



Developing Educational Games Based on PjBL to Improve Science Literacy

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Abstract: Students' scientific literacy skills are still categorized as very low, this occurs due to the lack of innovative learning media capable. This research aims to develop educational games based on Project Based Learning (PjBL) to improve the scientific literacy of elementary school students. This research is a type of development research (R&D) with the ADDIE development model. The methods used in this research are quantitative and qualitative methods. Data were collected through model validation assessment sheets, implementation observations, and documentation. The model was tested on 115 fifth-grade students from three elementary schools in Kulon Progo Regency. Data were analyzed quantitatively and qualitatively, then analyzed inferentially with a paired sample t-test. The results of the study indicate: (1) the validation of the educational game product obtained an average score of 89.91% from experts and 82.82% from practitioners and (2) The analysis results show a probability value of $0.00 < 0.05$, meaning there is a difference between the results of the pretest of science literacy skills and the posttest. So it can be concluded that the development of PjBL-based educational games is proven to be valid, feasible, and effective in improving the scientific literacy of elementary school students.

Keywords: Educational games; Elementary school; Project based learning; Science literacy

Introduction

Education is a crucial tool for improving the quality of a nation's future generations and ensuring sustainable national development (Sukmawati et al., 2024). Students need to possess the knowledge, personality, and skills appropriate to current learning styles, particularly in science content. Science learning is a subject directly related to students' environment, emphasizing the development of students' abilities to scientifically explore the natural environment, providing students with access to high-quality human resources (Juniati et al., 2017).

Science education creates innovative human resources with superior capabilities in both soft and hard skills, who can compete and address various global

challenges. Through science education, students can directly engage with the impact of science on everyday life. Furthermore, science learning helps students understand natural phenomena, develop critical thinking skills, and build the knowledge base necessary for advanced learning in science and technology (Anggraeni et al., 2021; Forawi, 2016).

Learning science is about adding, modifying, and sometimes removing elements from a complex of meanings and understandings (Taber, 2019). The teacher's task in science teaching is to help students explore, modify, and develop their personal frameworks of understanding to incorporate the desired aspects of scientific understanding. Meanwhile, students are responsible for asking questions, designing inquiry methods, interpreting data, reaching conclusions, and

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constructing convincing arguments (Zydney et al., 2016).

The reality on the ground shows something contradictory. The science learning process in elementary schools has tended to make students learn science concepts by simply memorizing them, which of course makes science learning boring for students (Rizkia et al., 2025). Based on the results of interviews with teachers and fifth-grade students at public elementary schools in Kulon Progo Regency, it was apparent that students felt bored and sleepy in class because teachers occasionally only used YouTube videos. Around 70% of students had difficulty understanding science learning materials and concepts, making it difficult for them to draw conclusions and apply them in everyday life. This was caused by the lack of innovative media that made students actively construct their own knowledge. Through this educational game as a substitute for traditional exercises that can motivate students to be more active in doing exercises and provide opportunities for teachers and/or teaching assistants to monitor student progress (Wu et al., 2012).

Educational games are games created for the purpose of teaching a subject in the form of software that runs on computers such as desktops, laptops, and handheld devices (Kokotsaki et al., 2016). Educational games have graphics that stimulate students' interest (Yang et al., 2018). Feedback in educational games allows students to know their learning outcomes immediately, because it is easily accessible. Many digital games have been found to develop the brain or some skills for players (Liu et al., 2019). Various educational game development models are presented so that a computer game is prepared with minimal costs and maximum benefits (Korkusuz, 2013).

Specifically, students use educational games to develop decision-making and problem-solving skills in a dynamic learning environment (Adachi et al., 2013). These easy-to-use tools can facilitate understanding and memorization of difficult material (Hanus et al., 2015). In other words, through the use of educational games, the learning process is considered more engaging, motivating (Sun-Lin et al., 2019), promotes knowledge retention (Gros, 2007), improves attention (Prensky, 2021), and can even enhance communication and scientific literacy skills.

Scientific literacy also refers to the diversity of literacy skills related to the use of digital technology in the field of science. Scientific literacy can be improved through problem-solving skills in personal and social life (Husniyyah et al., 2023). Every individual is required to possess scientific literacy, which encompasses scientific knowledge, scientific process skills, and scientific attitudes. A scientifically literate society is able

to use scientific knowledge, identify questions, and draw conclusions based on evidence to understand and make decisions regarding nature and changes resulting from human activity.

According to Erman et al. (2020), developing scientific literacy is crucial because it can contribute to social and economic life and improve decision-making skills at the community and individual levels. This is reinforced by Wen et al. (2020) who state that someone with scientific and technological literacy skills is someone who is able to solve problems using scientific concepts acquired in education according to their level, recognize technological products around them, and their positive impacts.

Pre-research data related to the questionnaire on student needs in science learning in grade V of Kalibawang State Elementary School, Kulonprogo, Yogyakarta in June 2025 showed the results of the questionnaire on student needs in science learning related to aspects of the situation and conditions of science learning with the first indicator, namely students' views on science lessons, obtaining the lowest percentage of 60%. In the aspect of the learning process related to scientific literacy, especially the eleventh indicator containing obstacles in science literacy also obtained a low percentage of 58.33%. This proves that students still experience difficulties in understanding science learning materials and concepts, so they have not been able to solve problems, draw conclusions, and apply them in everyday life. In addition, the results of the use of media, methods and development of science literacy instruments in the sixth, seventh, and twelfth indicators respectively obtained percentages of 62.5%, 58.25%, and 69.5%, included in the low category. This is caused by the lack of innovative media, models, and development of science literacy instruments that make students actively construct their own knowledge in science learning.

Facts on the ground show that Indonesian students' scientific literacy skills are still low. This fact is supported by survey results (OECD, 2019) stating that scientific literacy achievement is low in all aspects (content, process, and context). The results of the 2018 PISA for science competencies, Indonesia ranked 62nd out of 71 participating countries. Judging from the distribution of literacy itself, nationally only 25.38% of scientific literacy was considered sufficient, while 73.61% was considered insufficient. This is reinforced by (Justin et al., 2019) that the learning environment and climate in schools influence variations in student literacy scores. A similar statement was expressed by Jufri et al. (Jufri et al., 2016) that the science learning process only focuses on memorization rather than understanding. This condition is the cause of students' low scientific literacy skills. Therefore, we need learning that can train

students' scientific literacy skills. Learning that can train scientific literacy skills is learning that integrates the Project-Based Learning (PjBL) approach.

The impact of Project-Based Learning (PjBL) and direct teacher instruction on student academic achievement in primary, secondary, and tertiary education demonstrates a learning process in which students engage in authentic projects and product development (Chen et al., 2019). Through involvement in real-life projects, students are encouraged to collaborate, explore, solve problems, and communicate their findings. This makes the learning process not limited to theory alone, but more applicable in everyday life (Syarifudin et al., 2024). Similarly, Guo et al. (2020) project-based learning (PjBL) refers to an inquiry-based teaching method that engages students in knowledge construction by requiring them to complete meaningful projects and develop real-world products (Brundiers et al., 2013; Krajcik et al., 2014). This creation process requires students to collaborate to find authentic solutions or problems in the process of integrating, applying, and constructing knowledge (Guo et al., 2020).

PjBL focuses on providing the stimulus needed for students to actively participate in their learning, thereby maximizing their understanding and critical and creative thinking capacity (Zulyusri et al., 2023). The syntax of the PjBL model is as follows: (1) project identification and formulation; (2) project completion design; (3) schedule preparation; (4) project completion; (5) report preparation; (6) evaluation and presentation of project results (Hendrawati et al., 2024; Permana et al., 2021; Widiastuti et al., 2024).

Previous research findings indicate that game development has many potential benefits as a teaching aid for computer science, software engineering, art design, and other fields, thereby improving students' knowledge, skills, attitudes, and behavior (Wu et al., 2012). The results of the study (Juleha et al., 2019) showed that the score obtained from the N-Gain calculation in the experimental group was 0.467 and the control group was 0.350. There was an increase in students' scientific literacy scores after treatment with projects in problem-based learning. Similar to the results of previous research Jamaludin et al. (2023) that the average normalized change scores of the two groups were 69.7 and 39.8, respectively, in the high category for the experimental group and the medium category for the control group. Thus, the application of project-based learning assisted by POE can further improve the scientific literacy of high school students compared to problem-based learning in thematic learning.

The novelty of this research lies in the innovation and application of educational game media based on the Project Based Learning (PjBL) model to improve the scientific literacy of elementary school students. The

urgency of this research is based on the need for learning media that is not only limited to measuring students' scientific literacy, but also interesting, challenges students to complete a mission, is easily accessible, and suits the characteristics of digital natives in elementary school students today. Therefore, this research provides a more meaningful and contextual learning experience, because students are not only playing while learning, but also directly involved in the process of designing, working on, and reflecting on real problem-based learning projects.

This research aims to develop a PjBL-based educational game to improve scientific literacy. This PjBL-based educational game will help students better understand ecosystems, thereby improving scientific literacy and applying it to everyday life. The novelty of this research is the creation of an educational game that fosters scientific literacy by integrating the PjBL model.

Method

This research was conducted in three public elementary schools: Semaken, 1 Dekso, Kalibawang, and Banjarharjo. The population consisted of fifth-grade students and teachers at three elementary schools in Kulon Progo Regency. The sample was selected using purposive sampling, a deliberate selection based on specific criteria aligned with the research objectives (Campbell et al., 2020). A limited trial was conducted in grade V of Kalibawang and Banjarharjo Public Elementary Schools, with 61 students. A broader trial was conducted in Semaken Public Elementary School, with 24 students as the control class, and Dekso Public Elementary School, with 30 students as the experimental class. The research began in May 2025. The selected teachers were senior class teachers, experienced in teaching science, and willing to participate in all stages of product validation and implementation.

The selection of fifth-grade elementary school students as the target for implementing PjBL-based educational games to improve scientific literacy was based on their suitability with Phase C Learning Outcomes (CP) in the Independent Curriculum, namely the characteristics of educational game applications that are appropriate to the level of ability and psychological development of children.

This study used the Research and Development (R&D) method with the ADDIE model (Misesani et al., 2020; Nadiyah et al., 2015). The research methods used were both qualitative and quantitative. Qualitative data were obtained through observations, criticism, and suggestions from validators. Quantitative data were obtained from the results of an assessment questionnaire administered to media, materials, and language experts, practitioners PjBL-based educational game products,

and the results of a science literacy test. The stages of development of this educational game product are described as follows.

The first stage of R&D was conducting a needs analysis, literature review, observation, and interviews with teachers. The needs analysis was conducted to identify initial learning challenges, the literature review was conducted to determine ideal learning conditions in schools, and observations and interviews were conducted to identify field issues, such as collecting research information/data, implementing the Independent Curriculum, and utilizing learning resources (Priska et al., 2021; Rustandi et al., 2021).

The second stage in research and development is design. After analyzing the problem, researchers then conduct research design. At this stage, the process begins with establishing learning objectives, designing scenarios or teaching and learning activities, designing learning tools, designing learning materials, and developing learning outcome evaluation tools. Researchers design educational game applications based on the needs analysis and existing problems.

The game developed is a matching game related to harmony and ecosystems in the Natural and Social Sciences (IPAS) subject. The third stage is development. The educational game development process involves several stages, including product creation, product validation by experts (media, language, materials, and practitioners) (Montes et al., 2023), product revision, and limited trials. These stages are carried out to determine the feasibility of the developed product before testing it on elementary school students.

The fourth stage in research and development is implementation. Products that have been declared suitable for use are then used in research and trials. A limited trial was conducted at Kalibawang Elementary School 5, and a broader trial was conducted at Dekso Elementary Schools 2 and 5. The implementation stage aims to determine the effectiveness of the product after using PjBL-based educational games to improve science literacy. This stage is the final revision of the product, refined based on input and the results of the broader trial. The product is assessed by teachers and students. The following is a flowchart of research into the development of PjBL-based educational games to improve scientific literacy.

This research employed several data collection techniques, including questionnaires (expert validation, media validation, language validation, and practitioner validation), observation, and documentation. Observations were conducted in three main stages to obtain a comprehensive picture of the learning ecosystem and develop more effective educational game products. The documentation study involved analyzing

documents that could provide data to support educational game development.

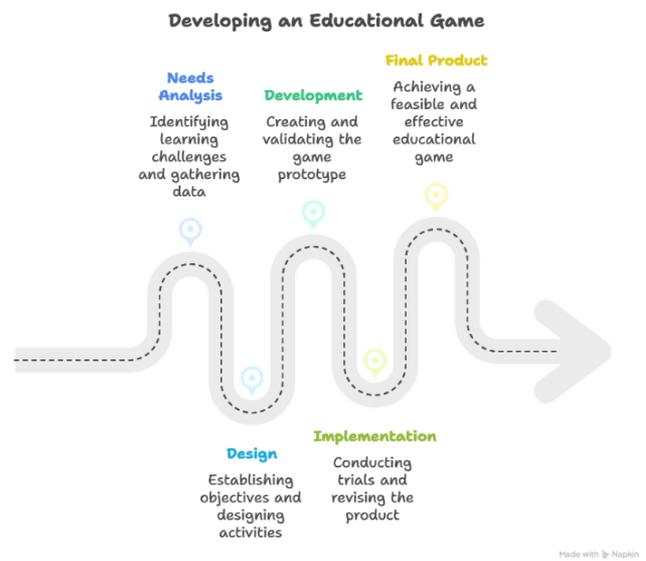


Figure 1. Flowchart of PjBL-based educational game development

All instruments used in this study were validated before being applied to the trial phase. According to Taherdoost et al. (2017) validity is the degree to which the items in an instrument reflect the content to be generalized by the instrument. The assessment was carried out by three expert validators using a four-point scale (1 = not feasible, 2 = less feasible, 3 = quite feasible, and 4 = very feasible). The data analysis techniques used in this development used quantitative and qualitative descriptive techniques. Quantitative analysis involved data from expert team validation (materials, media, and language) to determine the average score, which was then analyzed qualitatively. All results in the form of comments, suggestions, and feedback were explained in descriptive descriptions. The measurement scale used in this study was a Likert scale. The total of each data was also converted into percentage form, with the formula:

$$P = \frac{f}{N} \times 100\% \tag{1}$$

Where, P = percentage; F = total value of collected results data; and N= maximum score. The percentage results obtained are implemented in the following criteria:

Table 1. Assessment Criteria (Riduwan, 2012)

Percentage	Eligibility Criteria
0-20%	Not suitable
21-40%	Less suitable
41-60%	Quite suitable
61-80%	Suitable
81-100%	Very suitable

Next, the data were analyzed inferentially using a paired sample t-test using IBM statistic 25 to see the difference in scientific literacy improvement before and after implementing PjBL-based educational games. Before conducting the paired sample t-test, the research data were tested for normality and homogeneity using the Shapiro-Wilk and Levene tests. If the data did not meet the assumptions of normality or homogeneity, the data analysis was continued using Quade's Rank Analysis of Covariance.

Result and Discussion

These findings outline two aspects: the feasibility and practicality of PjBL-based educational games for improving scientific literacy. The full description is as follows:

The Feasibility of PjBL-Based Educational Game Products to Improve Science Literacy

The analysis results indicate that teachers have understood the concept of the PjBL approach and scientific literacy. However, teachers do not yet have extensive experience in using PjBL-based educational games in learning. Teachers need information on upgraded ways to improve students' scientific literacy through the implementation of educational games. The development of PjBL-based educational games is also needed by teachers as an innovative medium to face the challenges of education and current technological developments. Unfortunately, the use of educational games in classroom learning has not been maximized by teachers. Furthermore, the implementation of PjBL-based educational games has never been done at all by teachers in schools. This statement is based on the results of a questionnaire analysis regarding teachers' needs for PjBL-based educational games. Complete data is in Table 2.

Table 2: Percentage Results of the Questionnaire on Teachers' Needs for PjBL-Based Educational Games

Qualification	Score Percentage	Aspect
The need for educational games	81.5%	High
The need for integrated teaching materials	83.1%	Enough
The need for LKPD PjBL	76.05%	High

Based on research questionnaire data from elementary school teacher respondents, it was identified that the percentage of teachers' need for PjBL-based educational games reached 80.22%. This means that teachers still need PjBL-based educational games. Educational games can quickly hone students' problem-solving skills. The use of educational games is part of

technological developments that educators can leverage to meet learning needs. A complete description is as follows.

These findings became the basis for researchers to address existing problems by designing an educational game based on PjBL. The game design has several components. First, the homepage contains the topic title "harmony and ecosystems". Second, the menu section covers the material related to the process of eating and being eaten, food chains, food chain elements, examples of food chains, food webs, food pyramids, harmonious ecosystems, causes of extinction, and efforts to maintain a harmonious ecosystem. In the edu game 1 menu section, there is a "matching game" from levels 1-4 with increasingly complex questions. In the LKPD menu section, there is an introduction to PjBL-based mini-research consisting of problem identification, project planning, project schedule preparation, project implementation and monitoring, project presentation, and project evaluation and reflection.

The educational game was developed following expert input, media, language, and content. Improvements were made to several aspects, such as the cover, completeness of the material, and the level of questions. There was input to improve the cover so that it was not only plain without color but could be highlighted with images related to the material, namely ecosystems, so that it could attract students' attention. There were improvements to the layout of the text placed on the left side of the home menu. The nuances created have a multi-colored pattern. The use of ecosystem images adds a natural feel that is liked by elementary school students. The selected image themes were also adjusted to the theme of the material in the study. The results before and after the revision are presented in Figure 2.



Figure 2. Changes to the cover on the home menu

The completeness section contains game usage instructions and material related to harmony and

ecosystems. Each section of the material is presented concisely and comprehensively. The material is supported by various relevant images. This makes it easier for students to remember each topic covered in this educational game application. It would be beneficial to provide captions for each section containing a collection of images to avoid multiple interpretations. The images presented are also clear and high-resolution. Educational game development also highlights the availability of user instructions. These instructions are intended for teachers and students to understand the process of using an educational game before using it. Game user instructions can also be termed a user guide. A user guide is a document that provides detailed instructions on how to use a product. It serves as the primary communication tool between the creator and the end user. Guides are designed to help users understand and use the product effectively (Unger et al., 2023).

The next section covers the content of Harmony and Ecosystems. The main topics include eating and being eaten, the food chain, elements of the food chain, examples of food chains, food webs, food pyramids, harmonious ecosystems, extinction, and how to maintain a harmonious ecosystem. The materials are outlined based on the learning outcomes that students must achieve. The materials are also interspersed with colorful images to increase student concentration and facilitate understanding. Figure 3 shows the results of the material development in a PjBL-based educational game to improve scientific literacy.

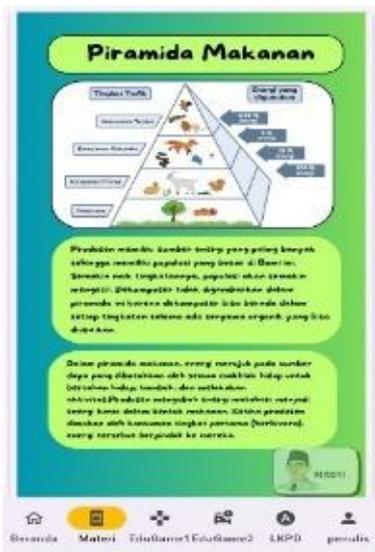


Figure 3. Material related to the food pyramid

Furthermore, in the question level menu, there are several levels and matching questions and answers. The higher the level, the more complex the questions. Each level in this educational game represents each topic

related to "Harmony and Ecosystems." There are questions and short answers that are interconnected. To use this game, open each board provided and find the matching answer board. Each board with a matching question and answer will remain open, and vice versa, if it does not match, the board will close again. Each level in this educational game starts from basic level questions to complex or high-level questions. This is because the complexity of understanding increases, so teachers must increase the game level while monitoring students' absorption and understanding for continuous evaluation (Dwiharja, 2015). The results are as shown in Figure 4.

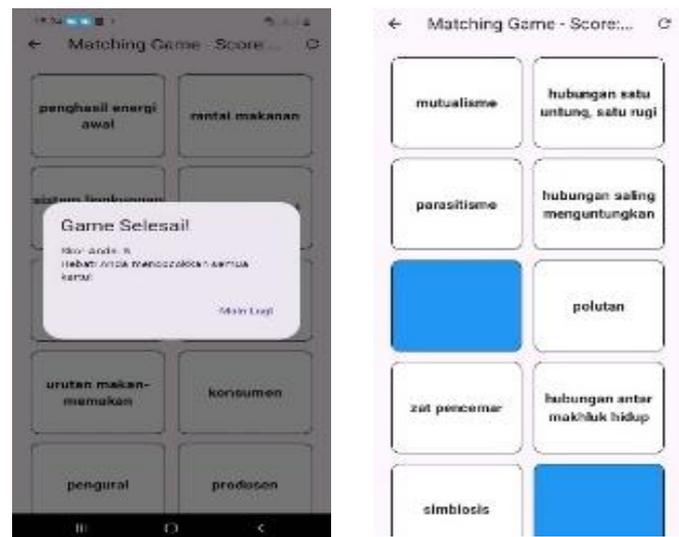


Figure 4. Educational Game "Matching Game" at Levels 1 and 4

The product was then tested for validity by media, content, and language experts. Media validation aspects included the cover layout of the educational game, cover typography, educational game illustrations, content layout, content typography, and content illustrations. Language validation aspects included language suitability, reading suitability, vocabulary selection accuracy, writing accuracy, and paragraph accuracy. The things assessed from the material aspect were presentation, content, language, and graphics. The results of expert validation can be seen in Table 3.

Based on Table 3, it was found that all validation aspects (media, language, and materials) were qualified as adequate. The validation results by media experts for the PjBL-based educational game product obtained an average percentage score of 79.11%, qualifying as adequate. From the media aspect, the feasibility of the educational game has reached a high category based on the feasibility of illustrations, colors, fonts, user interface, educational games, and functionality. Several of these indicators have been adjusted according to expert opinion. As found by Daryanes et al. (2023),

media validation highlights three things: the product's display design, the animation used, and the product's content presented. In line with this, the findings of Dolo et al. (2023) also explain that media validation emphasizes the appearance of the product being developed. Their findings concluded that the local wisdom-based hybrid audiovisual e-book product was declared valid in terms of media aspects.

Table 3. Expert Validation Results

Validation	Aspects	Final Validation Results	
		Score	Qualification
Media expert	Illustration feasibility	100%	very worthy
	Color feasibility	70.25%	worthy
	Font feasibility	79.28%	worthy
	User interface feasibility	80%	worthy
	Educational game feasibility	82%	very worthy
	Functional feasibility	85%	very worthy
Linguist	Language suitability	87.5%	very worthy
	Suitability of reading	90%	very worthy
	Accuracy of vocabulary selection	75%	worthy
	Accuracy of writing	81.25%	very worthy
Material Expert	Paragraph Accuracy	80%	worthy
	Presentation	71.15%	worthy
	Content	71.05%	worthy
	Language	72.92%	worthy
	Contextual	70.31%	worthy
	Appropriateness Material	73.31%	worthy
	Appropriateness with Tri-N Syntax Worksheet	75%	worthy
	Appropriateness with PjBL Syntax		
	Illustration	80%	worthy
	Appropriateness		

The educational game features engaging visuals for students. Through the use of technology, the images become more relevant to students' lives and align with the characteristics of elementary school students. The integration of visual elements and student activities in educational games is attractive to students (Yulia et al., 2024). The use of visual elements in the form of images and animations bridges students' information processing in their brains by utilizing two cognitive channels (verbal and visual) (Howard et al., 2022). In relation to educational games, AI visualizations containing ecosystems not only deepen content but also stimulate students' critical thinking through observation

and independent knowledge construction (Garzón, 2021). Thus, the development of PjBL-based educational games addresses the characteristics of elementary school students and maximizes their potential through innovative learning strategies.

Furthermore, the average score from linguists was 82.75%, qualifying as very appropriate. Indicators in the language assessment include language suitability, reading suitability, vocabulary selection accuracy, spelling accuracy, and paragraph accuracy. This language assessment indicates that the language in the educational game has been adapted to the characteristics and abilities of elementary school students. With this in mind, words and sentences in the reading are kept simple for users. Font usage and font size are also considered to ensure clear reading. The results of the study on the language suitability of the product have also been agreed upon by other researchers. According to Ishaq et al. (2022) concluded that the educational game product they developed met the criteria for language suitability. Indicators focused on language aspects include sentence use, spelling, and paragraphing.

The results of content validation showed an average of 73.39% with adequate qualifications. There are seven things emphasized, namely presentation, content, language, contextual appropriateness, suitability of material with PjBL syntax, suitability of Student Worksheets (LKPD) with PjBL syntax, and suitability of illustrations. In terms of content, PjBL-based educational game products contain coherent presentation results, contain material content that is appropriate between learning outcomes and learning objectives with the latest material content, contain communicative, contextual language, material breakdown that integrates the PjBL model, LKPD has applied PjBL syntax, and the illustrations used are appropriate to the topic of the material by utilizing technology.

Expert opinion indicates that this educational game product contains content appropriate for the science subject. The instructions in this educational game are also precise and clear, allowing users to follow the instructions coherently. The components targeted in this study were also implemented by previous researchers. Hafiz et al. (Hafiz et al., 2022) conducted development research and highlighted content validation on several items, such as the use of images, graphics, and product presentation. Their validity test results achieved a percentage above 80%. This value was declared accurate. Their opinion is agreed with by Yusoff (2019), who emphasized content validation in the presentation of material within the product. This is done to ensure users understand the material well.

This finding aligns with the function of content validity. Content validity is used to identify the suitability of the content and materials being developed, primarily regarding the suitability of learning outcomes to learning objectives (Hutama, 2016; Nuri et al., 2023). This suitability aligns with previous findings that a valid product must contain competencies and topics with clearly developed learning objectives (Rahman et al., 2021; Rini et al., 2021).

Practicality of PjBL-Based Educational Game Products to Improve Science Literacy

The results of the practicality test were obtained after implementing a PjBL-based educational game. The learning implementation included activities carried out by teachers and students while using the educational game. Implementing the educational game involved three stages: planning, implementation, and evaluation. The planning stage involved developing an educational game product based on the material to be taught. In this case, an educational game application was developed with ecosystem-related material components integrated with the PjBL model. One example of documentation of the educational game utilization activity is presented in Figure 5.

After implementation, the PjBL-based educational game product to improve science literacy was assessed by education practitioners and students. The purpose of the assessment was to gather information to improve the product in subsequent revisions. The assessment was carried out by a fifth-grade elementary school teacher by providing practitioners with a validation sheet for the PjBL-based educational game product. The results of the practitioner response test are presented in Table 4.

Table 4 shows that the educational game assessment results from practitioners reached 89.91%, qualifying as very appropriate. This achievement indicates that PjBL-based educational game products have received a positive response from teachers as practitioners in the field (classroom). This positive response is due to the sophistication of the educational game technology developed. The applications in

educational games contain material different from the textbooks teachers typically use. For example, science and science subject matter and student worksheets (LKPD) are linked to the PjBL model, thus enhancing students' thinking processes and developing scientific literacy skills. These skills are developed through the learning process of understanding, applying, and communicating scientific knowledge in various life contexts (Akhter et al., 2021).

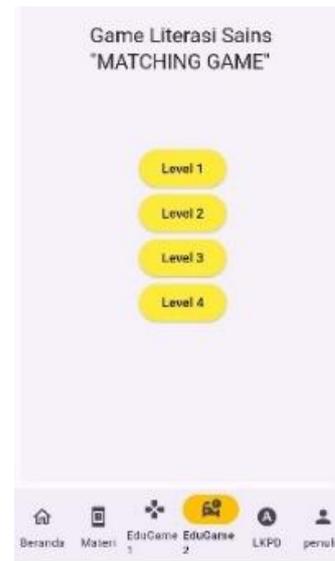


Figure 5. Utilization of educational games in learning

Another positive response emphasized the use of materials that stimulate scientific literacy in their creation. The visualization of material in the form of images in educational games motivates students to follow the learning process to completion. The material is also presented systematically and integrated with the PjBL model. The problems presented are still relevant to the students' environment. Many moral messages and social values are learned after using PjBL-based educational games. Educational games include material descriptions, matching games, and student worksheets (LKPD) that encourage the development of scientific literacy skills.

Table 4. Validation of Teaching Materials by Practitioners

Aspect	Percentage			Qualification
	Practitioner 1	Practitioner 2	Average	
Self-Instruction	90%	93.2%	91.6%	Very Worthy
Self-Contained	88%	95%	91.5%	Very Worthy
Stand Alone	84.5%	78%	81.25%	Very Worthy
Adaptive	95%	91%	93%	Very Worthy
User Friendly	92%	92.42%	92.21%	Very Worthy
Average			89.91%	Very Worthy

The developed teaching materials met the criteria of self-instruction, self-contained, stand-alone, adaptive,

and user-friendly. These five indicators demonstrate that the educational game product is considered

practical for improving elementary school students' scientific literacy skills. These results align with previous findings that the developed product achieved a high practicality score (Rofi et al., 2023). Other research also shows that gamifying education products meet practicality requirements and are categorized as valid (Dichev et al., 2017).

In addition to the practitioner assessment results, student responses to the PjBL-based educational game were also examined. This data was obtained from distributing questionnaires to students. The complete results are shown in Table 5.

Table 5 shows that student responses to the PjBL-based educational game reached 82.82%, qualifying as

very good. Several comments were made by students regarding the PjBL-based educational game. Students gave a positive response, indicated by their desire to conduct similar learning in future lessons. Students were impressed with the learning that utilized educational games. This was because they were not yet accustomed to using educational game-based technology via smartphones. They also felt limited in the harmony and ecosystem material in the learning, as it was grouped according to the stages of the PjBL model. The presence of this PjBL-based educational game brought the nuance that students had longed for.

Table 5. Validation of Teaching Materials by Students

Aspect				Percentage		Qualification
	High Category Students	Medium Category Students	Low Category Students	Average		
Self-Instruction	88%	91.5%	93.25%	90.92%	Very Worthy	
Self-Contained	83.5%	84.75%	90.25%	86.17%	Very Worthy	
Stand Alone	75%	80%	88%	81%	Very Worthy	
Adaptive	83%	75%	75%	77.67%	Worthy	
User Friendly	75%	80%	80%	78.33%	Worthy	
Average				82.82%	Very Worthy	

The book's instructions are also easy to follow. The sentences used are coherent and clear. They were also attracted by the visuals in the teaching materials. The material in the educational game application is familiar to students, making it easy for them to follow along. The material in this educational game is considered sufficient when other learning media are not available. This is because the learning process aligns with the educational game application's content, which can be implemented anywhere and anytime. They can learn flexibly, as it can be studied anytime and repeated. Furthermore, the teaching materials also include factual examples of ecosystem learning, particularly those related to problems that disrupt ecosystems and efforts to preserve them. According to students, this educational game application can be taken anywhere and anytime because it is digital. Parents can also review the educational game application that students are learning through this media.

Students' responses to the practicality of the teaching materials indicate that they have passed the quality assurance test. This aligns with Hamweete's theory (Hamweete, 2012), which states that teaching materials must pass the quality assurance test. Quality assurance procedures must be in place to achieve the objectives of procuring these teaching materials, especially in educational institutions (Kankaew et al., 2021). These procedures also ensure that the quality of

educational game applications meets the needs of today's educational environment.

The positive assessments given by students also align with previous findings. Other findings also claim that gamed products can be applied to digital educational game development projects for all grades (Kokotsaki et al., 2016). This is consistent with the statement (Miller et al., 2017) that educational games must have content that is developmentally appropriate, taking into account children's skills and abilities. This is also in line with the findings of Sungkaew et al. (2022), who claim that educational game evaluations have been received with adequate qualifications. However, teachers continue to be guided and encouraged to consider attractive features in the product as an important part of the material. An educational game product must be innovative and motivate student learning.

Validation of PjBL-Based Educational Game Products to Improve Science Literacy Normality and Homogeneity Tests

Science literacy skills were measured through questionnaires and cognitive tests. Optimal achievement of these parameters can be influenced by the learning model applied in the classroom. The results of the Shapiro-Wilk and Levene analyses of the data obtained in this study are presented in Table 6. The results of the Sig. value of science literacy skills (questionnaire and

cognitive test) from the Shapiro-Wilk test shown in Table 6 are 0.068 and 0.060, while the Levene test obtained a sig. value of 0.205. Thus, all data obtained

from this study have met the assumptions of normality and homogeneity.

Table 6. Results of the Normality and Homogeneity Test of Research Data

Data	Shapiro-Wilk Statistical Test	Levene's Statistical Test
Science literacy skills (questionnaire)	0.068	0.205
Science literacy skills (cognitive)	0.060	

Paired Sample T-Test

A paired sample t-test was conducted after the pretest and posttest scores were confirmed as normal using the Shapiro-Wilk test for normality and the Levene

test for homogeneity. The data, which were deemed normal and homogeneous, were then processed using the paired sample t-test using SPSS 22, as shown in Table 7.

Table 7. Paired Sample T-Test

		Paired Samples Test								
		Mean	Std. Deviation	Std. Error	Paired Differences		T	Df	Sig. (2-tailed)	
					Mean	95% Confidence Interval of the Difference				
					Lower	Upper				
Pair 1	Pre- science literacy (cog) - Post science literacy (cog)	-6.963	3.094	.596	-8.187	-5.739	-11.692	26	.000	
Pair 2	Pre-science literacy (questionnaire) - Post science literacy (questionnaire)	-4.407	2.223	.428	-5.287	-3.528	-10.301	26	.000	

Based on the table above, the sig. (2-tailed) value is 0.000, this value is smaller than 0.05 or $0.000 < 0.05$, so it can be seen that there is a significant difference between the pretest results of scientific literacy skills that have not been treated and the posttest that has implemented PjBL-based educational game products in Natural and Social Sciences (IPAS) subjects in elementary schools. Thus, it can be concluded that the implementation of PjBL-based educational game products has a significant effect on scientific literacy skills.

The data obtained were then analyzed descriptively. Table 8 shows that the average score for students' scientific literacy skills before and after implementing the PjBL model increased from 32.22 to 39.19. Meanwhile, the average score for the scientific literacy skills questionnaire before and after implementing the PjBL-based educational game product increased from 13.74 to 18.15. This indicates an increase in scientific literacy skills after being introduced to PjBL-based educational games in elementary school science

Table 8. Average Science Literacy Skills Before and After Implementing the PjBL Model

		Paired Samples Statistics				
		Mean	N	Std. Deviation	Std. Error Mean	
Pair 1	Pre-science literacy (cog)	32.22	27	3.457	.665	
	Post-science literacy (cog)	39.19	27	2.856	.550	
Pair 2	Pre-science literacy (questionnaire)	13.74	27	2.877	.554	
	Post-science literacy (questionnaire)	18.15	27	1.748	.336	

The results of the study showed an increase in scientific literacy skills after the implementation of PjBL-based educational game products. Based on the Paired Sample T-Test, it showed that there was a significant difference between the pretest results of scientific literacy skills that had not been treated and the posttest that had implemented PjBL-based educational game products. The descriptive results related to the average pretest and posttest of scientific literacy skills after the implementation of PjBL-based educational game

products in the Natural and Social Sciences subjects also experienced an increase, which is presented in Table 9.

Project-Based Learning (PjBL) emphasizes that students are the focus of learning and invites them to participate in long-term, complex, and interdisciplinary projects (Fatimah, 2018; Perez et al., 2020). These projects are designed to address real-world problems or relevant research questions, requiring students to plan, execute, and apply their work independently (Simbolon et al., 2020; Yustina et al., 2020). Isabekov and Sadyrova reported that implementing project activities in learning

is an innovative breakthrough that can transform the learning process into a means of developing student creativity (Isabekov et al., 2018). Furthermore, a similar explanation was provided by Movahedzadeh, who stated that project activities require students to solve problems by producing a product creatively (Movahedzadeh et al., 2012).

These findings collectively indicate that students' scientific literacy skills have increased with an average post-test score of 83.16 and an overall N-Gain value of 0.57 and is included in the moderate category. Furthermore, the effect size test results of 3.23 (high) indicate that the PjBL-STEM model has an effect on improving students' scientific literacy (Berliana et al., 2024). In agreement with previous results (Wahyu et al., 2023) showed that the potential of the STEM-based PjBL approach, combined with authentic Manggarai science content, is an effective way to improve scientific literacy among elementary school students. The same thing was expressed (Wahyu et al., 2023) that the T-test of the average student's scientific literacy skills showed that the integrated module of the STEM-assisted PjBL model affected scientific literacy skills. Meanwhile, according to Dibyantini et al. (2023), scientific literacy skills were 0.46, categorized as moderate, and significantly increased by 81% in the aspect of explaining scientific phenomena. According to Marjanah et al. (2021), scientific literacy skills increased by 0.56% after implementing a PjBL-based practical module. Therefore, it can be concluded that the implementation of PjBL-based educational game products is effective in improving students' scientific literacy skills in elementary schools.

Research conducted by Restiani et al., (2024) showed that there was an influence of the LAGA game design assisted by wardwall on self-efficacy and scientific literacy. In line with the results of this study, Widyaningrum et al. (2024) showed that the guided inquiry model assisted by the wardwall educational game had a positive effect in improving the scientific literacy skills of fourth-grade students at Welahan State School 4. Further research was conducted by Handayani et al. (2023) with results showing that there was an influence of the PjBL model through the manufacture of bioplastic preservation on students' creative thinking skills and scientific literacy. In addition, research conducted by Karmana (2024) also showed that the application of the Project Based Learning model contributed positively to improving critical thinking skills, problem solving, was able to improve scientific literacy, and was able to improve student learning outcomes.

However, this study has several limitations, which are outlined below. First, the study was conducted on a small sample size and at a single level, thus limiting the

generalizability of the results. Second, the instrument used to assess scientific literacy skills was only used at the beginning and end of the learning process, thus not being able to accurately describe scientific literacy skills at each phase of the learning process. Furthermore, the generalizability of the study results may be limited, as this study focused exclusively on fifth-grade students who received science and science material related to ecosystems and harmony. The limited duration of the study, which was limited to one semester, raises concerns about how to capture the long-term impact of the PjBL model on student outcomes, retention, and professional development.

Conclusion

The PjBL-based educational game product has been proven valid, feasible, and effective in improving the scientific literacy of elementary school students. The product was declared feasible after undergoing one revision with the addition of several components to each material in the application by content, language, and media experts. In terms of practicality, the product was declared practical because it met the aspects of independent, self-directed, self-directed, adaptive, and user-friendly learning. Furthermore, the results of the Paired Sample T-Test showed a significance value (sig. 2-tailed) of 0.000. This indicates that the development of PjBL-based educational games can improve the scientific literacy of elementary school students. This educational game product can be applied in learning to stimulate students' scientific literacy skills. This research can enrich the literature on technology-based learning strategies that not only function as visual and interactive aids, but are also able to internalize scientific thinking processes and educational values. Limitations in this study include the use of media that can only be accessed digitally and requires an internet network. Further research can introduce the latest technology to be applied in learning to create a communicative learning environment.

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