

The Effectiveness of Problem-Based Learning in Improving Students Scientific Literacy Skills and Scientific Attitudes

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Abstract: Scientific literacy skill is a key factor for overcoming real-life problems, but scientific literacy learning in schools has not been well trained. Therefore, the purpose of this study is to analyze the effectiveness of Problem Based Learning (PBL) in improving students scientific literacy skills and scientific attitudes. This research was part of research and development, with the Dick & Carey model. The research trial used one group pre-test and post-test design on 29 students of XI IPA 1 class in SMAN 5 Banjarmasin. The instruments of data collection were a scientific literacy test and scientific attitude questionnaires. Data were analyzed by the n-gain equation. The results showed that the n-gain score of students scientific literacy and scientific attitudes were 0.55 and 0.57; it means the increase was in moderate criteria. Therefore, PBL is effective to improve students scientific literacy skills and scientific attitudes.

Keyword: Scientific attitudes, scientific literacy skills, problem-based learning

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INTRODUCTION

Literacy development in learning physics plays an important role in innovation and technology (Insani & Sunarti, 2018; Sutarto, Indrawati, Concerned, & Dwi, 2018). Physics concepts understanding will be useful to students lives as adults in the era of industrial revolution 4.0, in line with scientific literacy which is the focus of attention for international student assessment (PISA) programs (Tsai, 2015; Pramuda, Mundilarto, Kuswanto, & Hadiati, 2019). Scientific literacy is the ability to use scientific knowledge to explain scientific phenomena, understand

and design scientific inquiry, interpret data and provide scientific evidence (OECD, 2013; 2016). Scientific literacy as a media link between science, technology, and society (Insani & Sunarti, 2018; Ratini, Muchtar, Suparman, Tamuri, & Susanto, 2018). Students are trained with creative thinking, flexible, and adaptive to various increasingly complex and diverse problems (Dewi & Sunarti, 2018; Ratini et al., 2018).

In the era of industrial revolution 4.0, scientific literacy is getting major attention for education in various parts of the world, including in Indonesia (Sunarti, Wasis, Madlazim, Suyidno, & Prahani, 2018; OECD, 2016). Literature is not only limited to science; but also as a scientific inquiry

process, making decisions and solving real-problems (Narut & Supradi, 2019; Shellawati & Sunarti, 2018). However, literacy learning is completed during the teaching and learning process of students attitudes in searching and finding scientific knowledge. Scientific attitude is a disposition of thought which is an integrated research trend in learning thinking such as critical, creative, making decisions and solving real-problems (Hunaepi, 2016). Two reasons why scientific literacy important for students are: (1) meeting the needs of personal needs and excitement; and (2) countries in the world need scientific information and scientific thinking to make decisions and the interests of many people need to be informed such as forest fires, air control, etc. (Zuriyani, 2011).

In fact, the results of the PISA analysis from 2006 to 2015 show that the students scientific literacy skills in Indonesia is still low which is below the international score (OECD, 2006; OECD, 2009; OECD, 2013; Dewi, Khery, & Erna, 2019; Ratini et al., 2018; Shellawati & Sunarti, 2018; Utomo, Narulita, Yuana, Fikri, & Wahono, 2018). At this level, Indonesian students are generally judged to only be able to remember scientific facts, principles, laws, and draw simple conclusions (Lailly & Wisudawati, 2015). This is reinforced by the results of the initial study of researchers at one of the high schools in Banjarmasin that 3% of students have enough criteria of scientific literacy skills; 55% are in poor criteria, and 42% are not good criteria. The low level of scientific literacy abilities of students is influenced by the implementation of learning (Nurhairani, Fahrur Rozi, Septian Prawijaya, 2019). It's relate with the results of interviews with physics teachers at the school obtained information that scientific literacy has not become a culture in the schools. The teacher often applies direct teaching in class, where the teacher explains the material in front of the class either by writing on the board or lecturing. So far, there are no teaching

materials specifically designed to practice scientific literacy and scientific attitudes, so they rarely carry out a scientific inquiry, make decisions and solve problems.

An effort to improve students scientific literacy skills and scientific attitudes is the implementation of Problem-Based Learning (PBL). PBL is a learning design that presents authentic and meaningful problems for students to be scientific in carrying out scientific inquiry, decision making and problem-solving (Arends, 2012; Fauziah, Hakim, & Andayani, 2019). This is confirmed by the results of Setiani, Ngazizah, & Kurniawan (2016) that PBL can increase the ability of scientific literacy in the experimental class compared to Cooperative Learning, although the research has not focused on the scientific attitudes of students. Besides, Azmi, Rahayu, & Hikmawati (2016) found a positive correlation between scientific attitudes and student learning outcomes in PBL based on experiments.

Based on the description above, the main objective of this study is to analyze the effectiveness of PBL in improving scientific literacy skills and scientific attitudes of students. The strengths of this study are the conditional PBL design in schools (Table 1); where each lesson plan at the initial meeting focused on individual and group investigations, then continued to develop and present the work at meeting 2.

METHOD

This research is part of Research and Development (R&D) using the Dick & Carey model which is emphasized at the formative evaluation stage. In this research; the independent variable is the PBL tool, while the dependent variable is the students scientific literacy skills and scientific attitude.

Before class trials; the researcher has developed a PBL tool and conducted validation tests on three physics learning experts in order to obtain validity and reliability values for lesson plan (3.28; 0.92); teaching material (3.34; 0.98);

worksheet (3.41; 0.98); and assessment sheets (3.29; 0.92); its means package PBL that have been developed including valid and reliable as a support package to practice the scientific literacy skills and students scientific attitudes, and those instruments are ready to be tested in real classrooms.

The research trial design using one group pre-test and post-test design: O1 X O2 on 29 students of class XI IPA 1 at SMA Negeri 5 Banjarmasin consisting of 8 men and 21 women. The research trials began with a pre-test (O1); where students are initially asked to take a scientific literacy test and then fill in the questionnaire responses. Furthermore, 2 lesson plan-PBL (X) were applied for 4 meetings as presented in Table 1.

Table 1 PBL Activity

Phase	Meeting			
	LP 1		LP 2	
	1	2	3	4
Orient students on the problem	x	x	x	X
Organizing students to learn	x	x	x	X
Help group and independent investigations	x	-	x	-
Develop and present the work	-	x	-	X

Analyze and evaluate the problem-solving process	x	x	x	x
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Note: LP = Lesson Plan, x = activity class; - = non-activity class

Based on Table 1; PBL in Lesson Plan 1 is designed for meetings 1 and 2. At meeting 1, the teacher starts with problem orientation and organizes students, guides independent and group investigations then ends the analysis and evaluation of the problem-solving process. This meeting 2 is a continuation of meeting 1. The teacher recalls the orientation of the problem and the previous group, then guides students to present their work at meeting 1, then ends with an analysis and evaluation of the problem-solving process. PBL in Lesson Plan 2 is also designed as Lesson Plan 1; the independent and group investigations carried out at meeting 3, then proceed to develop and present the work at meeting 4.

The research trial was ended by asking students to do a post-test (O2), which is to re-do the Scientific Literacy Test and fill in the Scientific Attitude Questionnaire. Data on the results of scientific literacy tests are adjusted to the criteria in Table 2.

Table 2 Rubric assessments of scientific literacy skills

Scientific Literacy indicator	Assessment Rubric	Point
1. Identify scientific questions	The first choice is correct	0-2
	The second choice is correct	0-2
	The third choice is correct	0-2
2. Explain the phenomenon	Write down concepts that apply to phenomena	0-2
	Explain concepts on phenomena	0-3
	Explain the relationship between concepts and phenomena	0-3
3. Identify research variables	Manipulation variables matches the answer key	0-2
	Response variable matches the answer key	0-2
	Control variable matches the answer key	0-2
4. Obtain/evaluate conclusions based on evidence	Expressed in statement form.	0-2
	Made based on data observation/data analysis	0-2
	It is written briefly and clearly	0-2
5. Applying scientific conclusions in everyday life	Explain the function of tools/phenomena that occur	0-3
	Explain the concepts used	0-3
	Explain the relevance of the concept to the tool/phenomenon described	0-3
6. Identifying scientific issues that underlie decision making	Advise without mentioning strengths	0-2
	Advise by explaining the advantages of the first	0-2
	Advise by explaining the advantages of the second	0-2
	Advise by explaining the third advantage	0-2

7. Using mathematics in science	Write down the known variable	0-1
	Write down the variable in question	0-1
	Write down the steps to solve the problem	0-3

(Sunarti, Wasis, Madlazim, Suyidno, & Prahani, 2018)

Scientific attitude has emphasized the behavior of students like a scientist in seeking and finding knowledge. This emphasizes indicators of curiosity, critical thinking, respect for data/facts, perseverance, and cooperation. Scientific attitude data are assessed on a Likert scale as presented in Table 3.

Table 3 Rubric assessments of scientific attitudes

Statement	A	O	S	N
Positive	4	3	2	1
Negative	1	2	3	4

Note: A = always, O = often, S = sometimes, N = never

The score of scientific literacy/scientific attitude is the number of points obtained divided by total points multiplied by 100. The value is adjusted according to the criteria in Table 4 below.

Table 4 Criteria of scientific literacy and scientific attitude

Score	Criteria
$100 \geq X > 80$	Very good
$80 \geq X > 65$	Good
$65 \geq X > 55$	Enough
$55 \geq X > 40$	Poor
$X \leq 40$	Not good

Furthermore, to determine the level of improvement in scientific literacy skills and scientific attitudes, then

Table 6 Pre-test and post-test scores of students scientific literacy skills

Indicator	Pre-test		Post-test	
	Score	Criteria	Score	Criteria
1. Identify scientific questions	48.27	P	62.06	E
2. Explain the phenomenon	8.62	NG	48.70	P
3. Identify research variables	54.74	P	85.05	VG
4. Obtain / evaluate conclusions based on evidence	32.18	NG	74.71	G
5. Applying scientific conclusions in everyday life	35.24	NG	49.42	P
6. Identifying scientific issues that underlie decision making	90.51	VG	97.41	VG
7. Using mathematics in science	48.5	P	54.98	P

analyzed with the n-gain equation. The n-gain value is adjusted according to the criteria Table 5 below.

Table 5 n-gain criteria

Score	Criteria
$\langle g \rangle \geq 0.7$	Height
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

(Hake & Richard, 1999)

RESULTS AND DISCUSSION

The effectiveness of PBL illustrates the level of achievement of students scientific literacy abilities and scientific attitudes which will be described below.

Scientific Literacy Skills

The results of the pre-test and post-test scientific literacy before the n-gain test were tested for normality. The results of the normality test obtained a significance value of 0.06 for pre-test and 0.54 for post-test; means the pre-test and post-test scores of scientific literacy of students are normally distributed because the results obtained are more than $\alpha = 0.05$ for the significance level of assessment in education. Furthermore, the results of the calculation of scientific literacy are presented in Table 6 below.

Note: NG = Not Good, P = Poor, E = Enough, G = Good, VG = Very Good

Based on Table 6, the scientific literacy skill of students at the first was still low because only 1 indicator of scientific literacy was in very good criteria, while 6 other indicators are not good criteria. The cause is the unavailability of package scientific literacy that can practice science literacy. Students are rarely trained in experimental learning so that the experimenting skills they have are very minimal. This learning facilitates students to be actively involved in constructing their scientific literacy and searching for the truth of scientific content. Experimental-based learning helps students develop their intellectual abilities (Puryadi, Sahono, & Turdjai, 2017).

The indicators that get the lowest scores are explaining natural phenomena, evaluating conclusions based on evidence, and applying scientific conclusions in everyday life include unfavorable criteria. This is in line with some of the results of previous studies that students are only able to remember scientific knowledge (scientific facts, principles, laws) and draw simple conclusions, let alone apply them in real life (Dewi et al., 2019; Ratini et al., 2018; Utomo et al., 2018). Students only provide simple scientific explanations and follow explicit evidence (Angraini, 2014). The highest value is to identify scientific issues that underlie decision making with very good criteria. Means, students dare to decide to deal with a case. Also, students consider the good and the bad of each decision they make.

Conversely, after PBL was applied, the indicators of students scientific literacy skills have increased. The teacher was able to facilitate students in understanding current science issues and identifying problems (phase 1); scientific literacy learning needs (phase 2); scientific inquiry, problem-solving, and decision making related to science issues (phase 3); presenting the work (phase 4); and evaluating the results and processes of scientific literacy (phase 5). Thus, PBL can be used to improve the ability of scientific literacy.

After applying PBL for 4 meetings; although the students skills in explaining natural phenomena, applying scientific conclusions in life and mathematics in science have increased; but still in poor criteria. Limitations of research time and the lack of early literacy provisions of students, making efforts to practice scientific literacy requires a long time from the lesson plan. Also, some students are less focused and pay attention to the activity of reading information. Teachers should be able to manage a conducive learning environment, especially practical learning, master the methods of teaching true practice because practical learning has its characteristics that cannot be equated with mere theory learning (Sutrisno, 2016). Students are expected to be more skilled in experimental activities and obtain theoretical knowledge through reading teaching material activities. However, there is an increase in the mean value from pre-test to post-test of students scientific literacy skill as presented in Table 7.

Table 7 N-gain of students scientific literacy skills

Σ Pre-test	Σ Post-test	N-gain	
		<g>	Criteria
40.32	66.12	0.55	Medium

Table 7 shows PBL can increase the mean value from pre-test to post-test

respectively by 40.32 and 66.12. This is reinforced by the n-gain test results of

0.55; means the level of improvement of students scientific literacy skills is in the criteria of being. In line with Fauziah et al. (2019); Student activities in PBL are deliberately designed to train scientific attitudes through scientific inquiry, decision making and problem-solving so that they have a positive impact on students scientific literacy skills. Problem-based learning is closely related to the real-life reality of students, so students learn not only in the area of knowledge but also experience and feel (Nurhairani, Rozi, Prawijaya, 2019). This is following cognitive theory (Sutarto, 2017) that the involvement of

mental activities in students as a result of the process of active interaction with others and the environment to obtain changes knowledge, understanding, behavior, skills, and scientific attitudes that are relative.

Scientific attitude

Scientific attitudes describe the students behavior like scientists such as curiosity, critical thinking, respect for data/facts, have perseverance, and work together in constructing scientific literacy. The results of students scientific attitude analysis are presented in Table 8.

Table 8 Students pre-test and post-test scores on scientific attitudes

Aspect	Pre-test		Post-test	
	Score	Criteria	Score	Criteria
1. Want to know	65.0	Enough	81.3	Very Good
2. Critical thinking	65.0	Enough	80.0	Very Good
3. Respect for data/facts	61.0	Enough	75.8	Good
4. Perseverance	67.0	Good	80.5	Very Good
5. Cooperation	72.5	Good	84.8	Very Good

Based on Table 8, the students scientific attitude at first in the criteria is enough, except for the indicators of cooperation and perseverance in good criteria. Good collaboration has been seen since the first meeting of learning, shown by the activeness of all members in each group in conducting experiments. Then, their attitude in trying to understand and operate Phet media as a virtual laboratory shows that they had a good perseverance since the beginning of learning. But in some case, when students already have the stock of knowledge and understanding in being scientific well, they lack the awareness

to apply scientific attitudes in life situations well. Learning should be done with interactive processes that are objective and appropriate to the context of the real-life (Hunaepi, 2016). Also, external factors that influence scientific attitudes are the ability of teachers to choose learning strategies that will be used in learning activities (Puryadi et al., 2017). After applying PBL, all indicators of scientific attitude are in good criteria. It means; PBL can involve students scientific attitudes in exploring and discovering physics material properly. This is reinforced by the n-gain value as presented in Table 9.

Table 9 N-gain of students scientific attitudes

Σ Pre-test	Σ Post-test	N-gain	
		$\langle g \rangle$	Category
66.51	80.73	0.57	Medium

Table 9 shows PBL able to increase the average value from pre-test to post-test scientific attitudes respectively by

66.51 and 80.73. Students who initially understand scientific attitudes are limited to knowledge, the application of

PBL can inspire students to apply scientific attitudes in supporting the success of the learning process. This is reinforced by the n-gain test result of 0.57 which means there is an increase in scientific attitude in the medium criteria. PBL has been proven effective in improving students scientific attitudes within the criteria of being. This is following the theory of complex cognitive processes which states that the main characteristics of creative individuals are the mastery of scientific knowledge and science process skills (Moreno, 2010). In line with Saadi, Halidjah, & Kartono (2013); the learning process is said to be effective if statistically the aspects studied show a significant difference between students understanding before and after learning (significant gain). Teachers in practicing students scientific attitudes are not sufficiently taught in the form of knowledge alone, but they need to be involved in situations and conditions in which they actualize their scientific attitudes in learning activities (Arifuddin, Suyidno, Nur, & Yuanita, 2018). At the end, a very short process will not be enough to shape the character of scientific attitudes to the personal self of students, cause the formation of scientific attitudes takes quite a long time and the process of self-habitation must be repeated and continuously (Arini, Hartono & Khumaedi, 2019).

Based on Tables 6 and 8, PBL models can improve students scientific literacy skills and scientific attitudes within enough criteria. Through PBL, students are accustomed to being scientific in constructing their scientific literacy skills. PBL contributes to students development, especially to build an effective collaborative knowledge, helping students to make explicit the relationship between attitudes towards collaboration & achieving learning outcomes, identifying

specific collaborative ability needed by students, and obtained through the results of group collaboration (Tan, Molen, & Schmidt, 2015; Siagian, Saragih, & Sinaga, 2019). This is inseparable from the success of the teacher's role in each PBL phase.

In phase 1, the teacher conditions students to learn to remember previous lessons and presents the motivation for students to mention as many scientific questions as possible, then conveys learning objectives and reminds students about the importance of practicing scientific attitudes during the teaching-learning process. The starting motivation is realistic and helps students learn to contextualize problems within a scenario (Kim, 2019). In Phase 2; teachers can present the needs of students in conducting experiments in a clear and coordinated manner so that they can recognize the tools and materials and research variables as well as possible. This is following the theory of reciprocity that the learning environment greatly influences and encourages students to convey their creative ideas (Moreno, 2010).

Phase 3 is the core PBL phase, the teacher can guide students to scientific inquiry independently by referring to worksheet based scientific literacy. PBL worksheet that are developed of course can be used as a guide for students in working on questions that are tailored to the steps contained in experiment activities (Puspasari & Puspasari, 2019). Also, teachers ensure the readiness of initial skills in experimenting so that students are actively involved able to participate in activities in this phase. Teachers included visibly more student interactive activities through team work, however, they revealed various ways of defining roles of learners and teachers in the PBL process and communicating with students (Al-Said, Du, Al-Khatib, Romanowski & Barham, 2019). Students with high initial skills in the

learning process are more active than those who have low initial skill, it is caused by their understanding of a better concept (Hasrida, 2017). Students are actively involved in planning and implementing scientific inquiry, making decisions, and solving real-life problems. These skills are very useful to train the ability to use thoughts, reason, and actions efficiently and effectively to achieve a certain result (Solihah, Purwoko, & Gunawan, 2018).

Furthermore, in Phase 4 students are allowed to present their performance results in front of the class and discuss physics material that is not yet understood guided by worksheet based on scientific literacy. Worksheet facilitates teachers in integrating information, exercises, and students feedback (Asmirani, Putra, & Asrizal, 2013). Also, in this phase students can connect physics with technology, society, and the environment. This is supported by complex cognitive theories (Moreno, 2010) that experiences involving creativity and imagination can increase intrinsic motivation. Furthermore, in phase 5 the teacher can facilitate the evaluation of the results of scientific literacy and reflection of scientific attitudes during the learning process properly. Students can be involved in assessing the process and learning outcomes, learning from the process, and applying what is learned to improve future actions (Moreno, 2010). Thus, the teacher can condition a learning atmosphere that is conducive to habituating students scientific attitudes and developing scientific literacy skills.

CONCLUSION

The application of PBL in physics subjects in high schools is effective in increasing students' scientific literacy and scientific attitudes in the moderate criteria. Students are accustomed to being scientific students in the success of scientific inquiry, make decisions and

solve real-life problems. The fundamental implication of this research is that PBL can be applied in education to practice the students scientific literacy skills and scientific attitudes. However, limitation of research time and the lack of students initial understanding of physics material and PBL have an impact on the lack of students scientific literacy and scientific attitudes. In further research, teachers are expected to be able to train students in PBL, so that learning activities are more effective and efficient to improve students scientific literacy and scientific attitudes.

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