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Enhancing Students' Critical Thinking and Communication Skills Through Problem-Based Learning with Science Writing Heuristic Approach in Physics Learning

M. MUSLIM, R. A. SIHOMBING, B. K. PRAHANI, A. SAMSUDIN

ABSTRACT

Introduction. The development of critical thinking and communication skills is essential for the educational growth of junior high school students. These skills are fundamental in enabling students to analyze information critically, solve problems effectively, and express ideas clearly in both written and oral forms. However, traditional teaching methods often fall short in cultivating these competencies, highlighting the need for more innovative and student-centered learning approaches. One promising solution is the integration of a problem-based learning (PBL) model with the science writing heuristic (SWH) approach. Therefore, this study aimed to explore the enhancement of critical thinking and communication skills among junior high school students through the application of the PBL-SWH model, specifically focused on the topic of work and simple machines.

Research methods. This study used a pre-experimental one-group pretest-posttest design, involving 25 eighth-grade students from a junior high school in Bandung, West Java, Indonesia. The learning intervention combined the Problem-Based Learning (PBL) model with the Science Writing Heuristic (SWH) approach. Data were collected using a critical thinking test, observation sheets, communication assessment rubrics, and a student response questionnaire. Students were grouped into high, medium, and low categories based on their proficiency levels to observe variations in outcomes. The instruments were validated and analyzed using normalized gain (N-gain), descriptive statistics, and paired sample t-tests to determine the effectiveness of the intervention on cognitive and communicative skills.

Results. The findings showed significant improvements in students' critical thinking and communication skills. The average N-gain score for critical thinking was 0.51 (moderate category), with the highest improvement in making simple clarifications (0.60) and the lowest in developing strategies and tactics (0.45). The paired sample t-test revealed a significant difference between pretest and posttest scores ($t = -3.623$, $p < 0.001$). Written communication skills increased steadily from "Less" to "Good" across four sessions, and oral communication skills also improved, particularly in eye contact and body language. Student responses were highly positive, with an average approval rate of 85.37%, indicating that the PBL-SWH approach enhanced both the learning experience and student engagement.

Conclusion. The findings suggest that integrating problem-based learning with the science writing heuristic can be an effective strategy for enhancing critical thinking and communication skills among junior high school students. This approach not only promotes deeper understanding of science concepts such as work and simple machines, but also helps students to express their ideas more confidently and reflectively. Given the positive student responses and observed learning outcomes, this model holds strong potential for broader application in science education to foster essential 21st-century competencies.

KEYWORDS

critical thinking skills, communication skills, problem-based learning model, science writing heuristic approach

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INTRODUCTION

UNESCO emphasizes that in order to face the challenges of the 21st century, students must be equipped with competencies that go beyond cognitive skills, extending to social and personal domains [1; 2]. One of the key competencies is critical thinking, the ability to analyze information, evaluate arguments, and make reasoned decisions based on evidence. In line with this, the Partnership for 21st Century Learning outlines critical thinking and communication as two of the essential 4Cs (Critical Thinking, Communication, Collaboration, and Creativity) that learners need to thrive in a global society. Communication skills, in particular, are crucial for expressing ideas clearly, engaging in scientific discourse, and collaborating effectively. Therefore, education today must focus on developing both critical thinking and communication skills from an early stage through active, inquiry-based, and student-centered learning approaches.

In today's era of globalization, the demand for human resources capable of easily adapting to changing times is increasingly high [3]. Therefore, human resources produced from education must reflect graduates who can think critically, possess problem-solving skills, be creative, innovative, competent in information and communication technology (ICT), communicative, and multilingual [4; 5]. To achieve these competencies, educational institutions, especially teachers or lecturers as learning agents, are required to change the existing teaching methods.

According to previous studies, science education is an essential field in schools to support the development of science and technology [6; 7]. This field not only provides knowledge in the form of facts, concepts, and principles but also comprises a discovery process emphasizing direct scientific experience [8]. Several studies have shown that effective science education must have relevant and contextual content for long-term learning [9; 10]. However, in practice, its implementation in junior high schools still faces several challenges, such as limited preparation time, inadequate facilities, learning environments, and large class sizes. Science teaching also often focuses on tests or exams, causing students to memorize without deeply understanding the concepts [11; 12].

In line with these findings, the success of science education is expected to be more optimal when teachers consider students' conditions and potential, as well as other supporting resources. These include teachers' abilities, availability of facilities, and stakeholder engagement. The curriculum must also provide guidelines without limiting freedom and creativity in designing lessons, thereby fostering curiosity and interest in students [13; 14]. The implementation of science education must equip students with thinking skills, which is one of the intellectual goals of the curriculum.

Previous interviews with junior high school science teachers revealed data a lack of data on students' 21st century skills, such as critical thinking, creative thinking, problem-solving, communication, and collaboration. Developing 21st century skills from an early age is necessary to prepare for future challenges [15; 16]. Implementing science education that can train these skills is essential by focusing on thinking skills, learning abilities, curiosity, and attitudes of care and responsibility.

One approach that is consistent with constructivist views is the Science Writing Heuristic (SWH). The SWH approach, also known as argument-based inquiry, encourages students to engage in directed scientific inquiry activities in the laboratory and work collaboratively in groups to discuss and build knowledge [17; 18]. In addition, it integrates inquiry activities, collaborative work, and meaning-making through Argumentation and writing-to-learn strategies, facilitating the development of 21st century skills [19; 20].

The SWH approach can be applied through problem-based learning (PBL) model, which requires students to actively solve real-life problems using their knowledge through scientific methods [21; 22]. The PBL model develops high-level thinking skills, independence, and self-confidence. The model is often conducted in groups, encouraging students to collaborate, discuss, share ideas, respect opinions, and interact [23; 24].

Based on these findings, the current study is crucial because it can contribute to improving the quality of science education in junior high schools, particularly in enhancing 21st century skills. It also offers an alternative solution for science teaching that encourages students to develop 21st century skills, enabling the expression of ideas or opinions in learning activities. Therefore, this study aimed to clarify the following:

1. Improvement in critical thinking skills of junior high school students through Problem-Based Learning Model with Science Writing Heuristic Approach.
2. Improvement in communication skills of junior high school students through Problem-Based Learning Model with Science Writing Heuristic Approach.
3. Students' response on the Problem-Based Learning Model with Science Writing Heuristic Approach in Science Learning.

LITERATURE REVIEW

This led to various initiatives aimed at identifying steps to enhance essential 21st century skills in education. Consequently, it was summarized that the skills that can be developed through a Problem-Based Learning Model with a Science Writing Heuristic Approach include:

A. Problem-Based Learning Model

The Problem-Based Learning (PBL) model is a student-centered learning model that focuses on problem solving. Through the PBL model, students are guided to connect concepts with the facts they discover. Students are presented with real-life scenarios or problems that require solutions [21; 22]. In the process, students analyze problems and contexts by applying deductive and inductive processes to understand the issues and find solutions.

The selection of the PBL model is based on students' backgrounds, expectations, and interests. Students tend to be more motivated and show greater effort when using the PBL model compared to traditional learning methods. One important aspect to consider in implementing the PBL model is the teacher's role in facilitating discussions among students that foster inquiry and critical analysis [23; 24]. Teachers act as facilitators, while students are responsible for the knowledge they acquire. The process in the PBL model usually ends with the presentation of solutions and an evaluation of the problem-solving process.

The main objective of the PBM model is to develop critical thinking skills and problem-solving abilities, as well as to develop students' ability to actively construct their own knowledge. The PBM model is also intended to develop students' independence in learning and social skills. Independence in learning and social skills can be formed when students collaborate to identify relevant information, strategies, and learning resources to solve problems [25].

The syntax of the PBM model consists of five steps, beginning with the teacher introducing students to a problem situation and ending with the presentation and analysis of students' work. These systematic steps have the potential to develop students' problem-solving abilities. The syntax of PBM model is presented in Table 1.

Table 1

Syntax of Problem-Based Learning Model

Stages	Teacher and Student Activities
Stage 1 Students orientation to the problem	Teachers explain the learning objectives and the necessary resources or logistics. Teachers motivate students to engage in real-world problem-solving activities that have been selected or determined.
Stage 2 Organizing students for learning	Teachers help students define and organize learning tasks related to problems that have been oriented in the previous stage.
Stage 3 Guiding individual and group investigation	Teachers encourage students to gather relevant information and conduct experiments to obtain the clarity needed to solve problems.
Stage 4 Develop and present work	The teacher helps students to share tasks and plan or prepare appropriate work as a result of problem solving in the form of reports, videos, or models.
Stage 5 Analyze and evaluate the problem-solving process	The teacher helps students to reflect on or evaluate the problem-solving process that has been carried out.

Source: [25]

The main principle of the PBM model is the use of real-world problems as a means for students to develop knowledge while also developing critical thinking and problem-solving skills. The selection or determination of these real-world problems can be done by teachers or students in accordance with specific basic competencies. The problems are open-ended, meaning they have multiple answers or solutions, which encourages students' curiosity to identify those strategies and solutions [25].

B. Science Writing Heuristic Approach

Science Writing Heuristic (SWH) is a learning approach in science designed to deepen student understanding through laboratory inquiry activities [17; 18]. The approach shifts the focus from laboratory practices that simply test and recall information, towards activities that more closely resemble the way scientists work on a day-to-day basis, such as conversations, writing, and debates based on evidence gathered [26; 27]. SWH involves the teacher as a facilitator who encourages students to explore, participate in inquiry, and negotiate their understanding in a structured way [19; 28]. SWH templates for teachers guide this process, while templates for students provide a structured framework that assists in building their reasoning and reflection on their laboratory experience.

C. Problem-Based Learning Model with Science Writing Heuristic Approach (PBL-SWF)

21st century skills are becoming increasingly important in global education due to the shift of economies and industries towards the age of information and innovation, the demand for new job skills, and efforts to reduce the gap between high- and low-talent.

PBL-SWF syntax describes the general pattern of learning activities with characteristics at each learning step that can facilitate the improvement of critical thinking skills and communication skills in learning activities. The PBL-SWF syntax developed elaborates the syntax of the PBL model and includes SWF activities at each stage applied to science learning. The learning process at each stage of PBL-SWF can train critical thinking skills (CTS) and communication skills (CS).

D. 21st Century Skills

21st century skills are gaining importance in global education due to the transition of economies and industries toward the information and innovation age, the need for new job skills, and efforts to bridge the gap between high- and low-talent learners [29; 30]. The concept originated in the United States and has been adopted by countries like Singapore, Hong Kong, and Australia. 21st century skills encompass critical thinking, creativity, communication, collaboration, technological literacy, contextual learning, and information and media literacy [31; 32].

In Indonesia, the development of 21st century skills is emphasized in Curriculum National, focusing on competencies like critical thinking, collaboration, communication, and problem-solving. The Education Process Standards also underline the importance of the scientific approach, integrated learning, and the utilization of technology to improve learning efficiency. These principles aim to build competency-based skills and respect individual diversity and cultural backgrounds in the context of learner-centered learning.

E. Critical Thinking Skills

Critical thinking involves actively and skillfully conceptualizing, applying, analyzing, synthesizing, and evaluating information from various sources [33]. It is essential in problem solving and is applied at all levels of education and disciplines [35; 36]. Ennis [34], identifies critical thinking skills in five main indicators, including analysis of arguments, assessment of source credibility, and assessment of decision value. In the context of science learning, critical thinking skills are expanded to include identification of questions, analysis of reasons, and application of acceptable principles [37; 38]. The importance of critical thinking is not only as an additional skill, but as a key element in preparing students to explore, question and solve problems in an ever-changing world.

F. Communication Skills

The skills to communicate is a crucial skill in the 21st century, defined as the skills to convey ideas or findings effectively, both orally and in writing [39; 40]. Aririguzoh [41] explains that communicating involves a social process that uses symbols to create and interpret meaning in an individual's environment. This includes the skills to organize reports systematically, explain empirical data using graphs or tables, and discuss the results of experiments or research [42; 43]. Aspects of communicating, both written and oral, include eye contact, speaking intonation, content development, argumentation, and writing organization.

MATERIALS AND METHODS

1. Methodology Perspective

This study used a pre-experimental approach and implemented a one-group pretest-posttest design, which involved observing a single group before and after treatment [44]. In this study, students underwent a specific learning intervention. Initially, a pretest was administered to assess their baseline abilities in critical thinking and communication skills. Subsequently, the students received instruction through PBL model using the SWH approach. After the intervention, a posttest was conducted to evaluate the improvements in their critical thinking and communication skills.

2. Population and Sampling of the Study

This study was conducted at the Junior High School in Bandung, West Java, Indonesia, comprising 1 class of 25 eighth-grade students. For analysis, the students in the experimental group were categorized into 3 proficiency levels, namely high, medium, and low. This grouping aimed to observe patterns in critical thinking and communication skills as a result of the implemented learning model.

3. Study Flow

The study flow was presented in stages as displayed in Figure 1.

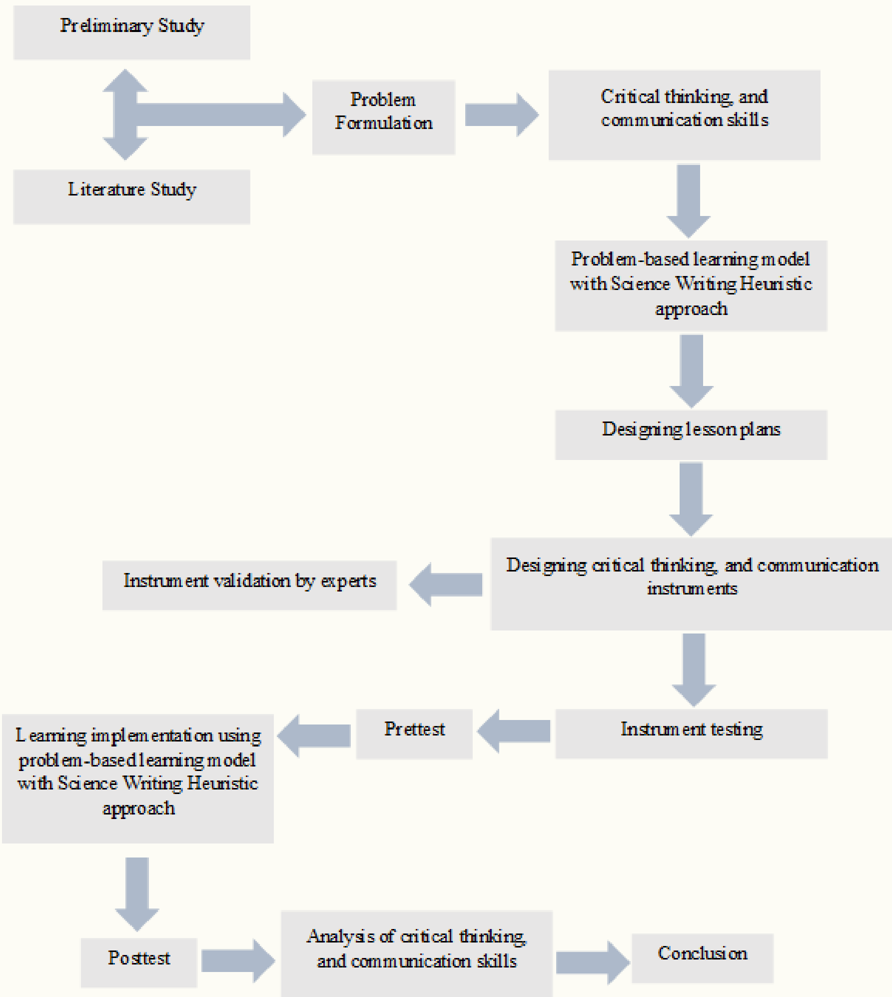

Figure 1 Study flow

Based on Figure 1, the research began with a preliminary study and a literature review to formulate the problem. The focus was then directed toward improving critical thinking and communication skills through a problem-based learning model using the Science Writing Heuristic (SWH) approach. The researcher then designed learning tools and assessment instruments to measure these skills. Experts validated the instruments and underwent pilot testing before use. The next stage involved implementing the learning process, which was accompanied by a pretest and posttest. The results of the pretest and posttest were analyzed to determine the improvement in students' skills, which then served as the basis for concluding the study.

4. Study Tools

The instruments used in this study included observation sheets, critical thinking tests, oral and written communication skills assessment rubrics, and questionnaires. These instruments were detailed in Table 2.

Table 2

Instrument Types	Functions
Observation sheet	To measure the implementation of each stage of learning activities using a problem-based learning model with science writing heuristic approach.
Critical thinking skills test	To measure critical thinking and communication skills as quantitative data
Oral and Written Communication Skills Assessment Rubric	To measure oral and written communication skills
Questionnaire	To capture students' responses to the implementation of a problem-based learning model with a science writing heuristic approach.

5. Data Processing Technique

a. Data Analysis of Critical Thinking Skills Results

The improvement in their critical thinking skills was analyzed using the normalized average gain score formula by Hake [45]. The criteria for interpreting the normalized gain (N-gain) were outlined in Table 3.

Table 3

Criteria for the average normalized gain score

Value <g>	Criteria
$g \geq 0,7$	High
$0,3 \leq g < 0,7$	Medium
$g < 0,3$	Low

b. Data Analysis of Written and Oral Communication Skills

Students' communication skills were assessed through both written and oral components using structured rubrics. Oral communication skills were evaluated during students' individual presentations of their findings, assessed with a rubric adapted from San Diego University and the International Reading Association. Written communication skills were assessed based on students' worksheets during experiments, using a rubric adapted from Salt Lake Community College and the Association of American Colleges and Universities. Both written and oral communication skill assessments covered multiple aspects, each scored on a scale from 1 to 4. The detailed categories and results of the communication skills assessment are presented in Table 4 and Table 5.

Table 4

Score criteria of written and oral communication skills

Total Score		Criteria
Written Communication	Oral Communication	
6 – 9	5 – 8	Very Less
10 – 13	9 – 11	Less
14 – 17	12 – 14	Pretty Good
18 – 21	15 – 17	Good
22 – 24	18 – 20	Very Good

Table 5

Score criteria aspects of written communication and oral skills

Total Score	Criteria
≥ 1	Very Low (VL)
1 < Score ≤ 2	Low (L)
2 < Score ≤ 3	Medium (M)
3 < Score ≤ 4	High (H)

d. Data Analysis of Questionnaire Results

A questionnaire was designed to align with the primary objectives and sub-hypotheses of the study. It used a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Criteria were used to interpret the percentage of respondents' responses, as presented in Table 6.

Table 6

Respondent response criteria

Percentage Interval Learning Applicability (LA)	Criteria
R = 0%	No one
0 % < R < 25%	A small portion
25% ≤ R < 50%	Almost half
R = 50%	Half
50% < R < 75%	Most
75% ≤ R< 100%	Almost all
R = 100%	All of it

RESEARCH PROGRAM

PBL-SWF Syntax

Problem-Based Learning Model with the Science Writing Heuristic Approach (PBL-SWF) syntax described the general pattern of learning activities with characteristics at each learning step that could facilitate the improvement of critical thinking and communication skills in learning activities. The PBL-SWF syntax developed elaborated the syntax of the PBL model and included SWF activities at each stage applied to science learning. The learning process at each stage of PBL-SWF trained critical thinking (CTS) and communication skills (CS). PBL-SWF learning stages and activities were shown in Table 7.

Table 7

PBL-SWF Learning Stages and Activities

Stages of PBL-SWF	Learning Activity		Skills Developed	
	Teacher	Student	CTS	CS
Orienting students to the problem (Exploration + Pre-laboratory Activities)	Present images/video of science phenomena and facilities encountered in daily life, explore students' prior knowledge and understanding of the science context by asking questions, present contextual problems, explain learning objectives and benefits of learning science concepts, and design pre-laboratory investigations.	Looking at images/videos of science phenomena and facilities presented, answering questions, expressing initial knowledge, looking at contextual problems presented, listening to explanations about learning objectives and benefits of learning concepts, and looking at pre-laboratory investigation designs.	Make basic clarifications and build basic skills	Oral communication
Organizing students to learn (Participation)	Helping students organize learning tasks related to the problem, dividing groups, providing student worksheets, directing students to: read the student worksheet before the experiment, prepare tools and materials, and follow up on the problem formulation, encourage students to engage in scientific inquiry activities.	Organize problem-related learning tasks, receive student worksheets, read student worksheets carefully before experimental activities, preparing the tools and materials needed, following up on the problem formulation, engaging in scientific investigation activities.	Building basic skills	Oral communication
Guiding individual and group investigations (Participation + Negotiation Phase I, II, III)	Direct students to: conduct experiments and engage in scientific inquiry activities, organize and write down observational data, think about the meaning of the data obtained through journal writing, interpret and analyze data, discuss understanding of data, make conclusions about experimental results, and negotiate understanding of data, make claims in the form of explanations according to data, compare ideas with textbooks to underlie justification in answering problems that arise at the beginning of learning.	Conduct experiments and actively engage in scientific inquiry, organize and write observational data in observation tables, think about the meaning of data, interpret and analyze data, discuss data, make conclusions, negotiate understanding of data, make claims according to data, compare ideas with textbooks to justify answering problems.	Build basic skills, draw conclusions, and make further clarifications	Oral communication and written communication
Developing and presenting work (Negotiation Phase IV)	Direct students to present alternative problem-solving in the form of reports, posters, or models, provide responses, compare findings, and provide suggestions, input, or constructive criticism of other groups' findings.	Communicate understanding of the results of the investigation in the form of reports, posters or models, provide responses, compare findings, and provide suggestions, input, or constructive criticism of other groups' findings.	Build basic skills, draw conclusions, and make further clarifications, build strategies and tactics	Oral communication and written communication
Analyzing and evaluating the problem-solving process (Exploration)	Directing students to reflect on the problem-solving process carried out and reflect on the understanding of the concepts obtained from experiments in the laboratory.	Reflect on the problem-solving process carried out and reflect on the understanding of the concepts obtained from experiments in the laboratory.	Make further clarifications, build strategies and tactics	Oral communication and written communication

RESEARCH RESULTS

a. Demographic Results

Frequency and percentage were computed for the demographic characteristics of the study sample (Table 8). The results revealed that the largest proportion of respondents were female.

Table 8

Demographics statistics

	f	%
Gender		
Male	8	20
Female	17	68
Total	25	100

b. Critical Thinking Skills Improvement

A multiple-choice reasoning test administered before and after the learning sessions assessed the students' critical thinking skills. Data included pretest and posttest scores converted to a 1 to 100 scale, with N-gain scores presented as percentages or within the 0 to 1 range. The improvement in critical thinking skills was evaluated through average N-Gain. Results were outlined in Figure 2.

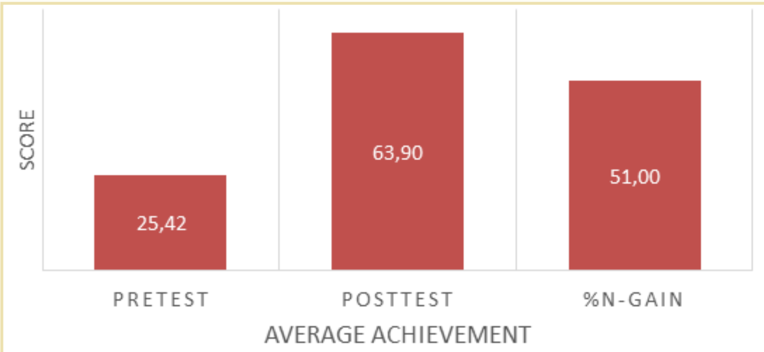

Figure 2 Comparison of Mean Pretest, Posttest, and %N-Gain Scores for Critical Thinking Skills

Based on Figure 2, it was evident that the N-gain score of 0.51 fell into the moderate category. This indicated an improvement in students' critical thinking skills following the implementation of the PBL model using the SWH approach in science education. The average N-gain scores for the indicators of basic skill development, drawing conclusions, making clarifications, making further clarifications, and developing strategies and tactics were categorized as moderate. Mean scores for pretest, posttest, and N-gain for each indicator of students' critical thinking skills were presented in Table 9.

Table 9

Average pretest, posttest, and n-gain scores for each indicator of critical thinking skills

Critical Thinking Indicators	Average Score			Category
	Pretest	Posttest	N-gain	
Makes simple clarifications	24.59	69.84	0.60	Medium
Building basic skills	22.76	63.66	0.53	Medium
Drawing conclusions	25.05	62.85	0.50	Medium
Making advanced clarifications	23.29	60.87	0.49	Medium
Building Strategies and Tactics	31.43	62.30	0.45	Medium

Table 9 outlined moderate improvements across all 5 indicators of critical thinking skills. The indicator "making simple clarifications" achieved the highest N-gain score of 0.60, while "developing strategies and tactics" had the lowest at 0.45. This suggested that implementing PBL with the SWH approach in science education significantly enhanced students' skills in making simple clarifications. The improvement in critical thinking skills was analyzed using N-gain, which indicated an increase of 0.51, categorized as moderate. The PBL model with the SWH approach had been proven to enhance critical thinking skills.

c. Communication Skills Improvement

The improvement in communication skills was assessed according to written entries in student worksheets completed during experimental activities. In this study, communication skills were evaluated using a scoring rubric.

1) Written Communication Skills

The average scores for students' written communication skills for each session were presented in Table 10.

Table 10

Average score of students' written communication per meeting

Meeting Number	Concept	Average Score	Criteria
1	Work	13.40	Less
2	Lever	17.16	Pretty Good
3	Pulley	17.84	Pretty Good
4	Inclined Plane	20.98	Good

Based on Table 10, the ability to communicate in writing using PBL-SWF, which included student worksheets, showed improvement from the first to the fourth meeting. The results of the recapitulation of writtten communication skills for each aspect were presented in Table 11.

Table 11

Recapitulation of written communication skills in each aspect

Written Communication Aspect	Concept, Score, Performance			
	Work	Lever	Pulley	Inclined Plane
Context and Purpose of Writing	2.28 (M)	3.12 (H)	3.20 (H)	3.80 (H)
Content Development	2.12 (M)	2.48 (M)	2.88 (M)	3.40 (H)
Argumentation	2.36 (M)	2.72 (M)	2.92 (M)	2.92 (M)
Strengthening Argumentation	1.98 (L)	2.60 (M)	2.68 (M)	3.04 (H)
Writing Rules	2.48 (M)	3.08 (H)	3.28 (H)	3.92 (H)
Organization	2.12 (M)	3.16 (H)	2.88 (M)	3.88 (H)

According to Table 11, there was an improvement in written communication skills in each aspect from the first to the fourth meeting. The achievement of written communication skills in the aspects of Context and Purpose of Writing, Content Development, Argumentation, Writing Conventions, and Organization increased from Medium (M) on the concept of work to High (H) on the concept of the inclined plane. Meanwhile, the achievement of written communication skills in the aspect of Strengthening Argumentation improved from Low (L) on the concept of work to High (H) on the concept of the inclined plane.

2) Oral Communication Skills

The average scores for students' oral communication skills for each session were presented in Table 12.

Table 12

Average score of students' written communication per meeting

Meeting Number	Concept	Average Score	Criteria
1	Work	11.61	Less
2	Lever	11.68	Less
3	Pulley	12.21	Pretty Good
4	Inclined Plane	14.18	Pretty Good

Based on Table 12, overall, the ability to communicate orally using the PBL-SWF has increased, although it was not optimal. The results of the recapitulation of oral communication skills for each aspect were presented in Table 13.

Table 13

Recapitulation of oral communication skills in each aspect

Oral Communication Aspect	Concept, Score, Performance			
	Work	Lever	Pulley	Inclined Plane
Eye contact	1.65 (L)	1.79 (L)	2.34 (M)	2.41 (M)
Speaking Intonation	2.38 (M)	2.41 (M)	2.44 (M)	2.66 (M)
Content	2.51 (M)	2.45 (M)	2.42 (M)	2.73 (M)
Audience Enthusiasm/Attention	2.47 (M)	2.37 (M)	2.54 (M)	3.02 (H)
Attitude and Body Language	2.59 (M)	2.76 (M)	2.47 (M)	3.36 (H)

Based on Table 13, there was an increase in oral communication skills in each aspect from meeting 1 to 4. This achievement in the aspect of Eye contact experienced an increase in criteria from Low (L) on the concept of effort to Medium (M) on the concept of an inclined plane. The achievement of written communication skills in the aspects of Strengthening Argumentation and Attitude and Body Language experienced an increase in criteria from Medium (M) in the concept of effort to High (H) in the concept of an inclined plane. Meanwhile, the achievement of oral communication skills in the aspects of Speaking Intonation and Content did not experience an increase in criteria.

d. Student Response to Learning

The questionnaire consisted of 4 measurement aspects, elaborated into 20 questions grouped into 4 categories. Student responses were outlined in Table 14 based on the measured aspects.

Table 14 showed an average student response rate of 85.37%, indicating that most students responded positively to the science lessons using the PBL model with the SWH approach. This model was effective in making science learning enjoyable and improving students' critical thinking and communication skills.

e. Classical Assumption Test Results

A normality test was performed to determine whether the pretest and posttest data on critical thinking skills followed a normal distribution. The results of this test were shown in Table 15.

Table 14

Percentage of students' response to learning

No.	Question Indicator	Student Response Percentage (%)
1.	The science learning model applied by the teacher provides a new learning experience and can be applied to other learning materials.	80.35
2.	The learning model applied by the teacher makes students happy and more interested in learning work and simple machine material.	85.54
3.	The learning model applied by the teacher encourages students to be more courageous to ask questions and express ideas.	83.75
4.	The learning model applied by the teacher causes students to easily understand the subject matter, train critical thinking skills and communication skills.	91.68
Average		85.37

Table 15

Results of the Normality Test Conducted Using SPSS

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking	Pretest	.127	25	.200*	.961	25	.441
	Posttest	.135	25	.200*	.946	25	.199
*. This was a lower bound of the true significance.							
a. Lilliefors Significance Correction							

From Table 15 it was evident that all data had a significance value (sig.) greater than the significance level of $\alpha = 0.05$. This indicated that all data were normally distributed. Following the normality test, a homogeneity test was also required to determine when the data were homogeneous. The homogeneity presented in Table 16.

Table 16

Homogeneity Test Results Using IBM SPSS Statistics Test of Homogeneity of Variances

		Levene Statistic	df_1	df_2	Sig.
Variable	Based on Mean	.383	1	48	.539
	Based on Median	.357	1	48	.553
	Based on Median and with adjusted df	.357	1	47.341	.553
	Based on trimmed mean	.378	1	48	.542

According to Table 16, the homogeneity test results indicated that the pretest and posttest data had a significance value of 0.539 in the "based on mean" row. This value was greater than the significance level $\alpha = 0.05$, therefore, it could be concluded that the variances of the pretest and posttest data were homogeneous. The impact of the application PBL model using the SWH approach on students' critical thinking skills was assessed using the paired sample t-test. The results of the t-test were presented in Table 17.

Based on Table 17, the significance value was less than 0.001, which was below the threshold of 0.05. This indicated that Ha was accepted, while H0 was rejected, showing that the application PBL model using the SWH approach in learning had a significant effect on students' critical thinking.

Table 17

Paired Sample T-test Using IBM SPSS Statistics Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Critical Thinking	Pretest-Posttest	-204.20000	281.79736	56.35947	-320.52023	-87.87977	-3.623	24	.001

DISCUSSION

a. Improved Critical Thinking Skills

The improvement in students’ critical thinking skills was analyzed using the N-gain formula, which resulted in a value of 0.51. This score falls into the moderate category, indicating a meaningful enhancement in students’ ability to think critically. The implementation of the Problem-Based Learning (PBL) model combined with the Science Writing Heuristic (SWH) approach was effective in fostering critical thinking development. This approach engaged students in a structured inquiry process, encouraging them to ask questions, analyze data, construct scientific explanations, and reflect on their learning experiences.

Previous studies have also confirmed that PBL significantly enhances students' critical thinking skills. Research conducted by [48] as well as [49] demonstrated that students exposed to PBL exhibited greater improvements in their ability to evaluate problems, analyze information critically, and formulate logical conclusions. These findings align with the results of this study, reinforcing the notion that inquiry-based and student-centered learning models are effective in promoting higher-order thinking skills.

Critical thinking is a crucial skill in science education, as it enables students to engage in systematic problem-solving and make informed decisions based on logical reasoning. According to [50] and [51], critical thinking plays a vital role in evaluating information from multiple perspectives, identifying biases, and constructing well-reasoned arguments. These skills are particularly essential in the 21st century, where students must navigate complex problems and rapidly changing information landscapes.

In this study, the five critical thinking indicators proposed by [52] were used to assess students' progress. These indicators include (1) making simple clarifications, (2) analyzing arguments, (3) drawing conclusions, (4) evaluating credibility, and (5) developing further explanations. Among these indicators, the most significant improvement was observed in students’ ability to make simple clarifications. This suggests that students became more adept at articulating scientific concepts, defining key terms, and explaining their reasoning clearly. Such improvements are essential, as the ability to clarify and communicate ideas effectively forms the foundation for more advanced critical thinking processes.

Overall, these findings highlight the effectiveness of integrating PBL with the SWH approach in developing students’ critical thinking abilities. By engaging students in inquiry-driven learning, promoting active discussion, and encouraging evidence-based reasoning, this approach equips students with essential skills needed for scientific exploration and lifelong learning.

b. Improved Communication Skills

1) Written Communication Skills

Written communication skills improved with the use of the PBL model and SWH approach, assisted by student worksheets. This showed the effectiveness of the student worksheet in articulating their ideas. This finding was consistent with [53], who found that the worksheets could enhance students' communication abilities. Using worksheets as a tool to articulate their ideas during experimental activities significantly helped in improving their written communication skills.

The achievement of written communication skills showed a significant improvement from the first to the fourth meeting. The aspect of Context and Purpose of Writing increased from a score of 2.28 (M) in the first meeting to 3.80 (H) in the fourth meeting, suggesting that students became better at understanding and conveying the context and purpose of their writing. Content Development showed an increase from 2.12 (M) in the first meeting to 3.40 (H) in the fourth meeting, reflecting the ability of the students to develop their writing content in-depth. Although the Argumentation aspect increased from 2.36 (M) to 2.92 (M), its improvement was slower compared to other aspects, showing that the ability to construct arguments still needed enhancement. Furthermore, the aspect of Strengthening Argumentation displayed a significant increase from 1.98 (L) in the first meeting to 3.04 (H) in the fourth meeting, demonstrating an improvement in students' ability to support their arguments with stronger evidence. The aspect of Writing Conventions consistently increased from 2.48 (M) to 3.92 (H), reflecting better adherence to writing rules. Finally, the aspect of Organization increased from 2.12 (M) to 3.88 (H), although there was a slight decline in the third meeting, indicating that students became better at structuring their writing clearly and logically.

The written communication skills in all aspects improved from Medium (M) on the concept of work to High (H) on the concept of the inclined plane, with the Strengthening Argumentation aspect showing an increase from Low (L) to High (H). This improvement indicated that student worksheets had a positive impact on improving students' written communication skills [33; 34]. With structured and guided worksheets, students could easily understand and develop each aspect of their writing skills, from understanding the context as well as the purpose of writing, developing content, constructing arguments, and adhering to writing conventions to organize their writing effectively [54].

2) Oral Communication Skills

The results of oral communication skills using the PBL-SWF approach indicated a significant improvement from the initial to the final sessions. Aspects such as eye contact, speaking intonation, and content maintained consistent criteria throughout the observation period, although no remarkable score increase was shown. In addition, the ability to generate enthusiasm and audience attention, as well as the use of a supportive attitude and body language, experienced a significant rise from medium criteria initially to high criteria at the end of the observation period.

It was important to note that despite these improvements, the results were not yet optimal. While aspects such as eye contact, speaking intonation, and content showed consistency in their criteria throughout the observation period, no significant score increase was exhibited. Meanwhile, the abilities to generate enthusiasm and capture audience attention, as well as the use of a supportive attitude and body language, displayed a notable rise from medium to high criteria by the end of the observation period.

It was evident that certain aspects still required further refinement to meet the desired standards in oral communication. For instance, enhancing the clarity and relevance of content delivery, refining the consistency of eye contact, and ensuring effective modulation of speaking intonation were areas that could benefit from continued focus and development [55; 56]. These adjustments were crucial in optimizing the effectiveness of the PBL-SWF approach in improving oral communication skills.

c. Student Response to Learning

Students' responses to PBL with the SWH approach on simple machine material indicated generally positive attitudes and engagement. They expressed satisfaction with the learning process and reported that it helped them understand science concepts more effectively compared to traditional teaching methods. The integration of problem-based learning (PBL) and the Science Writing Heuristic (SWH) approach encouraged students to actively participate in scientific investigations, ask questions, and construct explanations based on evidence.

Additionally, this learning approach provided opportunities for students to develop critical thinking and communication skills. Through collaborative problem-solving, discussions, and written reflections, students were able to articulate their reasoning, analyze different perspectives, and improve their ability to communicate scientific ideas clearly. These aspects are crucial in fostering scientific literacy and preparing students for real-world problem-solving situations [57].

From a psychological perspective, students who found the learning process enjoyable were more motivated and engaged. A positive emotional response, such as liking the learning experience, contributed to increased intrinsic motivation, making it easier for teachers to achieve learning objectives. When students feel a sense of enjoyment and relevance in their learning, they tend to demonstrate greater persistence, curiosity, and willingness to explore scientific concepts beyond the classroom. This highlights the importance of designing engaging and student-centered learning experiences that align with their interests and cognitive needs.

Thus, implementing PBL with the SWH approach not only enhances conceptual understanding but also nurtures essential skills such as critical thinking, problem-solving, and effective communication. These findings suggest that incorporating inquiry-based strategies into science education can significantly improve both student learning outcomes and their overall learning experience.

CONCLUSION

In conclusion, the implementation of a problem-based learning model with SWH approach on the topic of work and simple machines significantly impacted science education in Junior High Schools. Students' critical thinking skills improved to a moderate level, while, communication skills progressed from poor to good. Positive student responses indicated the method's broad applicability. Similar studies had also highlighted the benefits of PBL in enhancing critical thinking and communication skills. However, this study uniquely integrated the SHW approach, demonstrating its added value in conceptual mastery compared to traditional PBL methods. Theoretically, the study suggested that this integrated approach could effectively enhance critical thinking and communication skills in science learning. Teachers were encouraged to adopt this approach in enriching science teaching. This study introduced a novel integration of the SWH approach with PBL model, providing empirical evidence of its effectiveness in improving critical thinking, and communication skills, among junior high school students, therefore offering a new perspective in science education methodologies. Despite the potential, the study's limitations included a relatively small sample size and the focus on a single topic (work and simple machines), which could limit the generalizability of the findings. Longitudinal studies were also recommended to assess the long-term impacts of the problem-based learning model with the SWH approach. Furthermore, enhancing teacher training programs to equip educators with the skills needed to effectively implement this method was crucial to maximize its benefits in science education.

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Authors

Muslim Muslim
(Indonesia, Bandung)
Associate Professor, Department of Physics Education
Universitas Pendidikan Indonesia
E-mail: muslim@upi.edu (Corresponding Author)
ORCID ID: 0009-0006-2395-8408

Rizky Agassy Sihombing
(Taiwan, Taipei)
M.S in Graduate Institute of Science Education,
College of Science
National Taiwan Normal University
E-mail: rizkyagassy@upi.edu
ORCID ID: 0000-0002-7167-2862

Binar Kurnia Prahani
(Indonesia, Surabaya)
Associate Professor, Department of Physics Education
Universitas Negeri Surabaya
E-mail: binarprahani@unesa.ac.id
ORCID ID: 0000-0002-5606-6629

Achmad Samsudin
(Indonesia, Bandung)
Associate Professor, Department of Physics Education
Universitas Pendidikan Indonesia
E-mail: achmadsamsudin@upi.edu
ORCID ID: 0000-0003-3564-6031

Author's contribution

Muslim Muslim: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition
Rizky Agassy Sihombing: Conceptualization, Methodology, Software, Investigation, Writing - Original Draft, Writing - Review & Editing
Binar Kurnia Prahani: Software, Formal analysis, Writing - Original Draft, Writing - Review & Editing
Achmad Samsudin: Formal analysis, Writing - Original Draft, Writing - Review & Editing

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