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Project Baced Learning E-book: Training Ecopreneurship Skills for Students with Technological Innovation Material

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ABSTRACT

Purpose – This study addressed the absence of interactive e-books to assist high school students in learning technological innovation, particularly biotechnology, while developing their ecopreneurship skills. In the era of 21st-century learning and the Merdeka Curriculum, students are expected to possess creative thinking, collaboration, and problem-solving skills. Therefore, this study aims to develop a Project Based Learning (PjBL) e-book on technological innovation materials that are engaging, interactive, and capable of strengthening students' ecopreneurship competencies.

Methodology – The research employed the 4D development model (Define, Design, Develop, Disseminate). Though limited to the development and validation stages, a purposive sampling technique involved three expert validators specializing in content, pedagogy, and biology. The assessment instrument covered content accuracy, visual presentation, and language quality. The data were analyzed using descriptive quantitative methods and validity percentages.

Findings – The validation results indicated that the developed e-book is highly valid for use in learning, with a score of 99.25% for presentation, 97.8% for content, and 87.37% for language. The e-book is also equipped with multimedia features such as videos, images, and active links, which enhance interactivity and accessibility, making the learning process more engaging and meaningful.

Contribution – This study contributes to educational technology by introducing a project-based digital learning medium that contextually fosters students' ecopreneurship skills. The developed e-book serves as a practical model for digital learning media that integrates scientific knowledge, environmental awareness, and entrepreneurial values.

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INTRODUCTION

Entering the 21st century and the era of the Fourth Industrial Revolution, education faces significant challenges in preparing students to compete globally. Focusing solely on academic knowledge is no longer sufficient; education must also cultivate critical thinking, creativity, problem-solving, collaboration, and communication skills (Makmuri & Harun, 2025). These 21st-century competencies are crucial for high school graduates to adapt to real-life challenges and a rapidly changing job market.

In response to these demands, the Indonesian government introduced the Merdeka Curriculum, which promotes entrepreneurship education across subjects. This initiative aims to equip students with practical soft skills relevant to work and entrepreneurship (Kemdikbud, 2022). One subject that holds great potential in this context is biotechnology, which involves scientific concepts and offers opportunities for students to engage in hands-on learning through utilizing local resources and waste materials.

However, biotechnology learning at the high school level is still theoretical and lacks opportunities for students to build critical, creative, and innovative thinking skills. This is unfortunate, given that biotechnology is highly relevant to ecopreneurship—a form of environmentally conscious entrepreneurship that encourages the transformation of local resources and waste into valuable products. Ecopreneurship supports sustainability and environmental literacy goals (Suryaningsih & Aripin, 2020). Studies show that incorporating ecopreneurship into biology learning increases students' interest in entrepreneurship by encouraging them to create creative and economical green products (Suryaningsih & Aripin, 2020).

At the same time, the rapid development of digital technology following the COVID-19 pandemic highlights the growing need for accessible, interactive learning media. One effective solution is the interactive e-book, which has enhanced students' creativity and engagement (Wahyuni & Rahayu, 2021). When combined with a Project-Based Learning (PjBL) approach, interactive e-books offer students authentic opportunities to design, implement, and reflect on real-world projects—key components of 21st-century education (Handiani, 2025). In biotechnology, PjBL has improved students' scientific literacy, process skills, and sustainability awareness (Ayudyaningsih et al., 2024). Moreover, integrating PjBL with bioentrepreneurship can significantly foster creative thinking through biotechnology-based projects (Shiyamsyah, Yuliani & Rahayu, 2024).

Despite these promising findings, research focused on developing PjBL-based interactive e-books that incorporate ecopreneurship within biotechnology education remains limited. For instance, ecopreneurship-based student worksheets (LKPD) have demonstrated high effectiveness (99–100%) in enhancing creativity and innovation, but they are still in printed form and lack interactivity (Tohiroh, Isnawati, & Dewi, 2020). Likewise, PjBL e-books designed for other biology topics—such as ecosystems or plant growth—have been found valid and practical (Wahyuni & Rahayu, 2021; Widyasmoro, Sulianto & Buchori, 2023), yet they have not fully integrated the ecopreneurship concept into biotechnology content. In addition, many existing learning media still lack multimedia features such as videos, hyperlinks, audio, and self-navigation—essential for supporting project-based learning processes and ecopreneurial skill development.

A review of existing literature indicates that among more than 30 studies on digital media in biology education, only a small fraction—fewer than five—have addressed the integration of ecopreneurship, and none have combined it with biotechnology e-books using a Project-Based Learning (PjBL) approach. For example, Tohiroh, Isnawati, and Dewi (2020) developed ecopreneurship-based worksheets that effectively increased students' creativity, yet these materials remain in printed form and lack interactive features. Meanwhile, digital e-books with PjBL have been designed for other topics such as ecosystems and plant growth (Wahyuni & Rahayu, 2021; Widyasmoro et al., 2023), but no existing work has fully incorporated ecopreneurship into PjBL-based interactive e-books for biotechnology content. This gap underscores the need for a comprehensive digital learning tool that unites biotechnology, sustainability, and entrepreneurial thinking in an accessible, student-centered format.

Therefore, there is a pressing need to develop an interactive e-book based on Project-Based Learning integrated with ecopreneurship, specifically for high school biotechnology learning. This digital media would not only overcome the limitations of conventional printed resources but also serve as an innovative tool that

merges science education, technology, and environmentally conscious entrepreneurship. Such media has the potential to make biotechnology learning more contextual, engaging, and effective in shaping globally competitive learners aligned with the values of the Pancasila Student Profile.

Based on this analysis, this research aims to (1) produce a PjBL e-book of technological innovation material (biotechnology) to train students' ecopreneurship skills (2) develop the first interactive PjBL-based e-book integrating ecopreneurship in high school biotechnology material, designed to train students' ecopreneurship skills, and (3) describe the validation of this innovative e-book as an effective learning media to enhance students' ecopreneurship competencies. This objective is based on the success of PjBL and e-books in increasing students' creativity (Wahyuni, L., & Rahayu, Y. S., 2021) and the effectiveness of ecopreneurship in the context of biotechnology (Tohiroh, N. A., Isnawati, I., & Dewi, S. K., 2020) The e-book product equipped with videos, images, and hyperlinks are expected to encourage students to design and produce products such as liquid organic fertilizer from agricultural waste, activities that are by the Merdeka curriculum and 21st-century skills, and at the same time reduce the use of paper for environmental sustainability.

METHODOLOGY

Research Design

This study employed a developmental research design using the 4D model by Thiagarajan (1974), consisting of four stages: Define, Design, Develop, and Disseminate. The 4D model was selected due to its clear, systematic framework that effectively supports the development of educational products like interactive e-books integrating Project-Based Learning (PjBL) and ecopreneurship. Compared to ADDIE and Borg & Gall models, the 4D model offers a more streamlined yet comprehensive process suitable for timely product development within the constraints of this study.

In the Define stage, needs analysis was conducted through curriculum review, stakeholder consultation, and evaluation of existing learning media to identify gaps and learning objectives. The design phase focused on developing the e-book's instructional framework, incorporating PjBL strategies and ecopreneurship content, and implementing multimedia planning. The Develop stage involved content creation, multimedia integration, prototype testing, and iterative refinement based on user feedback. The dissemination phase was limited in scope due to practical constraints, but it aimed to gather initial implementation feedback. The research took place from September to December 2024.

Participant

Three validators participated in the product validation phase: an education expert with over 10 years of experience in instructional media development, a biotechnology content specialist, a university lecturer with multiple scientific publications in the field, and a high school biology teacher actively implementing the Merdeka Curriculum. These validators were purposively selected based on their expertise and relevance to the subject matter to ensure the validity and applicability of the developed product. Additionally, readability tests and initial feedback sessions were conducted with several high school students to strengthen end-user validation to gather direct input from the target users.

Data Collection

Data collection was conducted in three primary stages. In the Define phase, data were obtained through document analysis to examine curriculum requirements, student characteristics, and core content. In the Design phase, the planning included media selection and the initial creation of the E-book prototype using Flip PDF Professional software. The development phase focused on validation activities through structured instruments, where validators assessed the prototype based on predetermined criteria.

Instrument

The validation instrument was designed to assess the feasibility of the e-book in three main aspects: presentation, content, and language. Each aspect consisted of indicators and assessment items that served as the basis for expert validation, as shown in Table 1.

Table 1. Aspects, Indicators, and Assessment Items of the Validation Instrument

Presentation Feasibility		
No	Indicator	Assessment Item
1	E-book display	The suitability of the display with learning objectives
2	Layout	Neatness of page layout and systematic organization
3	Text quality	Legibility of fonts, consistency of presentation, and clarity of illustrations
Content Feasibility		
No	Indicator	Assessment Item
4	E-book components	Compatibility of components with the curriculum
5	Quality of material concept	Accuracy, depth, and breadth of the material
6	Project-Based Learning aspect	Integration of PjBL steps in learning activities
7	Ecopreneurship aspect	Relevance of material to ecopreneurship skills
8	Supporting features of ecopreneurship	Availability of features, exercises, or projects supporting ecopreneurship
Language Feasibility		
No	Indicator	Assessment Item
9	Language usage	Appropriateness of language level for students and communicativeness
10	Accuracy of terms	Correct and consistent use of scientific terms

The validation of the e-book was carried out using a four-point Likert scale, where each score corresponds to a specific level of validity. The criteria are presented in Table 2 below.

Table 2. Likert Scale Criteria

Scala Value	Criteria
4	Highly Valid
3	Valid
2	Quite Valid
1	Less Valid

Sumber: (Riduwan, 2019)

The scores from the validators were averaged to obtain a validity score using the following equation:

$$V = \frac{\sum \bar{X}}{n}$$

Note:

V = validation score

$\bar{X}$ = average score of all validators

n = many items in each aspect

The results of the validation score were then converted into a percentage (%) using the following equation:

$$P = \frac{V}{m}\ x\ 100\%$$

Note:

P = validity percentage (%)

V = validity score

m = maximum validity score

The validation data were then interpreted, as shown in Table 3. The developed e-book can be considered valid if it reaches a validity percentage score of ≥ 71%.

Table 3. Likert Scale E-book Validation Data Interpretation Criteria (Riduwan, 2019)

Percentage	Criteria
86,0% – 100%	Highly Valid
71,0% – 85,9%	Valid
56,0% – 70,9%	Quite Valid
41,0% – 55,9%	Less Valid
25,0% – 40,9%	Invalid

Data Analysis

This study employed a combination of descriptive quantitative and qualitative approaches. Quantitative data in the form of validation scores were analyzed using descriptive statistics with the following formula:

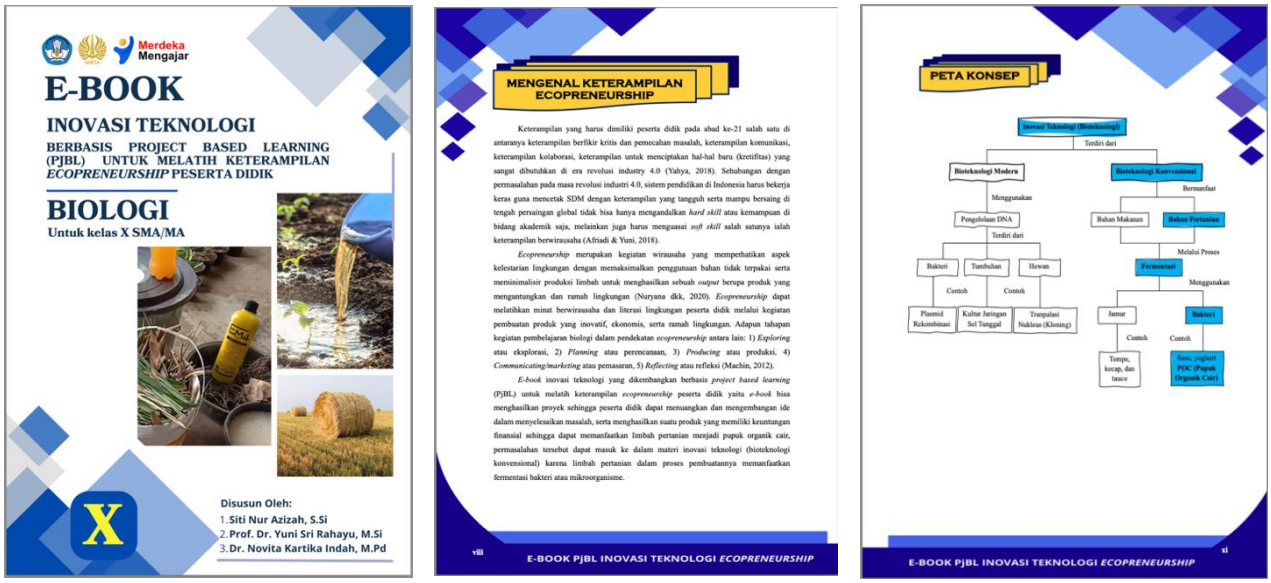
$$\text{Validity Percentage} = \frac{\text{Obtained Score}}{\text{Maximum Score}} \times 100\% \quad \text{.....(Riduwan, 2019)}$$

An e-book was considered valid if the validity percentage reached ≥ 71%. Qualitative data were obtained from written suggestions by validators and used to revise the product, such as adjusting font color for better readability and correcting scientific terms to align with proper standards.

FINDINGS

Development and Key Features of the Project-Based Learning E-Book for Ecopreneurship Skills

This study developed a project-based learning e-book focused on technological innovation aimed at enhancing ecopreneurship skills.



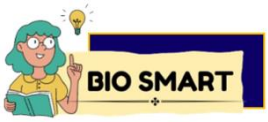
(a) (b) (c)

Figure 1. Display of the project-based learning e-book on technological innovation for training ecopreneurship skills: (a) e-book cover, (b) section on recognizing ecopreneurship skills, (c) concept map included in the e-book.

One of the main characteristics of the developed e-book is its resemblance to a flipbook, an interactive e-book equipped with page transition effects, providing a reading experience similar to that of a printed book. This e-book can be accessed on both laptops and smartphones and is available for use online or offline. Video content within the e-book can be played without an internet connection, while hyperlinks direct users to relevant web pages when the device is connected to the internet.

The developed e-book includes several key features designed to support the learning of technological innovation and the development of ecopreneurship skills, as summarized in Table 4.

Table 4. Description of E-Book Features

No.	Featur	Description
1.		It contains essential and brief explanations of the article to add insight and help learners find solutions to the topic presented.
2.		It contains offline or online videos about the material presented using links and barcodes to increase knowledge and insight into the biotechnology material and projects that students will make in the e-book.
3.		It contains questions about environmental problems in making liquid organic fertilizer to train ecopreneurship skills.
4.		This section contains project tasks using project-based learning steps to train ecopreneurship skills, such as presenting tables for product manufacturing timelines, product production, product observations, SWOT tables (Strengths, Weaknesses, Opportunities, Threats), and calculating the profit and loss of the products made.
5.		It contains questions as evaluation material for students on the sub-material and after carrying out activities to make liquid organic fertilizer projects from agricultural waste.

These features include concise explanations to enhance insight and problem-solving; offline and online videos accessible via links and barcodes to enrich biotechnology knowledge; questions related to environmental issues in the production of liquid organic fertilizer to train ecopreneurship skills; project-based learning tasks such as product timelines, observations, SWOT analysis (which includes identifying the Strengths, Weaknesses, Opportunities, and Threats of the students' proposed products), and profit-loss calculations; and evaluation questions based on sub-material and project activities.

These features make the e-book relevant and effective for modern digital learning environments, where the integration of technology in education is essential. This is supported by Ambarita (2020), who states that engaging and interactive electronic teaching materials are necessary in current learning environments.

Validation Results of the Project-Based Learning E-Book for Ecopreneurship Skills

Expert validators provided feedback and recommendations on the final version of the e-book, including formatting corrections, proper attribution of image sources, and better alignment between certain learning objectives and ecopreneurship skill indicators. Validation was conducted to confirm the theoretical feasibility of the e-book based on the research findings.

The feasibility assessment used a Likert scale ranging from 1 to 4, where one corresponds to "less good," 2 to "quite good," 3 to "good," and 4 to "very good." The validators' scores were analyzed descriptively to evaluate the overall quality of the e-book. The aspects validated included presentation feasibility, content feasibility, and language feasibility.

Table 5. The result of presentation component validation (Feasibility of Presentation)

No	Aspects assessed	Assessment Score			Average	Percentage	Criteria
		V1	V2	V3			
1	E-book Display	4	4	3.75	3.91	97.75 %	Highly Valid
2	Layout Quality	4	4	4	4	100 %	Highly Valid
3	Text Quality	4	4	4	4	100 %	Highly Valid
Average		4	4	3.92	3.97	9.,25 %	Highly Valid

Due to its well-organized layout, attractive design, and supportive visual elements, the e-book achieved a presentation score of 99.25%. Apart from containing questions that help in developing ecopreneurship skills, this e-book is also equipped with videos that are available both online and offline (Azizah & Budijastuti, 2021). Further interpretation shows that the main strength of the presentation lies in the layout and text quality, which were rated consistently high. However, the e-book appearance (97.75%) scored slightly lower, suggesting the need for refinement of visual design to make it more interactive and accessible for students.

Table 6. The result of content component validation (Feasibility of Content)

No	Aspects assessed	Assessment Score			Average	Percentage	Criteria
		V1	V2	V3			
4	E-book Components	3.71	4	4	3.9	97.5 %	Highly Valid
5	Quality of Material Concept	3.83	3.66	4	3.83	95.75 %	Highly Valid
6	Aspects of PjBL	4	4	4	4	100 %	Highly Valid
7	Ecopreneurship aspect	3.5	4	4	3.83	95.75 %	Highly Valid
8	Ecopreneurship Supporting Features	4	4	4	4	100 %	Highly Valid
Average		3.81	3.93	4	3.91	97.8 %	Highly Valid

In the validation of the e-book, the content aspect received a score of 97.8%, which includes the completeness of the e-book elements, preface, instructions for use, the quality of the material concept, and the completeness of the biological technology innovation material (BSKAP, 2023). Although all content aspects were rated highly valid, the ecopreneurship aspect (95.75%) and conceptual quality of material (95.75%) indicate areas for improvement, especially in linking theory to eco-friendly entrepreneurial practices. Therefore, revisions focused on adding concrete examples of ecopreneurship activities and providing more practical explanations.

Table 7. The result of language component validation (Feasibility of Language)

No	Aspects assessed	Assessment Score			Average	Percentage	Criteria
		V1	V2	V3			
9	Language Usage	3.25	3.75	4	3.66	91.50%	Highly Valid
10	Use of Terms	3	3	4	3.33	83.25%	Highly Valid
Average		3.13	3.38	4	3.49	87.37%	Highly Valid

Indicating a need for improvement in clarity and effectiveness. The language component achieved a score of 87,37%, indicating the need for clarity and effectiveness improvement. Terminology (83,25%) was the lowest among all validated components, reflecting inconsistencies in scientific and pedagogical terms that may confuse students. Revisions were made by standardizing technical terminology, improving sentence structures for better readability, and ensuring consistent use of commas (,) in numerical data. Additionally, the validators' feedback regarding formatting, image source attribution, and alignment of learning objectives with ecopreneurship skill indicators was followed up with concrete revisions. For instance, missing image references were corrected, learning objectives were revised to align with ecopreneurship indicators, and the e-book layout was refined for better consistency.

Although the e-book was rated "highly valid" in all aspects, the validation process also revealed areas for improvement, particularly in the language component. This is significant because the primary objective of developing the e-book is to train students' ecopreneurship skills. By refining language and terminology, the e-book becomes technically valid and more effective in achieving its pedagogical goals, namely equipping students with both conceptual understanding and practical skills in ecopreneurship.

DISCUSSION

Development and Key Features of the Project-Based Learning E-Book for Ecopreneurship Skills

E-books in the learning process positively impact the interaction between teachers and students, especially in remote learning contexts. The engaging features embedded in the e-book, such as images, videos, and links, significantly help students understand the subject more deeply. This aligns with the findings of Muhammad (2017), who stated that e-books enhance learning effectiveness by providing interactive and easily accessible content. Therefore, this project-based learning e-book not only addresses the needs of distance learning during the pandemic but also offers an innovative approach to teaching ecopreneurship that is both engaging and practical.

The comprehensive features integrated into the e-book, including multimedia content and project-based learning activities, offer a practical and engaging platform for developing ecopreneurship skills. The validation process, which involved experts from multiple disciplines, ensured both the theoretical and practical appropriateness of the content and its presentation. This addresses the gap in previous studies, which tended to emphasize the technological aspects of e-books without directly linking them to the development of sustainable entrepreneurship skills. Accordingly, this study highlights the novelty of integrating PjBL with ecopreneurship, particularly in the context of conventional biotechnology, which has been underexplored in the existing literature.

Furthermore, the alignment between learning objectives and ecopreneurship skill indicators and real-world problem-solving tasks contributed to a deeper understanding and skill acquisition among students. These findings are consistent with studies by Ambarita (2020) and Harahap et al. (2019), yet differ in focus: previous research primarily emphasized motivation and comprehension through digital media, while this study adds the practical dimension of sustainable business practices. Thus, the main contribution of this research lies in presenting a project-based learning model that is contextually integrated with ecopreneurship.

Validation Results of the Project-Based Learning E-Book for Ecopreneurship Skills

A well-presented e-book will increase understanding and produce a productive learning environment (Andini & Qomariyah, 2022). Given that most Southeast Asian learners already have access to mobile devices, e-books are easily accessible through electronic devices and can be accessed anytime with an internet connection (Siddiquah & Salim, 2017; Essel et al., 2018; Apuke & Ivendo, 2018; Muthuprasad et al., 2021). According to Tutkun (2011), this encourages more flexible learning by allowing learners to access information whenever and wherever they need it. In addition, an engaging presentation is expected to increase learners' enthusiasm for learning (Harahap et al., 2019).

This e-book contains material about conventional biotechnology with a Project-Based Learning (PjBL) approach, aiming to train students' ecopreneurship skills. The content assessment aims to ensure the suitability of the material with the curriculum and its relevance to improving students' understanding of learning (Rosyidah & Rahayu, 2022). The e-book adopts the latest concepts in biological technology and provides an applicable learning experience. The suitability aspect of the PjBL model was also rated as valid, based on six main steps, namely: 1) Start with the Essential Question, 2) Design a Plan for the Project, 3) Create a Schedule, 4) Monitor the Students and the Progress of the Project, 5) Assess the Outcome, 6) Evaluate the Experience (Wahyuni & Rahayu, 2021). This e-book follows the Project-Based Learning (PjBL) model to help teachers provide appropriate and engaging learning media.

The material in the e-book involves practical projects, such as recycling waste into liquid organic fertilizer, allowing learners to directly engage in activities relevant to everyday life. With this approach, learners are

expected to achieve basic competencies in knowledge and skills and develop the ability to solve problems creatively and independently. The stages of ecopreneurship combined with PjBL include: 1) Question-Exploring, 2) Plan & Schedule-Planning, 3) Monitoring-Production, 4) Assess-Communicating/Marketing, and 5) Evaluate-Reflecting (Machin, 2012). Research shows that applying Project-Based Learning (PjBL) integrated with ecopreneurship can train entrepreneurial skills in students (Saerozi et al., 2017; Akbar & Yuliani, 2019; Wulandari, 2019). This approach allows learners to develop business ideas that focus on sustainability and improve their ability to solve problems and innovate, which is crucial in entrepreneurship. This synthesis illustrates that integrating PjBL and ecopreneurship in the e-book is conceptual and practical, as demonstrated in student projects such as recycling waste into liquid organic fertilizer and marketing the products.

The validation results also reinforce the feasibility of implementing the e-book more widely in secondary schools. However, potential challenges remain, such as students' varying levels of digital literacy, access to devices, and school infrastructure. These factors need to be considered to ensure effective implementation. On the other hand, the multi-disciplinary validation provides a strong foundation for further development of the e-book in biotechnology education and other areas of entrepreneurship education that emphasize sustainability.

However, the linguistic aspect was considered less than optimal because the use of language was not entirely in accordance with PUEBI rules. Therefore, revisions are needed to improve the quality of the language and make it more effective in helping students understand. Widjajanti (2008) states that language is a key component in preparing e-books, so it must be used straightforwardly, clearly, and with correct spelling. The linguistic assessment aims to evaluate the accuracy of the words, sentences, and language structure used in project-based learning e-books to support the development of ecopreneurship skills. The selection of the right words and sentences is essential so that the message of the material can be conveyed clearly and easily understood (Hermawan, 2019).

CONCLUSION

This study aims to develop a Project-Based Learning (PjBL) e-book on technological innovation material (biotechnology) to train students' ecopreneurship skills. The validation results show that the developed e-book has a very valid feasibility level with an average score on the presentation aspect of 99.25%, content aspect of 97.8%, and language aspect of 87.37%. This e-book has multimedia features such as videos, hyperlinks, and project-based evaluations to support an active and contextual learning process. The integration of PjBL and ecopreneurship models is proven to provide a learning stimulus that not only strengthens the cognitive aspects of learners but also fosters the ability to think creatively, collaboratively, and environmentally sound. This finding shows that the development of digital media can answer the challenges of 21st-century education and support the implementation of the Merdeka Curriculum. Therefore, this e-book is recommended as an alternative teaching medium for technological innovation (biotechnology) that is adaptive, innovative, and environmentally friendly. This research contributes positively to the development of educational science, especially in biology and environmental entrepreneurship, and provides concrete solutions to creating a young generation that cares about sustainability. For further development, it is recommended to test the practicality and effectiveness of the product widely in various learning contexts.

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