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Implementation of Digital Project Based Learning Model to Enhance Science Literacy in Physics Learning

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ABSTRACT

Introduction. Digital project based learning (DPjBL) model implementation is closely related with technology in learning. This model involves students in complex projects that encourage in-depth exploration of a particular topic using digital technology. In DPjBL, students work collaboratively to complete projects that are relevant to the real world, and use technology to help solve problems, thus encouraging student involvement in the learning process. DPjBL model encourages the implementation of digitalization in education and brings students closer to the times. The use of technology can help students to explore more deeply the problems of physics. *The aim of this research* is to develop a model DPjBL to improve science literacy skills in high school physics learning.

Study participants and methods. This study utilized a development research methodology based on the Plomp model, which consists of preliminary investigation, design, realization/construction, testing, evaluation, and revision. The research was conducted with 60 senior high school students in Padang, Indonesia. To evaluate the effectiveness and practicality of the developed digital project-based learning model, several instruments were employed, including expert validation sheets, practicality assessment forms completed by both teachers and students, student questionnaires, and a scientific literacy test designed to measure key competencies.

Results. The results indicate that average score percentage is in the competence of explaining phenomena scientifically, which is 89.5%, meaning that students can understand phenomena well and have basic concepts. Competency of evaluating and designing scientific investigations has the lowest average score percentage compared to other competencies, which is 82.3%, competency of data interpretation and scientific proof, an average score of 86.3% was obtained, so that the scientific literacy skills of students can be categorized as very good.

Conclusion. The findings of this study indicate that the integration of DPjBL model contributes meaningfully to the development of students' scientific literacy, particularly within high school physics instruction. This approach not only fosters a deeper understanding of scientific concepts but also promotes critical thinking, collaboration, and the practical application of knowledge in real-world contexts.

KEYWORDS

digital, project based learning, science literacy, physics learning

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INTRODUCTION

Education has become a central concern of international development agendas, as reflected in initiatives led by UNESCO, the United Nations, and the Council of Europe. The United Nations Sustainable Development Goal 4 (SDG 4) calls for inclusive and equitable quality education and lifelong learning opportunities for all, emphasizing scientific literacy and digital competence as critical foundations. UNESCO (2023) highlights that scientific literacy, understood as the ability to apply knowledge, think critically, and engage with scientific phenomena, is essential for preparing global citizens. Similarly, the OECD through its Programme for International Student Assessment (PISA) positions scientific literacy as a benchmark for educational quality worldwide. These frameworks show that strengthening literacy through innovative and technology-based pedagogies is a global priority.

The development of the 21st century era has made technology and information develop rapidly. Therefore, quality human resources are needed that can keep up with and anticipate the development of the era. Education is an important element to ensure that students have learning skills, technology skills and life skills. The relationship between science and technology cannot be separated in this modern era. Science education is an important part of preparing students who have science literacy, meaning being able to take the initiative, critical thinking and creative thinking about issues that develop in the community [1].

Regulation of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 32 of 2022 concerning the minimum technical standards for educational services in Article 11 states that the quality of student outcomes at the senior high school level includes literacy competencies more specifically in science learning known as scientific literacy. Scientific literacy is defined as scientific knowledge and skills so that students are able to identify questions, gain new knowledge, explain scientific phenomena, and draw conclusions based on scientific facts and characteristics. In general, the results of the assessment of student literacy are included in the Indonesian education report card [2].

Based on the national education report, the literacy skills of students at the high school level are included in the poor category. Literacy skills in the education report are reported in 4 achievement indices that are depicted in different colors according to the description of school attributes and student attributes. This means that more than 50% of high school students have not been able to find explicit information in readings and have not been able to make simple interpretations. Of course, they really need guidance to understand readings in order to be able to analyze readings well [4].

The importance of all subjects to contribute to improving literacy skills, including in physics learning, especially at the high school level. Literacy skills are the basis for developing scientific literacy skills. Systematically, physics learning deals with matter and energy, with the laws governing the motion of particles and waves, with the interactions between particles, and with the properties of molecules, atoms, and with larger-scale systems such as gases, liquids, and solids. Some people consider physics as a fundamental science or knowledge because it is the basis of all other fields of science. To enhance students' scientific literacy in Indonesia, improvements are needed in physics learning, including teacher competence, classroom processes, and assessment practices. Previous research has highlighted the need for strengthening teacher pedagogical skills [3] and for reforming evaluation systems to better foster scientific literacy [5].

Several efforts have been made by the government to improve science literacy, including launching the National Literacy Movement and the School Literacy Movement, implementing a scientific approach to the independent curriculum, and developing science literacy instruments to measure students' abilities [6]. This shows that the government has paid attention to encouraging increased literacy in schools.

However, based on observations and interviews with Physics teachers at several high schools in Padang City in January 2025, it was found that physics learning activities in class X were quite conducive, teachers used several learning methods, so that students' responses in physics learning took place well. Furthermore, in interviews with teachers, it was stated that science literacy skills were not applied enough during physics learning, so that students were not yet able to provide the right answers in answering questions and solving problems in the form of discourse given. Then the use of technology in physics learning is less than optimal, because there are no quality, meaningful learning modules and support in the use of technology for teachers and students.

Informal interviews between researchers and high school students after conducting a trial of the scientific literacy test revealed that according to students, the test questions were quite difficult and complicated, previously they rarely encountered such questions in class. This shows that students are not accustomed to working on problems requiring scientific literacy, which contributes to their low performance. Previous studies also indicate that limited exposure to science-based problem-solving in classrooms leads to low levels of scientific literacy among students [7], and that instructional practices often fail to prepare learners for literacy-oriented assessments [8].

Furthermore, according to research conducted by [4], it shows that the average scientific literacy of high school students is in the low category with a score of 33.7. The findings in this study state that students are not yet accustomed to problems in the form of discourse, then students are less able to analyze problems found in everyday life. In line with that, physics learning in schools is oriented towards understanding and is not associated with everyday life [2].

Based on the explanation above, the researcher analyzed that the problems related to low student literacy were caused by the learning model or approach applied so far by teachers in the classroom having weaknesses, namely not explicitly covering aspects of scientific literacy in it. This is supported by Osborne and Allchin [1], if aspects of scientific literacy are not integrated into the learning model, it can cause students' scientific literacy not to develop. Therefore, based on the independent curriculum, one of the recommended models according to the profile of Pancasila students is the model project based learning (PjBL).

PjBL learning can be done through investigative activities and constructing problems, researching solutions, planning, presenting, providing feedback, and revising plans, then presenting [9; 11]. One of the learning models that can improve students' scientific literacy skills and technology usage skills is through the model digital project based learning (DPjBL). This model involves students in complex projects that encourage in-depth exploration of a particular topic using digital technology. In DPjBL, students work collaboratively to complete projects that are relevant to the real world and use technology to solve problems, which encourages student involvement in the learning process. Previous studies have shown that this approach fosters teamwork and problem-solving [12], enhances the use of digital tools for learning [13], and improves student engagement [14]. This DPjBL model encourages the implementation of digitalization in education and brings students closer to the times. Digital project based learning is a learning model that links the use of technology in project-based learning. The use of technology can help students to explore more deeply the problems of physics. This study developed a model digital project based learning to improve scientific literacy skills in high school physics learning.

RESEARCH METHODS

1. Research design

This study used development research design which designed and developed an intervention to overcome a problem [15]. Based on the objectives, design research distinguished above development studies and validation studies. Educational design research with type development studies aims to develop solutions to complex problems in educational practice. While the types of validation studies aim to develop and validate a theory [Ibid]. This research included educational design research with type development studies and validation studies. Because in this research an educational intervention is developed, namely, a model digital project based learning in high school physics learning to improve students' science literacy skills.

2. Research Procedure

The research procedures in developing models digital project based learning in physics learning based on Plomp's are briefly presented in Table 1.

Table 1 Research procedures for model development digital project based learning in physics learning

Level	Criteria	Research Activities	Brief Description of Activities
Preliminary research	Content validity	Needs and Context Analysis	Analysis of potential user needs, curriculum analysis, concept analysis, analysis of student characteristics
		Literature review	Analyze theories and concepts related to the model digital project based learning in physics learning
		Development of a conceptual framework or theoretical framework	Designing and developing a conceptual framework for the model digital project based learning in physics learning
Development or prototype stage	Construct validity and practicality	Designing a prototype	Designing a model digital project based learning in physics learning
		Formative evaluation	Assessment of the prototype in terms of validity is carried out through self evaluation And expert review. After being revised and declared valid, the practicality of the prototype is assessed with one to one evaluation and small group evaluation
		Revision	Conduct revisions to the prototype based on the results of the formative evaluation.
Assessment Phase	Practically And effectiveness	Summative Evaluation	Conducting practicality and effectiveness tests on prototypes through field testing stages

RESULTS

1. Analysis of the needs of teacher and student

Need analysis is carried out by making observation, assignments, and tests on senior high school student in Padang. The results of the report analysis showed that student understanding of science literacy found that only 30% of student were able to provide explanation about scientific phenomena, meaning that most student, or 70% could not analyze complex data or information, syntesize or evaluate evidence, and make plans or sequences of steps to solve problems. Students argue that the learning activities are challenging to understand. They need media or digital technology to improve science literacy.

2. Digital project based learning syntax design

The integration of technology in education has been shown to positively impact student engagement in learning. Studies indicate that technology-supported instruction increases learners' motivation and active participation [10], enhances collaboration and interaction among students [11], and promotes deeper involvement in classroom tasks [16]. Digital project based learning (DPjBL) is a learning approach that seeks to develop students' creative skills. The use of technology in PjBL provides more opportunities for students to explore their experiences and skills, resulting in more meaningful and useful projects. Integration of technology into project-based learning, by transforming conventional PjBL classrooms into digital project based learning (DPjBL), of course requires teachers to plan digital projects in detail. Not only mastering technology and digital platforms, but teachers must also focus on teaching content knowledge pedagogically [18].

Model digital project based learning (DPjBL) is a learning model that integrates technology into project-based learning. This model can be used in various digital media, such as e-modules, e-LKPD, e-books, e-portfolios, virtual laboratories, e-learning and Moodle [19].

Model digital project based learning is a project with the help of technology media related to students' daily lives. Model digital project based learning help students to develop the 4C skills which are very necessary in this 21st century.

Table 2 Syntax digital project based learning

Level	Teacher Activities	Student Activities
Level 1 Orienting students to the problem	The teacher explains the learning objectives, the logistics needed, motivates students to be active in problem-solving activities.	Students pay attention to the teacher's explanation and students find problems
Level 2 Organizing students to learn with the help of technology	Teachers help students limit and organize learning tasks related to the problems they face.	Students define the problem
Level 3 Guiding individual or group investigations digitally	Teachers encourage students to collect appropriate information, carry out experiments, and seek explanations and solve problems.	Students collect facts, make hypotheses, conduct research
Level 4 Develop and present work results digitally	Teachers assist students in planning and preparing appropriate artifacts, such as reports, video recordings, and other models.	Students conclude alternative solutions collaboratively
Level 5 Analyze and evaluate the problem solving process	Teachers help students reflect or evaluate their investigations and the processes they use during problem solving.	Students propose solutions to problems

In implementation of digital project based learning model, teachers need to have skills in; identifying basic competencies, selecting materials or topics that will be used as project themes, motivating students, ensuring time compliance with the given schedule.

3. Model development results

Model development digital project based learning in this physics learning using the Plomp model which has three stages, namely; (1) Preliminary research stage; (2) Development or prototype stage; and (3) Assessment stage. This model was chosen because it is in accordance with the objectives of this study and each stage of this model includes development activities that can be aligned with the characteristics of the study.

4. The relationship between digital project based learning and science literacy

Learning with models digital project based learning can improve students' scientific literacy achievement, because the learning process does not only emphasize memory and memorization, but is also oriented towards the process and achievement of scientific attitudes, as well as helping students practice understanding scientific phenomena.

Model digital project based learning provide freedom for students to explore in every learning activity, thus producing a creative product [12]. Thus, the model digital project based learning can improve students' science literacy skills.

Table 3 Model relation digital project based learning with scientific literacy

Stages on Digital Project Based Learning	Aspects of Scientific Literacy
Level 1 Orienting students to the problem	(1) The ability to explain phenomena scientifically
Level 2 Organizing students to learn with the help of technology	(2) The ability to explain phenomena scientifically (3) Evaluate and design scientific investigations
Level 3 Guiding individual or group investigations digitally	(2) Evaluate and design scientific investigations (3) Interpret data and evidence scientifically
Level 4 develop and present work results digitally	(3) Interpret data and evidence scientifically
Level 5 Analyze and evaluate the problem solving process	(1) Ability to explain phenomena scientifically (2) Evaluate and design scientific investigations (3) Interpret data and evidence scientifically

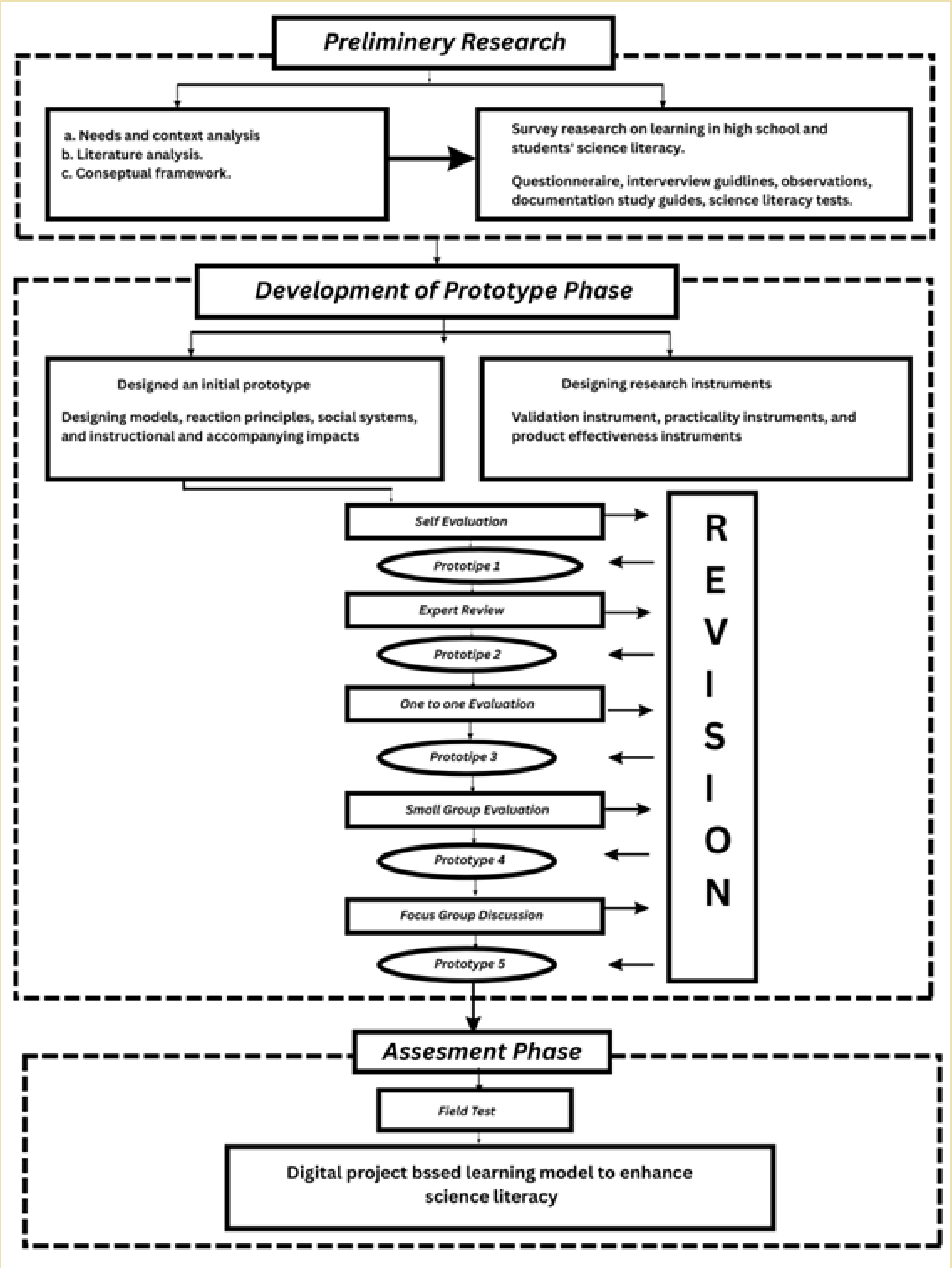

Figure 1 Development model of digital project based learning

Based on the table above, it can be seen that each stage of the digital project based learning model includes aspects of scientific literacy. Thus, it is hoped that with the implementation of the model digital project based learning can improve students' scientific literacy skills in physics learning, especially in static fluid material for class XI.

5. Product validation results and feasibility of digital project based learning model

According to Plomp's development approach, preliminary research comes first. A context analysis and literature review on digital project based learning in physics learning are needed at this point. According to Table 1, the digital project based learning model contains five phases: context, science literacy, reflection, project action, and evaluation. In the entire framework for introducing digital project based learning into physics learning, teachers facilitate group work, explain technology use, explain science literacy activities, provide digital feedback, and manage evaluations. It also highlights students' enthusiastic engagement with teacher explanations, collaborative problem-solving in groups, confidence in science literacy, active listening, asking clarifying questions, presenting solutions to the class, and commitment to excellence.

Figure 2 demonstrates that, overall, the digital project based learning model prototype has very valid criteria, with an 84,91-feasibility achievement percentage and a total average of 4,25. The logic model and background, syntax, social system, principle of reaction, supporting systems, instructional impact, learning implementation, language, and graphics are all addressed in many ways.

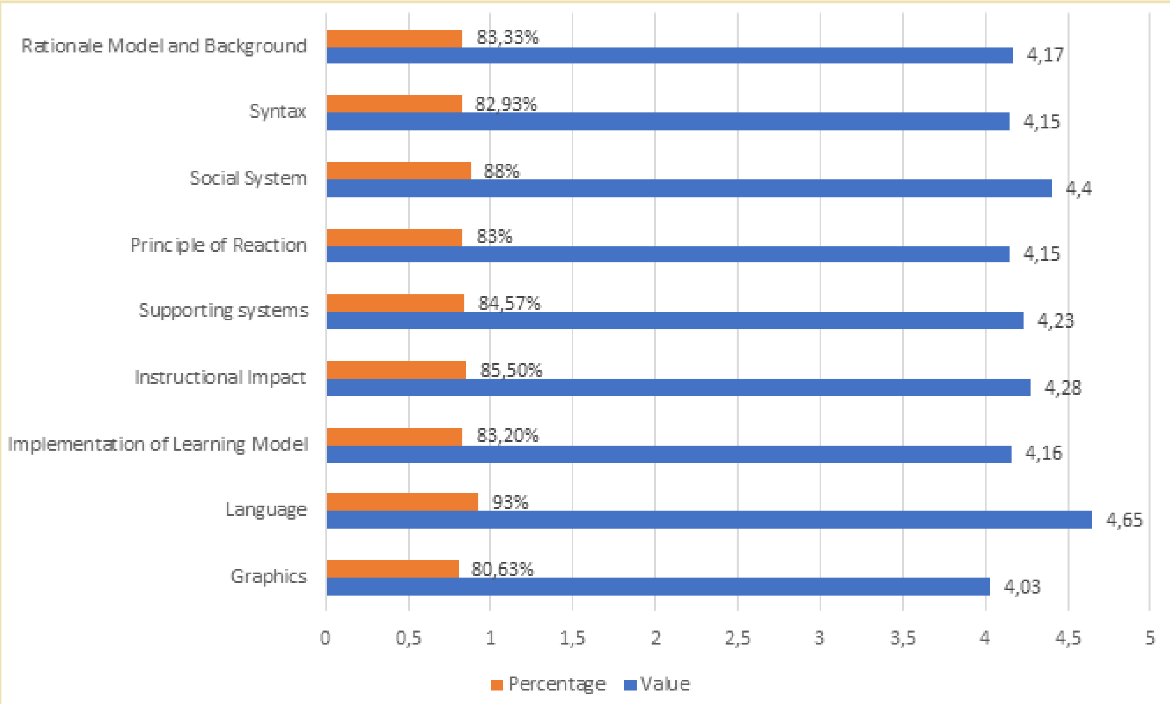

Figure 2 Validation result of digital project based learning model handbook

6. Science literacy test

Validation of the science literacy test instrument product was carried out to perfect and obtain validation of the instrument results of the development and to determine the advantages and disadvantages both logically and empirically. Validity and reliability were logically obtained from the results of internal testing conducted by five validators. There are three aspects of internal testing, namely the material aspect, the construction aspect and the language aspect. Expert validation aims to obtain input and suggestions and at the same time provide an assessment of each question indicator using a Likert scale, the results of expert validation are presented in the following table 4.

Table 4 Expert validation results

Validator	Koefisien Aiken's V	Criteria
Subject Matter Expert	0,83	Very Valid
Construction Expert	0,89	Very Valid
Linguist	0,89	Very Valid

The development of this science literacy test instrument produces an instrument that can be used to measure the level of student understanding. Each student has different learning experiences, so students have varying levels of understanding. This instrument consists of a science literacy test that includes a question outline, instructions for working on it, test questions and descriptions, answer keys and scoring guidelines. The question outline is the basis for compiling the test. The outline provides guidelines for writing questions.

Based on the results obtained from the small group trial, item analysis was conducted at each stage in the development research of the static fluid science literacy test for grade XI high school students. The analysis includes validity, reliability, discriminatory power, and level of difficulty of the questions. The results when the expert-validated science literacy instrument was given to the limited trial participants. The question instruments that have been developed in this study as a whole have good quality in terms of validity, reliability, discriminatory power and level of difficulty. The results of logical validation from the validators obtained an Aiken's V coefficient value of 0.83, which is included in the very valid interpretation.

Teachers' responses to the science literacy test were very good, based on the results of interviews with teachers to find out their responses to the science literacy test questions. This test is in accordance with the learning outcomes and learning objectives in the independent curriculum so that it can be used for physics learning evaluation activities on static fluid material. The language used in the questions is good, it does not confuse students with the readings in the discourse or in the questions. The readings in the questions and the images used are neatly arranged. The questions designed are in accordance with the criteria for science literacy so that students who want to answer the questions must be accustomed to reading first before being able to answer the questions. It is very helpful, because in schools it is still rare for teachers to use physics tests with science literacy criteria.

7. Formative stage of the experiment

7.1. Implementation of digital project based learning model to enhance science literacy in physics learning

a. Step 1. Problem Orientation

In this first stage, students will be given problems related to everyday life. These problems are designed to strengthen students' scientific literacy by helping them analyze scientific knowledge and identify scientific phenomena within real-world contexts. Previous studies have shown that presenting authentic, daily-life problems enhances students' ability to apply scientific concepts [21] and supports the development of analytical skills needed to recognize and interpret scientific issues [22]. Here is one example of a scientific problem given.

Private vehicles that have been used for long trips will certainly look dirty and full of mud so we have to clean them. An alternative to washing a car is to take it to a car wash. At a car wash, the car is parked in a certain place. Then the car is supported by a certain diameter iron, then lifted up. Why can the support lift a very heavy car?

After students discuss this problem, the next step is to carry out stage 2, organizing students.

b. Step 2. Organizing Students

At this stage, students are divided into several groups, each group consisting of 2-3 people. Then they discuss the problem and answer the following questions: (1) What problem is there in the discourse above?, (2) What physical phenomena occur in the problem above?, (3) What hypothesis can be given regarding the problem above?

Figure 3 Car wash place [Source Author's own work]

c. Step 3. Guiding the research

In this section, students begin to conduct investigations related to the problems in the given discourse. The investigation is carried out digitally using the Phet application. First, students open the link https://phet.colorado.edu. Then select and run the simulation as shown in the image below. In the application, click the grid and select atmosphere on. Using Phet is the same as using real media.

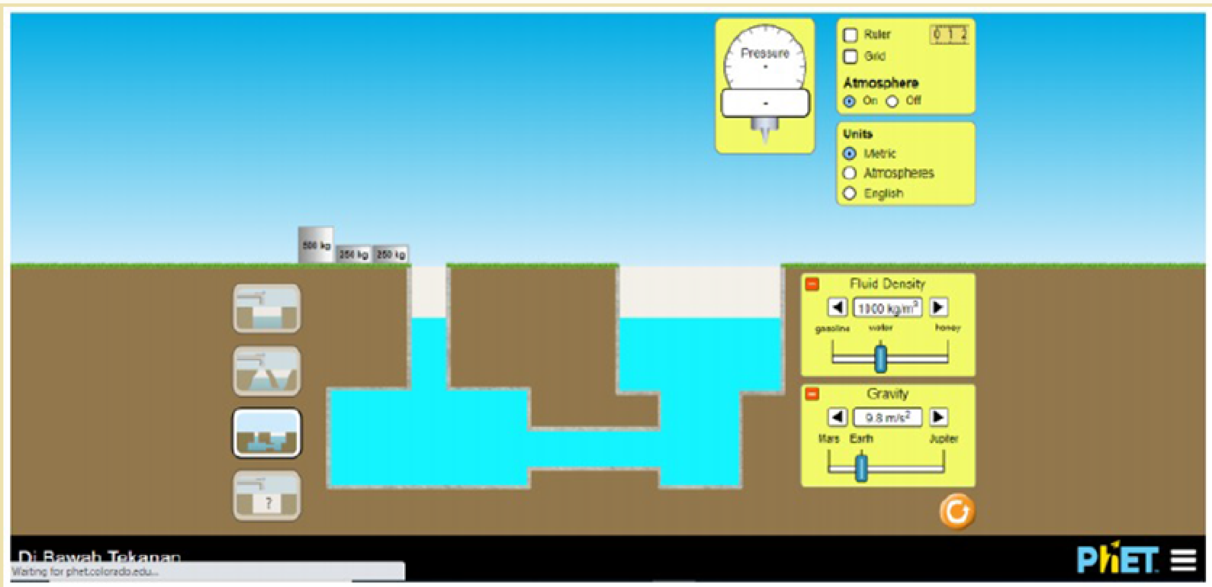

Figure 4 Phet aplication [Source: https://phet.colorado.edu/en/simulations/under-pressure ?]

Students can select several loads that are inserted into the liquid. Furthermore, students observe the measured pressure value at each additional load. The results of the investigation are written in table 5 below. Next, students analyze the results of their observations, including: (1) Does the measured pressure value change after a load is added to the liquid? (2) Does the change occur evenly? (3) Based on the investigation, provide your conclusion!

d. Step 4. Develop and present the results of the work

In this section, students present the results of their group discussions in front of the class. Then other students provide responses in the form of questions or comments.

e. Step 5. Analyze and evaluate the problem solving process

In this section, students analyze what obstacles they face during the problem-solving process. Things that are considered less understood are discussed and asked to the teacher.

7.2. Science Literacy

The scientific literacy test given in this study refers to Alexiou and Skoumios [20] where science literacy has four aspects and several sub-aspects; (1) Science Knowledge; presenting facts, concepts, principles and laws, presenting hypotheses, theories and models, and asking students to recall knowledge or information, (2) Scientific research; requires students to answer questions through the use of materials, requires students to answer questions through the use of graphs, tables, etc., requires students to make calculations, require students to explain answers, and engaging students in experiments and thinking activities, (3) Science as a way of thinking; describe how a scientist conducts an experiment, shows the historical development of an idea, emphasizing the empirical nature and objectivity of science, illustrating the use of assumptions, shows how science works with inductive and deductive considerations, provide cause and effect relationships, and discussing facts and evidence; (4) Interaction of science, technology and society; describing the role of science and technology in society, identifying their negative impacts, discussing socio-scientific issues, and recognizing related careers. Previous research confirms that this four-aspect framework provides a comprehensive basis for measuring students' science literacy and has been effectively applied in educational contexts to evaluate students' competencies [23].

Figure 5 Diving in Water [Source Tribun Travel, 2023, https://travel.tribunnews.com/]

Problem 1

Diving is one of the most popular entertainment alternatives. The charm of the underwater world increasingly makes many people want to explore and see the marine life in it up close. In diving, the depth issue needs to be considered because there is a maximum limit for someone to dive in the sea. The maximum limit for a recreationist is at a depth of less than 30 meters, because at a depth of more than 30 meters the diver will get very great pressure. So for a beginner, there is no need to dive to the deepest ocean to be able to enjoy the beauty of various marine life.

1. Based on the text above, for a beginner the deeper he dives into the pool his ear hurts. Why do divers feel pain in their ears as they dive deeper?
2. Based on the text above, how is the relationship between the diver's depth (depth/h) and the water pressure felt?
3. What is meant by hydrostatic pressure?

Problem 2

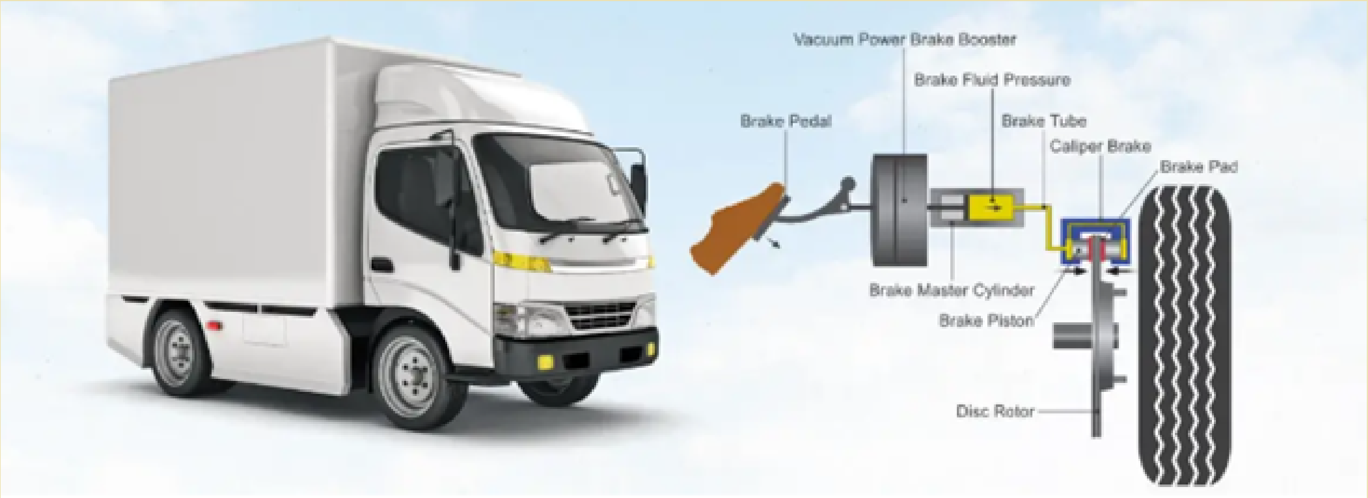

Figure 6 Hydraulic Brake [Source: https://blog.transtrack.co/teknologi/rem-hidrolik/]

Hydraulic brakes are also commonly called disc brakes because they use iron disc media as a tool for braking. This brake has a hydraulic pipe filled with brake fluid to help brake.

At each end of this pipe there are two pistons, namely the pedal piston and also the disc piston. The pedal piston is the piston that is close to the brake pedal while the disc piston is the piston that works to stop the speed of the disc so that braking can be done. The following is a sketch of the components of a hydraulic brake.

1. Based on Pascal's principle, to design a hydraulic brake on a vehicle. What is the most important thing to consider?
2. In a car, each brake is connected to one pedal (the brake pedal). If when the pedal is pressed, the pressure produced by the rear wheels is greater than the front wheels, then what should be done to the rear wheel disc brakes?

7.3. Control stage of the experiment

In the evaluation stage for the effectiveness test of the digital project-based learning model, the percentage of the average score of students' scientific literacy skills was obtained according to the predetermined scale. The percentage results can be seen in the table 5.

Based on table 5, it shows that the highest average score percentage is in the competence of explaining phenomena scientifically, which is 89.5%. This indicates that students are able to understand phenomena well, apply basic concepts, and provide scientifically sound explanations of the problems presented. Previous studies have similarly found that students often demonstrate stronger performance in competencies related to scientific explanation [24] and that this skill is a reliable indicator of overall scientific literacy. In the competence of explaining phenomena scientifically, students can be categorized as having very good scientific literacy skills.

Table 5 Score of Science Literacy

No.	Competence	Average Score Percentage	Category of Students' Science Literacy Skills
1.	Explain phenomena scientifically	89,5 %	Very good
2.	Evaluate and design scientifically	82,3 %	Good
3.	Interpret and evidence scientifically	86,3 %	Very good
Overall average score percentage		86,0 %	Very good

Furthermore, the competency of evaluating and designing scientific investigations has the lowest average score percentage compared to other competencies, which is 82.3%. Nevertheless, students' scientific literacy in this area remains in the "good" category, indicating that they are generally able to evaluate and design investigations by identifying key terms for information searches and selecting appropriate representations or images. Previous research has shown that students often face challenges in scientific investigation skills [25] but that targeted instructional strategies can improve their ability to plan and evaluate experiments effectively.

For the competency of data interpretation and scientific proof, an average score of 86.3% was obtained, so that the scientific literacy skills of students can be categorized as very good, meaning that students are able to interpret data and prove scientifically by determining the relationship between two variables, reading table data and others. Thus, the overall average score percentage was obtained of 86.0% so that overall the scientific literacy of students is categorized as very good. These findings align with previous research indicating that digital project-based learning (DPjBL) effectively enhances students' scientific literacy, particularly in high school physics education, by fostering analytical and evidence-based thinking [26].

DISCUSSION

The implementation of the digital project-based learning (DPjBL) model demonstrated significant improvements in students' scientific literacy skills, with overall achievement categorized as very good (86.0%). The strongest competence was the ability to explain phenomena scientifically (89.5%), followed by interpreting data and evidence (86.3%), while the lowest was evaluating and designing investigations (82.3%). These findings reflect both progress and challenges in embedding inquiry-based practices into Indonesian physics classrooms.

The high performance in explaining scientific phenomena is consistent with findings by Milanto, Setyarsih, and Zainuddin [3], who reported that students are generally stronger in conceptual recall and explanation than in inquiry and design. Similarly, Widodo, Yuliati, and Parno [4] showed that Indonesian high school students tend to rely on descriptive knowledge when approaching fluid mechanics tasks, which mirrors the emphasis on explanation over investigation in this study. By contrast, Eivers and Kennedy [7] noted in the PISA framework that across many education systems, students' weakest domain is inquiry design and evaluation, which aligns with the relatively lower scores found here. This suggests that the limitations are not unique to the Indonesian context but represent a broader global challenge in fostering authentic investigative skills.

The effectiveness of DPjBL in raising literacy levels also supports earlier evidence that project-based learning enhances critical thinking, problem-solving, and literacy competencies. For example, Winarni and Purwandari [6] demonstrated that PjBL improved postgraduate students' scientific literacy in science subjects, while Santyasa, Rapi, and Sara [11] confirmed its role in reducing procrastination and improving outcomes in physics learning. What distinguishes the current study is the digital integration: using tools such as PhET simulations, e-modules, and collaborative platforms enabled students to visualize and manipulate abstract physics concepts. This finding is consistent with studies by Dewi et al. [19] and Nurhasanah, Iswanto, and Nasbey [13], who found that digital supports increased motivation and engagement in physics contexts.

The comparatively weaker results in inquiry design highlight a persistent gap in Indonesian classrooms, where traditional teaching methods often emphasize memorization and formula application over authentic scientific investigation. Previous studies have documented this trend, showing that students struggle with higher-order inquiry skills when instruction focuses primarily on rote learning [2] and that lack of exposure to investigation-based tasks limits the development of scientific literacy [8]. Although DPjBL provided opportunities for inquiry, students required more scaffolding to formulate hypotheses, control variables, and evaluate data. This echoes Osborne and Allchin's [1] argument that scientific literacy must be explicitly embedded into instructional models, rather than assumed to develop incidentally. The results suggest that while DPjBL successfully integrates technology and collaboration, further emphasis is needed on teacher professional development in guiding inquiry-based learning.

From a global standpoint, the results resonate with UNESCO's call for technology-enhanced pedagogies to foster 21st-century skills, including scientific literacy and digital competence [17]. OECD/PISA assessments have also highlighted that students in many countries can explain phenomena but struggle with open-ended investigation tasks requiring evaluation and design [7]. Thus, the challenges observed in this study are not isolated but reflect a global pattern. However, the improvements achieved through DPjBL provide a promising pathway for aligning Indonesian physics education with international standards, particularly SDG 4, which emphasizes equitable access to quality education and relevant skills for sustainable development.

Overall, this study contributes to both local and global discussions on science education. Locally, it provides empirical validation of DPjBL as an effective model to improve scientific literacy in Indonesian high schools, complementing government efforts such as the National Literacy Movement. Globally, it illustrates how digital project-based approaches can respond to UNESCO and OECD frameworks by embedding inquiry, collaboration, and digital competence into science learning. Future work should focus on strengthening inquiry design competencies through teacher training and iterative refinement of the DPjBL syntax, ensuring that students are not only consumers of digital tools but also active investigators capable of designing and evaluating scientific research.

CONCLUSION

Scientific literacy involves the ability to meaningfully understand scientific concepts, explain natural phenomena, interpret them based on scientific evidence, and apply this understanding to real-life situations. These skills are particularly vital for senior high school students as they prepare to engage with scientific and societal challenges. The comprehensive development and validation of the digital project-based learning (DPjBL) model in this study demonstrated both effectiveness and practicality. The model was designed through a structured, research-based process and has been shown to significantly enhance scientific literacy. By fostering inquiry, collaboration, and the application of knowledge in real-world contexts, the digital PjBL approach offers a promising strategy for improving science education at the high school level.

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