop their critical thinking abilities when studying equilibrium-related content. However, there hasn't been much research on combining online learning resources like electronic worksheets with PBL models to enhance students' critical thinking abilities. To raise students' interest, educators must be creative and innovative in creating engaging lesson plans and learning resources. Research on developing digital teaching materials as online learning media in the form of PBL-based sound wave electronic student worksheets is essential, as stated in the previous description. Students in high school will benefit from this as they develop their critical thinking skills.

2 Method

Research and development is the style of research that is used. Sugiyono [28] defined research and development as research utilized to manufacture specific items and assess the viability of developing products. The ADDIE model, modified by Abdurrahman [29], is the framework for development research. A simple development design concept is the ADDIE model. The five stages of development using the ADDIE model are analysis, design, development, implementation, and evaluation. The goal of the analysis phase is to examine data about field circumstances so that it may serve as a more solid foundation for creating research products. The initial analysis, the study of student preparation, and the analysis of the material features were all conducted at this point.

The planning step, or design, tries to create plans for research goods. A product is to be developed during the development stage regarding the various elements currently being planned, including the creation of electronic worksheets, a syllabus, lesson plans, and tools for developing critical thinking abilities. Development is creating rough product drafts, validating experts, and validating practitioners. Drafts of the final product's design, instructional materials, and learning models are developed. It is digitally based and was created using the live worksheet tool, free to download from Google. Professionals and practitioners will subsequently approve the created product draft. Product modifications and enhancements are made at every step of development. The viability of the generated items was evaluated using practitioner validation and expert validation questionnaires. It is likely viable if the product receives validation findings from validators with legitimate categories.

The implementation step also seeks to ascertain how students will react to the final product of this time; class XI MIPA PC students of SMA Negeri 3 Mataram will participate in a little trial. The effectiveness of product development was analyzed in this study using the N-Gain test. N-gain is calculated using the formula proposed by Hake [30]. Finally, the ADDIE model is particularly adaptable when it comes to making changes to the product that is being developed because the assessment stage can be completed at each step that has already been completed. Only formative assessment was used in this study's evaluation (Fig. 1).

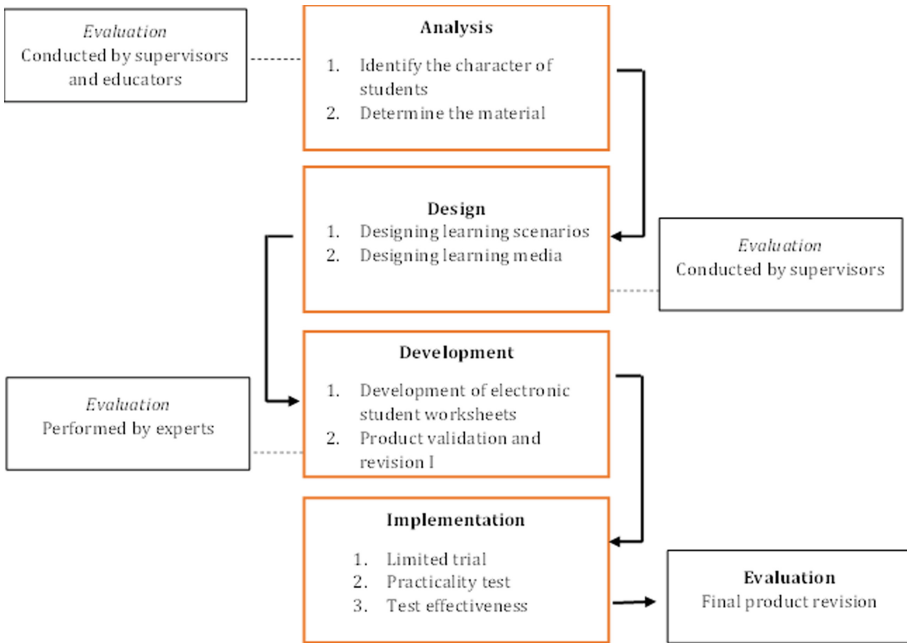


Fig. 1. Design of the ADDIE Model by Researchers

The formative evaluation aims to assess a product based on its format and validity so that this evaluation is carried out repeatedly to produce a good product.

$$N - gain = \frac{Spost - Spre}{Smaks - Spre} \times 100\% \tag{1}$$

Information:

N-gain = gain score

Spost = *posttest* scores

Spre = *pretest* scores

Smaks = ideal maximum score

N-gain values are grouped into high, medium, and low categories. The N-Gain criteria are presented in Table 1.

Giving categories aims to determine the qualifications of students' critical thinking skills. Critical thinking skills are divided into 5 calculations, and categories can be seen in Table 2.

$$Value = \frac{Score\ obtained}{Maximum\ score} \times 100 \tag{2}$$

Table 1. N-Gain Score Criteria

N-Gain Value	Category
>70%	High
30%–70%	Middle
<30%	Low

Hake, [30].

Table 2. Criteria for Critical Thinking Skills

Acquisition Scale	Category
>85	Very good
70–85	Good
55–70	Enough
40–55	Less
<40	Very less

Arikunto, [31].

3 Results and Discussion

3.1 Electronic Student Worksheet Development Using the Liveworksheets.com Application

A PBL-based electronic student worksheet created with the help of the live worksheet application is the result of this project. You can get the live worksheet program for free at <https://www.liveworksheets.com>. Two menu options are available in this application: teacher access and student access. By logging in as students, users can access materials created by educators or teachers. Students can open teacher-made materials and study whenever they have time because they can be accessed anytime with an internet connection. These electronic student worksheets can be accessed multiple times to meet the demands of students and teachers, making them ideal for use in classroom instruction with constrained study time. Teachers can add content or tasks based on the needs of their pupils. The disadvantage is that professors or students cannot access these electronic student workbooks offline (Fig. 2).

Electronic student worksheets for sound waves were created using a live worksheet application and adhering to the PBL learning model's stages. Since this live worksheet tool is freely accessible on Google, educators, and students can use it. Using worksheets with the live worksheet application teaches students to approach challenges critically and imaginatively to develop better answers [32]. By engaging in the most fundamental mental tasks, children can think critically while solving problems, draw conclusions, evaluate, and form relationships using problem-based student worksheets [32, 33]. Research conducted by Dibyantini et al. [34], Fauziah et al. [35], and Mufidah et al. [36] stated



Fig. 2. Display of electronic worksheets in the liveworksheets.com application

that problem-based learning has a positive influence on students' motivation, activeness, and learning outcomes.

3.2 Product Effectiveness Test

The effectiveness test is a test conducted on products that have been developed by involving potential product users. Electronic student worksheets were implemented in the form of a limited trial with 25 students in class XI MIPA PC SMA Negeri 3 Mataram. This trial was conducted to determine the effectiveness of electronic student worksheets on sound wave material. The results of the PBL-based electronic student worksheet effectiveness test are explained in more detail as follows.

3.2.1 Empirical Results of Electronic Student Worksheets

The empirical results of using this electronic student worksheet are to assess students' critical thinking skills while participating in the learning process in class. The empirical results of using these electronic student worksheets can be seen in Table 3.

3.2.2 Product of Trial Results

Trials using PBL-based electronic student worksheets were conducted to determine the value of students' critical thinking skills. The outcomes of the pretest are used to gauge students' critical thinking abilities and sound wave-related prior knowledge. After using the electronic student worksheet to facilitate learning, the posttest is utilized to gauge students' critical thinking abilities. Table 4 details the importance of critical thinking abilities and cognitive learning outcomes for pupils.

Table 3. Value of Students' Critical Thinking Skills

Meeting	Value					Average	Category
	Basic clarification	Basic decision	Inference	further explanation	Reasoning and integration		
I	87	75	82	83	85	82,40	Good
II	88	75	82	85	87	83,40	Good
III	88	82	84	84	92	86,00	Very good

Table 4. Data on the Value of Students' Critical Thinking Skills

Critical thinking skills		Min Value	Max Value	number of questions	Question form		
	Pretest	30,0	62,5			10	essay
	Posttest	70,0	97,5				

3.2.3 N-Gain Test Results

After using electronic student worksheets to study, the N-Gain test measures the improvement in learning outcomes and students' critical thinking abilities. The following N-Gain test results demonstrate the importance of learning objectives and the students in class XI MIPA PC SMA Negeri 3 Mataram's capacity for critical thought (Tables 5 and 6).

Table 5. N-Gain Value of Students' Critical Thinking Skills

Critical thinking skills		Average value	Max Value	N-Gain	Category		
	Pretest	41,9	100			0,78	High
	Posttest	87,5					

Table 6. N-Gain Value of Students' Critical Thinking Skills Indicators

No	Indicators	Skor Nilai		N-Gain	Kategori
		Pretest	Posttest		
1.	Basic clarification	148	187	0,75	High
2.	Basic decision	105	192	0,91	High
3.	Inference	60	178	0,84	High
4.	further explanation	53	170	0,79	High
5.	Reasoning and integration	53	147	0,63	Middle

Students' critical thinking abilities improved after learning was conducted utilizing PBL-based electronic worksheets on sound wave material. This finding is consistent with studies by Nafiah et al. [37] and Ningsih et al. [38], demonstrating that problem-based learning improves students' critical thinking abilities.

This PBL-based sound-wave electronic student worksheet was created to hone high school pupils' critical thinking abilities. Students' motivation, activity, and learning outcomes are all positively impacted by problem-based learning, according to studies by Dibyantini et al. [34], Fauziah et al. [35], and Mufidah et al. [36]. This electronic worksheet was developed using the Liveworksheets.com application, available on Google for free. Teachers widely use this application in developing electronic worksheets because of how easy and interactive it is to use. The student worksheets developed by the researcher contain sound wave material following the PBL model learning stages. The PBL stages used include: a) reviewing and presenting the problem. In this phase, students are presented with real-world problems related to sound wave material. By responding to the problems presented, students also convey indicators of critical thinking skills, namely, basic clarifications. b) Developing a strategy Students prepare simple experiments related to the material being studied at this stage. c) Implement the strategy. Students conduct simple experiments at this stage and look for references related to the experiment and the material being studied. At this stage, the indicators of critical thinking skills are basic decisions and applied inferences. d) Discuss and evaluate the results. At this stage, students present the results of observations based on simple experiments and learning videos that have been listened to. At this stage, the indicators of critical thinking skills provide further explanations. The fifth indicator, reasoning, and integration, is applied in this last phase by answering self-test questions at the end of each electronic worksheet. Ennis [39] defines critical thinking as the capacity to offer explanations (that are reasonable) and to analyze one's beliefs and actions. According to Elaine [40], critical thinking is a precise and deliberate mental process utilized to carry out tasks like problem-solving, decision-making, persuasion, assumption analysis, and scientific inquiry.

4 Conclusion

The PBL-based sound wave electronic student worksheets successfully hone high school students' critical thinking abilities. After using electronic worksheets, students' critical thinking abilities are rated as being of a high caliber. Four indicators of critical thinking skills are based on the largest N-gain values on basic decision indicators, while one indicator is in the medium category, namely reasoning and integration indicators.

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