International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 5, October 2024, pp. 3139~3150
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i5.29835

Online problem-based learning and 3D digital books to improve pre-service teachers' scientific literacy

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Article Info

Article history:

Received Jan 2, 2024
Revised Feb 12, 2024
Accepted Mar 11, 2024

Keywords:

3D animations
Digital book
Optical subject
Pre-service teachers
Problem-based learning
Scientific literacy

ABSTRACT

Scientific literacy skill is needed by pre-service physics teachers (PSPTs) since it involves mastering thinking and using scientific thinking in recognizing and addressing social issues. However, low scientific literacy for PSPTs is a problem that needs to be solved, resulting in effectively teaching science to their students. Therefore, to increase the scientific literacy of PSPTs, this study aims to develop an online problem-based learning assisted with digital books with 3D animation (OPBLA3DB). This study employs a quasi-experimental design for educational research with subject 72 PSPTs in one university in Indonesia. The data were collected using written tests, questionnaires, observation sheets, and validity sheets. The findings of this study demonstrate how highly valid and reliable the research tools developed are. The implementation results also show how practical learning is. This teaching model can improve PSPTs' scientific literacy effectively, along with obtaining positive responses from them. This study implies that the OPBLA3DB model can be widely applied to enhance scientific literacy.

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1. INTRODUCTION

The main objective of physics education around the world is the growth of scientific literacy [1]–[3]. The ability to apply scientific knowledge to evaluate and design scientific investigations, interpret data, and provide scientific evidence is known as scientific literacy [4]. A literate science, particularly physics, is a person who uses physics concepts, process skills, and values in making everyday decisions [5]. Without scientific literacy, a person will find it difficult to solve problems related to education, science, and social hardships encountered daily. Unfortunately, the scientific literacy ability of students in Indonesia is still relatively low. Based on data from the 2018 Programme for International Student Assessment (PISA) in scientific literacy, Indonesia has a score of 396 out of an average of 489; hence, it ranks 71 out of 81 participating countries [6]. Physics belongs to one of the subjects evaluated on scientific literacy [7]. Some empirical studies have found that students' scientific literacy abilities, even pre-service physics teachers (PSPT), are still low criteria and unsatisfactory [8]–[10]. This problem needs to be resolved immediately because if the PSPT as a teacher has low scientific literacy skills, it will affect the science ability of the students taught.

Many factors influence scientific literacy, including learning models and teaching materials [11]. The learning characteristics that can improve scientific literacy are student-centered, authentic commonality, designing scientific investigations; and directing students to interpret scientific evidence [12]. The learning model that meets these criteria is problem-based learning (PBL) because the learning process begins with problems that the teacher can raise, then students deepen their knowledge of what they know and need to know to solve the problem [13], [14]. In the process of solving problems, students can carry out scientific research activities, collect data, and interpret the data to affect aspects of students' scientific literacy competencies positively. Previous research [15], [16] shows that PBL models can effectively improve students' scientific literacy skills. However, as e-learning advanced during the coronavirus disease 2019 (COVID-19) pandemic, the learning process moved online, and this model eventually came to be known as online problem-based learning (OPBL) [17]. The only significant distinction between OPBL and conventional PBL is how media and technology are used during the learning process [18].

Digital books, which also include textbooks that affect scientific literacy, are one of the technologies that can support the implementation of OPBL [19]. The availability of digital books is a result of technological advancements that have permeated the educational field. Digital books have several benefits, such as greater practicality, simplicity, durability, portability, ease of duplication, ease of distribution, and environmental friendliness [20], [21]. Digital books can also be integrated into several visual components, such as 3D animation [22]. The 3D animation will aid students in visualizing and comprehending abstract concepts [23], such as optics. Optical materials, both physical and geometric, require abstract thinking skills that make it difficult for students to understand them [24]. This will certainly be a barrier for students in improving scientific literacy. Thus, an OPBL model assisted by a digital book with 3D animation is needed to strengthen PSPT scientific literacy in optical materials.

While Prahani *et al*. [17] used an OPBL model aided by a digital book with 3D animations in previous research to improve problem-solving skills in magnetic field topics, the study also recommended using an OPBL model with a digital book featuring 3D animations for other physics topics. Other previous studies have utilized 3D visualization-based learning technology in augmented or virtual reality [25]–[28]. However, no research has been conducted to improve scientific literacy in optical subjects using the OPBL model aided by a digital book featuring 3D animations. Therefore, this study presents an OPBL model supported by a digital book featuring three-dimensional animations (OPBLA3DB). According to Nieveen [29], prototyping to reach educational product quality, this research objectives describe the validity, practicality, and effectiveness of the OPBL model. This research is expected to help improve the scientific literacy of PSPT as a prospective teacher who can teach it to students.

2. RESEARCH METHOD

2.1. Research design

This research design is educational design research with a quasi-experimental type [30]. This iterative design involves designing, implementing, and refining educational interventions in collaboration with practitioners to improve the educational product OPBLA3DB. The study involved two classes with different treatments using the OPBLA3DB and conventional groups. This research was conducted from May 2022 to June 2023. The research subjects were 72 PSPTs from one university in East Java Province, Indonesia, who took the optics course. The Slovin equation for the entire population was used to calculate this number [31]. Because the university selected the class at random, random cluster sampling was the sampling strategy employed. The sample was divided into two groups: experimental and conventional. The experimental class had a sample of 51 PSPTs, while the conventional one had a sample of 21 PSPTs.

2.2. Research instruments

The instruments in this study consist of a syllabus, lesson plan, digital book application with 3D animation, student worksheets, test sheets, validation questionnaires, and observation sheets. Although the lesson plans in both classes use various learning strategies, the learning syllabus in both groups has been modified to fit the university's current curriculum. Five syntaxes are used by the experimental class to implement OPBL: i) problem orientation, ii) student organization, iii) supporting group investigation, iv) producing and presenting findings, and v) examining and assessing the problem-solving procedure [32]. In each of these syntaxes was integrated with digital books with 3D animation. The conventional class follows standard teaching methods for instruction. It involves reading and listening to written material on theories, concepts, and examples of phenomena in addition to working on questions and having class discussions about them. All learning activities for both classes are carried out online through several supporting platforms, such as WhatsApp, Zoom, and Google Classroom. The digital book that has been developed has a *.apk* extension that can be installed on the Android mobile phone platform with a size of 47 MB. For online learning, the application can be used offline to reduce network usage. Figure 1 shows some appearance of the digital book.

All instruments developed went through a rigorous validation process resulting in a feasible and reliable instrument. This is essential because it enhances the overall robustness and credibility of the research outcomes, making them more valuable for informing educational practices and policies. The results of instrument validity and reliability are clarified in the results and discussion chapter.

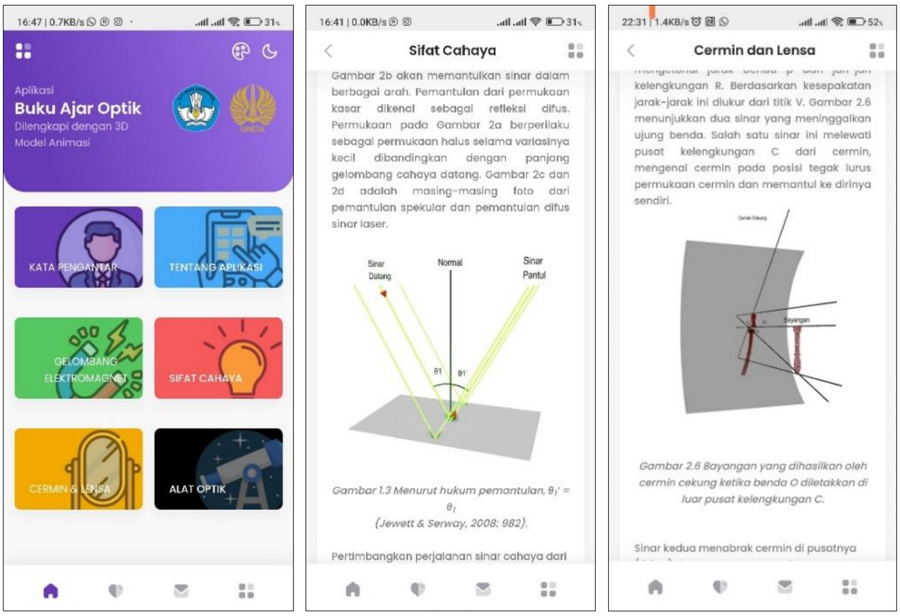

Figure 1. Some screenshots of digital book applications with 3D animation

PSPTs also learn using worksheets as teaching materials that make it easier for them to understand the material provided in accordance with the OPBL learning steps. Test instruments consist of two types: pre and post-test, which contain indicators of scientific literacy. The indicators are: i) explaining scientific phenomena, ii) interpreting scientific data and evidence, and iii) evaluating and designing scientific investigations [6], [33]. Each of these indicators consists of two to three questions in the form of a description. The validation questionnaire is used to assess the validity and feasibility of the OPBL model assisted by a digital book with 3D animations and its supporting research instruments. This questionnaire is arranged with a Likert scale of 1-4, where 1=very bad and 4=very good. Finally, the observation sheet is used to observe the implementation of learning. These sheets are also arranged using a Likert scale, similar to a validity questionnaire.

2.3. Data collection

The data collection process contains three main steps: validity, practicality, and effectiveness, as depicted in Figure 2. Firstly, a problem and need analysis related to the product that will be developed was conducted. Afterward, the OPBLA3DB was developed to address the problem. In order to reach the product's quality, validity, practicality, and effectiveness tests are required. The product's validity is evaluated by assessing the OPBLA3DB and supporting research instruments by two physics education experts and one physics expert. The target of validation is the content and construct of the instruments. Validation is carried out to obtain revisions from experts through validation sheets. The recommendations provided by the expert are used to improve the quality of the OPBLA3DB until the model instrument is declared feasible and can be used in the implementation.

When it comes to the practicality of the OPBLA3DB, it includes the level of implementation of the model using observation instruments. The observation was carried out by two observers, namely associate professor and expert assistant lecturers. The implementation of this learning model is the level of teacher achievement at the trial stage, where the data obtained illustrate the suitability of the implementation of the learning stages based on the lesson plan made. The model is said to be practical if the implementation of the model is at least a good category.

Finally, effectiveness is a measure of the quality of learning models through PSPTs' scientific literacy that can be analyzed based on pre-test and post-test scores. To investigate, it was used a non-equivalent conventional group design consisting of two classes: experiment and traditional. Both classes had homogeneous initial scientific literacy scores, as evidenced by the homogeneity test. The control variables of the two classes include curriculum type, teaching hours, credit weight, teacher, and optics materials. At first, the PSPTs in both classes were given a pre-test as an initial scientific literacy score. After that, PSPTs in the experimental group were given learning treatment with an OPBLA3DB, whereas in conventional class were provided direct instruction through lectures, general discussion, and structured tasks. At the end of the lesson, both classes were given a post-test to determine the final scientific literacy, and only the experimental class also provided PSPTs' response questionnaires. The questions used in the test were scientific literacy questions that apply to the OECD assessment guidelines 2019 [6], which consist of: i) explaining phenomena scientifically, ii) interpreting data and scientific evidence, and iii) evaluating and designing scientific investigations.

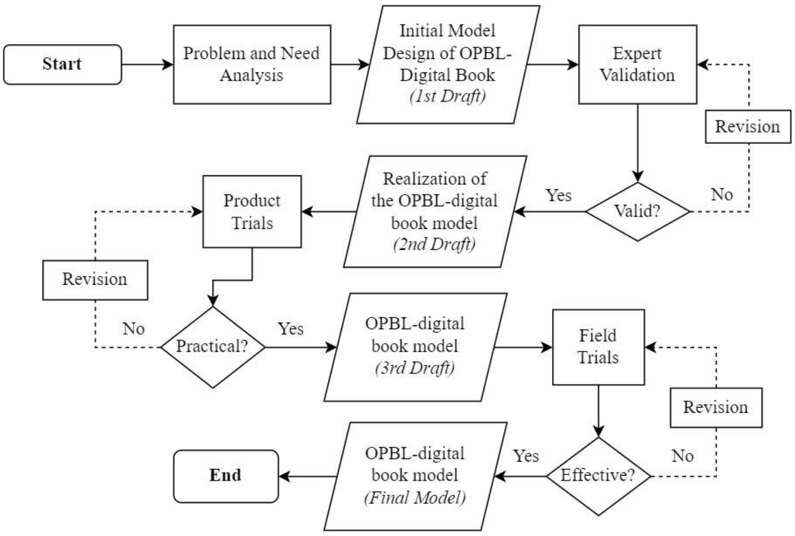

Figure 2. Research stages [34]

2.4. Data analysis

The average score of the assessment results among the three experts is used to assess the validity of OPBLA3DB models. Next, the average assessment results will be adjusted in compliance with Table 1 standards. An instrument's reliability is also evaluated using the Cronbach's Alpha coefficient; if the value is ≥0.7, the instrument is considered reliable [35]. The outcomes of the OPBLA3DB implementation observation will be subjected to descriptive qualitative analysis. The table also displays the average score derived from the model's observations. The reliability calculation of the instrument is enhanced through the application of Cronbach's alpha analysis. The instrument is said to be practical if the results of the observations have at least good criteria.

Table 1. Determination of validity and practicality criteria [35]

Validity criteria		Practicality criteria	
$1.00 \leq V < 1.75$	Invalid	$1.00 \leq P < 1.75$	Impractical
$1.75 \leq V < 2.50$	Less valid	$1.75 \leq P < 2.50$	Less practical
$2.50 \leq V < 3.25$	Valid	$2.50 \leq P < 3.25$	Practical
$3.25 \leq V < 4.00$	Very valid	$3.25 \leq P < 4.00$	Very practical

Note: V: average validity score, P: average implementation score

The effectiveness of learning can be seen through the following criteria: i) science literacy scores are in the medium category, ii) N-gain scores have medium criteria, iii) there are significant differences between pre and post-test scientific literacy results, iv) the effect size score should be in medium criteria, and v) there are significant differences between two classes in scientific literacy (adopted from Prahani *et al*. [36]). The determination of science literacy, N-gain scores, and effect size using Cohen's d, as comprised in Table 2 [37]–[40]. Meanwhile, the determination of significance is using the t-test inferential statistics. Additionally, the results of the PSPTs response questionnaire were analyzed descriptively through percentage values.

Table 2. Determination of scientific literacy, N-gain, effect size, and PSPTs response criteria

Scientific literacy		N-Gain criteria		Cohen's d		PSPTs response	
L≤57	Low	g<0.3	Low	0.2	Small	1–25%	Deficient
57<L≤71	Medium	0.3≤g<0.7	Medium	0.5	Medium	26–50%	Low
71<L≤100	High	g≥0.7	High	≥0.8	Large	51–75 %	Moderate
						76–100%	High

Note: L: average scientific literacy score, g: N-gain score

3. RESULTS AND DISCUSSION

3.1. Validity

Validation targets the content and constructs of all research instruments. Three experts carried out this validation assessment. The implementation of online validation is due to the COVID-19 pandemic. The results of the validity assessment can be seen in Table 3. It can be seen that the validity assessment results for all learning tools are stated to be very valid and reliable. According to validators, both learning tools and applications are suitable after minor revisions. After minor revisions, OPBL learning tools assisted by digital book applications with 3D animation can be tested for their implementation and effectiveness in improving PSPT scientific literacy.

Table 3. The results of the validity assessment

Instrument	Score	Validity	α	Reliability
Syllabus	3.44	Very valid	0.91	Reliable
Lesson plan	3.52	Very valid	0.95	Reliable
PSPT worksheet	3.66	Very valid	0.70	Reliable
Test instruments	3.70	Very valid	0.75	Reliable
Digital book app	3.73	Very valid	0.85	Reliable

Compared to conventional PBL, this research instrument has the latest in that learning is carried out online, so distance learning activities are possible using internet media to connect PSPT with its lecturers [41], [42]. In addition, this learning activity also functions in reinforcement so that it can create more effective learning optics [43]. As for each syntax on the OPBL model, it is inseparable from the application of digital books with 3D animation. The use of animation is beneficial for students in understanding abstract optical material when solving problems individually or in groups [44], [45]. Thus, the expert assesses that this learning is valid and feasible to implement after minor revisions have been made.

Additionally, the instruments' reliability scores instill confidence in the instruments' consistency and reliability, providing a solid foundation for the validity of the study's findings and the subsequent implications for educational practice. It is confided that the variations observed in the study are likely to reflect true differences or trends in the constructs being measured, rather than being influenced by inconsistencies or errors in the measurement tools [46]. This implies that the study's conclusions and any subsequent recommendations or interventions based on these findings are more likely to be valid and applicable. Educators, policymakers, and other stakeholders can have confidence in the reliability of the instruments used to assess aspects in a practical context.

3.2. Practicality

The implementation of the OPBLA3DB in the classroom involves a PBL model that is implemented online. As comprised in Table 4, the learning model has a well-structured series of activities designed to enhance scientific literacy among PSPTs. It is tremendously important to ensure that the learning model is designed in compliance with the learning objectives.

Meanwhile, the results of the practicality assessment can be seen in Table 5, indicating that the implementation of OPBL learning assisted by digital book applications with 3D animation can be carried out properly so that it can be said to meet very practical criteria. Only in the guiding phase do individual and group investigations have practical criteria. In addition, the results of measuring the practicality of this learning include reliability, as evidenced by the Cronbach alpha value of >0.7 for the entire implementation phase. The learning instruments developed are valid and can be used as support in their implementation.

The practicality of the OPBLA3DB can be seen from the implementation level, yielding that the entire phase has a very practical and reliable level, except for the guiding individual and group investigation phase, which has a practical level. This is because, in this phase, PSPT is still not used to conducting online investigations, even though they can do it in the end. Generally speaking, learning is going well because the application is compatible with all mobile phones so that it can be easily integrated into learning [47], [48]. PSPT is also familiar with the use of technology in learning because, during the COVID-19 pandemic, e-learning is increasingly massive and digital technology interventions in learning are commonplace [49]–[51].

The lecturer can practically implement the learning activities in each phase planned in the lesson plan to help students learn PSPT. Teaching useful resources and simplifying them for teachers and students are called practical resources. This is reinforced by research by Limatahu [40], Astutik and Prahani [52], which shows that practical learning is well-implemented learning that impacts the effectiveness of its output, especially scientific literacy.

Table 4. OPBLA3DB model's learning activity

OPBL syntax/phase	Activity	Scientific literacy indicator
Orienting problem	The teacher orientates the PSPTs (students) to a relevant problem according to the sub-topic being studied. The teacher asks the students to hypothesize related to the problem.	Interpreting scientific data and evidence
Organizing students	The teacher asks students to get into groups and distributes worksheets along with digital books with 3D animation.	Evaluating and designing scientific investigations
Assisting group investigation	Students conduct investigations and discussions to solve relevant problems with the help of digital books with 3D animation. The teacher becomes a facilitator in students' investigation.	
Developing and presenting results	Students develop solutions to solve problems and present the results to classmates. The teacher facilitates question-and-answer activities conducted by students.	Explaining scientific phenomena; Interpreting scientific data and evidence
Analyzing and evaluating problem-solving process	The teacher provides feedback and evaluates students' problem-solving results. Students ask questions about material that is still not fully understood.	

Table 5. The results of the practicality assessment

Phase	Implementation score	Practicality	α	Reliability
Orienting problem	3.25	Very practical	0.86	Reliable
Organizing students	3.62	Very practical	0.91	Reliable
Assisting group investigation	3.00	Practical	1.00	Reliable
Developing and presenting results	3.25	Very practical	1.00	Reliable
Analyzing and evaluating problem-solving process	3.25	Very practical	0.90	Reliable

3.3. Effectiveness

The first indicator of effectiveness is that the experimental class's post-test score of scientific literacy is at least medium. The results of descriptive statistical tests on scientific literacy pre-test and post-test scores in both classes can be seen in Table 6. It can be seen that generally, the initial pre-test score in the experiment class had a score of 64.79 in the medium criteria. They are still unfamiliar with the scientific literacy test model never taught in schools or universities. This is also consistent with the research by Pahrudin *et al*. [10], Fakhriyah *et al*. [53], which shows that the scientific literacy ability of pre-service teachers in Indonesia is relatively low. In addition, these findings also corroborate Indonesia's PISA results, which are far below average [6]. Meanwhile, the initial pre-test score in the conventional class was 60.85 (medium). It's the same category as the experiment class. After being given the learning treatment without the OPBLA3DB model and conducting a post-test, PSPTs had a final score of 83.86 (medium). The N-gain value between the pre- and post-test is 0.59 (medium).

Table 6. Scientific literacy pre-test, post-test, and N-gain results

Class		N	Scientific literacy		St. Dev	N-gain		*p*
Experiment	Pre-test	51	64.79	Medium	15.47	0.74	High	0.00*
	Post-test		90.97	High				
Conventional	Pre-test	21	60.85	Medium	15.34	0.59	Medium	0.00*
	Post-test		83.86	High				

*$p<0.05$

After being given the OPBL learning treatment assisted by a digital book application with 3D animation and conducted post-test, PSPTs had a final score of 90.97 or on high criteria. The standard deviation value in the data is 15.47 and is smaller than the average value of the entire data, so the data is more accurate to the mean. Thus, the first indicators of effectiveness have been fulfilled. The next indicator of effectiveness is that the value of N-gain has a medium category. The N-gain value between the pre-test and post-test is 0.74, which is in the high category. Thus, the second indicator of effectiveness has been fulfilled.

To make it more straightforward, the increase in scientific literacy of PSPTs can be seen from each indicator, as shown in Figure 3. Based on the results of the data analysis shown in Figure 3, it can be seen that the number of PSPTs that can explain phenomena at a high level in the experimental class, which was initially only 20%, has increased to 97.5%. This condition is different from the conventional group, where initially there was 25% PSPT, and after attending lectures, it only increased to 80%; likewise, in the two indicators of scientific literacy where the increase in the number of PSPTs after attending courses using the OPBLA3DB model was more significant in the experimental class.

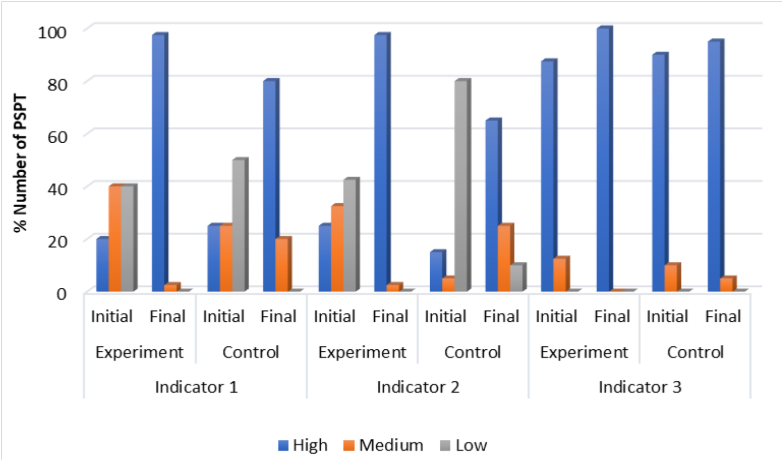

Figure 3. The level of scientific literacy each indicator

However, even so, the final ability of the PSPTs for each indicator of scientific literacy has increased primarily in the experiment class, as shown in Figure 4. Based on the analytical data on improving scientific literacy skills, as shown in Figure 4, two indicators were seen in the experimental class, namely the ability to interpret data and scientific evidence (indicator 2) and the ability to evaluate and design scientific investigations (indicator 3) which experienced an increase in the high category. In contrast, indicator 1, namely the ability to explain phenomena, has increased in the medium category. Likewise, with the conventional class, the scientific literacy skills of the PSPTs on all indicators increased to the medium category.

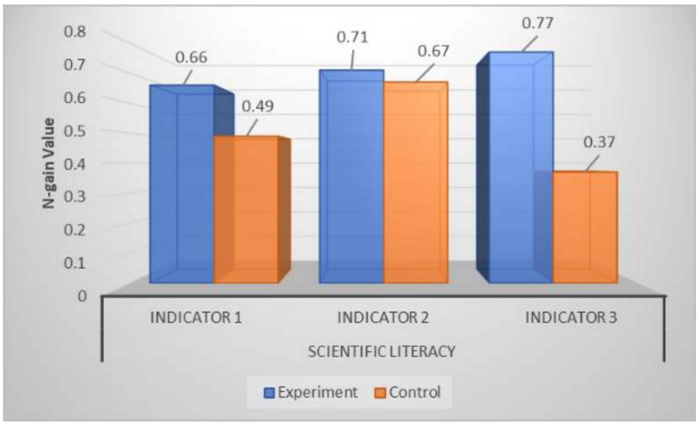

Figure 4. The level of increasing scientific literacy for each indicator

Table 7 demonstrates the results of normality, homogeneity, and independent t-test. It can be seen that the pre-test and post-test data have a normal and homogeneous distribution, so the subsequent tests use parametric statistics. To determine the significance between the two types of tests, use an independent t-test. The test results showed a significant value, implying a significant difference between the pre- and post-test of scientific literacy. Therefore, all indicators have been fulfilled, and the OPBLA3DB learning model is effective.

Table 7. The results of normality, homogeneity, and independent t-test

Group	Normality test		Homogeneity test		T-test	Effect size	
	p	Criteria	*p*	Criteria	*p*	Cohen's d	Criteria
Experiment	0.10	Normal	0.14	Homogenous	0.01*	0.46	Medium
Conventional	0.15	Normal					

*$p < 0.05$

In addition to the test, PSPT's response to learning through questionnaires was also obtained. Table 8 shows the PSPT's response to the OPBLA3DB model. In general, PSPT responds positively to this learning, including evaluation of interest in learning, renewal of learning, understanding of learning materials, continuity of learning, clarity of material and teaching, and learning activities on worksheets. Especially in the pre-test and post-test questions evaluation, some PSPTs consider the questions given to be less easy and not easy.

Table 8. PSPTs response in the OPBLA3DB model

Aspect	Percentage (%)	Criteria
Interest in learning	87.04	Highly interested
Learning instruments novelty	84.25	Highly novel
Understanding of learning instruments and materials	72.22	Moderately easy
Interest in innovation sustainability	85.19	Highly innovative
Clarity of material and teaching	89.82	Highly clear
Convenience of the learning process through worksheets	76.84	Highly convenient
Difficulty level in pre- and post-test	62.04	Moderately easy

Using the OPBL model can help PSPTs improve scientific literacy because all learning activities focus on training their scientific literacy. Scientific literacy has three indicators [6], [33]: i) explaining scientific phenomena, ii) interpreting scientific data and evidence, and iii) evaluating and designing scientific investigations. The learning model has five stages [32], namely stage 1 problem orientation, where at this stage, PSPT is given content sourced from scientific news to train them in interpreting scientific data and evidence (2^{nd} indicator). In phase 1, case studies related to authentic socio-scientific issues positively impact their scientific literacy. In phase 2, PSPT is expected to be able to find problems in the content and propose solutions to solve them. In phase 3, PSPT conducts a scientific investigation. In phase 4, PSPT presents the results of the work in the form of research data, images, and graphs. Starting from phases 2 to 4 can train PSPT to evaluate and design scientific investigations (3^{rd} indicator). Finally, in phase 5, PSPT analyses and evaluates a problem through questions that can help them explain scientific phenomena (1^{st} indicator). Thus, these five stages can help PSPT improve all indicators of scientific literacy skills.

The OPBLA3DB model requires PSPT to carry out a problem-solving process to obtain solutions so that they are unwittingly trained in solving problems that subsequently indirectly create scientific literacy skills [54]. This is because learning with the OPBL model helps students become independent learners. Investigation activities can develop PSPT skills to collect and sort data and present an easy-to-understand result to grow scientific literacy [55]. In addition, through OPBLA3DB, PSPTs develop their scientific literacy skills while becoming accustomed to being scientists. OPBL helps PSPTs develop their literacy by helping them improve effective collaborative knowledge, identifying specific collaborative skills that they need and can acquire through group collaboration, and helping them to make explicit the connection between attitudes toward collaboration and learning outcomes [56].

These findings are consistent with several empirical evidence, indicating that using PBL models can improve students' scientific literacy [57]–[59]. According to Arends [32], the PBL model requires students to explore various disciplines and carry out authentic investigations to achieve deeper and more complex knowledge and make the learning process meaningful for students. Piaget's cognitive constructivism learning theory is another fundamental for PBL. The learning model allows students to construct their own knowledge by interacting with their environment through assimilation and accommodation processes [60].

The use of digital books with 3D animation can greatly benefit PSPTs' understanding of abstract optical subjects. This is because 3D animation enhances PSPTs' visual and spatial comprehension [61], [62]. The study conducted by Ahied *et al*. [63] supported these results, which demonstrate that the incorporation of 3D animation-based media into online learning can enhance scientific literacy. Technology in education, such as digital books, has the potential to guide, question, and assist students in creating their own knowledge, potentially replacing the roles of teachers and students. The OPBL model and this digital book's integration can assist in learning and improving PSPTs' scientific literacy.

Overall, PSPT responds positively to the OPBLA3DB, as shown in Table 8. This is because this learning model is considered innovative and not monotonous like lectures in common. Supported by clear, practical, and accessible learning instruments so that the implementation of learning becomes fluent and good [40]. However, some PSPTs have a tendency to feel that pre- and post-test questions are not easy. This is because scientific literacy is not used as the final bill for lectures by design, so they rarely encounter scientific literacy-based questions and consider it difficult. Meaningful learning for PSPTs is positive learning, where they feel happy and interested in the implementation of learning so that there is an increase in scientific literacy [64]. PSPTs' scientific literacy is very related and directly proportional to their response to the learning process that has been carried out. The scientific literacy level of PSPT should be good because they are the ones who later teach students after becoming teachers in schools.

This research contributes as one of the innovative learning models that can improve the PSPTs' scientific literacy as a prospective physics teacher. They should have a good level of scientific literacy to teach it to students in school. This needs to be done considering that the scientific literacy score in Indonesia is still below average, as well as for other developing countries. Scientific literacy is very important for students because it can make them able to solve independent problems, think creatively and scientifically, and make decisions on socio-scientific issues. It is also recommended that the education curriculum should train students' science literacy. The use of digital books with 3D animation is also relevant today because it is an emerging technology in digital era teaching and learning. Moreover, this research has practical implications for educational policy because incorporating digital books with 3D animations in the OPBLA3DB model highlights the importance of technology in modern education. This suggests a need for educational policies that support the integration of digital resources, ensuring that schools have access to appropriate technological infrastructure and resources, as reinforced by Gadelha [65]. Policymakers may need to consider initiatives to provide training for educators on effectively utilizing digital tools in teaching and learning processes.

4. CONCLUSION

A valid, practical, and effective OPBLA3DB has been developed to improve PSPTs' scientific literacy. The validity assessment of this model instrument, including the syllabus, lesson plan, worksheets, test instruments, and digital book app, is declared very valid and reliable. This model has also been well implemented so that it meets practical criteria. In the aspect of effectiveness, the application of this model shows that the post-test results of scientific literacy are 60.79 (moderate criteria), N-gain is 0.34, and there is a significant difference between the pre-test and post-test results. Therefore, this model is declared effective for improving scientific literacy. PSPTs also respond positively to the learning provided. The syntax of the OPBL model has been adapted to scientific literacy indicators, and the assistance of digital books with 3D animation can help PSPT understand abstract optical material.

The limitation of this study is that the number of samples is still small, so the statistical strength is still not very strong. The digital book application is also only compatible with the Android operating system and is limited to optical materials only. Moreover, this research only focuses on using the OPBL model, optical physics material, and improving PSPTs science literacy. The recommendations for further research are to: i) use other learning models beyond OPBL (e.g., guided inquiry and collaborative learning) to find the most effective combination in improving science literacy; ii) measure other variables beyond science literacy, such as creativity, critical thinking, learning motivation, self-efficacy, knowing the broader benefits of the OPBLA3DB model; iii) add other materials besides optics that require extra visualization, like thermodynamics, modern physics, electricity and magnetism; and iv) investigate teacher responses to this learning model, resulting in knowing the level of teacher acceptability of the OPBLA3DB model. Thus, a broader and more comprehensive research result can be obtained to complement the findings in this research.

ACKNOWLEDGEMENTS

The authors express their gratitude to LPPM Universitas Negeri Surabaya for providing funding for this research with contract number B/35056/UN38.9/LK.04.00/2022.

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