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Development of an Inquiry-Based e-LKPD High School Science on the Topic of Pressure to Improve Scientific Literacy

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Abstract

The low scientific literacy of Indonesian students, as reported by PISA and the 2023 ANBK at SMP Negeri 3 Samalantan, is driven by abstract, teacher-centered science instruction on the topic of Pressure. This study aims to develop and evaluate the feasibility, practicality, and effectiveness of an Inquiry Learning-based Electronic Student Worksheet (e-LKPD) to improve students' scientific literacy. This Research and Development (R&D) study applied the ADDIE model. Data were collected using validation sheets, response questionnaires, and OECD-aligned scientific literacy pretests/posttests. The results showed that the e-LKPD is highly feasible based on content (80%), syntax construction (78%), and language (82%) evaluations. It was also deemed highly practical due to interactive multimedia elements that foster independent learning via devices. In the limited-scale trial, the students' average score increased significantly from 36 to 65 ($0.000 < 0.05$). In the large-scale trial, the inquiry e-LKPD group achieved a higher score increase (37.12 to 58.85) than the conventional group (32.14 to 43.33). The MANOVA test ($0.002 < 0.05$) confirmed that integrating structured scientific investigations and real-world phenomena (e.g., submarines and hydraulic brakes) is significantly superior in enhancing scientific reasoning compared to standard methods. In conclusion, this e-LKPD is an effective instructional innovation to transition from passive to active, student-centered learning.

Keywords: ADDIE, e-LKPD, Inquiry Learning, Pressure, Scientific Literacy

1. Introduction

Indicator of the quality of education in Indonesia can be seen through the results of the Programme for International Student Assessment (PISA), particularly in the aspect of scientific literacy (OECD, 2023). Scientific literacy is the ability of individuals to understand scientific concepts, apply scientific knowledge to solve problems, and make decisions based on scientific evidence in everyday life (Ke, L., et.al, 2021). This ability has become increasingly important in the 21st century because the development of science and technology requires students to possess critical and analytical thinking skills and to understand scientific phenomena contextually (Pertiwi, N. P.,et.al, 2024).

The PISA results indicate that the scientific literacy ability of Indonesian students is still relatively low compared to other countries. Based on the OECD report, Indonesia remains in the lower group in terms of scientific literacy achievement. PISA 2018 results that Indonesian students' scientific literacy ranked 73rd out of 79 participating countries (OECD, 2023). These findings indicate that most students still experience difficulties in understanding scientific concepts, interpreting data, and applying scientific knowledge to solve real-life problems. Another study by Rahayu, (2023) also found that the scientific literacy ability of students in Bandung City was still low, highlighting the need for learning approaches that train students to think scientifically and participate actively in the learning process.

The low level of scientific literacy can also be observed through the results of the Computer-Based National Assessment (ANBK). Based on the 2023 educational report of SMP Negeri 3 Samalantan, students' ability to identify explicit information and make simple interpretations was still categorized as low. This condition indicates that students' abilities to understand information, reason logically, and connect concepts with real-life situations still need improvement. In fact, scientific literacy is not only related to mastering science concepts but also to the ability to apply such knowledge logically and scientifically in everyday life (Harefa, 2023).

One of the factors contributing to the low level of students' scientific literacy is the learning process, which remains predominantly teacher-centered and provides limited opportunities for students to engage in authentic scientific inquiry. Science instruction frequently emphasizes the acquisition of factual knowledge and memorization of concepts rather than fostering students' abilities to observe phenomena, formulate investigable questions, design investigations, analyze evidence, and construct scientific explanations. Consequently, students often demonstrate difficulties in applying scientific concepts to real-life contexts, evaluating scientific evidence, and making evidence-based decisions, which are core components of scientific literacy (Eugenio-Gozalbo, et.al, 2022).

To address this issue, Inquiry Learning has been widely recognized as an effective instructional approach for developing students' scientific literacy. Inquiry is a learning process that actively engages students in constructing scientific knowledge through investigation and evidence-based reasoning (Antonio, et.al, 2024). Through inquiry activities, students develop essential scientific competencies, including questioning, experimenting, interpreting data, and drawing conclusions. Previous studies have consistently reported the positive effects of inquiry-based learning on conceptual understanding, science process skills, and scientific literacy (Fajeriadi et al., 2024). Furthermore, a meta-analysis conducted by Uthaikanchanakul, (2025) concluded that inquiry-oriented instruction significantly improves students' conceptual understanding and scientific process skills across different educational settings.

In parallel with the rapid advancement of educational technology in the era of the Industrial Revolution 4.0, digital learning media have emerged as promising tools to support inquiry-based instruction. One such innovation is the e- LKPD, which integrates multimedia elements such as text, images, videos, animations, and interactive simulations to facilitate independent and collaborative learning. Inquiry-based e- LKPD can guide students through systematic scientific investigations while promoting active engagement in the learning process (Agustina & Aloysius, 2026). Firdaus, Ramli, and Wati (2021) reported that inquiry-based e- LKPD significantly enhanced students' scientific literacy by supporting observation, data collection, and interpretation of experimental findings. (Andriana et al., 2022)

Despite these promising findings, several research gaps remain. First, previous studies have primarily focused on examining the effectiveness of inquiry learning or electronic LKPD separately, with limited attention given to the integration of inquiry pedagogy within interactive electronic worksheets designed specifically to foster all dimensions of scientific literacy. Second, many existing electronic LKPDs mainly emphasize conceptual understanding and science process skills, while relatively few explicitly address the competencies of scientific literacy as defined by international assessment frameworks, such as explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific evidence and data. Third, most previous studies have been conducted in general science learning contexts, with limited research investigating inquiry-based electronic LKPD in chemistry learning, particularly on abstract topics that require visualization and active investigation. This limitation suggests that the potential of inquiry-based electronic LKPD to improve students' scientific literacy in chemistry has not been fully explored.

Therefore, this study aims to develop and evaluate an inquiry-based electronic LKPD designed to facilitate scientific investigation and strengthen students' scientific literacy. By integrating inquiry learning stages with interactive digital features, this study is expected to provide an innovative learning resource that not only enhances students' conceptual understanding but also develops their ability to apply scientific knowledge, evaluate evidence, and solve real-world scientific problems.

At the junior high school level, one science topic that requires scientific literacy skills is the topic of pressure. The concept of pressure is related to various phenomena in everyday life, making it highly suitable to be learned through investigation activities. However, the concept of pressure is often considered abstract by students when learning is conducted only theoretically without experiments or direct observation. Therefore, learning media are needed to facilitate students in actively investigating, analyzing phenomena, and connecting the concept of pressure with real-life situations.

Based on the explanation above, the development of an inquiry learning-based electronic science worksheet (electronic LKPD) on the topic of pressure is considered important as an effort to improve junior high school students' scientific literacy. Electronic LKPD designed with inquiry stages is expected to help students understand concepts more deeply, develop science process skills, and improve scientific thinking abilities in solving problems related to everyday life.

2. Methods

This study employed a Research and Development (R&D) method aimed at developing an Inquiry Learning-based e-LKPD on the topic of pressure to improve junior high school students' scientific literacy. Research and Development is a method used to produce a specific educational product while also testing its effectiveness in the learning process. The development model used in this study was the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides systematic, simple, and appropriate procedures for developing digital learning media. In addition, this model allows continuous evaluation at every stage of development so that the resulting product can be adjusted to students' needs and learning objectives (Sugiyono, 2023).

The first stage was analysis, which aimed to identify learning needs and students' scientific literacy problems in science learning at SMP Negeri 3 Samalantan. At this stage, classroom observations, interviews with science teachers, student questionnaires, and analysis of the curriculum and pressure material were conducted. The analysis focused on students' scientific literacy skills, particularly in explaining scientific phenomena, interpreting scientific data and evidence, and applying scientific concepts in daily life. The results showed that the learning process was still teacher-centered and had not optimally utilized digital learning media. Therefore, an Inquiry Learning-based E-LKPD was needed to increase students' engagement in scientific investigation activities.

The second stage was design, which involved designing the E-LKPD product according to learning needs. At this stage, learning objectives, scientific literacy indicators, pressure material, and Inquiry Learning activities were prepared. The E-LKPD was designed with interactive features containing observation activities, simple experiments, data analysis, and conclusion-making activities. Research instruments were also developed at this stage, including validation sheets, teacher and student response questionnaires, observation sheets, and scientific literacy test instruments. The scientific literacy indicators referred to the OECD framework, which includes the ability to explain scientific phenomena, evaluate and interpret scientific evidence, and apply scientific knowledge to solve contextual problems.

The third stage was development, which involved producing the E-LKPD based on the prepared design. The product was developed by integrating pressure material, scientific literacy-based exercises, images, animations, and navigation features that support inquiry activities. After the product was completed, it was validated by material experts, media experts, and language experts to assess the feasibility of the content, media appearance, and language use. The validation results were used as the basis for revising the product to ensure that the developed E-LKPD met the criteria of validity and appropriateness for classroom use.

The fourth stage was implementation, in which the product was tested on ninth-grade students of SMP Negeri 3 Samalantan. At this stage, students used the E-LKPD during science learning activities on the topic of pressure using the Inquiry Learning approach. The implementation aimed to determine the practicality of the media, teacher and student responses, the implementation of learning activities, and the effectiveness of the product in improving students' scientific literacy. During the learning process, students were actively involved in observing phenomena, formulating questions, conducting investigations, analyzing experimental results, and drawing conclusions based on scientific evidence.

The final stage was evaluation, which was conducted throughout every stage of development and after the implementation process. The evaluation aimed to identify the strengths and weaknesses of the developed E-LKPD so that final revisions could be made to produce a feasible product. The evaluation focused on the validity, practicality, and effectiveness of the product in supporting the improvement of students' scientific literacy.

The subjects of this study consisted of expert validators and ninth-grade students of SMP Negeri 3 Samalantan. The expert validators included material experts, media experts, and language experts who assessed the feasibility of the product. Meanwhile, the ninth-grade students became the subjects of the product trial using the Inquiry Learning-based E-LKPD. The object of the study was the quality of the E-LKPD in terms of content, media appearance, language, and its ability to improve students' scientific literacy.

The research data consisted of quantitative and qualitative data. Quantitative data were obtained from expert validation results, teacher and student response questionnaires, and scientific literacy test scores. Qualitative data were obtained from interviews, observations, validator comments, and field notes collected during the research process. The research instruments included expert validation sheets, teacher and student response questionnaires, scientific literacy pretest and posttest instruments, and observation sheets of learning implementation.

Data collection techniques included observation, interviews, questionnaires, tests, and documentation. Observation was conducted to examine the condition of science learning and the implementation of the E-LKPD during classroom activities. Interviews were conducted with science teachers to obtain information regarding classroom learning conditions and students' scientific literacy problems. Questionnaires were used to identify students' needs, product validity, and teacher and student responses toward the use of the E-LKPD. Tests were administered in the form of pretests and posttests to measure the improvement of students' scientific literacy before and after using the product. The test items were developed based on scientific literacy indicators, including the ability to explain scientific phenomena, interpret data, and apply scientific concepts in daily life. Documentation was used as supporting data in the form of research activity photographs, students' work, and other relevant documents.

Data analysis techniques were conducted using descriptive quantitative and qualitative methods. Practicality data were analyzed based on teacher and student response questionnaires as well as observations of learning implementation. Meanwhile, the effectiveness of the product in improving scientific literacy was analyzed using pretest and posttest scores calculated through the N-Gain formula. The N-Gain results were categorized as high if the score was greater than 0.70, moderate if it ranged from 0.30 to 0.70, and low if it was below 0.30. Qualitative data from interviews, observations, and validator comments were analyzed descriptively through data reduction, data presentation, and conclusion drawing. The E-LKPD product was considered feasible if it met the criteria of validity, practicality, and effectiveness in improving students' scientific literacy.

Figure 1. ADDIE Research and Development Model

3. Result and Discussion

The development of the Electronic Student Worksheet (E-LKPD) based on Inquiry Learning on the topic of pressure was conducted using the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation stages. The product was specifically designed to improve students' scientific literacy skills, particularly in explaining scientific phenomena, interpreting scientific data, and applying scientific concepts in daily life contexts.

Analysis Phase (Analyze) on Scientific Literacy

In the analysis phase, the researcher identified the learning needs at SMP Negeri 3 Samalantan, specifically focusing on the topic of pressure. The analysis activities were conducted through classroom observations, interviews with science teachers, distribution of student questionnaires, and a documentary study of the instructional materials used in the school. The results indicated that students' scientific literacy skills were still relatively low. This was evident from their poor ability to explain scientific phenomena, connect science concepts with daily life, and use scientific evidence to solve problems.

The ongoing learning process had been predominantly teacher-centered, causing students to receive information passively. Teachers primarily relied on lectures and textbooks as the main learning resources. Furthermore, the worksheets (LKPD) used were still conventional printed worksheets that only contained practice questions without engaging students in scientific inquiry. This condition caused students to be less active in learning and unaccustomed to scientific thinking processes, such as observing, formulating problems, formulating hypotheses, analyzing data, and drawing conclusions.

The analysis also revealed that students faced difficulties understanding the concept of pressure because the material was considered abstract and lacked connection to real-world phenomena in their surroundings. Consequently, students merely memorized formulas without understanding their practical applications. In fact, one crucial indicator of scientific literacy is the students' ability to apply science concepts to explain phenomena occurring around them.

On the other hand, the needs analysis showed that most students already owned smartphones and were quite familiar with using digital devices in their daily lives. This presents an opportunity to develop digital-based learning media that is more interactive and engaging. Based on these conditions, the researcher developed an Inquiry Learning-based Electronic Worksheet (e-LKPD) as a solution to increase active student engagement while simultaneously developing their scientific literacy skills. Thus, the analysis phase indicated that developing an Inquiry Learning-based Electronic Worksheet is highly relevant to implement, as it aligns with the students' needs and the school's learning conditions. The product development is directed toward creating science learning that is more contextual, interactive, and oriented toward scientific processes to improve students' scientific literacy.

Table 1. Result of Analysis

Aspect	Findings	Implication for Product Development
Scientific literacy	Students had difficulty explaining scientific phenomena and interpreting evidence	e-LKPD integrates scientific literacy indicators
Learning approach	Teacher-centered instruction	Inquiry Learning implemented
Learning materials	Conventional printed worksheets	Interactive digital worksheet developed
Student readiness	Most students owned smartphones	Mobile-accessible e-LKPD designed

Design Phase (Design) on Scientific Literacy

In the design phase, the researcher began designing the Inquiry Learning-based Electronic Worksheet, focusing its development on improving students' scientific literacy. The product design was structured based on the results of the previously conducted needs analysis. In this phase, all learning components were designed to train students' skills in understanding scientific concepts, explaining science phenomena, conducting investigations, and making decisions based on scientific evidence.

The topics developed in the Electronic Worksheet included the pressure of solids, fluid pressure, Pascal's law, and Archimedes' principle. These topics were presented through various real-world phenomena close to the students' daily lives. For example, students were guided to understand why the tip of a nail is made sharp, how a hydraulic jack works, and why ships can float on water. Presenting the material contextually aimed to enable students to connect science concepts with their surroundings, making learning more meaningful.

The Electronic Worksheet was designed based on the Inquiry Learning syntax, which consists of problem orientation, problem formulation, hypothesis formulation, data collection, data analysis, and drawing conclusions. Each stage of inquiry was designed to support the indicators of students' scientific literacy. In the problem orientation stage, students were provided with contextual phenomena to observe and analyze. This stage trained students' ability to recognize scientific problems in daily life. Next, in the problem formulation and hypothesis formulation stages, students were directed to develop critical thinking skills and scientific reasoning.

In the data collection stage, students conducted simple observations or simulations related to the concept of pressure. This activity was designed to provide students with hands-on experience in the scientific process. Afterward, students were asked to analyze the observed data through tables and investigative questions. The data analysis stage is vital in developing scientific literacy as it trains students to interpret scientific information based on the evidence obtained. In the final stage, students formulated conclusions based on the results of the investigations they carried out.

In addition to structuring the inquiry activities, the design of the Electronic Worksheet also took visual aspects and media interactivity into account. The product was designed with an attractive layout, proportional color use, contextual illustrations, and easy navigation via smartphones or laptops. Digital media was chosen because it was deemed capable of increasing students' learning motivation and helping visualize abstract concepts within the topic of pressure. Thus, the design phase produced an Electronic Worksheet blueprint that was not only visually appealing but also capable of optimally supporting the development of students' scientific literacy.

Figure 2. Cover e-LKPD IPA

Development Phase (Development) on Scientific Literacy

In the development phase, the blueprint of the Electronic Worksheet was developed into a tangible product ready for validation and testing. The main focus of this phase was to ensure that the developed product was truly suitable for supporting the improvement of students' scientific literacy. The developed Electronic Worksheet product featured various scientific activities aligned with the characteristics of scientific literacy. Students were not only required to read the material but also to observe, formulate hypotheses, collect data, analyze experimental results, and draw conclusions based on scientific evidence. Additionally, the Electronic Worksheet was equipped with investigative questions aimed at training students' critical thinking and problem-solving skills.

Once the product was fully developed, the next step was expert validation involving content experts, media experts, and language experts. Validation was conducted to determine the product's feasibility before being implemented in the classroom. The expert validation results indicated that the developed Inquiry Learning-based Electronic Worksheet (e-LKPD) met the required feasibility standards for classroom implementation. As presented in Table 3, the content aspect obtained a feasibility score of 80%, which falls into the highly feasible category. The validators confirmed that the learning materials were scientifically accurate, aligned with the curriculum, and appropriately integrated scientific literacy competencies. Furthermore, the contextual learning activities were considered effective in encouraging students to explain scientific phenomena, apply scientific concepts, and use evidence-based reasoning.

The construction aspect achieved a feasibility score of 78%, also categorized as highly feasible. The validators agreed that the sequence of learning activities was consistent with the Inquiry Learning model, beginning with problem orientation and progressing through hypothesis formulation, data collection, data analysis, and conclusion. This instructional structure was considered capable of promoting active student engagement and facilitating the development of inquiry skills. Nevertheless, the validators recommended strengthening several inquiry components by incorporating more explicit hypothesis-generation activities and additional analytical questions to further enhance students' scientific literacy.

The language aspect obtained the highest feasibility score, 82%, and was likewise classified as highly feasible. According to the validators, the language used throughout the e-LKPD was clear, communicative, and appropriate for junior high school students' cognitive level. The use of concise scientific terminology, supported by understandable explanations and instructions, was considered effective in helping students comprehend scientific concepts and participate actively in inquiry-based learning. Overall, the average validation score indicated that the developed e-LKPD was highly feasible and suitable for implementation as a learning medium to improve students' scientific literacy on the topic of pressure.

The language used was considered communicative, easy to understand, and appropriate for the cognitive development level of junior high school students. The use of simple yet scientific language is essential in supporting scientific literacy learning, as it helps students understand science concepts more clearly. The validation results demonstrated that the Inquiry Learning-based Electronic Worksheet met the criteria of validity and was fit for use to improve students' scientific literacy skills on the topic of pressure.

Table 3. Expert Validation Results

Validation Aspect	**Score (%)**	**Category**
Content	80	Highly Feasible
Construction	78	Highly Feasible
Language	82	Highly Feasible
Average	**80.0**	**Highly Feasible**

Implementation Phase (Implementation) on Scientific Literacy

The implementation phase was carried out to determine the effectiveness of the Inquiry Learning-based Electronic Worksheet in improving students' scientific literacy. Implementation was conducted through two stages: a limited-scale trial and a large-scale trial. In the limited-scale trial involving 10 ninth-grade students at SMP Negeri 3 Samalantan, results showed that students' scientific literacy skills improved after using the Inquiry Learning-based Electronic Worksheet. The students' average pretest score of 36 increased to 65 on the posttest. This improvement indicates that using the Electronic Worksheet helped students understand the concept of pressure better through scientific inquiry processes. The statistical results of the paired sample t-test showed a significance value of $0.000 < 0.05$. This means there was a significant difference between the pretest and posttest scores after using the Inquiry Learning-based Electronic Worksheet. Therefore, the Electronic Worksheet proved effective in improving students' scientific literacy.

In the large-scale trial, the improvement in students' scientific literacy also showed positive outcomes. The group using the Inquiry Learning-based Electronic Worksheet experienced an increase in average scores from 37.12 to 58.85. Meanwhile, the group using conventional Electronic Worksheets only increased from 32.14 to 43.33. On the other hand, the group using inquiry worksheets from the textbook increased from 37.04 to 58.33.

These results indicate that inquiry-based learning is more effective in improving scientific literacy compared to an expository approach. Through inquiry learning, students are more active in observing phenomena, investigating problems, analyzing data, and drawing conclusions. These activities strongly support the development of students' scientific thinking skills.

The MANOVA test results also showed a significance value of $0.002 < 0.05$, meaning there was a significant difference among the treatment groups. Furthermore, the Tukey HSD post-hoc test results showed that the Inquiry Learning-based Electronic Worksheet group achieved higher scientific literacy outcomes than the expository group. These findings indicate that active student involvement in the inquiry learning process is the primary factor driving the improvement in scientific literacy.

Table 4. Pretest and Posttest Scores in the Limited Trial

Test	Mean Score
Pretest	36.00
Posttest	65.00

Evaluation Phase (Evaluation) on Scientific Literacy

The evaluation phase was conducted continuously at every stage of the ADDIE model to ensure that the developed Electronic Worksheet was genuinely capable of supporting the improvement of students' scientific literacy. Evaluation was carried out formatively during the development process and summatively after product implementation.

In the analysis evaluation phase, the researcher ensured that the problems identified were genuinely related to the students' low scientific literacy skills. The evaluation results confirmed that students indeed required learning media that was more interactive and capable of engaging them in scientific processes.

In the design evaluation phase, the researcher reviewed the alignment of the material, inquiry activities, and evaluation questions with scientific literacy indicators. This evaluation resulted in several improvements, such as simplifying instructional language and adding contextual examples to make them easier for students to comprehend. In the development evaluation phase, the expert validation results were used as the basis for product revision. Refinements were made to the structure of inquiry activities, the inclusion of hypotheses, and the perfection of analytical questions to better train students' scientific thinking skills.

In the implementation evaluation phase, the researcher assessed student responses, learning feasibility, and students' pretest and posttest scientific literacy scores. The evaluation results showed that students responded positively to the use of the Electronic Worksheet, as the media was deemed engaging, easy to use, and helpful in understanding the concept of pressure more realistically.Overall, the evaluation results indicated that the Inquiry Learning-based Electronic Worksheet is effective in improving the scientific literacy of junior high school students on the topic of pressure. The developed product successfully helps students understand science concepts scientifically, trains critical thinking skills, and accustoms students to using scientific evidence to solve everyday problems.

Discussion

The increase in students' scientific literacy in this study confirms that the implementation of Inquiry Learning-based Electronic Student Worksheets (e-LKPD) is capable of transforming conventional science learning patterns into a process of meaningful knowledge reconstruction that is oriented toward future scientific skills. Epistemologically, scientific literacy must no longer be reduced merely to a low-level cognitive ability for mechanically memorizing science terms, formulas, or concepts (Zou, Y., Xue, X., Jin, L., Huang, X., & Li, 2024). Referring to the framework of the Organisation for Economic Co-operation and Development (OECD, 2023) scientific literacy is a multidimensional competence that encompasses an individual's ability to use scientific knowledge, identify questions, explain scientific phenomena, interpret data and evidence, and draw valid conclusions in order to understand and make decisions regarding the natural world and the changes made to it through human activity. Therefore, the structure of science learning at the secondary school level ought to shift from a linear information transfer paradigm (teacher-centered) toward the provision of authentic learning experiences that challenge students to think and act like a scientist. In the context of this study, the Inquiry Learning-based e-LKPD serves as a pedagogical bridge that facilitates this transformation, ensuring that the dimensions of process, content, and context in scientific literacy can be accommodated in a balanced manner within the classroom (Bhardwaj, et.al, 2025).

Based on empirical research data, the significant increase in students' scientific literacy is deeply rooted in the design of the e-LKPD, which adopts the syntax of Inquiry Learning strictly and consistently. Learning no longer positions students as passive consumers of information, but rather as active conceptors through a series of structured scientific investigation stages. This discovery syntax provides positive intervention for each indicator of student scientific literacy through specific activities (Sholahuddin, et.al, 2023). In the orientation and problem formulation stage, students are presented with digital visual stimuli that trigger cognitive conflict, encouraging them to formulate exploratory scientific questions. Subsequently, the hypothesis formulation stage trains students' deductive thinking skills to predict relationships between variables based on the baseline theoretical knowledge they possess. Through the e-LKPD, students then perform data collection and analysis using virtual or guided experiments to test the validity of their hypotheses. They observe phenomena directly, record changes in variables, and organize information into tables or graphs, until finally reaching the conclusion-drawing stage where students reflect on the results of data analysis to construct conceptual generalizations independently. This holistic activity is highly aligned which states that inquiry learning is a crucial strategy that allows students to build deep conceptual knowledge through direct investigational experiences. By engaging in this discovery process, students' memory retention of science concepts becomes significantly stronger because the knowledge is constructed independently, rather than merely transferred from a textbook to an answer sheet (Ruiz-Martín, H., & Bybee, 2022).

One of the vital determinants triggering the surge in scientific literacy scores in this study is the integration of contextual problems close to the students' socio-technological environment (Darwish, 2025). Pressure, a topic often considered abstract and laden with complex mathematical calculations, is deconstructed within the e-LKPD through the presentation of real, everyday phenomena. Students are invited to explore the principles of physical mechanics behind the functionality of surrounding objects, such as the mechanism of a sharp nail that easily penetrates surfaces related to the concept of solid pressure,the working principle of a submarine capable of floating and submerging in the vast ocean based on Archimedes'

Principle, the system of force multiplication in automotive hydraulic brakes according to Pascal's Law, and the variations in air pressure fluctuations within the respiratory system of living organisms or barometers. This presentation of real context validates Bybee's (2013) theory, which states that one of the main pillars of scientific literacy is the ability to apply scientific concepts to real-world situations (Anggraeni, D. M., & Andina, 2024). This contextualization eliminates misconceptions and verbalism, so that students do not just memorize the mathematical formula for pressure, but are fluently capable of using it to explain concrete phenomena, such as the webbed structure of a duck's foot that prevents it from easily sinking into the mud.

In addition to contextual factors, optimizing multimedia aspects within the e-LKPD contributes substantially. The characteristics of the pressure material, which involves microscopic and abstract aspects such as the movement of gas particles or the invisible distribution of fluid force are beautifully visualized through the integration of text, high-resolution images, moving illustrations, and short interactive instructional videos. (Wong, J. T., & Hughes, (2023) asserts that digital learning media has an inherent advantage in clarifying the presentation of complex material and can massively increase students' cognitive attention. The effect of digital visualization in this e-LKPD reduces students' extraneous cognitive load, allowing their mental capacity to be fully allocated toward constructing an understanding of more complex scientific concepts. The scientific literacy competence measured in this study also emphasizes the aspect of scientific reasoning and data interpretation skills. Within the developed electronic worksheets, there is a specific section requiring students to read, analyze, and evaluate data presented in experimental tables or linear trend graphs. This analytical process trains critical thinking skills as students are directed to read data trends, such as the relationship between the depth of a liquid and the magnitude of hydrostatic pressure. Students then identify causal relationships among the independent, dependent, and control variables, and detect patterns of data inconsistency before ultimately formulating a valid scientific conclusion based on physical evidence (evidence-based decision making). This ability to interpret data and evidence objectively is a core scientific literacy competence required in global assessments (Istyadji, 2023) . Through the habit of analytical thinking within this e-LKPD, students are trained not to easily accept information without a clear empirical basis, a pattern that contrasts sharply with the conventional lecture-based learning model where data interpretation is rarely practiced because the confirmation of scientific truth is always dictated directly by the teacher.

Another interesting finding in this study indicates an important dynamic regarding instructional media. When an empirical comparison was conducted, the increase in students' scientific literacy between the class using the inquiry-based e-LKPD and the class using the print version of the inquiry-based LKPD did not show an overly extreme quantitative gap. This fact indicates a fundamental pedagogical conclusion that the primary determining factor driving scientific literacy is not the physical form of the media used (digital versus paper), but rather the essence of the learning design and the quality of the students' active engagement in the scientific inquiry process. This theory is in line with Richard Clark's classic thesis on the media debate, which states that media is merely a vehicle that delivers instruction but does not influence student achievement any more than the truck that delivers our groceries changes our nutrition; it is the instructional method that drives cognitive processing and learning outcomes. The success of science learning lies in how students explore phenomena, test variables, and reason through problems scientifically. Although the inquiry method is the driving engine, the e-LKPD still holds a competitive advantage that cannot be replaced by print media in the context of modern learning efficiency. These comparative advantages include flexibility of access because it can be accessed asynchronously anytime and anywhere via devices to support extended learning time outside school hours; multimodality features capable of integrating interactive simulations like PhET Interactive Simulations directly within the worksheet; feedback efficiency through automated grading features or real-time data collection to accelerate the teacher’s mapping of student understanding; and aesthetic appeal in the form of dynamic layouts and multimedia elements that increase students' emotional engagement while reducing academic burnout.

The findings of this study consistently reinforce, validate, and expand the scope of empirical findings previously reported by past researchers in the field of science education. The success of the Inquiry Learning-based e-LKPD in boosting students' scientific literacy skills aligns with the large-scale meta-analysis conducted by Minner, Levy, and Century (2010), which concluded that inquiry-based instruction has a highly potent positive correlation with the improvement of students' conceptual understanding of science compared to expository strategies (Endah et al., 2026). Furthermore, this finding is also in line with the argument of Hofstein and Lunetta (2004), which states that investigation-based learning provides space for developing students' critical thinking and metacognitive capacities through direct interaction with challenging science problems. In a local context and regarding digital technology integration, the results of this study confirm the research of Putri, L. P. C. N., et.al, (2025), which posits that e-LKPD devices with guided discovery syntax are effective in triggering the mastery of core science competencies, particularly in formulating scientific explanations for everyday phenomena. Similarly, it aligns with the findings of Lestari et al. (2023), who highlighted that the utilization of interactive e-LKPDs exerts a significant impact or effect size on the achievement of scientific literacy scores among Junior High School (SMP) students. The convergence of these research results provides solid proof that the strategic integration between the pedagogical framework of Inquiry Learning and the flexibility of e-LKPD technology constitutes an instructional formula that is highly valid, reliable, and applicable for wider implementation.

Overall, the body of scientific evidence in this discussion confirms that the use of Inquiry Learning-based Science e-LKPDs for the topic of Pressure has proven theoretically and practically effective in facilitating the improvement of Junior High School students' scientific literacy quality. This innovative learning product successfully transforms how students interact with science from merely memorizing text to understanding scientific essence, from linear thinking to critical-analytical thinking, and from simply knowing to being skilled at applying scientific knowledge to solve real-world problems in their environment. Developing the aspect of scientific literacy through inquiry-based e-LKPDs carries vital long-term implications for the future of students in a global era. Scientific literacy proficiency is no longer just a complement to report card grades or a mere academic graduation requirement, but has mutated into one of the core pillars of competence absolutely needed to survive and compete in the 21st century (21st-century skills). Future society is characterized by massive technological disruption and an overwhelming influx of information (information overload). Through the strong cultivation of scientific literacy from an early stage in school, students are equipped with an intellectual shield in the form of critical, healthily skeptical, and systematic thinking abilities. They are also trained to filter information, distinguishing between scientific facts and pseudoscience or hoaxes, thereby enabling students to act as responsive, rational global citizens capable of making crucial, data-driven decisions for the sustainability of the environment, science, and technology.

4. Conclusion

Based on the research and development conducted using the ADDIE model, it can be concluded that the Inquiry Learning-based Electronic Student Worksheet (e-LKPD) for science on the topic of Pressure is highly valid, feasible, and practical for use in the learning process. The feasibility of this product is based on expert assessments, which show percentages of 80% for the material or content aspect, 78% for the syntax construction aspect, and 82% for the language aspect, which was deemed communicative and appropriate for the cognitive development level of junior high school students. In addition, its high level of practicality is evidenced by the positive responses from both teachers and students toward the integration of multimedia elements such as text, images, animation, and digital navigation which are engaging, easy to use independently via devices, boost learning motivation, and successfully visualize abstract concepts of pressure to make them more realistic.

This innovative e-LKPD has also proven to be significantly effective in improving students' scientific literacy skills. In the limited-scale trial, there was a noticeable increase in the average score from the initial stage before using the media to the final stage after the intervention was implemented. This advantage was further reinforced in the large-scale trial, where the group of students learning with the Inquiry Learning-based e-LKPD achieved a much higher score increase compared to the group of students following conventional or expository learning. Various statistical tests conducted confirm that the implementation of this investigation method delivers a far superior impact on improving scientific capabilities than standard learning patterns.

The primary driving factor behind the successful increase in scientific literacy is the active involvement of students in every stage of structured scientific investigation, ranging from orientation, problem formulation, and hypothesis formulation to data collection, data analysis, and drawing evidence-based conclusions. The presentation of real-world problems close to everyday life, such as the phenomena of nails, submarines, and hydraulic brakes, also successfully trains students' scientific reasoning skills and data interpretation capabilities.

Overall, this Science e-LKPD product has successfully become an effective instructional strategy solution to transform passive, teacher-centered learning into active, student-centered learning, while simultaneously addressing the challenges of preparing students' scientific skills to face the demands of the modern era.

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