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Development of Project-Based Learning E-Module Integrated with Local Wisdom of Kupang Sidoarjo to Improve Students Creative Thinking Skills

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Abstract
This study aimed to develop and evaluate a Project-Based Learning (PjBL) e-module integrating the local wisdom of Kupang Sidoarjo to support Grade X students' creative thinking in biodiversity learning. The study employed a Research and Development approach using the 4D model—Define, Design, Develop, and Disseminate—and a one-group pretest–posttest design at MAN Sidoarjo, East Java. Participants included two biology teachers and 36 students in the needs assessment, three expert validators, and 70 students in classroom implementation. Data were collected through interviews, questionnaires, validation and readability sheets, implementation observations, student responses, and four essay items assessing fluency, flexibility, originality, and elaboration. Data were analysed using descriptive statistics, the Fry Readability Formula, the Shapiro–Wilk test, the Wilcoxon Signed-Rank Test, effect size, and normalized gain. The e-module obtained a mean validation score of 3.56, indicating very high validity; its average readability corresponded to Grade 11, while classroom usability remained appropriate for Grade X students. Implementation fidelity reached 3.73, and all student-response dimensions exceeded 90%. Creative-thinking scores increased from 49.29 to 88.53, with a high N-gain of 0.76 and a significant pretest–posttest difference ($Z = -7.213$, $p < .001$, $r = .86$). These findings indicate that contextual PjBL activities grounded in documented local wisdom can facilitate authentic problem-solving and creative engagement, consistent with previous research on project-based and contextual learning. However, the single-school, one-group design and single-rater scoring limit causal inference and generalizability; future studies should employ controlled multisite designs, larger samples, and multiple raters.

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Introduction

Creative thinking is recognized as one of the essential competencies required for learners in the twenty-first century because it enables individuals to generate novel ideas, solve complex problems, and respond adaptively to changing social and environmental challenges. According to Ellis Paul Torrance, creative thinking comprises four dimensions: fluency, flexibility, originality, and elaboration (Torrance, 1974). Developing these dimensions requires learning environments that encourage students to actively explore ideas, investigate authentic problems, and construct knowledge independently rather than merely receiving information from teachers (Purnamasari et al., 2025). However, classroom instruction in many Indonesian schools remains predominantly teacher-centered, limiting students' opportunities to develop higher-order thinking skills, including creativity (Khafah et al., 2023).

In biology education, biodiversity offers considerable potential for cultivating creative thinking because it is closely related to environmental phenomena that students encounter in their daily lives (Islam et al., 2025). Through biodiversity learning, students are expected to observe biological diversity, analyse ecological relationships, and propose solutions to environmental problems based on scientific evidence. Nevertheless, previous studies have reported that biodiversity instruction is still largely oriented toward conceptual memorization and textbook-based learning, with limited opportunities for students to investigate authentic environmental issues or utilize the surrounding environment as a learning resource (Apriansyah et al., 2024). Consequently, students often experience difficulties in relating biological concepts to real-world situations, reducing both learning engagement and opportunities to develop creative thinking.

In addition to instructional models, teaching materials play a crucial role in fostering students' creative thinking skills. With the rapid advancement of digital technology, instructional materials should integrate technology, interactivity, and authentic real-life contexts that are relevant to students' experiences (D. I. Lestari & Kurnia, 2023). However, teaching resources used in many schools remain dominated by conventional textbooks that are general in nature, offer limited interactivity, and fail to connect biological concepts with students' local environment (Fahmi et al., 2025). To determine whether these challenges were also evident in the participating school and to inform the design of the developed e-module, a preliminary needs assessment was carried out. Semi-structured interviews were conducted with two biology teachers at MAN Sidoarjo, and questionnaires were administered to 36 Grade X students. The interviews revealed that biology instruction relied primarily on lectures, printed textbooks, and teacher explanations, while contextual digital learning resources supporting Project-Based Learning were unavailable. The questionnaire results further showed that 78% of students perceived classroom instruction as being dominated by lecture-based activities, 69% had never used an electronic module (e-module) in biology learning, and 83% reported difficulties in relating biodiversity concepts to their surrounding environment. These findings highlight the need for innovative digital teaching materials that integrate authentic local contexts and actively engage students in meaningful learning experiences.

One contextual resource with considerable educational potential is Kupang Sidoarjo, a small marine bivalve traditionally harvested by coastal communities in Sidoarjo Regency. Beyond its economic importance, Kupang represents a form of local wisdom reflecting community knowledge regarding coastal ecosystems, sustainable harvesting practices, traditional food processing, and environmental stewardship. Rather than treating local wisdom merely as cultural information, this study identified and documented relevant knowledge through interviews with local fishermen, Kupang processors, and representatives of the Fisheries Office of Sidoarjo Regency, complemented by a review of scientific literature and regional publications. These multiple sources were used to verify the ecological, cultural, and educational relevance of Kupang-related practices before integrating them into the biodiversity e-module. Accordingly, the contextual learning activities included in the e-module are based on documented community knowledge rather than anecdotal descriptions.

Project-Based Learning (PjBL) provides an instructional framework that complements the contextual nature of biodiversity learning. Through project planning, investigation, product development, presentation, and reflection, PjBL enables students to solve authentic problems while constructing scientific knowledge collaboratively (Bell, 2010; Thomas, 2000). Previous studies have consistently demonstrated that PjBL enhances students' creativity, scientific literacy, critical thinking, and learning motivation because students actively participate in designing solutions to real-world problems (Risnawati & Purwaningsih, 2025). When combined with interactive e-modules, Project-Based Learning can provide structured guidance throughout project implementation while supporting independent learning through digital resources.

Several previous studies have reported positive outcomes from integrating Project-Based Learning and local wisdom into digital learning materials (Zakiyah & Sudarmin, 2022; Sonia et al., 2024). However, most existing studies have focused primarily on conceptual understanding, scientific literacy, or general learning achievement. Only a limited number have specifically examined the development of e-modules intended to support creative thinking in biodiversity learning. Furthermore, previous studies generally describe local wisdom in broad terms without clearly explaining how cultural knowledge was identified, validated, and translated into learning activities. Few studies have integrated scientifically documented local wisdom from coastal communities into a Project-Based Learning e-module for biodiversity instruction. These limitations indicate an important research gap requiring the development of context-specific instructional materials grounded in validated local knowledge.

Accordingly, this study developed a Project-Based Learning e-module integrating the local wisdom of Kupang Sidoarjo into biodiversity learning for senior high school students. Unlike previous studies, the local wisdom incorporated into the e-module was identified through collaboration with community knowledge holders, government representatives, and documentary sources before being transformed into project-based learning activities. The developed e-module was subsequently evaluated in terms of validity, readability, practicality, implementation fidelity, and students' creative thinking performance following classroom implementation. Considering that this study employed a one-group pretest-posttest design, the observed changes in students' creative thinking are interpreted as improvements following. Therefore, this study aimed to develop a Project-Based Learning e-module integrated with the local wisdom of Kupang Sidoarjo for biodiversity learning and to evaluate its quality and classroom implementation as a context-specific instructional resource for supporting students' creative thinking skills.

Method

This study employed a Research and Development (R&D) approach using the Four-D (4D) instructional development model proposed by Thiagarajan, Semmel, and Semmel (1974). The model consists of four sequential stages: Define, Design, Develop, and Disseminate. The 4D model was selected because it provides a systematic framework for developing instructional products through iterative needs analysis, prototype development, expert validation, field implementation, and dissemination. Recent development studies have also demonstrated the relevance of this model for producing contextually grounded and systematically validated digital learning resources (Erlina et al., 2025; Koderi et al., 2023; Purnamasari et al., 2025).

To evaluate the developed e-module under authentic classroom conditions, a one-group pretest–posttest design was employed during the implementation stage. Students completed a creative thinking pretest before using the e-module and a posttest after the learning activities had been completed. This design was selected because the primary purpose of the study was to evaluate the feasibility of the developed instructional product. Therefore, changes observed between the pretest and posttest scores were interpreted as improvements following implementation. Nevertheless, a one-group pretest–posttest design does not fully control for alternative explanations, including maturation, testing effects, historical events, and teacher-related influences; therefore, causal conclusions should be drawn cautiously (Creswell & Creswell, 2023).

The study was conducted at MAN Sidoarjo, East Java, Indonesia. Different participants were involved at each stage of the development process. During the Define stage, a needs assessment was conducted through semi-structured interviews with two biology teachers and questionnaires administered to 36 Grade X students. These activities were intended to identify students' learning difficulties, instructional needs, digital learning experiences, and the availability of contextual digital learning resources. Conducting a systematic needs assessment is essential for ensuring that the instructional product is relevant to learners' characteristics and actual classroom conditions (Erlina et al., 2025; Koderi et al., 2023).

The Develop stage involved three expert validators, consisting of two biology content experts and one instructional media expert, who evaluated the validity of the developed e-module. During classroom implementation, the e-module was used by 70 Grade X students. Classroom implementation was independently observed by two experienced biology teachers, who assessed the fidelity of the Project-Based Learning implementation using structured observation sheets. Prior to data collection, permission to conduct the study was obtained from the school principal. All participants were informed about the objectives of the research, and their participation was voluntary. Student data were analysed anonymously and reported only in aggregate form to maintain confidentiality.

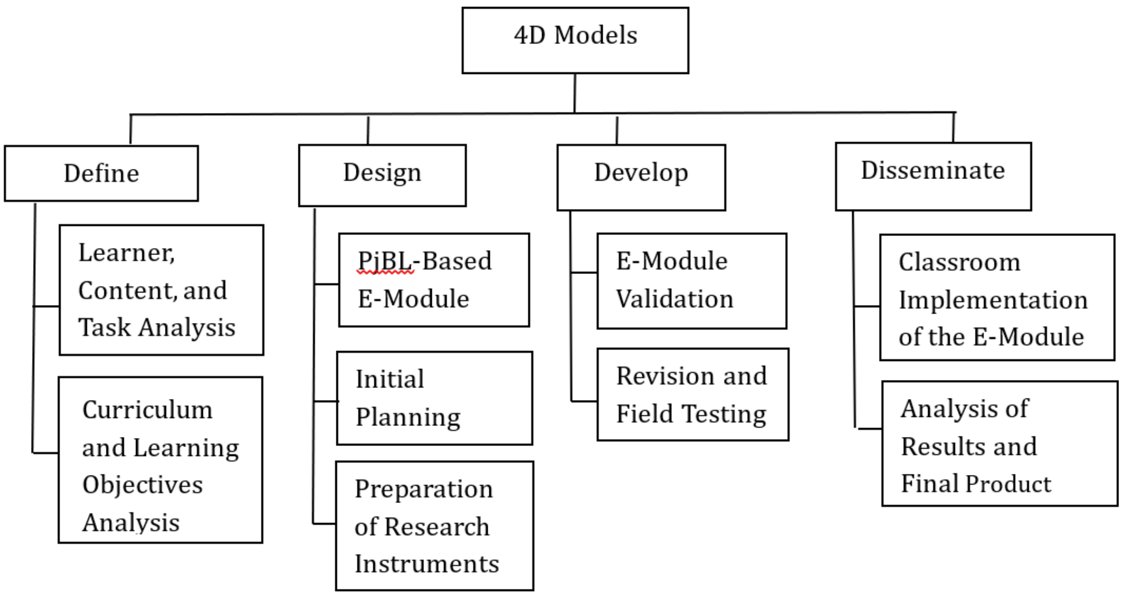

Figure 1. Flow Diagram of the 4D Model (Thiagarajan, 1974)

The Define stage aimed to identify instructional problems and determine the characteristics of the learning materials to be developed. Several analyses were conducted, including curriculum analysis, learner analysis, task analysis, concept analysis, and needs assessment. Curriculum analysis examined the alignment between the Indonesian senior high school biology curriculum and the biodiversity learning objectives. Learner analysis focused on students' learning characteristics and digital learning experiences. The needs assessment consisted of interviews with two biology teachers and questionnaires completed by 36 Grade X students. The needs assessment revealed that biology instruction was predominantly lecture-based (78%), most students (69%) had never used an e-module during biology learning, and 83% reported difficulties relating biodiversity concepts to their surrounding environment. These findings served as the primary basis for developing an interactive Project-Based Learning e-module integrated with the local wisdom of Kupang Sidoarjo.

To ensure the authenticity of the local wisdom integrated into the e-module, information regarding Kupang Sidoarjo was collected through interviews with local fishermen, Kupang processors, and representatives of the Fisheries Office of Sidoarjo Regency. Documentary analysis of scientific publications and regional documents was also conducted to verify the ecological, cultural, and environmental information before its incorporation into the learning materials. The documentation and validation of local knowledge are important because the educational integration of local wisdom should be based on credible cultural and contextual evidence rather than anecdotal descriptions (Koderi et al., 2023; Purnamasari et al., 2025).

Based on the results of the Define stage, an electronic learning module was designed for biodiversity learning using the Project-Based Learning model. The e-module was developed using Flip PDF Professional, which produces interactive HTML5 and PDF formats. The product includes interactive navigation buttons, hyperlinks, embedded instructional videos, images, project worksheets, formative quizzes with immediate feedback, reflective questions, glossary features, and self-assessment activities. The integration of text, images, videos, interactive navigation, and feedback was intended to facilitate students' active processing of learning materials in accordance with evidence-based multimedia learning principles (Mayer, 2024).

The e-module can be accessed both online and offline and is compatible with Windows computers, Android smartphones, and tablet devices, enabling flexible learning across different platforms. Such flexibility is relevant to contemporary digital learning because accessible instructional technology allows students to engage with learning materials across different locations, devices, and learning conditions (Haleem et al., 2022). The version evaluated during classroom implementation was identical to the final version described in this study, except for minor revisions suggested during expert validation.

Learning activities were organized according to the six phases of Project-Based Learning: (1) determining essential questions, (2) designing project plans, (3) preparing implementation schedules, (4) monitoring project implementation, (5) presenting project products, and (6) evaluating learning experiences. The contextual learning activities integrated biodiversity concepts with the local wisdom of Kupang Sidoarjo through authentic environmental investigations and project assignments. These activities are consistent with the principal characteristics of Project-Based Learning, which emphasize authentic problems, student-directed investigation, collaboration, product development, and reflection on the learning process (Guo et al., 2020; Haatainen & Aksela, 2021; Markula & Aksela, 2022).

Table 1. Four-Point Likert Scale Used for Expert Validation

Score	Category
4	Very Good
3	Good
2	Fairly Good
1	Poor

The initial prototype underwent expert validation before classroom implementation. The validation process involved three validators, comprising two biology content experts and one instructional media expert. The validation instrument assessed three aspects: content feasibility, presentation feasibility, and language. Each criterion was evaluated using a four-point Likert scale, as presented in Table 1. The use of clearly defined rating categories assists validators in providing systematic and consistent judgements regarding the quality of an instructional product (DeVellis & Thorpe, 2021; Erlina et al., 2025). The mean validation scores were interpreted according to the criteria presented in Table 2.

Table 2. Interpretation of Validation Scores

Mean Score	Interpretation
3, 26 – 4, 00	Very Valid
2, 51 – 3, 25	Valid
1, 76 – 2, 50	Fairly Valid
1, 00 – 1, 75	Less Valid

Qualitative comments provided by the validators were documented in a revision log and used to improve the prototype before implementation. Revisions included refinement of biodiversity content, simplification of scientific terminology, improvement of visual layouts, enhancement of multimedia quality, and revision of project instructions to improve clarity. Iterative revision based on expert feedback is an important stage of instructional product development because it improves the accuracy, accessibility, and usability of the resulting learning materials (Erlina et al., 2025; Koderi et al., 2023).

The final e-module was implemented in biology learning at MAN Sidoarjo and introduced to biology teachers as an alternative digital instructional resource. Dissemination also included communicating the development results through academic publication to facilitate broader adoption and future adaptation in similar educational contexts.

The research instruments consisted of an e-module validation sheet, a readability assessment sheet, an observation sheet for e-module implementation, a student response questionnaire, and a creative thinking skills test consisting of four essay questions. The selection of multiple instruments enabled the developed product to be evaluated in terms of content validity, readability, implementation fidelity, practicality, and students' creative thinking performance (Purnamasari et al., 2025).

The readability of the e-module was evaluated using the Fry Readability Formula (Fry, 1977), while the creative thinking test was developed based on the indicators of creative thinking skills, namely fluency, flexibility, originality, and elaboration (Purnamasari et al., 2025; Torrance, 1974). Expert validation employed a four-point Likert scale, and the mean scores were interpreted using the criteria shown in Table 2.

The readability of the e-module was evaluated using the Fry Graph Formula. Six representative paragraphs were selected from different sections of the e-module, including introductory content, conceptual explanations, project instructions, and evaluation sections. The selected paragraphs represented varying levels of language complexity across the module. Because the original Fry Graph was developed for English texts, the calculation followed the Indonesian adaptation by multiplying the number of syllables by 0.6, as commonly applied in Indonesian readability assessments (Purnamasari et al., 2025).

Readability analysis was complemented by classroom usability observations and student responses to ensure that the language, instructions, visual presentation, and navigation were appropriate for Grade X students. Combining formula-based readability analysis with classroom-based usability evidence provides a more comprehensive evaluation because readability formulas primarily estimate textual complexity and do not fully represent students' actual experiences when using interactive and multimedia learning materials (Haleem et al., 2022; Mayer, 2024).

Implementation fidelity was independently observed by two biology teachers. Each observation item was rated using a four-point Likert scale. The use of independent observers was intended to provide structured evidence regarding whether the planned stages of Project-Based Learning were implemented consistently during classroom instruction.

Table 3. Interpretation of Classroom Implementation

Mean Score	Category
3, 26 – 4, 00	Very Well Implemented
2, 51 – 3, 25	Implemented
1, 76 – 2, 50	Moderately Implemented
1, 00 – 1, 75	Poorly Implemented

Observer ratings were averaged to obtain the implementation score. Implementation fidelity was analysed separately from student responses because these instruments measured different aspects of practicality. Implementation observations assessed the extent to which the planned instructional procedures were performed, whereas student responses assessed students' perceptions of the usability and acceptability of the e-module (Guo et al., 2020; Purnamasari et al., 2025).

Student responses were collected using a Guttman scale, with a score of 1 indicating "yes" and a score of 0 indicating "no." Dichotomous response categories were used to obtain clear information regarding students' perceptions of the e-module features and learning activities (DeVellis & Thorpe, 2021). Response percentages were interpreted according to the criteria presented in Table 4. The questionnaire evaluated students' perceptions of usability, clarity, attractiveness, and ease of use. These results were interpreted as indicators of practicality rather than evidence of learning effectiveness.

Table 4. Interpretation of Student Responses

Percentage	Category
75-100	Practical
50-74	Fairly Practical
25-49	Less Practical
0-24	Not Practical

Creative thinking was measured using four essay questions representing the four dimensions proposed by Torrance (1974): fluency, flexibility, originality, and elaboration. These dimensions have also been employed in recent studies evaluating the contribution of project-based electronic learning materials to students' creative thinking development (Purnamasari et al., 2025). Each question was assessed using an analytic rubric with scores ranging from 1 (poor) to 4 (excellent). The raw total score ranged from 4 to 16 and was converted into a 0–100 scale using the following equation:

$$\textbf{Converted Score} = \frac{\textbf{Raw Score}}{\textbf{16}} \times \textbf{100}$$

The scoring rubric underwent content validation by expert validators before implementation to ensure that the criteria represented the intended dimensions of creative thinking and were appropriate for the participants' educational level (DeVellis & Thorpe, 2021; Erlina et al., 2025). All student responses were scored consistently by one trained rater using the same analytic rubric throughout the study.

Descriptive statistics were used to analyse the validity, readability, implementation fidelity, and student responses. Prior to hypothesis testing, the normality of the pretest and posttest creative thinking scores was examined using the Shapiro–Wilk test. The Shapiro–Wilk test was selected because it provides an appropriate procedure for assessing whether the distribution of quantitative data significantly deviates from a normal distribution (Field, 2024; Pallant, 2020).

Because both datasets were not normally distributed, differences between the pretest and posttest scores were analysed using the Wilcoxon Signed-Rank Test. This non-parametric procedure is appropriate for comparing two related measurements when the assumption of normality required for a paired-samples parametric test is not satisfied (Field, 2024; Pallant, 2020). The magnitude of the observed change was estimated using the following effect-size equation:

$$\mathbf{r} = \frac{\mathbf{Z}}{\sqrt{\boldsymbol{N}}}$$

where Zrepresents the standardized Wilcoxon statistic and Nrepresents the total number of participants. Reporting effect size alongside statistical significance provides information regarding the magnitude of the observed difference rather than merely determining whether the difference is statistically significant (Pallant, 2020).

Students' learning improvement was also described using the normalized gain (N-gain), calculated using the following equation:

$$\mathbf{N - Gain} = \frac{\mathbf{Posttest - Pretest}}{\mathbf{100 - Pretest}}$$

N-gain values were interpreted descriptively to indicate the magnitude of score improvement following classroom implementation. The use of N-gain complements pretest–posttest comparisons by describing the proportion of possible improvement achieved by students relative to their initial scores (Purnamasari et al., 2025).

Taken together, these analytical procedures provided a comprehensive evaluation of both the quality of the developed learning intervention and the changes in students' creative thinking skills following its implementation. Descriptive statistics were used to summarize validity, readability, implementation fidelity, and student responses, whereas the Wilcoxon Signed-Rank Test was employed to determine the statistical significance of changes between the pretest and posttest scores. Effect-size and N-gain analyses complemented the significance test by indicating the magnitude and practical meaning of the observed improvement. Thus, the interpretation of the findings was based not only on statistical significance but also on the strength and educational relevance of the learning gains (Field, 2024; Pallant, 2020; Purnamasari et al., 2025).

Result and Discussion

Developed E-Module

The results of the e-module development include: (1) the characteristics of the developed e-module, (2) the integration of the Project-Based Learning (PjBL) syntax, and the features of the e-module.

Characteristics of the Developed E-Module

The developed e-module was produced using Flip PDF Professional and published in both interactive HTML5 and PDF formats. The product included interactive navigation buttons, embedded instructional videos, hyperlinks, concept maps, project worksheets, formative quizzes with immediate feedback, reflective questions, glossaries, and self-assessment activities. The learning activities were organized according to the six stages of Project-Based Learning and implemented through four main features: Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluate. Biodiversity concepts were contextualized through authentic examples derived from the local wisdom of *Kupang* Sidoarjo, including biodiversity identification, sustainable utilization of marine resources, shell waste management, and environmental conservation practices documented from coastal communities. The characteristics of the developed e-module are presented in Table 5.

Table 5. Characteristics of the Project-Based Learning (PjBL)-based E- Module Incorporating Kupang Sidoarjo Local Wisdom to Foster Creative Thinking Skills.

No	Aspect	Characteristics
1	Organization	a. The e-module consists of two main learning units: (1) Biodiversity and (2) Kupang Sidoarjo-Based Biological Innovation. b. The introductory section includes a preface, user guide, learning objectives, and a concept map. c. The main content consists of four key features: Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluate. d. The concluding section contains an evaluation, reflection, references, and a glossary.
2	Content	a. The content is aligned with the Biology Learning Outcomes (Phase E) of the Merdeka Curriculum. b. Biodiversity concepts are presented contextually by integrating the local potential of Kupang Sidoarjo. c. The values of Sidoarjo local wisdom (economic, ecological, and cultural) are integrated into every learning activity. d. Project-based learning activities are designed to foster students' creative thinking skills and environmental awareness.
3	Presentation and Navigation	a. The learning sequence follows the syntax of Project-Based Learning (PjBL). b. The e-module includes learning instructions, project assessment rubrics, and reflection activities. c. The content can be accessed both online and offline in interactive PDF/HTML format. d. Interactive navigation facilitates movement between features through hyperlinks and navigation buttons.

4	Usability	a.	The e-module can be accessed on laptops and smartphones without requiring additional software installation.
		b.	Zoom-in and zoom-out functions are available to enhance reading comfort.
		c.	The e-module can be used for both independent learning and collaborative project activities in the classroom.
		d.	It encourages students' active participation in project-based learning.
5	Visual Design	a.	The visual design uses blue as the dominant color.
		b.	The layout is simple, with a balanced proportion of text and images.
		c.	Readable fonts and consistent icons are used throughout the e-module.
		d.	Illustrations of biodiversity and documentation of local wisdom support students' conceptual understanding.

(a) (b)

Figure 2. (a) Cover of the developed e-module and (b) sample pages of the e-module content

As shown, based on Table 5, the developed e-module has a well-structured organization, contextual content integrated with the local wisdom of Kupang Sidoarjo, and an interactive interface and navigation system designed to support project-based biology learning. The integration of the Project-Based Learning (PjBL) syntax is reflected in the design of the e-module through four main features: Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluate. These features were specifically designed to facilitate project-based learning while fostering students' creative thinking skills, including fluency (generating multiple ideas), flexibility (viewing problems from different perspectives), originality (producing unique ideas), and elaboration (developing ideas in greater detail).

The integration of the Project-Based Learning (PjBL) syntax, and the features of the e-module.

Each feature of the e-module was developed in accordance with the stages of the Project-Based Learning (PjBL) model, namely: (1) starting with an essential question, (2) designing the project, (3) creating a project schedule, (4) monitoring students and project progress, (5) assessing the project outcomes, and (6) evaluating the learning experience. These stages are systematically integrated into the four core features of the e-module - Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluate - to support project-based learning while simultaneously promoting the four dimensions of creative thinking skills: fluency, flexibility, originality, and elaboration. The integration of the PjBL syntax, creative thinking indicators, and e-module features is presented in Table 6.

Table 6. Integration of Project-Based Learning (PjBL) Syntax, Creative Thinking Indicators, and Features of the E-Module Based on Kupang Sidoarjo Local Wisdom.

No	Syntaks PjBL	Creative Thinking Indicators	E-Module Features and Layout
1	Start with essential question.	Fluency	Bio-Think

BAGIAN 2 Inovasi Biologi Berbasis Biodiversitas Kupang Sidoarjo

A. Tujuan Pembelajaran
Pada bagian ini kalian akan diajak untuk dapat
1. Mengemukakan tiga atau lebih ide kreatif yang logis dan relevan dalam memanfaatkan cangkang kupang sebagai bahan dasar produk inovatif (keterampilan berpikir kreatif: *fluency*)
2. Membandingkan dua pendekatan pemanfaatan cangkang kupang berdasarkan jenisnya serta menjelaskan keunggulan dan keterbatasan masing-masing pendekatan secara ilmiah (keterampilan berpikir kreatif: *flexibility*)
3. Mengembangkan ide orisinal yang menunjukkan keterkaitan jenis kupang dengan pemanfaatannya dalam konteks kearifan lokal (keterampilan berpikir kreatif: *originality*)
4. Mengevaluasi pemanfaatan keanekaragaman hayati sebagai pangan berdasarkan gambar atau hasil pengamatan serta mengaitkannya dengan potensi pemanfaatan kupang dalam praktik berkelanjutan berbasis kearifan lokal (keterampilan berpikir kreatif: *elaboration*)
5. Menyusun dan menyajikan hasil proyek pemanfaatan cangkang kupang dalam bentuk laporan tertulis, infografis, atau video presentasi yang mencerminkan pemahaman mendalam dan ide kreatif yang terelaborasi (keterampilan berpikir kreatif: *elaboration*)

B. Uraian Materi

Bio-Think
(Fluency) Sintak 1 PjBL – Penentuan pertanyaan mendasar
Pertemuan 1

Di materi sebelumnya kalian sudah mempelajari tentang keanekaragaman hayati mulai dari tingkat keanekaragaman hayati hingga pelestariannya. Selanjutnya kita akan mempelajari salah satu contoh manfaat keanekaragaman hayati. Dari berbagai jenis hewan kerang-kerangan, salah satunya kupang bisa dimanfaatkan kebutuhan pangan. Dalam pemanfaatannya menghasilkan limbah berupa cangkang yang jarang dimanfaatkan padahal memiliki potensi yang besar.
Sebagai generasi muda Sidoarjo, salah satu daerah penghasil kupang terbesar di Jawa Timur, kalian tentu akrab dengan limbah cangkang hasil pengolahan kupang yang selama ini terbuang sia-sia. Padahal, dibalik limbah tersimpan potensi besar. Bisakah limbah cangkang kupang yang sering dipandang tidak berguna justru menjadi solusi bagi masalah lingkungan di sekitar kita?

Tantangan proyek: kalian ditantang untuk "**menciptakan inovasi biologi berbasis cangkang kupang**" yang ramah lingkungan dan bermanfaat nyata bagi masyarakat.

24

2	Design project and create schedule.	Flexibility	Bio-Plan

Bio-Plan

(Flexibility) Sintak 2 & 3 Merancang Perencanaan Proyek & Penjadwalan
Pertemuan 1 & 2

Setelah kalian bekerja dalam kelompok pada tahap Bio-Think untuk mengidentifikasi permasalahan limbah cangkang kupang dan menghasilkan berbagai ide pemanfaatannya, kini saatnya kalian melangkah lebih jauh ke tahap Bio-Plan. Pada tahap ini, kalian akan mengembangkan ide-ide awal menjadi sebuah rencana eksplorasi proyek yang lebih terstruktur dan fleksibel.
Kalian akan tetap bekerja dalam kelompok kecil (4-5 orang). Dari berbagai ide yang sudah terkumpul sebelumnya, pilihlah 2-3 ide terbaik yang paling mungkin untuk dikembangkan. Dalam memilih, pertimbangkanlah:

1. Alat dan bahan
2. Jenis cangkang kupang
3. Manfaat ekologis, sosial, maupun ekonomis dari produk yang akan dihasilkan.

Ingat, dalam perencanaan proyek tidak hanya ada satu cara yang benar. Kalian ditantang untuk berpikir kreatif, adaptif, dan terbuka terhadap alternatif solusi. Jika ide utama tidak dapat diwujudkan, kalian tetap perlu menyiapkan ide cadangan yang relevan agar proyek dapat terus berjalan.

CLICK HERE

Klik di sini untuk menjawab!

Aktivitas Bio-Plan

Sekarang saatnya kelompokmu menguji ide-ide yang sudah kalian hasilkan. Gunakan tabel berikut untuk menyeleksi, menganalisis, dan merencanakan proyek utama maupun cadangan.

1. Dari ide-ide yang telah kalian buat, tuliskan 2 ide yang paling memungkinkan untuk dikembangkan. Mengapa kalian memilihnya?

Ide Inovasi dari Cangkang Kupang	Alasan Pemilihan Ide
Dst	

2. Tuliskan kelebihan dan tantangan dari masing-masing ide tersebut jika dilaksanakan dengan alat sederhana!

Ide Inovasi	Kelebihan	Tantangan
dst		

3 Monitoring the students and progress of project — Originality and Elaboration — Bio-Analyze

yang telah dibuat. Melalui tahap Bio-Analyze, kalian akan menguji ide dengan cara mengamati jenis kupang dan membandingkannya dengan rancangan inovasi yang telah direncanakan. Pada tahap ini, fokus kalian adalah menghubungkan hasil pengamatan dengan prediksi jenis kupang yang berperan, sehingga dapat dipastikan apakah jenis cangkang kupang sesuai untuk mendukung ide inovasi yang kalain kembangkan.

Bio-Analyze

(Originality & Elaboration) Sintak 4 PjBL – Monitoring & Analisis Ide
Pertemuan 3

Pada tahap ini, kalian akan menghubungkan prediksi dengan fakta nyata melalui pengamatan dan analisis produk inovasi. Tujuan tahap ini adalah memastikan bahwa ide yang kalian rancang memang memiliki dasar biologis yang kuat.

Aktivitas 1: Pengamatan
Intruksi Aktivitas:

1. Ambil cangkang dari berbagai jenis kupang
2. Amati dengan lup secara morfologi
3. Masukkan hasil pengamatan di tabel dan hubungkan dengan prediksi dari Bio-Plan
4. Dokumentasikan hasil dengan sketsa/foto

Pertanyaan pemandu:
"Apakah hasil pengamatan kalian sesuai dengan prediksi sebelumnya? Jika tidak, perbedaannya ada di mana?"

CLICK HERE

Klik di sini untuk menjawab!

Catatan: kalian tidak harus menemukan semua ciri dengan jelas, cukup fokus pada yang tampak menonjol, lalu analisis keterkaitannya dengan produk inovasi.

Tabel

No	Ciri morfologi	Kupang A	Kupang B
1	Bentuk cangkang		
2	Struktur cangkang		
3	Ukuran		
4	Warna		
	dst		

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4 Assess the outcome and evaluate the experience. — a. Elaboration b. Originality and Elaboration — Bio-Evaluate

Bio-Evaluasi

(Elaboration) Sintaks 5 & 6 PjBL – Menyusun & Menyajikan Hasil
Pertemuan 4

Petunjuk Umum
Pada tahap ini, kalian diajak menilai proses belajar, mengevaluasi hasil proyek, serta menyusun ide pengembangan dan presentasi produk. Jawaban yang dibuat harus menunjukkan pemahaman biologi, kreativitas, dan kaitannya dengan kearifan lokal Sidoarjo. Klik tombol "CLICK HERE" untuk membuka lembar Bio-Evaluasi. Pada lembar tersebut, kalian akan merefleksikan proses, mengevaluasi hasil proyek, dan menyusun presentasi produk inovatif secara mandiri, jelas, dan sesuai tujuan pembelajaran.

CLICK HERE

Klik di sini untuk menjawab!

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1. Refleksi Individu
   a. Apa hal paling menarik yang kalian alami selama menyelesaikan proyek ini?
   b. Prinsip pembelajaran apa yang paling terasa dalam kegiatan ini? (misalnya: kerja tim, pemecahan masalah, berpikir kreatif, literasi biologi)
   c. Apa tantangan terbesar yang kalian hadapi, dan bagaimana kalian mengatasinya?
   d. Bagaimana proyek ini membantu kalian memahami konsep manfaat keanekaragaman hayati dalam kehidupan?
2. Evaluasi Kerja Tim
   Diskusikan dan isi Bersama kelompok:

Aspek yang dinilai	Penilaian (skor 1-4)	Alasan Penilaian
Kerjasama dan pembagian tugas		
Komunikasi antaranggota		
Penyelesaian proyek tepat waktu		
Kualitas ide dan kreativitas		
Kedalaman analisis biologis		

3. Rencana Pengembangan Produk
   Jika produk kalian ingin dikembangkan lebih lanjut, tuliskan gagasan inovasi berikutnya:
   a. Apa yang bisa diperbaiki dari produk saat ini?
   b. Siapa saja yang bisa diajak bekerjasama untuk mewujudkannya?
   c. Apakah produk kalian bisa digunakan di lingkungan sekolah atau masyarakat?

Based on Table 6, each stage of the Project-Based Learning (PjBL) syntax is systematically integrated into the four main features of the e-module. The Bio-Think feature stimulates fluency by encouraging students to generate multiple ideas. Bio-Plan promotes flexibility through project planning and scheduling activities. Bio-Analyze develops originality and elaboration by guiding students to generate unique ideas and expand them in greater detail. Meanwhile, Bio-Evaluate strengthens students' reflective thinking and their ability to refine and further develop their ideas. This integration makes the e-module contextual, practical, and oriented toward fostering students' creative thinking skills in project-based biology learning.

Validation

The initial prototype was evaluated by three expert validators consisting of two biology content experts and one instructional media expert. Overall, the developed e-module obtained a mean validation score of 3.56, which falls within the Very Valid category according to the predetermined validation criteria (3.26–4.00). These findings indicate that the developed product met the quality standards required for classroom implementation after several revisions suggested by the validators.

Table 7. Results of E-Module Validation by Subject Matter and Education Experts

No	Component	Average skor	Percentage	Category
1	Presentation Suitability			
	Responsiveness & Accessibility	3.67	91.75	very valid
	Material Presentation Support	3.56	89.00	very valid
	Completeness of Presentation	3.81	95.25	very valid
	Layout Quality	3.57	89.25	very valid
	Average	3.65	91.31	very valid
2	Content Suitability			
	Quality of Concept Alignment with the Merdeka Curriculum	3.50	87.50	very valid
	Quality of Biodiversity Concepts	3.73	93.25	very valid
	Local Wisdom	3.89	97.25	very valid
	Currency and Contextual Relevance of the Concept	3.56	89.00	very valid

	E-Module Features Incorporating PjBL Syntax to Foster Creative Thinking	3.83	95.75	very valid
	Average	3.70	92.55	very valid
3	Language Suitability			
	Uses language in accordance with PUEBI (General Guidelines for Indonesian Spelling)	3.33	83.25	very valid
	Uses communicative sentences	3.33	83.25	very valid
	Uses sentences that do not give rise to multiple interpretations (ambiguity)	3.33	83.25	very valid
	Average	3.33	83.25	very valid
	Total average	3.56	89.00	very valid

The validation results for the presentation feasibility aspect showed an overall mean score of 3.65, which falls into the very valid category. The responsiveness and accessibility component obtained a mean score of 3.67, indicating that the e-module is lightweight, easy to operate, and accessible across various devices. The supporting presentation materials component achieved a mean score of 3.56, reflecting that the use of concept maps, illustrations, and practice exercises effectively assists students in understanding the learning materials. Furthermore, the completeness of presentation component obtained the highest mean score of 3.81, indicating that the structure of the e-module—from the introductory section to the main content and concluding section—is comprehensive and systematically organized. The layout quality component obtained a mean score of 3.57, demonstrating that the visual aspects, including color combinations, text readability, the balance between text and images, and page numbering, met the criteria for effective instructional presentation, although several minor revisions were suggested by the validators.

The validation results for the content feasibility aspect yielded an overall mean score of 3.70, categorized as very valid. This score was derived from five main components: the alignment of concepts with the Merdeka Curriculum (3.50), the quality of biodiversity concepts (3.73), the integration of local wisdom (3.89), the currency and contextual relevance of the concepts (3.56), and the Project-Based Learning (PjBL)-based e-module features designed to foster creative thinking skills (3.83). The integration of local wisdom component obtained the highest score, indicating that the learning materials are strongly integrated with the local context of Kupang, Sidoarjo. The quality of biodiversity concepts was also rated as very valid, suggesting that the breadth, depth, and scientific accuracy of the concepts have been appropriately presented. Although the alignment with the

Merdeka Curriculum received a slightly lower score than the other components, it remained within the very valid category. The PjBL-based features incorporated into the e-module—Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluation—obtained a mean score of 3.83, indicating that these features effectively facilitate the development of the four indicators of creative thinking, namely fluency, flexibility, originality, and elaboration.

The validation results for the language feasibility aspect showed an overall mean score of 3.33, which is categorized as very valid. This score was obtained from three indicators: compliance with the General Guidelines for Indonesian Spelling (PUEBI) (3.33), the use of communicative language (3.33), and sentence clarity without ambiguity (3.33). The PUEBI compliance indicator demonstrates that the spelling, punctuation, and sentence structures used throughout the e-module conform to standard Indonesian language conventions. The communicative language indicator suggests that the language used is clear, straightforward, and easily understood by students. Meanwhile, the sentence clarity indicator shows that most sentences are free from ambiguity, although several minor revisions were made to improve clarity. Overall, these findings indicate that the e-module content has met the substantive feasibility criteria and is ready to be implemented as a PjBL-based Biology teaching material integrated with the local wisdom of Kupang, Sidoarjo. Furthermore, the language used throughout the e-module satisfies appropriate linguistic standards and supports both readability and the clear delivery of instructional content.

Table 8. Reliability of the E-Module Instrument

Cronbach's Alpha	N of Item
0.929	39

As shown in addition to validity, the reliability of the e-module assessment instrument was evaluated using Cronbach's Alpha coefficient by including all instrument items. The summary of the reliability analysis conducted using SPSS is presented in Table 8. The analysis yielded a Cronbach's Alpha value of 0.929, indicating very high internal consistency. Therefore, the instrument is considered reliable and suitable for assessing the feasibility of the developed e-module.

Although the overall validation results indicated that the e-module was highly suitable for classroom use, the validators provided several suggestions for improvement. These suggestions were incorporated before field implementation.

Table 9. Summary of Revisions Based on Expert Feedback

Validator Feedback	Revision Implemented
Improve explanation of biodiversity concepts	Additional explanation and examples were included
Simplify scientific terminology	Technical terms were revised using language appropriate for Grade X students
Improve image quality	Several figures were replaced with higher-resolution image
Enhance project instructions	Project procedures were rewritten to improve clarity

Improve navigation	Navigation buttons and hyperlinks were refined for easier use

Practicality

The practicality of the Project-Based Learning (PjBL)-based e-module integrated with the local wisdom of Kupang, Sidoarjo was analyzed to determine its ease of use in the learning process. The practicality evaluation was conducted based on three aspects: readability, the implementation of student learning activities, and student responses. Practicality data were collected through a readability test using the Fry Formula, observations of the implementation of student learning activities during classroom instruction, and a student response questionnaire.

The readability of the developed e-module was evaluated using the Fry Graph Formula. Six representative paragraphs were selected from different sections of the e-module, including introductory material, conceptual explanations, project instructions, and evaluation activities.

Table 10. Summary of E-Module Text Readability

No	Sample Paragraph	Page	Number of Sentences	Number of Syllables x 0,6	Level
1	Part 1 Biodiversity	1	6.1	153.6	9
		9	4.3	158.4	11
		18	5.7	162.6	11
2	Part 2: Biological Innovation Based on Kupang Sidoarjo	24	6.8	167.4	11
		28	5.9	164.4	11
		32	7	168	11
	Total average		6.0	162.4	11

Based on Table 10, the number of sentences across the six sample paragraphs ranges from 4.3 to 7 per 100 words, while the number of syllables ranges from 153.6 to 168. The average number of sentences is 6.0, and the average number of syllables is 162.4. These average values from Table 10 are then plotted on the Fry graph, as shown in Figure 2, to determine the readability level of the e-module text.

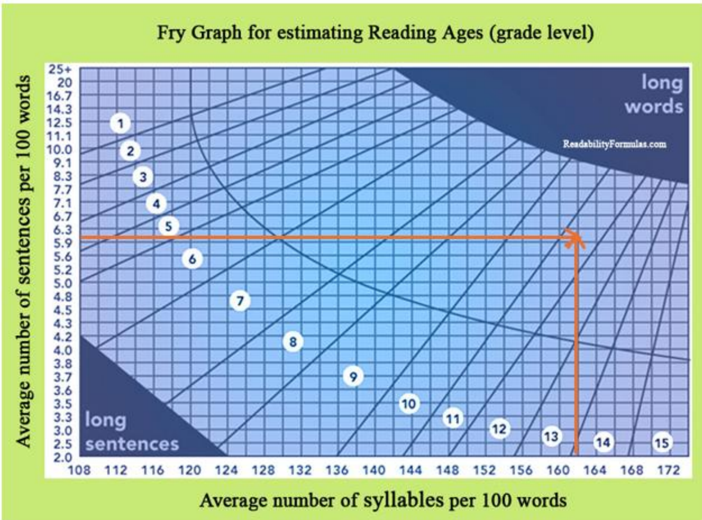

Figure 2. Fry Diagram Test Results.

Mapping results indicate that the readability level of the e-module text falls within the range of levels 9 to 11, with an average readability level of 11. One sample in Section 1 falls at level 9; this section contains the introduction to the initial material students will study. However, the average readability is at level 11, and the majority of samples fall within the appropriate range for Grade X students. The average readability level corresponded to level 11. Considering that Indonesian readability calculations require adjustment of syllable counts and that readability formulas provide only an estimate of linguistic complexity, additional usability evidence was collected during classroom implementation.

Table 11. Summary of Observation Results on the Implementation of E-Module Usage

No	Aspect	Average	Criteria
1	Indicators of Creative Thinking		
	Fluency	3.75	Highly implemented
	Flexibility	4.00	Highly implemented
	Originality	3.25	Well implemented

	Elaboration	4.00	Highly implemented
2	Student engagement	4.00	Highly implemented
3	Smooth flow of learning	4.00	Highly implemented
4	Time efficiency	3.25	Well implemented
	Average score	3.73	Highly implemented

Based on the observation results of the e-module implementation, the overall mean score was 3.73, which falls into the highly implemented category. This result indicates that all stages of the Project-Based Learning (PjBL) process facilitated through the e-module were implemented successfully in accordance with the planned instructional design.

Regarding the indicators of creative thinking skills, the highest level of implementation was observed in the flexibility and elaboration indicators, each obtaining a mean score of 4.00. These results indicate that students were able to generate ideas from multiple perspectives and further develop their ideas in greater detail. The fluency indicator was also categorized as highly implemented, with mean scores ranging from 3.50 to 4.00. In contrast, the originality indicator showed some variation, with one indicator obtaining a mean score of 3.00 (implemented) and another achieving 3.50 (highly implemented).

The student engagement aspect obtained a mean score of 4.00 (highly implemented), indicating that students actively participated in every stage of the learning process. Likewise, the learning process flow aspect achieved a mean score of 4.00 (highly implemented), demonstrating that the instructional activities proceeded smoothly as designed. Meanwhile, the time efficiency aspect obtained mean scores ranging from 3.00 to 3.50, indicating that it was implemented effectively, although several activities required slightly more time than initially planned.

The student response questionnaire indicated that students experienced little difficulty understanding the language used in the e-module, while classroom observations showed that students were able to complete learning activities without substantial language-related obstacles. These findings suggest that, despite the estimated readability level, the e-module remained appropriate for Grade X students when supported by interactive multimedia, contextual examples, and teacher facilitation.

Table 12. Student Responses to the E-module.

Aspect	Percentage	Category
Content	92.14%	Very practical
Learning activities	91.11%	Very practical
Appearance and ease of use	90.71%	Very practical
Total average	95.15%	Very practical

The student response questionnaire demonstrated that the developed e-module was perceived positively across all evaluated aspects, with content (92.14%), learning activities (91.11%), and appearance and ease of use (90.71%) all exceeding the predetermined practicality criterion. These findings suggest that students considered the e-module relevant, engaging, and easy to use during classroom learning.

The positive perceptions may be associated with the integration of contextual examples, multimedia features, and structured project activities, which are intended to facilitate students' interaction with the learning materials. Similar findings have been reported by Lavli and Efendi (2023), who found that interactive e-modules increased students' engagement in learning activities.

Likewise, Nur et al. (2025) suggested that integrating local wisdom into science learning can enhance students' appreciation of environmental and cultural contexts.

Nevertheless, these findings should be interpreted within the scope of the instrument used. The student response questionnaire measured perceived practicality and user experience, not conceptual understanding or creative thinking performance. Consequently, the positive responses provide evidence that the developed e-module was acceptable and practical for classroom use but do not constitute evidence that the e-module improved learning outcomes. Evidence regarding students' creative thinking performance is provided separately through the analysis of pretest and posttest scores.

Effectiveness

Learning Students' creative thinking performance following the implementation of the developed e-module was described using pretest and posttest scores. Individual learning performance was summarized descriptively based on the school's minimum mastery criterion (MMC) of 75, where students scoring 75 or above were categorized as achieving mastery and those scoring below 75 were categorized as not achieving mastery. To provide an overall description of students' performance, individual mastery results were further summarized as classical learning mastery. These descriptive results were intended to illustrate students' performance following the implementation of the developed e-module. A summary of the pretest and posttest results is presented in Table 13.

Table 13. Class Mastery of Learning based on Pretest and Posttest results

Mastery Category	Pretest		Posttest	
	Number of students	%	Number of students	%
Achieved mastery (≥ 70)	1	1.43	63	90,00
Not yet achieved mastery (< 70)	69	98.57	7	10,00
Total	70	100	70	100

As shown in Table 13, prior to the implementation of the Project-Based Learning (PjBL)-based e-module, almost all students (98.57%) had not achieved learning mastery. After participating in learning activities using the e-module, a substantial improvement was observed, with 63 out of 70 students (90.00%) achieving learning mastery, while 7 students (10.00%) had not yet achieved mastery.

These results indicate that the majority of students met the learning mastery criterion after participating in instruction using the PjBL-based e-module. The high percentage of learning mastery suggests that the project-based learning approach effectively supported students in developing a deeper understanding of biodiversity concepts.

Table 14. N-Gain Values for Creative Thinking Skills Based on Pretest and Posttest Comparison

No	Category	Test scores
1	Average Pretest	49.29
2	Average Posttest	88.53
3	N-Gain	0.76
4	Category	High

The analysis of the improvement in creative thinking skills was conducted to determine the extent of students' improvement after using the Project-Based Learning (PjBL)-based e-module. The improvement was evaluated using the normalized gain (N-gain) score, which was calculated from students' pre-test and post-test scores. As presented in Table 14, the students' mean pre-test score of 49.29 increased to 88.53 on the post-test, resulting in an N-gain score of 0.76, which falls into the high category. This result indicates that students' creative thinking skills improved substantially following instruction using the PjBL-based e-module.

These findings demonstrate a significant improvement in students' abilities before and after the implementation of the learning intervention. The increase in scores indicates that students became more capable of generating ideas, selecting appropriate approaches, and developing data-driven solutions after participating in learning activities using the e-module. Furthermore, to examine the improvement in each indicator of creative thinking skills, changes in the pre-test and post-test scores for the fluency, flexibility, originality, and elaboration aspects are presented graphically in Figure 3.

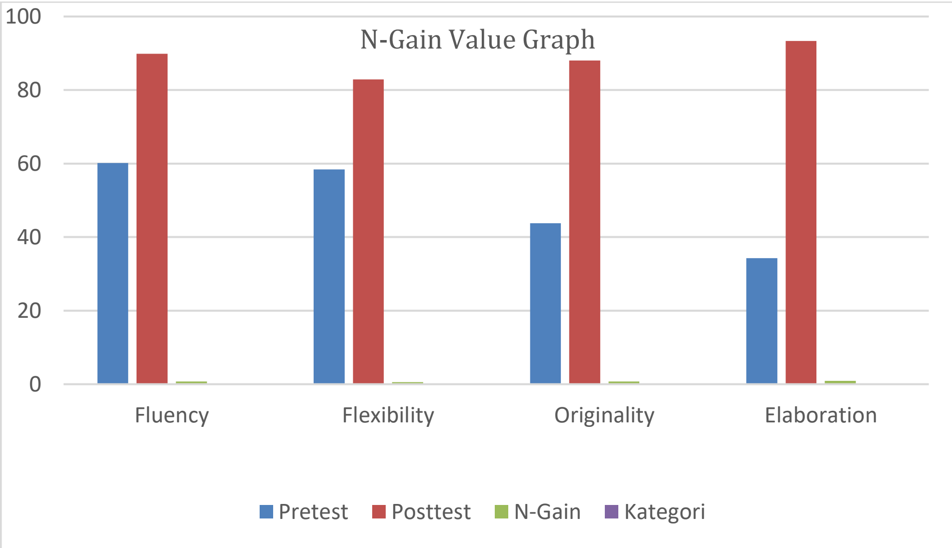

Figure 3. Graph of N-Gain values based on the comparison of pretest and posttest scores

Figure 3 presents the N-gain scores for students' creative thinking skills across each indicator. Based on the data presented in Table 15, all indicators showed improvement following the implementation of the Project-Based Learning (PjBL)-based e-module. The N-gain scores ranged from 0.55 to 0.88, corresponding to the moderate to high categories. Specifically, the fluency indicator achieved an N-gain score of 0.73 (*high*), flexibility obtained 0.55 (*moderate*), originality reached 0.72 (*high*), and elaboration achieved the highest N-gain score of 0.88 (*high*).

These findings indicate that the greatest improvement occurred in the elaboration indicator, while the remaining indicators demonstrated improvements ranging from moderate to high. Overall, all aspects of students' creative thinking skills improved following instruction using the Project-Based Learning (PjBL)-based e-module.

Table 15. N-Gain results for creative thinking skills

Indicators of creative thinking	N-Gain	Category
Fluency	0.73	High
Flexibility	0.55	Medium
Originality	0.72	High
Elaboration	0.88	High
Total Average	0.72	High

To determine whether there was a significant difference in students' learning outcomes before and after the implementation of the Project-Based Learning (PjBL)-based e-module, the pre-test and post-test scores (scoring range: 0–100) were analyzed. Prior to hypothesis testing, data normality was assessed using the Shapiro–Wilk test. The pre-test scores were not normally distributed ($W = 0.964$, $p = .040$), and the post-test scores also violated the normality assumption ($W = 0.849$, $p < .001$). Therefore, the Wilcoxon Signed-Rank Test was used to compare students' learning outcomes before and after the intervention.

The Wilcoxon Signed-Rank Test revealed a statistically significant improvement in students' learning outcomes following the implementation of the PjBL-based e-module ($Z = -7.213$, $p < .001$, $r = 0.86$), indicating a large effect according to Cohen's (1988) benchmarks. These findings suggest that the PjBL-based e-module produced a substantial improvement in students' learning outcomes. The detailed results are presented in Tables 16 and 17.

Table 16. Results of the Wilcoxon Signed-Rank Test on pretest and posttest scores

		Ranks		
		N	**Mean Ranks**	**Sum of Ranks**
Posttest-pretest	Negative Ranks	1[a]	1.50	1.50
	Positive Ranks	68[b]	35.49	2413.50
	Ties	1[c]		
	Total	70		

Table 16 presents the rank analysis of the pre-test and post-test scores. As shown in the table, the majority of students demonstrated improved learning outcomes following the implementation of the Project-Based Learning (PjBL)-based e-module, as indicated by 68 positive ranks, 1 negative rank, and 1 tie. To determine whether this improvement was statistically significant, a Wilcoxon Signed-Rank Test was conducted. The results of the statistical analysis are presented in Table 17.

Table 17. Wilcoxon Signed-Rank Test Results (Test Statistics)

	Posttest - pretest
Z	-7.213
Asymp. Sig. (2-tailed)	<0.001

As presented in Table 17, the significance value (Asymp. Sig. (2-tailed)) was < 0.001. This result indicates a statistically significant difference in students' learning outcomes before and after the implementation of the Project-Based Learning (PjBL)-based e-module. The results of the Wilcoxon Signed-Rank Test confirm that there was a significant difference between the pre-test and post-test scores, indicating that the e-module contributed to improving students' learning achievement in biodiversity.

The Wilcoxon test yielded a p-value of < 0.001, indicating that the difference between the pre-test and post-test scores was statistically significant. These findings demonstrate that the Project-Based Learning (PjBL)-based e-module was effective in enhancing students' creative thinking skills. Furthermore, the N-gain analysis presented in Table 15 showed moderate to high gain categories, indicating substantial improvements across the four indicators of creative thinking: fluency, flexibility, originality, and elaboration. These findings further suggest that integrating Project-Based Learning (PjBL) with the local wisdom of Kupang, Sidoarjo provided a contextual learning experience that enabled students to connect biological concepts with authentic real-world phenomena.

The present findings support the creativity theory proposed by Lavli and Efendi (2023), which argues that creativity can be developed through contextual learning experiences, opportunities for exploration, and authentic problem-solving activities. Moreover, these results are consistent with the findings of Purnamasari et al. (2025), who reported that Project-Based Learning (PjBL)-based e-modules integrated with local wisdom can enhance students' creativity while promoting more meaningful learning experiences.

Discussion

The present study developed a Project-Based Learning (PjBL)-based e-module integrating the local wisdom of Kupang, Sidoarjo for biodiversity learning and evaluated its validity, practicality, and students' creative thinking performance following classroom implementation. The development of the e-module was motivated by the need for instructional materials that not only present biological concepts but also connect them with students' everyday experiences. Based on the needs analysis and the local potential of Kupang, Sidoarjo, documented local wisdom was selected as the contextual basis for biodiversity learning to provide meaningful learning experiences while supporting students' creative thinking. Overall, the findings indicate that the developed e-module demonstrated high validity and practicality and was associated with improvements in students' creative thinking scores after implementation.

As shown in Table 5, the developed e-module features a well-structured organization, content aligned with the Biology Learning Outcomes for Phase E of the Merdeka Curriculum, and the integration of the local wisdom of Kupang, Sidoarjo throughout each learning activity. The e-module consists of two main learning units and incorporates four core features Bio-Think, Bio-Plan, Bio-Analyze, and Bio-Evaluate that collectively establish a project-based learning sequence. Its visual design is simple and user-friendly, with blue as the dominant color to represent the coastal identity of Sidoarjo, accompanied by interactive navigation and learning instructions. These characteristics demonstrate that the e-module functions not merely as a repository of learning materials but as an active learning environment that actively engages students throughout the learning process.

The integration of the Project-Based Learning (PjBL) syntax with the e-module features, as presented in Table 6, demonstrates a clear alignment between each stage of PjBL and the indicators of creative thinking. The Bio-Think feature facilitates the formulation of essential questions while stimulating fluency through the exploration of local phenomena related to mussel shells and waste. Bio-Plan guides students in designing projects and organizing work schedules, thereby fostering flexibility in selecting strategies and approaches. Bio-Analyze encourages students to generate original ideas and elaborate on them through observations and analyses of mussel shell utilization, supporting the development of originality and elaboration. Meanwhile, Bio-Evaluate facilitates assessment and reflection, reinforcing students' elaboration skills and encouraging the refinement and extension of their ideas.

This integration reflects the fundamental characteristics of Project-Based Learning, which emphasizes active student engagement in solving authentic problems. Previous studies have shown that PjBL effectively promotes creativity by providing opportunities for students to formulate problems, design solutions, and reflect on their learning both independently and collaboratively (Bell, 2010). Accordingly, the developed e-module not only follows the PjBL instructional framework but also deliberately aligns each project stage with specific indicators of creative thinking.

Expert validation indicated that the developed e-module achieved a very high level of validity, suggesting that its content, presentation and language met the criteria for classroom implementation. The validators' recommendations primarily concerned refinement of biodiversity concepts, simplification of scientific terminology, improvement of visual quality, and clarification of project instructions. Incorporating these suggestions strengthened both the scientific accuracy and pedagogical quality of the e-module before classroom implementation.

The systematic validation process is consistent with instructional material development principles that emphasize iterative revision based on expert feedback to improve product quality. Rather than viewing validation solely as a numerical outcome, the revision process ensured alignment between curriculum objectives, students' cognitive characteristics, and the intended Project-Based Learning syntax. These findings are also consistent with previous studies suggesting that well-designed digital learning materials can improve instructional quality and learning engagement (Clark & Mayer, 2023). From a theoretical perspective, integrating local wisdom provides authentic learning contexts consistent with constructivist learning principles, although the present study did not directly examine whether this contextualization was responsible for the observed learning improvements (Vygotsky, 1978).

The practicality evaluation was supported by three complementary sources of evidence: readability analysis, classroom implementation observations, and student responses. The Fry readability analysis indicated an estimated readability level corresponding to Grade 11. Although this level appears slightly higher than the target users (Grade X students), readability formulas estimate linguistic complexity rather than actual comprehension. During classroom implementation, students completed the learning activities with minimal language-related difficulties, and the response questionnaire indicated that the language, navigation, and learning instructions were generally easy to understand. These findings suggest that multimedia elements, contextual illustrations, teacher facilitation, and interactive navigation may have reduced the cognitive demands predicted by the readability formula alone. Similar findings have been reported by Lestari (2021), who found that multimedia-supported digital modules can enhance students' learning experiences and motivation.

Classroom observations further demonstrated that the Project-Based Learning procedures were implemented consistently throughout the instructional process. High implementation fidelity indicates that teachers were able to conduct each learning stage according to the instructional design. Nevertheless, implementation fidelity should not be interpreted as evidence of instructional effectiveness because it reflects procedural consistency rather than student learning outcomes.

Student responses further demonstrated that the e-module was perceived as practical and user-friendly. Most students reported that the e-module was easy to operate, visually attractive, and helpful for understanding biodiversity concepts through contextual project activities. These positive responses indicate good user acceptance of the developed learning resource. However, positive perceptions should be interpreted as evidence of usability rather than direct evidence of improved learning performance.

The Wilcoxon Signed-Rank Test revealed a statistically significant increase in students' creative thinking scores following implementation of the developed e-module. The large effect size (r = 0.86) suggests that the magnitude of the observed improvement was substantial from a practical perspective. Nevertheless, because the study employed a one-group pretest-posttest design, the observed improvement cannot be attributed exclusively to the developed e-module.

Several theoretical perspectives may help explain the observed changes. First, the design of the e-module intentionally aligned the stages of Project-Based Learning with indicators of creative thinking. The Bio-Think feature encouraged students to formulate essential questions and generate multiple ideas (fluency), Bio-Plan guided students in selecting strategies and organizing project activities (flexibility), Bio-Analyze encouraged the generation and refinement of original ideas (originality and elaboration), while Bio-Evaluate facilitated reflection and improvement of project outcomes. This instructional sequence reflects the fundamental characteristics of Project-Based Learning, which emphasizes active engagement in solving authentic problems (Thomas, 2000). Previous studies have likewise reported that PjBL can support creativity by providing opportunities for learners to formulate problems, design solutions, collaborate, and reflect on their learning (Bell, 2010). Although the observed improvements are consistent with these theoretical perspectives, the present study was not designed to determine whether the improvements resulted specifically from the PjBL process.

Second, integrating the local wisdom of Kupang, Sidoarjo provided authentic environmental contexts familiar to students. Rather than studying biodiversity through abstract textbook examples, students investigated biological diversity using environmental phenomena closely related to their daily lives, including the utilization of local marine resources. Contextual learning theory suggests that meaningful connections between scientific concepts and learners' experiences facilitate conceptual understanding and knowledge transfer (Johnson, 2002). Previous studies have similarly reported that integrating local wisdom into science learning can enhance environmental awareness and contextual understanding (Aura et al., 2023; Jannah & Viclara, 2025). However, because this study did not isolate the contribution of local wisdom from other instructional components, its specific influence on students' creative thinking cannot be determined.

Third, the multimedia features incorporated into the e-module—including videos, interactive navigation, project worksheets, reflective questions, and self-assessment activities—may have supported independent learning by allowing students to access information according to their individual learning pace. According to multimedia learning theory, appropriately designed combinations of verbal and visual information can facilitate meaningful learning while reducing unnecessary cognitive processing (Clark & Mayer, 2023). Nevertheless, the present study did not directly investigate students' cognitive load or learning engagement; therefore, this explanation remains theoretical.

Overall, the observed improvements are broadly consistent with previous studies reporting that Project-Based Learning supports creativity, scientific literacy, and higher-order thinking (Bell, 2010; Thomas, 2000; Purnamasari et al., 2025). Likewise, previous research has shown that contextual science learning based on local wisdom can make learning more meaningful and relevant to students' lives (Aura et al., 2023; Jannah & Viclara, 2025). However, rather than demonstrating a new theoretical mechanism explaining creativity development, the present study contributes a context-specific instructional prototype in which documented local wisdom from Kupang, Sidoarjo was systematically collected through interviews with community knowledge holders and representatives of the Fisheries Office before being integrated into a validated PjBL-based e-module for biodiversity learning.

Alternative explanations should also be considered. The observed improvements may have been influenced by repeated exposure to similar assessment tasks (testing effect), increased familiarity with classroom activities over time (maturation), teacher facilitation, or other classroom experiences unrelated to the intervention. Consequently, the present findings should be interpreted as improvements observed following implementation rather than evidence of causal relationships between the e-module and students' creative thinking performance. The present study provides a context-specific instructional prototype demonstrating how documented local wisdom can be systematically integrated into a Project-Based Learning-based e-module for biodiversity instruction. Rather than claiming theoretical novelty, the study offers a practical example of how authentic community knowledge can be translated into contextual digital learning materials that support biology learning while remaining aligned with curriculum objectives.

Several limitations should be acknowledged. First, the study employed a one-group pretest-posttest design without a comparison group; therefore, causal conclusions cannot be drawn. Second, classroom implementation was limited to a single school, restricting the generalizability of the findings. Future research should employ quasi-experimental or experimental designs involving comparison groups, larger and more diverse samples, multiple schools, and multiple raters. Further studies should also investigate the mechanisms through which Project-Based Learning, local wisdom integration, and digital learning features contribute to students' creative thinking and examine whether these effects are sustained across different biology topics and over longer periods.

Conclusion

This study developed a Project-Based Learning e-module integrating the local wisdom of Kupang Sidoarjo for biodiversity learning using the 4D instructional development model. The developed e-module demonstrated a very valid level of quality based on expert evaluations and was considered practical according to readability analysis, classroom implementation observations, and student responses. Following classroom implementation, students' creative thinking scores increased significantly, accompanied by a large effect size. However, because the study employed a one-group pretest-posttest design, these findings should be interpreted as observed improvements following implementation.

The study contributes a context-specific instructional prototype illustrating how validated local wisdom can be integrated into Project-Based Learning to support meaningful biodiversity learning. By connecting scientific concepts with authentic environmental practices familiar to students, the developed e-module provides an alternative digital learning resource that may assist biology teachers in promoting creative thinking through contextual learning experiences. Future research should employ controlled experimental designs involving multiple schools and larger samples to examine the effectiveness of this instructional approach under broader educational contexts.

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