



Development of Contextual Environmental Issues-Based Ecology E-Books to Improve Students' Critical Thinking Skills

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ABSTRACT

This research aims to develop a valid and effective contextual environmental issue-based ecology e-book to improve students' critical thinking skills. This research uses a Research and Development (R&D) approach with a 4D (Define, Design, Develop, Disseminate) model. The research population consists of junior high school students, and the test subjects (as the unit of analysis) comprise 61 grade VII students from two classes. This sample size was selected to ensure data representativeness and to more comprehensively measure the effectiveness of the media. Data collection techniques include validation sheets by subject matter experts, media experts, and science teachers, as well as pretest and posttest instruments based on critical thinking indicators. Data were analyzed using descriptive statistics, N-Gain analysis, and classical learning mastery percentage. The validation results showed an average score of 3.70, indicating high feasibility. The effectiveness test results showed an increase in the average score from 55 to 75, with an N-Gain of 0.44 (medium), and an increase in classical learning mastery from 31% to 85%. This study offers novelty by systematically mapping six critical thinking indicators into the interactive features of the e-book that specifically address local environmental issues. Thus, the developed e-book is highly feasible and proven to be effective as an innovative independent teaching material in science learning.

Keywords: *ecology e-book, contextual environmental issues, critical thinking skills.*

INTRODUCTION

Science learning at the junior high school level plays a strategic role in shaping students' scientific literacy and higher-order thinking skills. In the context of 21st-century education, students are not only expected to master scientific concepts but also to analyze phenomena, evaluate information critically, and make decisions based on scientific evidence. These competencies are essential for preparing students to face complex real-world challenges, particularly those related to environmental and societal issues. However, the results of the Programme for International Student Assessment indicate that Indonesian students' science literacy still needs significant improvement to compete at the global level (OECD, 2019). This condition suggests that current learning practices have not fully facilitated the development of higher-order thinking skills. Supporting this, Yusmar & Fadilah (2023) reported that many junior high school students still experience difficulties in connecting scientific concepts with contextual problems in their surrounding environment. This gap highlights the need for more innovative, context-based

learning approaches that bridge conceptual understanding with real-world applications, thereby fostering students' critical thinking and scientific literacy more effectively.

Reinforcing these findings, preliminary observations conducted at MTs Roudlotul Ulum, Mojoduwur, Mojowarno, Jombang, East Java, Indonesia, indicate that science learning still relies heavily on conventional printed textbooks, which tend to emphasize the transmission of conceptual knowledge rather than its application. As a result, students are often limited to memorizing ecosystem components. They are unable to analyze real environmental problems in their immediate surroundings, such as local water pollution or household waste management. This gap between conceptual understanding and real-world application reflects a lack of meaningful learning experiences that engage students in higher-order thinking processes. Moreover, the limited use of interactive and contextual learning media reduces students' opportunities to construct knowledge actively, thereby hindering the development of critical thinking skills, particularly in analysis, evaluation, and inference. These conditions highlight the urgency of developing innovative learning approaches and digital teaching materials that explicitly integrate real-world contexts and actively engage students in problem-solving activities, thereby fostering critical thinking skills more effectively and sustainably.

Ecological content plays an increasingly important role in developing students' critical thinking skills, as it inherently involves complex cause-and-effect relationships among biotic and abiotic components, dynamic interactions among living organisms, and the impact of human activities on ecosystem balance. These characteristics make ecology a highly relevant context for engaging students in higher-order thinking processes, particularly in analyzing environmental issues that are often multidimensional and require evidence-based reasoning. Critical thinking, as defined by Facione (1990), encompasses the skills of interpretation, analysis, evaluation, inference, explanation, and self-regulation, all of which are essential for enabling students to assess the validity of scientific information and construct well-reasoned arguments. In the context of ecological learning, these skills are not only used to understand concepts but also to evaluate real-world environmental problems and propose appropriate solutions. Supporting this, a systematic study by Ramadani (2025) demonstrates that the structured integration of critical thinking indicators in science learning significantly enhances the quality of students' scientific reasoning. Therefore, deliberately designed ecology learning that embeds critical thinking processes has strong potential to foster deeper understanding and more meaningful engagement with environmental issues.

Various studies over the past five years have consistently shown that active learning models have a significant positive impact on strengthening students' critical thinking skills. In the context of ecology learning, the application of guided inquiry has been proven not only to improve learning outcomes but also to enhance students' analytical abilities by encouraging them to investigate phenomena, formulate hypotheses, and draw conclusions based on evidence (Hajar et al., 2025). Similarly, the problem-based learning approach has been widely recognized as an effective strategy for developing higher-order thinking skills through engagement with contextual and authentic problems that require reasoning and decision-making (Purwanto, 2020; Agnesa & Rahmadana, 2022). In addition, the Writing to Learn strategy in junior high school science learning supports students in organizing their ideas systematically, thereby facilitating deeper conceptual understanding and improving scientific communication skills (Sintiawati, 2021).

Taken together, these findings indicate that reflective, inquiry-based, and problem-oriented learning activities play a crucial role in fostering critical thinking within ecological learning contexts. However, the effectiveness of these approaches largely depends on the availability of appropriate learning media that can integrate such activities in a structured and engaging manner. Therefore, there is a need for innovative instructional materials that not only present content but also embed inquiry processes, problem-solving tasks, and reflective activities to support the development of students' critical thinking skills more effectively.

The development of teaching materials is a crucial aspect of supporting the implementation of 21st-century skills-oriented learning. Digital-based learning media offer opportunities to present content in more interactive and contextual ways. The use of digital media, such as interactive flipbooks, has been shown to increase student involvement in science learning (Hadi, 2021). Problem-based learning supported by digital media can also significantly increase student participation and engagement (Jamaludin, 2023). The integration of values and context in science learning also enriches the meaning of learning and strengthens students' conceptual understanding (Amril, 2020). Thus, digital teaching material innovation has great potential in supporting the strengthening of critical thinking.

Contextual, issue-based environmental approaches are increasingly relevant in ecological learning at the junior high school level, as they enable students to connect scientific concepts to real-life situations in their immediate surroundings. Linking learning materials to local realities, such as pollution, conservation, and waste management, has been shown to enhance students' eco-literacy by making abstract concepts more concrete and meaningful (Erfariyah et al., 2024). In line with this, the development of learning media grounded in the local environment also positively impacts students' understanding of environmental pollution, as it provides authentic contexts that facilitate deeper conceptual engagement (Lesmanawati, 2024).

Furthermore, integrating such contextual approaches with digital learning media, particularly e-books, offers additional advantages in accessibility, interactivity, and flexibility. The use of e-books has been reported to be effective in improving students' science knowledge and increasing their learning motivation, especially when supported by multimedia features and interactive elements (Wahyuning & Subandowo, 2022). These findings suggest that the combination of contextual environmental issues and digital media not only enhances conceptual understanding but also creates more engaging and student-centered learning experiences. Therefore, strengthening local contexts within digital learning media is a promising strategy to make ecological learning more relevant, meaningful, and effective for junior high school students.

Although various studies have developed modules, e-modules, and interactive learning media on ecological materials, the opportunity to develop e-books that explicitly include critical thinking indicators in each learning feature remains open. Several studies emphasize the effectiveness of certain learning models (Hajar et al., 2025; Jamaludin, 2023), but the integration of mini-laboratories, contextual projects, self-reflection, and the strengthening of digital literacy into a comprehensive e-book design has not been widely reported at the junior high school level. This condition shows that there is a contribution space in the development of structured, contextual, and tested digital teaching materials.

The selection of e-books as a solution in this study is based on their flexibility in containing text, images, videos, and integrated interactive activities. This media allows the visual presentation of ecological materials, making it easier for students to interpret and analyze data. In addition, e-books provide space for students to reflect and evaluate themselves in line with self-regulation indicators in critical thinking (Facione, 1990). Thus, the development of ecological e-Books based on Contextual Environmental Issues to Improve Students' Critical Thinking Skills is a strategic step in supporting junior high school science learning that is adaptive to the demands of 21st-century skills.

Based on this description, this study aims to develop, validate, and examine the effectiveness of an ecology e-book focused on contextual environmental issues, with students' critical thinking skills as the unit of analysis. This study is designed not only to produce a feasible and effective learning product but also to provide empirical evidence regarding how contextual digital media can support the development of higher-order thinking skills in science learning. By integrating real-world environmental issues with structured critical thinking indicators, this research seeks to bridge the gap between conceptual understanding and its application in authentic contexts.

From a theoretical perspective, this study is expected to enrich the literature on science instructional design, particularly in the development of digital learning media oriented toward higher-order thinking skills. It also reinforces the importance of integrating contextual and problem-based approaches within digital platforms to support meaningful learning experiences. In practice, the results of this study are expected to serve as a valuable reference for educators in designing and using ecological learning media that are more contextually relevant, interactive, and aligned with the needs of 21st-century learning. Furthermore, the developed e-book is expected to support the implementation of student-centered learning and enhance students' reasoning abilities at the junior high school/MTs level.

METHODOLOGY

This research is a type of Research and Development (R&D) that aims to produce learning products in the form of ecological e-books based on contextual environmental issues. The development procedure refers to the 4D model, which consists of the Define, Design, Develop, and Disseminate stages. The selection of the 4D model is based on its systematic and practical characteristics for developing instructional media, making it more effective at producing products that are adaptive to real classroom needs than other development models. In the Develop stage, the product development process was conducted in October 2025 at Hasyim Asy'ari University. Furthermore, in the Disseminate stage, the field trial was conducted on November 13–14, 2025.

The population in this study included all grade VII students at MTs Roudlotul Ulum. The research subjects, who served as the unit of analysis in this large-scale trial, comprised 61 students from two study groups. The subjects were selected using purposive sampling, with consideration of equal academic ability across classes and the suitability of the ongoing curriculum material. The participants were aged 12–13 years, consisting of 23 males and 38 females. The selection of subjects with heterogeneous academic ability levels (low, medium, and high cognitive variations) was intended to ensure the comprehensiveness of the media effectiveness data.

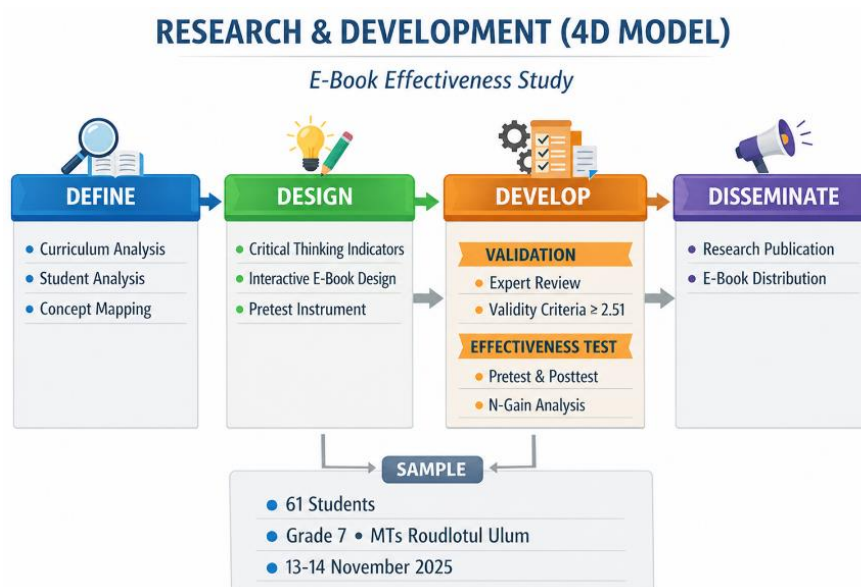


Figure1. Research Flow

In the Design stage, the initial design of the ecological e-book was developed by integrating six critical thinking indicators, as outlined by Facione: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The initial prototype of the e-book was designed in Canva and further developed into an interactive format using Flip PDF Professional to support multimedia

integration and contextual problem-based activities. At this stage, validation instruments and pretest essay questions were also prepared.

In the Develop stage, the product was evaluated for validity and effectiveness. The validity test was conducted by three validators, consisting of one material expert, one media expert, and one science teacher practitioner, using a Likert scale of 1–4. The product was considered valid if it obtained an average score of ≥ 2.51 . Furthermore, the effectiveness test was implemented using a one–group pretest–posttest design involving 61 students. Students were given a pretest before using the e-book and a posttest after the learning process.

Data collection techniques in this study included validation sheets, pretest and posttest instruments, and observation sheets of learning implementation. The main data were obtained from pretest and posttest scores measuring students' critical thinking skills. In contrast, supporting data were collected through classroom observations conducted by science teachers to ensure proper implementation of the e-book.

Data analysis was carried out using descriptive statistics, N-Gain analysis, and classical learning mastery percentage. The improvement in critical thinking skills was calculated using the N-Gain formula, and the results were categorized as high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), or low ($g < 0.3$). The e-book was considered effective if the improvement reached at least the medium category, and at least 71% of students achieved the minimum mastery criterion (KKTP ≥ 70). The use of N-Gain analysis was intended to minimize bias from heterogeneous pretest scores, thereby providing a more accurate measurement of learning effectiveness.

The final stage of this 4D model is the dissemination of products that have been tested for validity and effectiveness. Dissemination activities are carried out through the publication of academic research results in scientific articles, so they can be accessed by the academic community at large. In addition, practical dissemination is carried out by distributing this ecology e-book, tailored to contextual environmental issues, to fellow science teachers via digital links. This step aims to ensure that the innovations of teaching materials that have been developed can be adopted and implemented in real life in other classrooms as interactive media references to train students' critical thinking skills.

RESULT AND DISCUSSION

This section presents the results and discussion, specifically focused on the two main objectives of the study: analyzing the feasibility of the ecology e-book based on contextual environmental issues and testing its effectiveness in improving students' critical thinking skills in large-scale trials. These two aspects are essential as they not only determine the quality of the developed product in terms of validity and usability but also provide empirical evidence of its impact on learning outcomes. By integrating contextual environmental issues with systematically embedded critical thinking indicators, this study contributes to the development of innovative digital teaching materials that are both pedagogically meaningful and practically applicable in science learning. Furthermore, the findings of this study are expected to enrich the existing literature on interactive e-book development, particularly in supporting the implementation of student-centered learning and enhancing critical thinking skills in the context of junior high school science education.

E-Book Display

The development of this ecology e-book, based on contextual environmental issues, is designed to be functional and relevant teaching material for junior high school students. The product is designed with special attention to the presentation of contextual content, activities that trigger active engagement, and ease of access through digital formats. The e-book's visual design is

created in Canva to optimize readability and visual interest. At the same time, the digital format enables multimedia integration, providing students with a richer learning experience than conventional printed books (Ramadhanti & Azhar, 2022).

The main features of the product, such as the Information Corner, Activity Column, Mini Laboratory, Biology Quotes, and My Adventure Ecosystem, are designed to facilitate various types of cognitive activities. The Information Corner serves as an additional reading source that encourages evaluation of scientific information; in the practice of digital learning, the provision of curated reference sources has been proven to expand science literacy and help students assess the credibility of information (Sintiawati, 2021). Meanwhile, the Activity Column and Mini Laboratory provide space for small, practice-based activities on real problems. These kinds of activities encourage data interpretation and the development of scientific reasoning through hands-on experience (Hadi, 2025).

The learning character of the project and contextual tasks emerges strongly in the My Adventure Ecosystem feature. Through simple projects such as mapping local waste problems or analyzing the impact of pollutants on aquatic ecosystems, students are directed to identify problems, collect data, analyze findings, and formulate recommendations for measures that gradually build higher-level thinking skills. Findings from similar studies on teaching material development show that the context-specific project approach improves learners' cognitive engagement and problem-solving skills (Putri, 2024).

Technically, the choice of e-book format (not just a static PDF) prioritizes accessibility and interactivity. The integration of short videos, interactive images, and response buttons (e.g., links to assignment forms or short quizzes) supports a variety of learners' learning styles through a multimodal approach. Research on the development of interactive e-books and e-modules shows that multimedia and interactive features increase learning motivation and facilitate understanding of abstract concepts (Yudiyanto, 2024; Defianti, 2023).

From a pedagogical perspective, this e-book is designed to accommodate the six indicators of critical thinking according to Facione: interpretation, analysis, evaluation, inference, explanation, and self-regulation in a way that is integrated into each feature. For example, the assignment in the Activity Column asks students to transform quantitative data into graphs (interpretation and analysis), while reflective questions at the end of the activity facilitate explanation and self-regulation. The explicit integration of indicators into learning activities provides a more systematic framework for critical thinking exercises than tools that only present information (Maulida, 2024).

Designing features that encourage collaboration (e.g., educational poster-making group tasks) is also an important characteristic of this product. Creative activities such as poster creation combine the domain of application and student creativity, not only recording facts, but also synthesizing information into communicative visual messages. Empirical evidence from digital media development research shows that group creative tasks can improve students' scientific communication skills, creativity, and collaboration (Se'ke, 2025).

From an implementation perspective, the ease of distributing e-books via OJS/school links and the product's compatibility with smartphones add practical value to this product. However, the literature also shows that the effectiveness of digital media is greatly influenced by teacher readiness and school infrastructure; therefore, there needs to be teacher-assistance planning to ensure optimal use of e-books in classroom practice (Pratama & Widodo, 2022). It is important to note that even though the product design has accommodated features that support active learning.

Concisely and descriptively, the characteristics of the e-book, integrated with local contexts, mini-experiment activities, multimedia features, and project-based assignments, illustrate the developer's intention to make the e-book not just a repository of content but a means of learning that encourages scientific exploration and reflection. The placement of these applicative and

interactive features is consistent with the findings of the latest research on the development of effective digital teaching materials in the context of science learning (Hadi, 2025; Ramadhanti & Azhar, 2022).

E-Book Validation

The validation test of the Ecology e-book, based on contextual environmental issues, was conducted by three validators: one material expert, one media expert, and one science teacher-practitioner. The validation process aims to assess the feasibility of content, presentation, language, and the suitability of features with critical thinking skill indicators. A summary of the overall results of validation is presented systematically in Figure 2 and Table 1, which contains a recapitulation of the assessments of each validator.

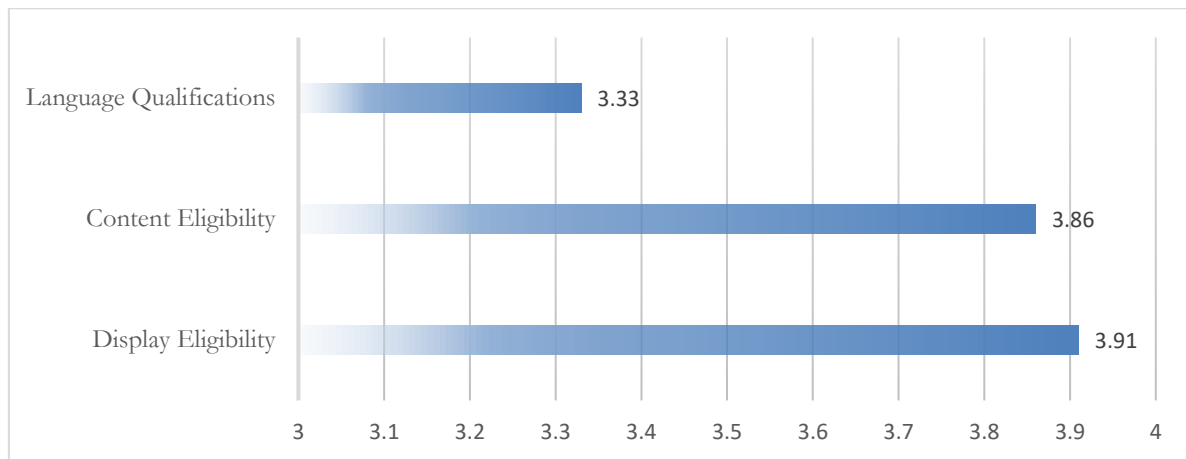


Figure 2. Validator Assessment Recapitulation

The feasibility of the developed ecology e-book was evaluated through expert validation covering display, content, and language aspects. This evaluation aimed to determine the overall quality and suitability of the e-book as a learning medium in science instruction. The detailed results of the expert assessment, including scores for each indicator and their corresponding criteria, are presented in Table 1.

Table 1. Recapitulation of Validation Results by Validators

No	Aspects Assessed	Average	Criteria
Display Eligibility			
1	The physical appearance of the e-book is attractive and neat.	4	Very Feasible
2	The page layout is structured systematically and consistently.	4	Very Feasible
3	The selection of typefaces and font sizes is easy to read.	4	Very Feasible
4	The use of colors supports the comfort of learning.	3,60	Very Feasible
5	The images used are clear and relevant to the material.	4	Very Feasible
6	Supporting media (videos/links) work well and support learning.	3,83	Very Feasible
7	The features in the e-book support learning activities and the development of critical thinking.	4	Very Feasible
Average Display score		3,91	Very Feasible
Content Eligibility			
8	The material presented is in accordance with the learning objectives.	4	Very Feasible
9	The concept presented is correct and in accordance with the ecological material.	4	Very Feasible

10	Learning activities in e-books support students' understanding.	3,67	Very Feasible
11	E-books support students' skills in analyzing environmental problems.	3,67	Very Feasible
12	The content of the e-book encourages students to think critically.	4	Very Feasible
Average Content score		3,86	Very Feasible
Language Feasibility			
13	The language used is clear and easy to understand.	3,33	Very Feasible
14	The sentence structure is well structured and effective.	3,67	Very Feasible
15	The use of terms is in accordance with the applicable rules.	3	Very Feasible
Average Language score		3,33	Very Feasible
Total		3,70	Very Feasible

Overall, the validity of the contextual environmental issue-based ecology e-book developed in this study demonstrates consistently very feasible criteria across all assessed aspects. The average overall score from the validators was 3.70 out of 4, indicating that the product meets a high standard of quality and is suitable for use as teaching material in junior high school science instruction. This high level of validity reflects the alignment of the e-book design with both pedagogical principles and content accuracy, ensuring that it can effectively support the learning process.

The validation process involved three validators: a material expert, a media expert, and a science teacher-practitioner, each providing a comprehensive evaluation from their respective perspectives. The assessment covered key aspects including visual appearance, content relevance and accuracy, and language clarity. The convergence of positive evaluations across these aspects suggests that the e-book not only presents scientifically accurate material but also offers an engaging design and clear communication, which are essential components of effective digital learning media. These results indicate that the developed e-book is well-prepared for implementation and has strong potential to support meaningful learning experiences.

In terms of display eligibility, the e-book received an average score of 3.91, which falls within the very feasible category. Visual features such as a clear page layout, easy-to-read fonts, and the inclusion of images and helpful media links have been designed to support learning. Information Corners, Activity Columns, and Mini Laboratories, for example, not only present text but also relevant combinations of images and multimedia to stimulate students' interest in learning. These findings align with previous studies that found that visually appealing, interactive digital media designs can increase student engagement and learning motivation in the context of science learning (Wibisari & Mulyani, 2023).

The content feasibility aspect received an average score of 3.86, indicating that the material presented in the e-book is consistent with the learning objectives and scientifically accurate. The ecological materials presented include not only basic concepts such as biotic and abiotic components, but also real-world contexts such as the impact of pollution on ecosystems, habitat conservation, and waste management, all of which can be found in activity features such as My Adventure Ecosystem. The comprehensive presentation of this material shows that the e-book not only conveys content but also connects it to students' real experiences, thereby supporting a deeper understanding. In line with other studies that discuss science e-books, the presentation of relevant and contextual content is an important indicator of the feasibility of digital teaching materials (Setyaedhi, 2024). In terms of language feasibility, the average score for validators was 3.33, still within the very feasible range, though lower than for the display and content aspects. The language in the e-book is quite clear and appropriate for junior high school students. However, some terms may need simplification or additional context to make them easier to understand. In previous

research on digital media development, the use of communicative language, in accordance with the rules, has been shown to help students understand the material more effectively (Safitri, 2023).

Overall, the very decent display, content, and language validity score indicate that this e-book meets the basic criteria for use in junior high school learning. The strong appearance and content indicate that the e-book is not only informative but also visually appealing, thereby supporting the learning process more actively. On the other hand, the slightly lower language score indicates a need for greater attention to the preparation of terms and sentences to make it easier for all students to understand, especially those still in the early stages of scientific literacy. The results of this validation show alignment with other studies that also develop e-book-based digital teaching materials, where digital media validated by experts tend to get a suitable predicate if the design, content, and language of consideration are well structured (Ramadhanti, 2022).

E-Book Effectiveness

The effectiveness of the ecology e-book, grounded in contextual environmental issues, in developing critical thinking skills is assessed through student learning outcomes and the achievement of critical thinking indicators integrated into each learning activity. Learning outcomes are derived from pretest and posttest scores, each consisting of 10 multiple-choice questions that assess critical thinking indicators according to Peter A. Facione. Students are declared complete if they obtain a minimum score of 70, as set by the school. Furthermore, pretest and posttest data are analyzed using N-Gain scores to determine the level of improvement in critical thinking skills after the use of the e-book in learning.

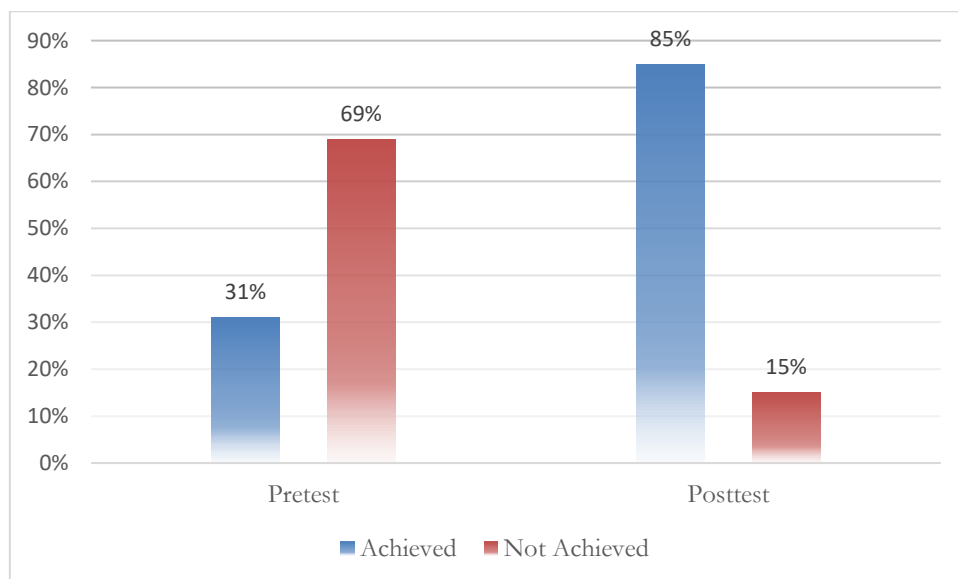


Figure 3. Comparison of Classical Completeness of Students' Critical Thinking Skills (N=61)

The effectiveness of the developed ecology e-book in improving students' critical thinking skills was evaluated by comparing pretest and posttest scores. This analysis aims to determine the extent of learning improvement after the implementation of the e-book in classroom instruction. As presented in Table 2, there is a significant increase in students' average scores, from 55 in the pretest to 75 in the posttest, accompanied by an increase in the number of students achieving learning completeness from 31% to 85%. In addition, the average N-Gain score of 0.44 indicates a moderate level of improvement, suggesting that the e-book has a meaningful impact on enhancing students' critical thinking skills.

Table 2. Recapitulation of The Sensitivity of The Question Item

Remarks	Pretest	Posttest
Grade Point Average	55	75
Completed Students (≥ 70)	19 Students (31%)	52 Students (85%)
Students Are Incomplete	42 Students (69%)	9 Students (15%)
Average <i>N-Gain</i>		0.44(Medium Category)

Based on the recapitulation data from large-scale trials ($N=61$), the study's results show that the ecology e-book developed with contextual environmental issues has proven effective, significantly improving students' critical thinking skills. It can be seen from the increase in the average pretest score from 55 to 75 during the posttest. The increase in learning outcomes is also directly proportional to the surge in the percentage of classical completeness, from initially only 31% (19 students) at the pretest to 85% (52 students) at the posttest. This shift in the distribution of completeness empirically demonstrates that most students develop cognitive capacity when answering question instruments that require analytical and evaluative skills.

This improvement in critical thinking skills is confirmed by an average *N-Gain* score of 0.44, which falls in the medium category. The *N-Gain* value in this medium category provides academic justification for the idea that improvements in critical thinking skills do not occur instantaneously but rather through a continuous process of adaptation and cognitive practice (Dwiyanti, 2021). This pattern of improvement at the moderate level is very rational for higher-order thinking skills. It is in line with other research, which found that the implementation of problem-based learning (PBL), assisted by an environment-integrated webbook, also has a stable, positive impact on the medium category, rather than an unnatural spike in height (Fithriatiz Zahro et al., 2025).

The level of effectiveness achieved is closely related to the e-book's design characteristics. Features such as the Mini Laboratory and the My Adventure Ecosystem require students not only to memorize facts but also to process empirical data and to be actively involved in completing contextual projects. PBL-based learning in this digital format facilitates reasoning skills because students are faced with real problems, such as waste or pollution issues around them, which directly trigger dissonance, analysis, and evaluation (Dwiyanti, 2021).

These findings are very much in line with previous literature reviews, which report that contextual digital media have been shown to accelerate critical thinking skills by integrating local contexts into science learning (Wicaksono et al., 2025). Furthermore, this pattern of success is consistent with the effectiveness of e-modules and digital modules based on the SETS (Science, Environment, Technology, and Society) approach on environmental change materials that have significantly succeeded in deepening students' conceptual understanding and reasoning power (Amanda et al., 2025; Kustantia et al., 2023). Comparatively, these findings are also in line with the international scientific literature, which affirms that integrating socio-scientific issues and local potentials into interactive learning platforms consistently outperforms traditional methods in developing the ecological literacy and scientific argumentation of secondary school students (Erfariyah et al., 2024; Falah et al., 2021).

Despite the overall improvement in learning outcomes, a more in-depth analysis revealed notable variations in individual student achievement. While many students demonstrated substantial gains, a small proportion showed limited or stagnant progress, with approximately 15% (9 students) not meeting the minimum mastery criteria on the posttest. This variation indicates that all learners do not uniformly experience the intervention's effectiveness and is strongly influenced by individual differences, including prior knowledge, learning styles, and the intensity of engagement during the learning process. Students with stronger initial understanding and higher engagement tend to benefit more from interactive, problem-based learning environments. In

contrast, those with lower cognitive readiness may require additional support to engage with the learning materials fully.

Supporting literature confirms that the effectiveness of digital media in fostering critical thinking skills is closely related to students' level of participation and activeness when interacting with the learning content (Fitanti et al., 2025). In addition, internal motivational factors play a crucial role in determining how effectively students utilize e-books as learning resources (Falah et al., 2025). It suggests that the success of digital learning interventions depends not only on the quality of the media but also on learners' readiness and willingness to engage actively in the learning process. Therefore, for students with weaker cognitive foundations and motivation, digital media alone may not be sufficient; more intensive pedagogical scaffolding, such as direct guidance, feedback, and structured teacher facilitation, is required to optimize their learning outcomes.

Furthermore, students' successful adaptation to the e-book is closely linked to the high validity and feasibility of its design. The use of user-friendly navigation and interactive features helps reduce cognitive load, allowing students to focus more on understanding content rather than struggling with the interface (Falah et al., 2021). It indicates that well-designed digital learning media can create a supportive learning environment; however, their effectiveness will be maximized when combined with appropriate instructional strategies that accommodate diverse student characteristics.

Thus, this ecology book, grounded in environmental contexts, makes a meaningful contribution to fostering students' critical thinking skills. The novelty of this study lies in systematically mapping critical thinking indicators to specific micro-digital features of the e-book, which has not been explicitly and integratively implemented in previous studies. While earlier research has emphasized the importance of contextual learning and digital media in science education, most studies tend to focus either on the use of contextual approaches or on the development of digital learning tools separately. In contrast, this study integrates both aspects into a single structured design by embedding Facione's critical thinking indicators directly into interactive learning features. This positioning indicates that the present study is not merely a replication but an advancement of previous work by operationalizing critical thinking components within a contextual digital learning environment (Amanda et al., 2025; Wicaksono et al., 2025).

From a theoretical perspective, this study enriches the science instructional design literature by demonstrating that contextual digital media can function as an effective form of cognitive scaffolding. In practice, the developed e-book offers educators a ready-to-use independent learning resource to address the limited time available for environmental exploration in face-to-face classroom settings. Methodologically, although the use of 61 participants provides substantial evidence, this study is still limited by the One-Group Pretest Posttest design. Therefore, further research is recommended to employ more rigorous designs, such as quasi-experimental studies involving control groups, as well as to extend the duration of intervention in order to examine the long-term retention of students' critical thinking skills.

CONCLUSION

This study demonstrates that developing a contextual environmental issue-based ecology e-book results in a learning product that is both highly feasible and effective in improving the critical thinking skills of grade VII students. The product's feasibility is supported by validation results from material, media, and practitioner experts, indicating that the e-book meets very high standards in content, design, and language, making it suitable for classroom implementation. In addition, the effectiveness test using a One Group Pretest Posttest design shows a significant improvement in student learning outcomes, as reflected by the increase in the average score from 55 to 75, an N-Gain value of 0.44 in the medium category, and an increase in classical learning

mastery from 31% to 85%. These findings confirm that integrating contextual environmental issues, problem-based learning activities, and interactive digital features meaningfully facilitates the development of students' critical thinking skills and supports deeper engagement with real-world scientific problems.

However, the findings also reveal that the effectiveness of the e-book is not uniformly experienced by all students, as evidenced by a small proportion of learners who did not achieve full learning. This variation is influenced by individual differences, such as prior knowledge, motivation, and learning engagement, suggesting that the use of digital learning media should be complemented by continuous teacher guidance and adaptive instructional strategies. In terms of contribution, this study provides both theoretical and practical implications by reinforcing the role of contextual digital media in enhancing higher-order thinking skills and offering an alternative student-centered learning resource in science education. Nevertheless, the study is limited by its use of a One-Group Pretest-Posttest design and a relatively short implementation period. Therefore, future research is recommended to involve larger and more diverse samples, apply more rigorous experimental designs such as quasi-experiments with control groups, and extend the duration of implementation to examine the sustainability and long-term retention of students' critical thinking skills.

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