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The Creation of Electronic Books to Encourage Biological Literacy

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Abstract Biological literacy is essential for students to understand and apply biological concepts. This study aims to develop an e-book on the ecosystem and examine its effect on the biological literacy of Grade X students at SMA Muhammadiyah 4 Jakarta. The research adopted the Hannafin & Peck development model. Based on the needs analysis, students require learning media that is portable and visually engaging. The created e-book has instructional texts that cover four areas of biological literacy: nominal, functional, conceptual, and procedural. It also has AKM-style questions that require reasoning and structured practice exercises. Feasibility testing covered aspects of construction, material, and language, with an average score of 3.4 in the valid category. The effectiveness test showed an increase in students' biological literacy, with pre-test and post-test average scores of 50.05 and 80.11, respectively. The N-gain score was 0.62 (categorized as medium), and the effect size was 2.98 (categorized as a strong effect). Although effective, the e-book has limitations, such as the inability to complete quizzes directly within the e-book and the requirement of an internet connection to access external practice features. These limitations are recommended to be addressed in future research and development.

Keywords: E-Book; Ecosystem; Hannafin & Peck; Literacy.

Introduction

The modern biology curriculum emphasizes technical proficiency, inventive problem-solving, creativity, and positive attitudes about science. The process of learning about living things from different problems and organizational levels is known as biology. Biological literacy is crucial; it refers to the ability to understand, interpret, and apply biological knowledge meaningfully (Karomah et al., 2023). An individual with biological literacy is capable of assessing a range of biological events they come across (Chamany et al., 2008; Rofieq & Fauzi, 2022). As an example, biological agents like *Beauveria bassiana* and *Metarhizium anisopliae* fungus can be used to combat grasshopper pests. A person lacking biological literacy will not be able to recognize possible agents for managing environmental pests. Additionally, biological literacy gives one an awareness of the environment and the link between humans and nature, which is a crucial basis for comprehending the ecosystem in its entirety (McBride et al., 2013; Wals et al., 2014; Kinslow et al., 2018). This lack of biological literacy poses a serious concern, as it can hinder students' ability to make informed decisions about environmental and health issues, reducing their preparedness to face real-world biological challenges. These challenges demand not just knowledge of biology but the ability to apply it critically and ethically, skills encompassed in the concept of biological literacy.

Uno & Bybee, (1994) propose a four-level model of students' conceptual understanding, which includes nominal, functional, structural, and multidimensional

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levels (Krauja & Birzina, 2018; Semlarski & Lauis, 2021; Anakara, 2021). Each student can show different levels of biological literacy, and to achieve the highest level requires meaningful and relevant biology learning (Mahanal et al., 2020). In ideal conditions, students who have high biological literacy are able to explain biological concepts to others and guide responsible moral actions in personal and social contexts. However, achieving this level is not easy.

Even scientists may only achieve multidimensional literacy in certain areas of biology but remain at the functional or nominal literacy level in other areas (Suwono et al., 2017; Onel Durdukoca, 2019). In this perspective, compared to scientific literacy, biological literacy has received less attention in the educational literature (Semilarski & Laius 2021). The difficulty in achieving multidimensional literacy illustrates the complexity of biological literacy and highlights the risk of fragmented understanding among students.

Furthermore, various studies indicate that students' biological literacy levels are still relatively low. Mahardika et al. (2016), recorded scores below 50%, while Djamahar et al. (2021) and Jamaluddin et al. (2023) found average scores ranging from 58 to 60%. These findings indicate an urgent gap between curriculum objectives and students' actual competencies. This gap is concerning because students may fail to transfer biological knowledge into real-life applications, struggle to make ethical judgments about biological issues, and lack awareness needed for sustainable behavior toward the environment.

Educators typically employ an assortment of instructional resources while imparting biological concepts. Media has long been utilized in the classroom to enhance instruction and learning. The electronic book (e-book) is one of the technology-based learning resources that can support the development of biological literacy, particularly in ecosystem-related topics (Firdausy & Prasetyo, 2020; Susilo & Pahlevi, 2021). Several studies have indicated that e-books can improve science literacy, digital literacy, and higher-order thinking skills in biology learning (Wahyudi et al., 2023; Yulianingsih et al., 2023). As e-books make reading more engaging, they can provide integrated, methodical, and comprehensive learning procedures for autonomous use (Embong et al., 2012; Bozkurt & Bozkaya, 2015; Kao et al., 2016). E-books utilize internet technology to ensure accessibility through computers, mobile phones, and other portable devices (Connaway, 2003; Firdausy & Prasetyo, 2020; Ismail & Zainab, 2005). Furthermore, e-books are distinctive due to their incorporation of color graphics, animations, simulations, audio, and videos (Herrlinger et al., 2017), all of which can enhance learning outcomes and reinforce the topics being covered in the material. Despite their potential, many existing e-books fail to address the conceptual demands of biological literacy. According to Uno and Bybee (1994), biological literacy includes levels such as nominal, functional, structural, and multidimensional understanding—levels that require more than just attractive visual elements or multimedia.

In fact, Shanahan (2022) notes that some e-books in science education may fall short in supporting deep conceptual engagement, particularly when they prioritize aesthetics over substance. For instance, an e-book designed to support biological literacy should include tools such as terminology glossaries (nominal level), interactive experiments or simulations (functional level), concept mapping and structured content (structural level), and real-world case studies (multidimensional level). This highlights the need for e-books that are systematically developed to target and improve specific aspects of biological literacy, ensuring that digital learning resources are not only visually appealing but also pedagogically aligned with the goals of biology education.

Lately, researchers and educators have increasingly developed digital learning media as strategic tools to improve students' biological literacy competencies. For example, Karomah et al. (2023) developed a digital magazine focused on bacterial material, while Djamahar et al (2021) introduced the Bio Repro Bed RMS website to support learning about the reproductive system. However, a review of recent studies through Google Scholar and international literature revealed a lack of e-book-based learning resources specifically designed to improve students' biological literacy. Most existing digital resources prioritize content delivery and visual appeal. However, they often fail to align with the biological literacy framework proposed by Uno and Bybee (1994) (Herrlinger et al., 2017).

Similarly, Shanahan (2022) and Burkott (2018) highlighted that although digital media can improve science and digital literacy, many still fall short in supporting deep conceptual learning if they are not pedagogically aligned.

Therefore, the main objective of this study is to develop a biology e-book focused on ecosystem content that is systematically designed to fulfill the requirements of biological literacy across all four levels. This study offers a novel contribution by embedding the Uno and Bybee (1994) framework directly into the e-book design, a feature rarely found in current digital learning resources. This design enables the e-book to present content while guiding learners through phases that foster critical thinking, deepen conceptual understanding, and support the real-world application

of biological knowledge, particularly in ecosystem topics.

Method

This study applies the Educational Design Research (EDR) method, which is based on a modification of the Hannafin & Peck (1988) model. This strategy encompasses three phases (Figure 1): 1) the needs assessment phase, involved identifying learning problems and requirements through surveys; 2) the design phase, included defining objectives and constructing e-book content; and (3) development and implementation, consisted of producing the prototype, validating it, and conducting trials with students. Each stage can be followed by revision and evaluation.

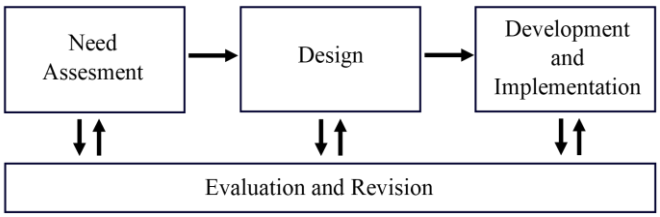

Figure 1. Flowchart Hannafin & Peck

Questionnaires were given to students and teachers during the needs analysis stage to find learning issues connected to the ecosystem subject and to investigate the need for interactive digital media to assist the teaching and learning process. Furthermore, learning objectives and content outlines were developed using an examination of the school curriculum and the biological literacy framework. A prototype of an interactive e-book including infographics, simulations, educational videos, and brief quizzes was produced throughout the design and development stage. The media was created with Adobe Photoshop CC 2020 and transformed into a flipbook format using the Heyzine Flipbook Maker platform.

The e-book prototype was then validated by experts to assess its content and design feasibility The e-book was validated to ensure its quality and relevance for educational use. A panel of five experts—three biology education lecturers and two high school biology teachers—evaluated it based on content accuracy, visual design, and pedagogical appropriateness using a 5-point Likert scale. The average score was 3.4 out of 4, indicating that the e-book is valid and suitable for classroom use. A limited trial was also conducted with a group of students to evaluate its readability, usability, and initial effectiveness. Feedback from this stage was used to refine the e-book before wider implementation.

This study took place during the 2023/2024 academic year at SMA Muhammadiyah 4 Jakarta, selected purposively due to its implementation of the independent curriculum and active integration of digital learning. The school selection aligned with the study's focus on digital education. The sample consisted of 315 tenth-grade students, with a subset of 120 students selected through a combination of sampling techniques: purposive sampling to determine the school and target students, cluster random sampling to select four classes, and simple random sampling to select 30 students from each class. Cluster random sampling ensured class-level representation, while simple random sampling minimized bias in selecting individuals. This combination maintained representativeness at the school, class, and individual levels while addressing logistical constraint. Instrument tests and questionnaires were utilized in the data collection process (Table 1).

Tabel 1. Data Collection Technique

Data Collection	Instrument	Evaluation Standards	Object
Media validation	Questionnaires (Likert scale)	Media and content	Lecture Teacher
		Legibility of e-book	34 students
Test validation	Questionnaires (Likert scale)	Validation items Reliability test Normality test Homogeneity test	Students class XI
Implementation outcome	Pre-post test	T-dependent test N-gain test Effectiveness test	Student class X

The refinement of the biological literacy test instrument was based on literacy indicators and core ideas of the ecosystem topic. The instrument was a two-level multiple-choice test consisting of 20 questions representing four levels of biological literacy: nominal, functional, conceptual (structural), and multidimensional (Table 2).

Before being used in data collection, the instrument was tested for validity and reliability. Thirty questions were designed, 20 were declared valid. The validation was conducted using expert judgment and item analysis,

while reliability testing yielded a correlation coefficient of 0.75, categorized as high reliability. This test uses tools in the form of the Question Item Analysis application in Microsoft Excel format.

Tabel 2. Dimensions of Biology Literacy

Dimensions	Characteristics
Nominal literacy	Determine the terms and ask biological questions. Describe the general idea of biology.
Functional literacy	Define the terminology appropriately Responding to face the problem
Structural literacy	Capable of possessing procedural abilities Describe the biological notion in your own words
Multidimensional literacy	Connecting biology to many other sciences Understand the relationship between society and biology

This study employed a pretest–posttest control group design to assess students' biological literacy before and after the use of a developed e-book. An independent sample t-test was used at a 0.05 significance level to determine whether the intervention group outperformed the control group in terms of literacy improvement. Prior to the analysis, data were tested for normality and homogeneity to ensure that parametric test assumptions were met.

To further examine the effectiveness of the e-book, the normalized gain (N-Gain) was calculated following Hake's (1999) method. The magnitude of the intervention's impact was also determined by computing the effect size using Cohen's formula (Cohen, Manion, & Morrison, 2007).

Result and Discussion

Need Assesment

E-book creation starts with a needs analysis phase that gathers data on issues, requirements, and resource limitations. Through the use of interviews, a study of 25 grade X students was carried out to identify the methods they frequently employed to find information sources during the learning process. According to the findings, 85% of students said they looked up information online using search engines like Google. Students who hardly ever use media to learn are likely to get disinterested and incapable of performing in-depth analysis. These results show that learning materials that may actively engage students and encourage a greater sense of curiosity are necessary when using a variety of learning media.

In order to continue the needs analysis, information was gathered through interviews with biology teachers. The application of educational techniques and the utilization of learning media were the main subjects of the analysis. According to the findings of the interviews, science instructors frequently utilize PowerPoint, videos, and complete PDF documents as teaching tools. There is a belief that using learning media is not optimal since teachers continue to serve as the primary information source during the learning process. In general, how engaging and pertinent the content is determines how involved students are in the learning process. Students' engagement and attention can be sustained with the correct mix of media (Yuberti et al., 2022).

Additionally, it has a strong interest in adopting media that can incorporate a variety of visual and symbolic representations and offer comprehensive resources for learning biology. These findings offer a solid foundation for further development of e-books, or digital books, that cater to students' interests and demands.

Design

The first stage is to analyze and provide ecosystem content in accordance with the school's peculiarities and independent curriculum. Next, make a storyboard to help with the e-book development using ecosystem content. The storyboard aids in establishing the color schemes, picture aggregations, and book components that will at this point be shown in the electronic book. At this point, a number of educational resources are created, such as summaries of the material, practice questions, important ideas, and so forth. Other tasks finished at this point include test question tools to gauge students' biological literacy and expert feasibility sheets, student and educator readability sheets, and research tools

Development and Implementation

An E-Book draft was created through three stages of development following the collection of data to support the contents of the E-Book. creating the E-book's cover and template first. With the aid of Adobe Photoshop CC 2020, the cover and template design were created. The images used in the template and cover are from the freepik website.

The second step is to package the content. The completed material comes packaged with the ready-to-use cover and template. Putting the content together using Microsoft Word. Text, pictures, and videos are used to describe the content, which is also filled with a variety of activities like experiments, problem-solving techniques, information-seeking, creative zones, and more. An assessment that comprises descriptive,

multiple choice, AKM model questions, and scientific performance is also included at this point. The document file that was originally packed is changed to a Portable Document Format (PDF) file.

Third, completing the e-book. Utilizing the website https://heyzine.com/, the PDF file is transformed. Heyzine is used for finalization in order to assist the e-book's release. Features like search, page effect (book), backdrop color, background audio, link, image, video, audio, web, and controls (show/hide, style, navigation) are also added while using this heyzine. The book's contents, template, and cover are as follows.

Figure 2. E-Book Media Display

Following the creation of a prototype, the product validation procedure (e-book) comes next. The goal of product validation is to determine whether the generated application product is suitable. The evaluation of e-books is done twice. Initially, the validator receives the e-book and evaluates its viability by offering recommendations for enhancements (Table 3). Second, the e-book is evaluated using the identified questionnaire components (Table 4).

Tabel 3. Validator's Suggestion

Validator	Suggest
Lecture	Learning objectives are not the same as the elements of developing
Lecture	Concept maps don't follow the guidelines
Lecture & Teacher	There are numerous errors in the writing
Teacher & Student	The next e-book feature deals with page numbers.
Teacher & Student	Some of the pictures are not clear

Media assessment was conducted by three biology education lecturers and two biology instructors to evaluate the created media's viability. Furthermore, 34 students took a readability test. The outcome of the preliminary evaluation shown in Table 3, and various recommendations were made to enhance the e-book. Figure 2 shows the changes that were made. Before and after the change are depicted in Figure 2. Following the completion of the revision process, the same components were used for a reassessment (Table 4).

Tabel 4. Result of Validation

Component of Assessment	Validator		Mean
	Lecture	Teacher	
Construction	3.6	3.5	3.3
Material	3.1	3.6	3.5
Language	3.6	3.3	3.4
Mean	3.4	3.5	3.4
Category	Valid	Valid	Valid

The outcome of validation using three elements construction, material, and language is shown in Table 4. The findings demonstrate that schools with a legitimate category can use the created media. Students also responded favorably to the utilization of e-books in the classroom, particularly when it came to ecosystem-related content.

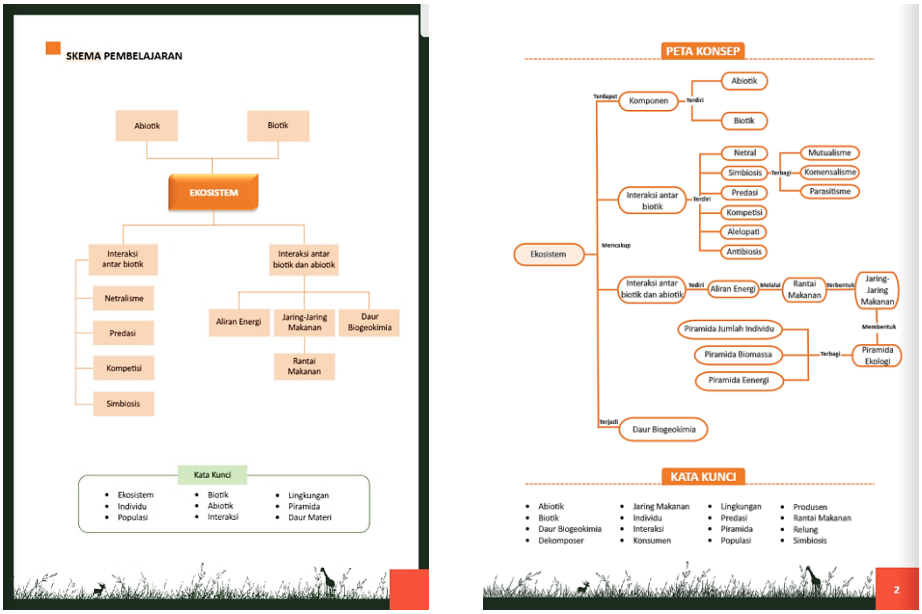

Figure 3. Before and After Revision

E-books that are suitable for use can be implemented in schools. There are sixty students involved in this process. E-book can be accessed via the following link: https://heyzine.com/flip-book/dd2e363cf9.html. The investigation of student's biological literacy abilities produced the Table 5.

Tabel 5. Data Result

Test	α	t-table	Sig.	Result
Normality Test	0.05	-	0.20	Regularly disseminated data
Homogeneity Test	0.05	-	0.10	Data were uniform.
T-dependent Test	0.05	-3.943	0.03	There are increasing score

Tabel 6. Data of Pretest-Posttest

Data	Sample	Standard deviation	Mean	N-Gain	Effect size
Pre-test	60	4.29	50.05	0.62 (Medium)	2.98 (Strong effect)
Post-test	60	5.77	81.11		

The Table 5 indicates that the data is regularly distributed according to the normality test and that the variance of the data is the same according to the homogeneity test. The t-dependent test demonstrates an increase in biological literacy as measured by the posttest.

Data from the pre-test and post-test were used to analyze the effects of e-book use in the classroom. A strong influence is shown by an effect size value of 2.98, while a medium category is indicated by a N-gain test of 0.62. These findings support the notion that students' biological literacy is improved by using e-books.

Table 7 presents detailed data on each dimension of students' biological literacy before and after using the e-book. Students' preliminary understanding of biology, particularly ecosystem content, is demonstrated by the pretest scores. Posttest scores show improvements across all dimensions of biological literacy—nominal, functional, structural, and multidimensional. The N-Gain values in Table 7 indicate improvement in all dimensions, with the functional dimension achieving the highest score (0.70), categorized as high. Along with the structural, nominal, and multidimensional dimensions, this aspect has increased significantly.

Tabel 7. Result of Biological Literacy

Dimensions	Mean		N-gain
	Pre-test	Post-test	
Nominal	51.66	79.58	0.57
Functional	51.66	85.91	0.70
Structural	47.41	81.00	0.63
Multidimensional	49.44	77.98	0.59

E-books are educational resources created to help students become more biologically literate, particularly with regard to ecosystem-related content. Students were really excited about the research since the media used included clear visuals, engaging visualizations,

educational films, and access to scholarly journals (Zulherman et al., 2021). These features helped students understand content better and engage actively with materials. Additionally, excellent content—such as literacy, AKM model questions, and activities supports the usage of e-books.

According to Table 7, the functional dimension is the most improved. The process of acquiring new information through comprehension, analysis, memorization, and the ability to repeat the information is known as the functional dimension (Birzina, 2011; Chen & Osman, 2017). Students can assess the scientific articles and material found in e-books based on the environment subjects they have studied. Students can improve their ability to communicate with others, make decisions, and voice their viewpoints in class by analyzing an article. This demonstrates the ability to interpret, critique, and reflect—core aspects of functional biological literacy. A person's literacy can be improved by being able to read, comprehend, analyze, and explain the material in an article, as well as by being able to exercise skepticism (Brewer, 2008; Suwono & Wibowo, 2018). According to Akcay et al. (2017), students' critical thinking skills can be enhanced by using media articles.

The structural level comes in second to the functional dimension (Table 7). Structurally literate students can comprehend biological facts and explanations, apply knowledge to novel contexts, and value biological information for themselves (Anakara, 2021). A number of activities, such as experiments, observations, information-seeking, conversations, questions and answers, and creativity, can enhance students' literacy skills with the use of the activity facilities in the created e-book. Students can be encouraged to comprehend biological phenomena and issues through a variety of tasks they complete while using the e-book. The structural level, according to Jamaluddin et al. (2023), is at the point where students can think clearly, differentiate concepts, come up with solutions, and present more convincing arguments regarding challenging topics.

The AKM model questions that students can access help the multidimensional level's rise to third place (Table 7). Students' comprehension of the course material and mastery of the set competencies can be assessed by working on these questions. Additionally, this offers insightful feedback to pinpoint their areas of strength and difficulty in comprehending the learning process, particularly with regard to ecosystem material. This practice question set can foster more creativity in the classroom, enabling students to engage with real-world learning problems (Kuhn et al., 2016; Görgülü & Meço, 2021). In order to solve problems, locate answers, and create opinions based on the information provided, students will be used to the tasks assigned (Mahanal et al., 2020; Suhadi et al., 2023).

In comparison to the other dimensions, the nominal dimension had the lowest N-Gain score (0.57), indicating students still face challenges in remembering biological terminology. This demonstrates that pupils struggle to retain the vocabulary used in the ecosystem content. Suhadi et al. (2023) claim that because biological terminology and concepts are of nominal quality, students are able to recognize them. Activities such as labeling visuals or conducting simple classification tasks can help enhance the nominal domain.

The overall increase in biological literacy is supported by the improved e-book design, which emphasizes interactivity, media integration, and literacy-rich content. The primary objective of these presentations is to increase students' biological literacy, even though some of them are differentiated according to the aspects of biological literacy that are developed (Görgülü & Meço, 2021; Sánchez & Bórquez, 2024).

Students' usage of e-books as a learning tool can encourage their senses—hearing, seeing, and touching—so that the information or messages are well received. Students' knowledge and abilities stored in long-term memory can be accessible again and are comparatively permanent when visualizations offered in the form of media enable them to engage, behave, and communicate (Feinberg & Murphy, 2000; Fuady & Mutalib, 2018).

The claim that using e-books improves students' biological literacy is supported by the existence of sensory involvement. Students who fully comprehend biological concepts and apply them through discussions, information gathering, table interpretation, problem solving, and comprehension of intricate ideas are the epitome of biological literacy (Berman & Kuden 2017; Vonny et al., 2021; Mater et al., 2022).

There are undoubtedly benefits and drawbacks to e-book development in advancing biological literacy. The excellent information included in this e-book, which includes literacy studies, AKM sample questions, a number of activities, and more, reviews the benefits of adopting it. A profile of a Pancasila teacher who can influence students' attitudes is also available. This book's shortcomings include the need for two devices to complete a QR code, the inability to complete assignments directly on the e-book, and the inability of the quizzes to determine right from wrong.

Conclusion

The development of an e-book using the Hannafin & Peck model proved suitable as a learning medium and biology content source, particularly on ecosystem

material. Validation by expert reviewers showed that the e-book met very appropriate criteria in both media and content aspects, with average feasibility scores in the "valid" category. The implementation results indicated that the e-book effectively enhanced students' biological literacy, especially in the functional and structural dimensions, as demonstrated by the N-Gain results. However, the study has limitations, such as the need for two devices to scan QR codes and the lack of interactive features in the quiz section. These findings suggest that well-designed e-books can support literacy-oriented learning, although further refinement and broader testing are recommended.

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Author Contributions
Faros, A. A.: conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, project administration, funding acquisition. Supriyatin: conceptualization, methodology, validation, supervision. Komala, Ratna: conceptualization, methodology, validation, supervision.

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