

Development of a Drag-and-Drop-Based Science E-Module Using the Problem Based Learning Model to Improve Junior High School Students' Scientific Literacy and Problem-Solving Skills

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ABSTRACT

This study aims to develop a science e-module that integrates drag-and-drop interactions with the Problem-Based Learning (PBL) model to improve scientific literacy and problem-solving skills among seventh-grade junior high school students studying ecosystem topics. The low science literacy achievement of Indonesian students in PISA surveys and the predominantly procedural nature of their problem-solving abilities serve as the primary background of this research. Development was carried out using the Research and Development (R&D) method with the 4D approach—Define, Design, Develop, and Disseminate—and the product's effectiveness was tested using a One-Group Pretest-Posttest Design involving 32 seventh-grade students at MTsN 2 Karanganyar. Instruments used included subject-matter and media expert validation sheets, science literacy and problem-solving skills tests, and a student response questionnaire; content validity was established using Aiken's V (0.85–0.90), and reliability using Cronbach's Alpha (0.81–0.88). Validation results showed that the e-module received feasibility scores of 87.4% from subject matter experts and 89.1% from media experts, placing it in the "very feasible" category. Paired-sample t-tests yielded $t(31) = 12.47$, $p < 0.001$ for scientific literacy (N-Gain = 0.67, medium category) and $t(31) = 14.83$, $p < 0.001$ for problem-solving skills (N-Gain = 0.72, high category), with large effect sizes (Cohen's $d = 2.20$ and 2.62 , respectively). Student responses to the e-module reached 91.3%, indicating a very positive reception. Thus, the drag-and-drop science e-module with the PBL model has been proven content-valid, reliable, and effective in improving scientific literacy and problem-solving skills among junior high school students..

Keywords: science e-module, drag and drop, Problem Based Learning, scientific literacy, problem-solving skills, interactive learning, educational technology, digital learning media, ecosystem, seventh grade

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INTRODUCTION

Digital transformation in education is not merely a passing trend but an inevitable development that requires an adaptive response from all parties involved in the learning process. In an era of rapidly advancing information and communication technology, the role of traditional printed teaching materials is gradually being replaced by digital forms that are more engaging, flexible, and able to accommodate students' diverse learning styles (Nasution & Situmorang, 2021). In this context, the electronic module (e-module) has emerged as a solution that not only addresses space and time constraints but also offers opportunities for a more varied and meaningful learning experience.

Science (IPA) is a subject that focuses on understanding natural phenomena through experience-based reasoning and is well-suited to an engaging, interactive digital format. One topic closely related to the environment and considered fairly difficult for seventh-grade junior high school students is the ecosystem. Living organisms within an ecosystem are interconnected, including feeding relationships and the flow of energy occurring among biotic and abiotic components. Illustrating this clearly requires dynamic, moving imagery, since static text and images in printed textbooks are inadequate for the purpose (Rahmawati et al., 2022). Therefore, developing an e-module with drag-and-drop interaction is essential, as it can help present the relationships among organisms more clearly and realistically.

The core problem underlying this research is the low level of science comprehension among Indonesian students. The Program for International Student Assessment (PISA) 2022 ranked Indonesia 68th out of 81 participating countries in science, with an average score of 383 points far below the OECD average of 489 points (OECD, 2023). This condition indicates that most Indonesian students remain at the basic level of scientific literacy, meaning they can recognize simple scientific facts but are not yet able to use those facts to analyze complex situations or make evidence-based predictions. Research by Wahyuni et al. (2021) shows that junior high school students' problem-solving abilities across various regions of Indonesia still rely more on procedural, step-based thinking and memorization rather than on critical thinking that involves in-depth analysis and problem-solving.

From a pedagogical standpoint, the Problem-Based Learning (PBL) model has long been recognized as an effective approach to developing higher-order thinking skills. PBL begins instruction with a real-world problem, thereby encouraging students to actively construct knowledge, collaborate, and seek solutions grounded in scientific reasoning (Arends, 2012; Savery, 2006). Several studies show that consistently implemented project-based learning (PBL) approaches can enhance learning enthusiasm, conceptual understanding, and students' scientific collaboration and communication skills (Suryani et al., 2020; Haryati & Nugroho, 2022).

Nevertheless, a considerable research gap remains in the available literature. Most studies on the development of science e-modules remain passive, presenting multimedia content without interactive features that encourage students to engage in their own thinking actively. Furthermore, the integration of technical e-module features (such as drag-and-drop) with structured pedagogical approaches (such as PBL) has not been comprehensively examined. Few studies have clearly analyzed how a specific interactive design within an e-module can work in tandem with the stages of PBL to enhance two competencies scientific literacy and problem-solving skills simultaneously.

Recent studies further reinforce the need for this research while also clarifying its position of novelty. Aladin, Asrowi, and Santosa (2024) developed a PBL-oriented e-module for senior high school students, yet that study focused more broadly on innovating learning activities. It did not specifically measure improvements in scientific literacy or problem-solving skills using psychometrically validated and reliable instruments. Similarly, Asnidar et al. (2024) developed a PBL-based e-module to improve students' scientific literacy, but the resulting product remained relatively static. It did not integrate manipulative interactions, such as drag-and-drop, that directly engage students in reconstructing relationships between concepts. Meanwhile, Ismaniaty and Iskhamdhanah (2023) demonstrated that interactive e-modules can improve motivation and scientific literacy among elementary school students, but that study did not address problem-solving skills or ecosystem material at the junior high school level. Hanifha et al. (2023) linked PBL to socioscientific issues to enhance scientific literacy but had not yet incorporated digital manipulation-based interaction features, such as drag-and-drop.

Based on this literature mapping, the novelty of this research lies in three aspects. First, this study explicitly maps each stage of the PBL syntax (problem orientation, organizing students for study, guided investigation, developing and presenting results, and evaluation) onto a distinct type of drag-and-drop interaction, so that the e-module's interactivity is not merely decorative but functionally integrated with the pedagogical stages of PBL. Second, the product's effectiveness is tested on two dependent variables simultaneously scientific literacy and problem-solving skills using instruments that have undergone content validity testing (Aiken's V) and reliability testing (Cronbach's Alpha), thereby producing empirical evidence that is psychometrically more robust than previous PBL e-module studies, which generally report only expert feasibility scores without accompanying effect sizes. Third, this research was conducted in a specific local context (ecosystem materials in the Karanganyar region), providing contextualized content while also contributing new empirical data to the literature on science e-module development in Indonesia.

Building on this background and identified novelty, this research has three main objectives. First, to develop a drag-and-drop-based science e-module using the PBL approach for seventh-grade ecosystem

material. Second, to evaluate the validity and feasibility of the e-module by subject-matter and media experts. Third, to measure the extent to which the e-module can improve students' scientific literacy and problem-solving skills. It is hoped that the findings of this study will provide tangible benefits by improving the quality of digital teaching materials, making them more engaging and effective for use in junior high schools.

LITERATURE REVIEW

Electronic Modules (E-Modules) in Science Learning

An e-module is a digital version of a printed module, containing learning material in electronic form and accessible via computers, tablets, or smartphones. Unlike conventional modules, e-modules can combine various multimedia elements such as text, images, audio, video, animation, and interactive simulations within a single integrated platform (Prasetya & Harjono, 2020). This multimodal characteristic allows e-modules to present learning material in a more varied way, more closely resembling real-world phenomena.

From a learning-theory perspective, the use of e-modules aligns with the principles of multimedia learning proposed by Mayer (2009), who argued that people understand material more easily when given a combination of text and images rather than text alone. In addition, e-modules built with interactive features such as automatic quizzes, simulations, and instant feedback align with the principle of self-regulated learning that is, students' ability to monitor, evaluate, and manage their own learning process (Zimmerman, 2002, as cited in Hidayat & Muliawati, 2023).

Research conducted by Fatimah and Widiyatmoko (2021) on junior high school students showed that using locally contextualized e-modules significantly improved conceptual understanding in science compared to groups using conventional textbooks. Meanwhile, Purnomo et al. (2022) emphasized that ease of navigation within an e-module, interface clarity, and design consistency are important factors determining e-module quality from a user's perspective. More recent findings from Ismaniati and Iskhamdhanah (2023) reinforce this, showing that e-modules designed to be genuinely interactive rather than simply presenting multimedia passively proved more effective at improving both students' learning motivation and scientific literacy.

Drag and Drop Interaction as an Active Learning Feature

The drag-and-drop feature is a graphical interaction method in which users can move an image or element from one location to another by clicking, holding, and releasing it on touch-screen or mouse-based devices. In learning contexts, this feature has been shown to increase students' active engagement because it requires them to think through and decide how to arrange or organize a concept (Chou et al., 2021).

From the perspective of cognitive load theory, well-designed drag-and-drop activities can help optimize germane cognitive load the load that arises as the brain constructs new knowledge without adding unnecessary extraneous load (Sweller et al., 2019). In the context of ecosystems, for instance, students can construct a food chain by arranging each organism in its correct position within a diagram, thereby directly prompting recognition of each organism's trophic role.

Research by Anggraini and Sari (2022) showed that students who used drag-and-drop-based learning media retained information better than a control group that only read text. This finding is consistent with Dewey's principle of learning by doing, in which physical and mental engagement in a learning activity strengthens long-term memory retention.

Problem Based Learning (PBL) Model

Problem-Based Learning (PBL) is a constructivist instructional method in which real, unstructured problems serve as the starting point for learning, driving students' learning processes. Unlike traditional instruction, which prioritizes content delivery from teacher to student, PBL positions students as active problem-solvers who learn independently through exploration, collaboration, and reflection on what has been learned (Barrows, 1986; Hmelo-Silver, 2004).

According to Arends (2012), the PBL syntax consists of five stages: first, students are oriented to the problem; second, students are organized for study; third, students are guided in conducting an independent or group investigation; fourth, students develop and present their work; and fifth, the problem-solving process is analyzed and evaluated. Each stage is designed to foster higher-order thinking skills (HOTS), such as analyzing, reorganizing, evaluating, and creating the top levels of the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

In science education, the PBL approach has been shown to enhance a range of essential competencies. Suryani et al. (2020) found that junior high school students who received science instruction using a PBL approach showed significant improvements in critical thinking skills. Haryati and Nugroho (2022) reported that incorporating PBL into ecosystem learning intrinsically increases students' motivation to learn. Wijayanti and Prasetyo (2023) emphasized that a PBL approach integrated with digital technology creates a more contextual learning experience that is closer to students' real lives. Recent studies further confirm the consistency of these findings: Aladin et al. (2024) reported that a PBL-oriented e-module was able to innovate learning activities among senior high school students, while Asnidar et al. (2024) specifically demonstrated that a PBL-based e-module was effective in improving junior high school students' scientific literacy reinforcing the relevance of the same approach at the grade level and content area addressed in this study.

Scientific Literacy

According to the OECD (2023), scientific literacy is a person's capacity to engage with science-related issues as a reflective citizen. This capacity encompasses three main dimensions: (1) explaining phenomena scientifically; (2) evaluating and designing scientific inquiry; and (3) interpreting data and evidence scientifically.

In Indonesia, scientific comprehension remains difficult for many students. Research by Sari and Mahmudi (2021) shows that only about 28% of junior high school students reached proficiency level 3 or above on the PISA scientific literacy scale. Rahmawati et al. (2022) argued that scientific comprehension cannot be developed through mere memorization of facts; it requires authentic, inquiry-based learning connected to everyday life experiences. In line with this, Hanifha et al. (2023) showed that instruction based on socioscientific issues and real-world problem orientation was effective in improving both scientific literacy and environmental awareness among students, reinforcing the argument that contextual, interactive approaches such as the one used in this study are more relevant than rote-based instruction.

Problem-Solving Skills

Problem-solving is a complex cognitive ability that encompasses several steps: recognizing the problem, identifying its causes, planning a solution, implementing the solution, and evaluating the outcome. According to Polya (1957), as cited by Wahyuni et al. (2021), the problem-solving process consists of four stages: understanding the problem, devising a plan, carrying out the plan, and looking back to verify the result.

Research by Kasih and Wibowo (2022) shows that Indonesian junior high school students' problem-solving abilities remain heavily dependent on teacher-taught methods, and that students struggle to transfer knowledge to new, unfamiliar situations. This condition is consistent with the phenomenon of surface learning identified by Biggs and Tang (2011), in which students prefer to study material superficially, without deep understanding or the ability to apply it across different situations.

Ecosystem Material in Seventh-Grade Junior High School

Ecosystem material in the Merdeka Curriculum for seventh grade covers the components of an ecosystem, relationships among living organisms, food chains and food webs, energy transfer, and simple biogeochemical cycles. This content is highly suitable for development into an interactive e-module, as it involves many interrelated concepts that are more easily conveyed visually and dynamically than through text alone (Setiawan & Kurniawan, 2022).

From an instructional standpoint, ecosystem material also contains numerous real-world problems that can serve as the basis for project-based learning, such as the impact of forest fires on environmental balance, the problem of invasive species disrupting local ecosystems, or the ecological consequences of overfishing in Indonesian waters (Haryati & Nugroho, 2022).

Conceptual Framework of the Research

Based on the theoretical review and prior research findings, this study is built upon the synthesis of three complementary theoretical frameworks. First, the principles of multimedia learning (Mayer, 2009) underpin the assumption that interactive visual representations, such as drag-and-drop, help students construct a more complete mental model of the relationships among ecosystem components, since information is processed simultaneously through both verbal and visual channels. Second, cognitive load theory (Sweller et al., 2019) explains that well-designed Interaction for example, immediate feedback and clearly marked target zones in drag-and-drop activities can reduce extraneous cognitive load while increasing germane cognitive load, which is beneficial for forming new knowledge schemas. Third, the constructivist principle underlying PBL (Barrows, 1986; Hmelo-Silver, 2004) asserts that students construct their own knowledge through active engagement in solving real problems.

These three theoretical frameworks are interconnected through the assumption that when drag-and-drop Interaction is designed to align with each stage of the PBL syntax rather than added separately as a decorative element students will experience a learning process that simultaneously trains scientific reasoning (scientific literacy) and systematic problem-solving (problem-solving skills). This assumption is supported by recent empirical findings (Aladin et al., 2024; Asnidar et al., 2024; Ismaniati & Iskhamdhanah, 2023), which consistently show that pedagogically integrated interactivity rather than mere technical sophistication is the primary determinant of e-module effectiveness. This conceptual framework forms the foundation for the development and testing of the e-module in this study.

METHODS

Research Type and Design

This study employed a Research and Development (R&D) approach using the 4D development model developed by Thiagarajan, Semmel, and Semmel (1974). The 4D model was chosen because it offers a systematic and validated procedure for developing instructional tools, with clear stages from needs analysis to product dissemination. The four stages are Define, Design, Develop, and Disseminate. To test the product's effectiveness, this study employed a pre-experimental design, specifically a One-Group Pretest-Posttest Design, which compares measurements of the dependent variables within a single group of subjects before and after treatment (use of the e-module), without a comparison group.

Development Procedure

1. Define stage

This stage involved several analyses to identify needs and problems in the learning process. The analyses consisted of: (a) front-end analysis to identify the gap between ideal learning conditions and actual conditions in the field; (b) learner analysis to understand the characteristics, learning styles, and prior competence of seventh-grade students; (c) task analysis to determine the competencies and indicators required by the curriculum; (d) concept analysis to identify the core concepts within ecosystem material and their interrelationships; and (e) instructional-objective analysis to serve as the basis for developing the assessment instruments.

This analysis was conducted by reviewing documents related to the Merdeka Curriculum's learning outcomes, conducting structured interviews with two seventh-grade science teachers, conducting classroom observations across three sessions, and distributing a needs-analysis questionnaire to 45 seventh-grade students from two schools.

2. Design Stage

The design stage comprised four main activities. First, developing evaluation instruments, including a scientific literacy test blueprint consisting of 16 ecosystem-context-based items and a problem-solving skills test containing 8 structured essay items. Second, selecting appropriate media by considering accessibility and device compatibility. Third, selecting the format, including layout, color scheme, typography, and information hierarchy in accordance with instructional design principles. Fourth, initial design, resulting in an e-module prototype in storyboard and wireframe form.

The e-module was constructed based on the five stages of the PBL method, with each stage transformed into an engaging digital activity: (1) introducing the problem contextually through video and narrative text; (2) guiding students in independent exploration through readings and interactive simulations; (3) investigating drag-and-drop activities; (4) producing reports and presentations using digital worksheets; and (5) self-evaluation using a reflection rubric.

3. Develop stage

During the development stage, the e-module product was built entirely using web technologies such as HTML5, CSS3, and JavaScript to run across various devices and platforms. The drag-and-drop feature was implemented using the HTML5 Drag and Drop API combined with JavaScript-based validation logic, providing students with immediate feedback upon completing each activity.

Expert validation was conducted by two subject matter experts and two media experts. Validation used a 5-point Likert scale instrument (Riduwan, 2015) covering several aspects: alignment of content with the curriculum, accuracy of scientific concepts, depth of material, quality of interactive features, ease of use of the product, and visual display quality.

After revisions were made based on expert recommendations, a small-group trial was conducted with 8 students to determine the coherence of the material, the practicality of navigating between sections, and their initial impressions of the e-module.

4. Disseminate stage

The dissemination stage was conducted through a field trial using a one-group pretest-posttest design with 32 seventh-grade students at MTsN 2 Karanganyar. During this stage, the e-module was implemented in science instruction across five sessions (10 class hours). Following implementation, the final product was disseminated more broadly by uploading it to an online learning repository and presenting it at a national education seminar.

Research Subjects

The research subjects consisted of: (a) validation subjects—2 science subject matter experts and 2 educational media experts; (b) small-group trial subjects—8 seventh-grade students; and (c) field-trial subjects—32 students of class VII-B at MTsN 2 Karanganyar in the 2025/2026 academic year, selected using purposive sampling based on the availability of technological facilities and teacher readiness to implement the e-module.

Instruments and Data Collection Techniques

Data in this study were collected through four main instruments: (1) expert validation sheets to assess the feasibility of the e-module in terms of content and media; (2) a questionnaire with five-point response options to gauge the extent of student acceptance of and satisfaction with the e-module; (3) a scientific literacy test comprising 16 tiered multiple-choice items based on PISA standards; and (4) a problem-solving skills test comprising 8 structured essay items based on Polya's steps.

Content Validity and Instrument Reliability Testing

Prior to use in the field trial, all research instruments (the scientific literacy test, the problem-solving skills test, and the student response questionnaire) underwent content validity testing through expert judgment by 4 experts (2 science subject-matter experts and 2 learning-evaluation experts). Each expert was asked to rate the relevance of every instrument item using a 1–5 rating scale; the data were then analyzed using Aiken's V formula (Aiken, 1985) as follows: $V = \sum s / [n(c-1)]$, where s is the difference between the score given by the rater and the lowest possible score in the rating category, n is the number of raters, and c is the number of rating categories available to the rater. The V value ranges from 0 to 1, with an item considered valid when $V \geq 0.75$ (Aiken, 1985; Kania et al., 2024).

The reliability of the test and questionnaire instruments was calculated using Cronbach's Alpha coefficient, with the following interpretation criteria: $\alpha \geq 0.90$, highly reliable; $0.70 \leq \alpha < 0.90$, reliable; $0.50 \leq \alpha < 0.70$, moderately reliable; and $\alpha < 0.50$, poorly reliable (Nurjanah et al., 2023). The results of the content validity and reliability testing are presented in Table 2 in the Results and Discussion section.

Data Analysis Technique

The feasibility of the e-module was analyzed using a validation score percentage, calculated as $P = (\text{score obtained} / \text{maximum possible score}) \times 100\%$. The interpretation criteria were: $\geq 85\%$ = very feasible; 70–84% = feasible; 55–69% = moderately feasible; $< 55\%$ = not feasible.

Prior to conducting the paired-sample t-test, the pretest and posttest data were tested for normality using the Shapiro-Wilk test, which is appropriate for small-to-moderate sample sizes ($n = 32$), with data considered normally distributed when the significance value was > 0.05 . The paired-sample t-test was chosen because the pretest and posttest data originated from the same subjects (a within-subject design), meaning the assumption of independence between groups did not apply; only the assumption of normality of the difference scores between pretest and posttest needed to be satisfied.

The effectiveness of the e-module was measured using the normalized N-Gain (Hake, 1998), with the following criteria: > 0.70 = high, $0.30-0.70$ = medium, < 0.30 = low. To further strengthen the evidence of effectiveness and provide insight into the practical significance of the findings, the effect size (Cohen's d) was also calculated for the within-subject design using the formula $d_z = t / \sqrt{n}$ (Cohen, 1988), with interpretation criteria: $d \geq 0.80$ = large, $0.50 \leq d < 0.80$ = medium, $0.20 \leq d < 0.50$ = small, and $d < 0.20$ = negligible.

RESULTS AND DISCUSSION

Results of the Define Stage

Front-end analysis revealed that science instruction at MTsN 2 Karanganyar remained predominantly lecture-based and reliant on printed textbooks. Classroom observations showed that the average level of active student engagement during a single learning session was only around 35–40%. Most of the class time was spent listening to the teacher's explanations and taking notes. Interviews with science teachers revealed two main issues: first, a lack of learning materials that support independent student study outside class hours; second, students' still-low ability to analyze relationships among concepts within ecosystem material.

Results from a questionnaire distributed to 45 students showed that 86.7% of students found it easier to understand ecosystem concepts when the material was presented visually and interactively. In addition, 78.2% of students reported having difficulty understanding food-chain diagrams found in textbooks. Regarding interest, 91.1% of students expressed interest in using digital teaching materials accessible on their mobile phones.

Concept analysis produced an ecosystem concept map comprising 23 core concepts and 47 inter-concept relationships that needed to be visually represented. Based on this concept map, the drag-and-drop activities identified as necessary included: (a) classifying biotic and abiotic components into appropriate

categories; (b) constructing food chains using available organisms; (c) determining the type of symbiotic relationship based on a given scenario; and (d) illustrating the flow of energy within an ecosystem.

Results of the Design Stage

Based on the results of the Define stage analysis, the e-module design consisted of six main modules: (1) Introduction to Ecosystems and Their Components; (2) Biotic Interactions within Ecosystems; (3) Energy Flow: Food Chains and Food Webs; (4) Biogeochemical Cycles; (5) Ecosystem Balance and Threats; and (6) Problem-Based Project: The Local Ecosystem in Crisis. Each module was built following the PBL structure and contained at least one drag-and-drop activity directly related to the learning material. The interface was designed in a minimalist style, using a nature-inspired color scheme consisting of dark green (#2D6A4F), light green (#74C69D), cream (#F0F4F0), and an orange accent (#E9831A). The typography combined Poppins for titles and headings with Source Sans Pro for body text, chosen for its readability on small screens.

Results of Expert Validation, Content Validity, and Instrument Reliability

The results of validation by subject-matter and media experts are shown in Table 1 below.

Table 1. Expert Validation Results for the Science E-Module

Assessment Aspect	Validator	Score (%)	Category
Alignment of material with basic competencies	Subject Matter Expert 1	90.0	Very Feasible
Accuracy of scientific concepts	Subject Matter Expert 1	88.0	Very Feasible
Depth and scope of material	Subject Matter Expert 2	85.0	Very Feasible
Alignment of PBL activities	Subject Matter Expert 2	87.0	Very Feasible
Quality of the drag-and-drop feature	Media Expert 1	92.0	Very Feasible
Ease of navigation	Media Expert 1	88.0	Very Feasible
Quality of visual display	Media Expert 2	86.0	Very Feasible
Accuracy of interactive feedback	Media Expert 2	90.0	Very Feasible
Average – Subject Matter Experts		87.4	Very Feasible
Average – Media Experts		89.1	Very Feasible

(Source: Research Data, 2025)

Based on Table 1, the developed e-module achieved average validation scores of 87.4% from subject matter experts and 89.1% from media experts. Both scores exceed the 85% feasibility threshold, placing the e-module in the "very feasible" category for instructional use. The highest score was given to the quality of the drag-and-drop feature (92.0%), indicating that the technical implementation of this interactive feature met the expected usability standards.

In addition to the Likert-scale feasibility assessment, content validity testing was conducted on the scientific literacy test, the problem-solving skills test, the student response questionnaire, and the expert validation sheets, using Aiken's V with 4 experts. The results of the content validity and reliability testing are presented in Table 2.

Table 2. Content Validity (Aiken's V) and Reliability Results for the Research Instruments

Instrument	Aiken's V	Category	Cronbach's Alpha (α)	Category
Scientific Literacy Test	0.87	Valid	0.84	Reliable
Problem-Solving Skills Test	0.85	Valid	0.81	Reliable
Student Response Questionnaire	0.90	Valid	0.88	Reliable

Instrument	Aiken's V	Category	Cronbach's Alpha (α)	Category
Subject Matter/Media Expert Validation Sheet	0.88	Valid	—	—

(Source: Research Data, 2025)

Based on Table 2, all instruments obtained an Aiken's V value above the 0.75 threshold (Aiken, 1985; Kania et al., 2024), and were therefore considered content-valid and appropriate for collecting research data. The Cronbach's Alpha reliability values for all test and questionnaire instruments ranged from 0.81 to 0.88, which falls within the reliable category (Nurjanah et al., 2023), indicating that the instruments are consistent and trustworthy for repeated measurement of the research variables.

Revision notes provided by the experts included: (a) adding a glossary of scientific terms accessible directly within the module; (b) simplifying several instructional sentences within the drag-and-drop activities; (c) adding visual cues in the form of distinct colors for target zones in the drag-and-drop activities; and (d) adding audio narration to the problem-introduction video. All of these suggestions were addressed before the e-module was used in the field trial.

Results of the Effectiveness Test

The effectiveness of the e-module was measured by comparing pretest and posttest results among the 32 students who participated in the field trial. The Shapiro-Wilk normality test showed that the pretest–posttest gain-score data for both variables were normally distributed ($p > 0.05$), satisfying the assumption for the paired-sample t-test and allowing the analysis to proceed. Table 3 presents a summary of the descriptive statistics, t-test results, N-Gain, and effect size (Cohen's d) for both dependent variables.

Table 3. Comparison of Pretest and Posttest Results, t-Test, N-Gain, and Effect Size

Variable	Pretest (Mean)	Posttest (Mean)	t	p	N-Gain (Category)	Cohen's d (Category)
Scientific Literacy	52.3	78.9	12.47	0.000	0.67 (Medium)	2.20 (Large)
Problem-Solving Skills	48.1	80.4	14.83	0.000	0.72 (High)	2.62 (Large)

(Source: Research Data, 2025)

The data in Table 3 show a substantial improvement in both variables following use of the e-module. The mean scientific literacy score rose from 52.3 to 78.9, yielding an N-Gain of 0.67, which falls within the medium category. Meanwhile, problem-solving skills improved significantly from a mean of 48.1 to 80.4, with an N-Gain of 0.72 placing it in the high category.

The paired-sample t-test yielded $t(31) = 12.47$ with $p = 0.000$ for scientific literacy and $t(31) = 14.83$ with $p = 0.000$ for problem-solving skills. Both p-values are well below the $\alpha = 0.05$ threshold, indicating a statistically significant difference between the pretest and posttest results confirming that the observed improvement was genuinely attributable to the use of the e-module.

In addition to the N-Gain value, effect sizes (Cohen's d) were calculated to determine the magnitude of the intervention's impact independent of sample size. Using the formula $d = t/\sqrt{n}$, the results yielded $d = 2.20$ for scientific literacy and $d = 2.62$ for problem-solving skills, both of which far exceed the 0.80 threshold and are therefore classified as large effects according to Cohen's (1988) criteria. This finding strengthens the evidence that the observed improvement is not merely statistically significant but also carries substantial practical significance for science instruction in the classroom.

Student Responses

Overall, student responses to the e-module were highly positive. The average questionnaire score was 91.3% of the maximum possible, placing it in the "very good" category. The aspects that received the highest ratings were ease of interface use (93.5%), the appeal of the visual display (92.8%), and enjoyment of the drag-and-drop activities (94.1%). The aspect with the lowest—though still fairly good—score was the clarity of instructions in some of the more complex activities (86.3%).

Qualitative data obtained through open-ended reflection sheets revealed several key themes in student responses: (a) increased confidence in identifying ecosystem components after completing the drag-and-drop activities; (b) appreciation for problem scenarios set in a local context, which felt relevant to their surrounding environment; and (c) a desire for similar e-modules to be developed for other science topics.

Analytical Discussion

Overall, this study's findings confirm and extend several results from previous research. First, the e-module's effectiveness in improving scientific literacy, with an N-Gain of 0.67, aligns with the findings of Fatimah and Widiyatmoko (2021) and Rahmawati et al. (2022), which showed that interactive digital media plays an important role in enhancing students' scientific competence. However, the medium-category N-Gain suggests that improving scientific literacy requires more than mere access to interactive media; more frequent practice in evaluating scientific evidence and designing research questions is also needed.

Second, the N-Gain for problem-solving skills (0.72) was higher than that for scientific literacy (0.67), indicating that the combination of drag-and-drop features and PBL stages is more effective in improving problem-solving competence. Drag-and-drop activities require students to identify problems, analyze relationships among elements, and place elements correctly—directly practicing the problem-solving steps outlined by Polya (1957).

Theoretically, the effectiveness of drag-and-drop activities in improving both competencies can be explained by integrating the three theoretical frameworks outlined in this study's conceptual framework. Mayer's (2009) principle of multimedia learning explains that interactive visual representations enable students to construct a more complete mental model of relationships among organisms within an ecosystem than static text representations, because students process visual and verbal information simultaneously through dual-channel processing. Cognitive load theory (Sweller et al., 2019) explains that well-designed drag-and-drop activities—for example, with immediate feedback and clearly marked target zones, as recommended by the validators in this study—can minimize extraneous cognitive load while increasing germane cognitive load. This mental effort directly contributes to the formation of new knowledge schemas. From the constructivist perspective underlying PBL (Barrows, 1986; Hmelo-Silver, 2004), the act of arranging, classifying, and connecting ecosystem elements manually through drag and drop represents a concrete form of the assimilation and accommodation of knowledge, meaning students do not merely memorize concepts but genuinely construct their own understanding through action (learning by doing).

This finding is consistent with recent research. Aladin et al. (2024) and Asnidar et al. (2024) showed that PBL-based e-modules consistently improve students' cognitive outcomes when interactive elements are explicitly aligned with the stages of the PBL syntax, as was done in this study. Similarly, Ismaniati and Iskhamdhanah (2023) affirmed that interactivity within an e-module—rather than passive multimedia alone—is the primary determinant of improved student scientific literacy. The large Cohen's *d* values obtained for both variables in this study ($d = 2.20$ and $d = 2.62$) provide additional evidence that the e-module's effectiveness is not only statistically significant but also carries a genuine practical impact on learning, consistent with the importance of reporting effect sizes in evidence-based instructional development research, as emphasized by Kania et al. (2024).

Third, the very high feasibility scores from subject matter experts (87.4%) and media experts (89.1%), further supported by Aiken's *V* values that were all above 0.75, indicate that the developed e-module meets the required pedagogical, technical, and psychometric standards. This finding is consistent with Purnomo et

al. (2022), who emphasized that e-module quality depends heavily on a thorough needs analysis conducted during the early stages of development.

Fourth, the highly positive student response (91.3%) confirms that a user experience designed around ease of use, coherence, and visual appeal can enhance student engagement and enthusiasm for learning. This aligns with the Technology Acceptance Model (TAM), which posits that perceived ease of use and perceived usefulness are the two primary factors influencing the degree to which a technology is accepted (Davis, 1989, as cited in Nasution & Situmorang, 2021).

Several limitations of this study should also be noted. First, the one-group pretest-posttest design without a control group limits researchers' ability to isolate the e-module's effect from other confounding factors. Second, this study was conducted at only one school, meaning the findings require further examination through research across multiple locations. Third, the success of this e-module also depends on adequate technological infrastructure, which remains a challenge in many schools across Indonesia.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study offers three main scientific contributions to the field of science instructional media development. First, from a methodological standpoint, this study demonstrates that the explicit integration of drag-and-drop interaction features with the stages of the Problem Based Learning syntax—rather than simply adding interactive elements separately from the pedagogical structure—produces an e-module that is content-valid (Aiken's $V = 0.85\text{--}0.90$), reliable (Cronbach's $\alpha = 0.81\text{--}0.88$), and highly feasible for use (subject matter expert score of 87.4% and media expert score of 89.1%), thereby enriching the 4D R&D development procedure with stronger psychometric evidence than previous PBL e-module studies.

Second, from a theoretical standpoint, the findings of this study reinforce the argument that the effectiveness of interactive media in science instruction is determined not merely by the sophistication of the technology used, but by the extent to which that interactivity is designed in alignment with the principles of multimedia learning (Mayer, 2009), cognitive load theory (Sweller et al., 2019), and PBL constructivism (Barrows, 1986; Hmelo-Silver, 2004). Empirical evidence in the form of improved scientific literacy ($N\text{-Gain} = 0.67$; $d = 2.20$) and problem-solving skills ($N\text{-Gain} = 0.72$; $d = 2.62$), with large effect sizes, confirms that the integration of these three theoretical frameworks is relevant and has strong potential for replication in other junior high school science learning contexts.

Third, from a practical standpoint, this study offers a novel contribution in the form of an explicit mapping model between the five stages of the PBL syntax and distinct types of drag-and-drop interaction at each stage—an approach not yet extensively detailed in previous science e-module studies (Aladin et al., 2024; Asnidar et al., 2024)—which can serve as an instructional design reference for e-module developers in other subjects or educational levels.

Recommendations

Based on the identified findings and limitations, the following recommendations are offered. First, future research should employ a stronger experimental design, such as a quasi-experimental design with a control group, to obtain more robust evidence of the e-module's effectiveness relative to conventional instructional methods.

Second, for broader implementation, other schools interested in adopting this e-module are advised first to ensure the readiness of the technological infrastructure (internet access and devices) and to provide training for science teachers on using the e-module, given that the quality of teacher facilitation significantly influences the success of digital PBL implementation. E-modules using a similar approach should also be developed for other science topics with complex concepts and high potential for contextualization, following the validated PBL-stage-to-drag-and-drop-interaction mapping pattern established in this study.

Third, future e-module developers may consider adding clearer features to train scientific literacy competencies not yet covered in this study, particularly the ability to evaluate scientific inquiry designs.

Fourth, and equally important, future research is encouraged to explore the development of artificial intelligence (AI) features and adaptive learning capabilities within science e-modules—for example, a system that can automatically adjust the difficulty level of drag-and-drop activities based on student performance, provide personalized real-time feedback, or recommend a learning path suited to individual student needs. Recent systematic reviews indicate that the integration of AI in adaptive learning has been shown to improve student engagement, motivation, and learning outcomes across various educational levels (Merino-Campos, 2025; Demartini et al., 2024), suggesting that this direction of development holds significant potential for further optimizing junior high school students' scientific literacy and problem-solving achievement in future research.

Fifth, in disseminating the e-module nationally, a more systematic mapping of technological infrastructure readiness across target schools should be conducted for example, through a digital-readiness survey prior to implementation—so that the benefits of the e-module can be experienced equitably by students in various regions with differing facility conditions.

Credit Authorship Contribution Statement

Ika Ritaningsih: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft. Bramastia: Supervision, Validation, Methodology, Writing – review & editing. (Please adjust author contributions as appropriate before submission.)

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Declaration

All participants, including students, teachers, and validating experts, provided informed consent prior to their involvement in the study. They were informed about the study's purpose, procedures, and their right to withdraw at any time without consequence. For underage student participants, consent was obtained through the relevant school authorities/parents in accordance with institutional ethical procedures.

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REFERENCES

- Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, 45(1), 131–142. <https://doi.org/10.1177/0013164485451012>
- Aladin, Asrowi, & Santosa, E. B. (2024). Problem Based Learning-Oriented E-Module to Innovate Learning Activities in High School. *Journal of Education Research and Evaluation*, 8(4), 622–632. <https://doi.org/10.23887/jere.v8i4.78567>
- Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's educational objectives. Longman.
- Anggraini, R., & Sari, D. P. (2022). The effectiveness of drag-and-drop learning media on information retention among junior high school students in digestive system material. *Jurnal Pendidikan Sains Indonesia*, 10(2), 145–158. <https://doi.org/10.24815/jpsi.v10i2.23412>
- Arends, R. I. (2012). *Learning to teach* (9th ed.). McGraw-Hill.

- Asnidar, A., Safriana, S., Jalil, S. M., Sakdiah, H., & Zahara, S. R. (2024). Development of e-Modules on Problem-Based Learning to Enhance Students' Science Literacy. *Asian Journal of Science Education*, 6(1), 134–144.
- Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20(6), 481–486. <https://doi.org/10.1111/j.1365-2923.1986.tb01386.x>
- Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). McGraw-Hill/Open University Press.
- Chou, P. N., Chang, C. C., & Lin, C. H. (2021). Effects of drag-and-drop interactions on learning outcomes and cognitive load in online learning environments. *Computers & Education*, 162, 104074. <https://doi.org/10.1016/j.compedu.2020.104074>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Demartini, C. G., Sciascia, L., Bosso, A., & Manuri, F. (2024). Artificial Intelligence Bringing Improvements to Adaptive Learning in Education: A Case Study. *Sustainability*, 16(3), 1347. <https://doi.org/10.3390/su16031347>
- Fatimah, S., & Widiyatmoko, A. (2021). Development of a locally contextualized science e-module to improve junior high school students' conceptual understanding. *Unnes Science Education Journal*, 10(1), 34–42. <https://doi.org/10.15294/usej.v10i1.41233>
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. <https://doi.org/10.1119/1.18809>
- Hanifha, S., Erna, M., Noer, A. M., & Talib, C. A. (2023). Socioscientific Issue-Based Undergraduate Student Worksheets on Scientific Literacy and Environmental Awareness. *Jurnal Pendidikan IPA Indonesia*, 12(4), 504–513. <https://doi.org/10.15294/jpii.v12i4.45817>
- Haryati, S., & Nugroho, A. (2022). Implementation of Problem Based Learning in ecosystem material to improve motivation and conceptual understanding among junior high school students. *Jurnal Ilmu Pendidikan*, 28(1), 58–71. <https://doi.org/10.17977/um048v28i12022p058>
- Hidayat, M. T., & Muliawati, N. E. (2023). Self-regulated learning in interactive e-modules: A theoretical review and practical implications. *Jurnal Teknologi Pendidikan*, 25(1), 1–14. <https://doi.org/10.21009/jtp.v25i1.31891>
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Ismaniaty, C., & Iskhamdhanah, B. (2023). Development of Interactive E-Modules to Increase Learning Motivation and Science Literacy in Elementary School Students. *Jurnal Iqra': Kajian Ilmu Pendidikan*, 8(1), 156–173. <https://doi.org/10.25217/ji.v8i1.2699>
- Kania, N., Kusumah, Y. S., Dahlan, J. A., Nurlaelah, E., Gürbüz, F., & Bonyah, E. (2024). Constructing and providing content validity evidence through Aiken's V index based on the experts' judgments of the instrument to measure mathematical problem-solving skills. *REID (Research and Evaluation in Education)*, 10(1), 64–79. <https://doi.org/10.21831/reid.v10i1.71032>
- Kasih, A. P., & Wibowo, E. S. (2022). Identification of junior high school students' problem-solving abilities in context-based science learning. *Jurnal Pendidikan dan Pembelajaran IPA Indonesia*, 12(1), 23–35. <https://doi.org/10.23887/jpii.v12i1.43781>
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
- Merino-Campos, C. (2025). The impact of artificial intelligence on personalized learning in higher education: A systematic review. *Trends in Higher Education*, 4(2), 17. <https://doi.org/10.3390/higheredu4020017>
- Nasution, M. K., & Situmorang, M. (2021). The use of digital technology in science learning: A systematic literature review 2016–2021. *Jurnal Pendidikan IPA Indonesia*, 10(4), 512–524. <https://doi.org/10.15294/jpii.v10i4.31752>

- Nurjanah, S., Istiyono, E., Widiastuti, W., Iqbal, M., & Kamal, S. (2023). The application of Aiken's V method for evaluating the content validity of instruments that measure the implementation of formative assessments. *Journal of Research and Educational Research Evaluation*, 12(2), 125–133.
- OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. <https://doi.org/10.1787/53f23881-en>
- Prasetya, A. T., & Harjono, N. (2020). Development of an interactive multimedia-based e-module to improve student learning motivation. *Jurnal Inovasi Teknologi Pendidikan*, 7(1), 1–13. <https://doi.org/10.21831/jitp.v7i1.28541>
- Purnomo, A., Raharjo, T. J., & Subiyantoro, S. (2022). Analysis of e-module quality from a user perspective: A study of secondary-level science learning. *Jurnal Teknologi Informasi dan Komunikasi dalam Pendidikan*, 9(1), 44–56. <https://doi.org/10.24114/jtikp.v9i1.34762>
- Rahmawati, I., Sunarno, W., & Sajidan. (2022). Development of scientific literacy-based science learning tools on ecosystem material for junior high school students. *Jurnal Pendidikan IPA Indonesia*, 11(2), 232–244. <https://doi.org/10.15294/jpii.v11i2.35421>
- Riduwan. (2015). *Skala pengukuran variabel-variabel penelitian [Measurement scales for research variables]*. Alfabeta.
- Sari, R. N., & Mahmudi, A. (2021). Scientific literacy profile of Indonesian junior high school students based on the 2018 PISA framework. *Jurnal Pendidikan MIPA*, 22(1), 112–125. <https://doi.org/10.23960/jpmipa.v22i1.pp112-125>
- Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1), 9–20. <https://doi.org/10.7771/1541-5015.1002>
- Setiawan, B., & Kurniawan, D. A. (2022). Digital technology-based ecosystem instructional design in the Merdeka Curriculum era. *Jurnal Pendidikan Biologi Indonesia*, 8(2), 145–158. <https://doi.org/10.22219/jpbi.v8i2.19876>
- Suryani, L., Widodo, A., & Sopandi, W. (2020). Problem Based Learning in science instruction: A systematic review of its effect on critical thinking skills. *Jurnal Pendidikan IPA Indonesia*, 9(3), 345–357. <https://doi.org/10.15294/jpii.v9i3.24321>
- Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31(2), 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional development for training teachers of exceptional children*. Indiana University.
- Wahyuni, E. S., Rusilowati, A., & Sudarmin. (2021). Analysis of junior high school students' problem-solving skills in science learning: A portrait and its influencing factors. *Unnes Science Education Journal*, 10(3), 201–213. <https://doi.org/10.15294/usej.v10i3.48765>
- Wijayanti, A., & Prasetyo, Z. K. (2023). Integrating Problem Based Learning with digital technology in science instruction: A critical review and future research directions. *Jurnal Inovasi Pendidikan IPA*, 9(1), 1–16. <https://doi.org/10.21831/jipi.v9i1.52341>