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Towards Meaningful Biology Learning: A Needs Analysis for Developing a Deep Learning–Project-Based E-Module

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Abstract

The increasing complexity of biological concepts and the growing demand for twenty-first-century competencies require innovative learning resources that support both conceptual understanding and collaborative learning. This study aimed to analyze the needs of teachers and students regarding the development of a Biology e-module integrating Deep Learning and Project-Based Learning (DL-PjBL). A descriptive mixed-methods design was employed within the Analysis phase of the ADDIE framework. Participants consisted of 30 senior high school students and one Biology teacher selected through convenience sampling. Data were collected using a student needs questionnaire, classroom observations, and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, while qualitative data were examined through thematic analysis. The findings revealed a strong need for innovative digital learning materials, with 93.3% of students expressing the need for interactive e-modules and 83.3% reporting difficulties in understanding abstract Biology concepts. Furthermore, classroom observations indicated limited collaborative interaction, fragmented conceptual understanding, and a predominance of teacher-centered learning practices. Interview findings confirmed the need for learning resources that combine authentic project activities with reflective and meaningful learning experiences. The convergence of quantitative and qualitative findings suggests that a DL-PjBL-based Biology e-module has substantial potential to address existing pedagogical challenges by fostering collaboration and facilitating deeper conceptual understanding. This study provides an empirical foundation for the subsequent design and development of digital instructional materials that align with contemporary educational demands and support meaningful Biology learning.

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INTRODUCTION

The rapid expansion of digital technology has transformed the landscape of science education and created new expectations for teaching and learning practices in the twenty-first century. Despite unprecedented access to information and educational resources, many students continue to experience difficulties in understanding scientific concepts, particularly in Biology, where numerous topics involve abstract, microscopic, and highly interconnected phenomena (Nurdin et al., 2025). This situation presents an interesting paradox: while educational technology has become increasingly available, meaningful conceptual understanding among students remains a persistent challenge. Contemporary educational reforms emphasize the importance of developing not only content knowledge but also higher-order thinking, collaboration, and problem-solving skills that prepare learners for complex real-world situations (Luciana et al., 2024). Consequently, science education is expected to provide learning experiences that are interactive, contextual, and cognitively engaging rather than relying solely on traditional information delivery. The growing demand for student-centered learning environments has encouraged educators to seek innovative instructional media capable of reducing cognitive barriers while simultaneously fostering active participation. In this context, digital learning resources have emerged as a promising solution to bridge the gap between technological advancement and meaningful learning outcomes. Therefore,

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investigating appropriate digital learning innovations for Biology education has become increasingly important in contemporary educational discourse.

One of the major challenges in Biology learning is the high cognitive load generated by abstract concepts that are difficult to visualize through conventional teaching methods. Topics such as cellular processes, biotechnology, genetics, and ecological interactions often require students to understand complex relationships that cannot be directly observed in everyday life (Hadi et al., 2025). As a result, many learners struggle to connect theoretical knowledge with authentic scientific phenomena, leading to fragmented understanding and misconceptions. Previous studies have reported that students frequently rely on rote memorization rather than meaningful conceptual construction when learning Biology (Saputra et al., 2023; Vorsah & Oginni, 2025). The persistence of teacher-centered instruction further exacerbates this problem because students are often positioned as passive recipients of information rather than active constructors of knowledge. Such learning conditions limit opportunities for inquiry, reflection, and collaborative problem-solving that are essential for developing scientific literacy. Moreover, inadequate learning media may increase extraneous cognitive load, making it more difficult for students to process and integrate scientific information effectively (Sweller, 2010). These challenges indicate a pressing need for learning environments that can facilitate conceptual visualization, active engagement, and meaningful knowledge construction simultaneously.

The emergence of electronic modules (e-modules) offers substantial opportunities to address these instructional challenges. Compared with conventional printed materials, e-modules provide greater flexibility, accessibility, multimedia integration, and interactive learning experiences that support independent learning (Jumiarni et al., 2024; Robiah et al., 2024). Research has consistently demonstrated that digital learning materials can improve conceptual understanding by presenting information through multiple representations, including text, animation, simulations, and interactive activities (Anggraini et al., 2024; Fatmianeri et al., 2021). Furthermore, e-modules can support differentiated learning by allowing students to regulate their learning pace according to individual needs and cognitive readiness (Nurdin et al., 2025). Advances in educational technology have also enabled the integration of reflective tasks, collaborative activities, and authentic assessments into digital learning environments. These features are particularly important in science education because conceptual understanding develops more effectively when students actively engage with scientific ideas rather than merely receiving information. Consequently, the development of high-quality Biology e-modules has become a strategic priority for improving science learning outcomes. However, the effectiveness of such digital resources largely depends on the pedagogical frameworks embedded within them.

Among the pedagogical approaches widely recognized for promoting active learning, Project-Based Learning (PjBL) has gained considerable attention because of its emphasis on authentic inquiry, collaborative investigation, and product creation. Through project-based activities, students are encouraged to solve real-world problems, communicate ideas, and work collaboratively to construct knowledge (Abas et al., 2024; Hidayah et al., 2024). Numerous studies have reported that PjBL positively influences critical thinking, creativity, collaboration, and scientific reasoning skills (Agustin et al., 2023; Fitrianingsih et al., 2025; Zulyusri et al., 2023). Nevertheless, several scholars have noted that project completion does not automatically guarantee deep conceptual understanding. In many cases, students become highly focused on producing project outputs while paying insufficient attention to the underlying scientific principles that should guide the learning process (Hamidah & Citra, 2021). This limitation suggests that project activities require additional instructional mechanisms that promote reflection, conceptual integration, and meaningful knowledge construction. Without such mechanisms, project-based learning may risk emphasizing procedural achievement over cognitive understanding. Therefore, integrating complementary pedagogical frameworks into PjBL is necessary to maximize its educational potential.

Recently, the concept of Deep Learning in education has received increasing attention as an approach that promotes thoughtful, meaningful, and joyful learning experiences (Hanum et al., 2026; Jamali et al., 2025). Unlike superficial learning approaches that emphasize memorization, educational deep learning encourages students to connect new information with prior knowledge, critically reflect on learning experiences, and transfer understanding to new situations. This perspective is closely aligned with constructivist learning theory, which emphasizes active knowledge construction through meaningful engagement and reflection (Biggs & Tang, 2011; Bransford et al., 2000). Studies have suggested that deep learning-oriented instruction contributes positively to conceptual understanding, critical thinking, and long-term knowledge retention (Mursid et al., 2025; Taufik et al., 2025). Moreover, deep learning principles provide opportunities to strengthen students' metacognitive awareness by encouraging them to evaluate and refine their own understanding continuously. Such characteristics make deep learning particularly relevant for Biology education, where students must integrate multiple concepts across different levels of scientific explanation. According to Bransford et al. (2000), meaningful learning occurs when learners actively connect new concepts with existing cognitive structures and transfer acquired knowledge to novel situations, which represents a central objective of Biology education. Consequently, combining deep learning principles with project-based activities may offer a powerful framework for addressing both cognitive and collaborative dimensions of learning. This integration has the potential to transform projects from product-oriented tasks into meaningful learning experiences that foster conceptual mastery.

A growing body of literature has examined the development of e-modules, project-based learning interventions, and deep learning-oriented instructional strategies across various educational contexts. Previous studies have reported positive outcomes from Biology e-modules integrated with STEM approaches (Jumiarni et al., 2024), SOLE models (Anggraini et al., 2024), differentiated instruction (Fatmianeri et al., 2021), socio-scientific issues (Rini et al., 2023), and environmental education contexts (Hanum et al., 2026). Similarly, research on PjBL has consistently demonstrated improvements in collaboration skills, creativity, engagement, and conceptual understanding (Abas et al., 2024; Agustin et al., 2023; Wahyuni et al., 2025). Studies focusing on educational deep learning have also highlighted its effectiveness in enhancing reflective thinking and meaningful learning experiences (Jamali et al., 2025; Mursid et al., 2025; Taufik et al., 2025). Furthermore, several needs-analysis studies have investigated teachers' requirements for digital learning resources and innovative instructional materials in science education (Agusningtyas et al., 2024; Heryensi et al., 2025; Kumala et al., 2025). Collectively, these studies provide valuable insights into contemporary trends in educational technology and innovative pedagogy. However, their findings remain fragmented across different instructional approaches and educational objectives.

Despite these advancements, several important limitations remain unresolved in the existing literature. First, most studies examine e-modules, PjBL, and deep learning as separate constructs rather than as an integrated pedagogical framework. Second, existing research predominantly focuses on product development and effectiveness testing while paying limited attention to comprehensive needs analysis involving both teachers and students before the design stage (Agusningtyas et al., 2024; Kumala et al., 2025). Third, studies exploring deep learning integration within Biology education remain relatively scarce compared with investigations conducted in other educational domains (Jamali et al., 2025). Fourth, little empirical evidence is available regarding how digital learning resources can simultaneously address conceptual understanding and collaboration skills through the integration of Deep Learning and Project-Based Learning principles. As a result, there is a significant gap concerning the pedagogical requirements necessary for developing Biology e-modules that effectively combine project-based investigation, collaborative engagement, and reflective conceptual learning. Addressing this gap is essential because the success of educational innovation depends not only on technological features but also on its alignment with the authentic needs of users. Therefore, a systematic needs analysis is required to establish a strong empirical foundation for future instructional design and development efforts.

Based on these considerations, this study aims to analyze the needs of teachers and students regarding the development of a Biology e-module based on the integration of Deep Learning and Project-Based Learning (DL-PjBL) to enhance collaborative skills and conceptual understanding. Specifically, the study seeks to identify learning challenges, instructional needs, and pedagogical expectations associated with Biology learning in secondary education settings. The findings are expected to contribute theoretically by extending the literature on the integration of deep learning principles, project-based pedagogy, and digital learning resources within science education. Practically, the results will provide evidence-based guidance for educators, instructional designers, and curriculum developers in designing Biology e-modules that align with contemporary educational demands. In addition, the study offers an empirical foundation for subsequent stages of educational product development within the ADDIE framework. By emphasizing both teacher and student perspectives, this research aims to ensure that future instructional innovations are grounded in authentic classroom realities. Ultimately, the study contributes to ongoing efforts to create meaningful, collaborative, and conceptually rich learning experiences that prepare students for the challenges of twenty-first-century science education.

METHOD

Research Design

This study employed a descriptive mixed-methods design to analyze the needs of teachers and students regarding the development of a Biology e-module based on the integration of Deep Learning and Project-Based Learning (DL-PjBL). A mixed-methods approach was selected because the research aimed not only to quantify the magnitude of educational needs but also to explore contextual factors underlying those needs from the perspectives of both teachers and students (Heryensi et al., 2025; Riawan et al., 2025). The study was situated within the Analysis phase of the ADDIE instructional design framework, which emphasizes systematic identification of learner characteristics, instructional challenges, and pedagogical requirements before educational product development begins (Jumiarni et al., 2024; Pantiwati et al., 2025). Previous studies have demonstrated that systematic needs analysis provides an important foundation for designing e-modules that effectively improve conceptual understanding and problem-solving skills (Pantiwati et al., 2025). The quantitative component focused on measuring students' perceptions regarding learning difficulties, collaboration experiences, and the need for digital learning resources, whereas the qualitative component explored classroom realities and pedagogical considerations through observations and teacher interviews. The integration of quantitative and qualitative findings provided a comprehensive evidence base to support the future design and development of the DL-PjBL Biology e-module (Hanum et al., 2026; Kumala et al., 2025). This approach is particularly relevant because recent systematic reviews of Biology e-module development have emphasized the importance of grounding product design in empirical analyses of learner and instructional needs (Riawan et al., 2025).

Research Setting and Duration

The study was conducted in a public senior high school in Indonesia where Biology was taught as part of the national science curriculum. The research took place during the second semester of the 2025/2026 academic year. The school was selected because it had implemented conventional Biology instruction and had not yet utilized a DL-PjBL-based e-module in its learning activities. The research setting provided a relevant context for examining existing instructional practices, student learning experiences, and the potential need for innovative digital learning materials. Data collection was conducted over a four-week period and included classroom observations, questionnaire administration, and semi-structured interviews. This timeframe allowed the researcher to obtain a comprehensive understanding of instructional conditions and participant perspectives before the initiation of product development.

Population and Participants

The population of this study consisted of all students enrolled in Biology classes and Biology teachers at the selected senior high school. Participants included 30 students from two Biology classes and one Biology teacher who actively taught the subject during the research period. Participants were selected using a convenience sampling technique because they were directly accessible to the researcher and represented the primary users of the proposed instructional product (Nurdin et al., 2025; Hudawati et al., 2024). Students were included if they were actively enrolled in Biology courses, regularly attended classes, and agreed to participate in the study. The participating teacher was selected because of direct involvement in Biology instruction and familiarity with classroom learning challenges. Although the sample size was relatively limited, it was considered appropriate for a needs-analysis study focused on generating contextual information rather than statistical generalization (Heryensi et al., 2025). The selected participants provided valuable insights into the pedagogical and technological requirements necessary for future e-module development.

Research Instruments

Data were collected using three complementary instruments: a student needs questionnaire, a classroom observation sheet, and a semi-structured interview guide. The student questionnaire was developed to assess learners' perceptions regarding difficulties in understanding Biology concepts, experiences of collaboration during learning, interest in project-based learning activities, and the need for interactive digital learning media (Agusningtyas et al., 2024; Mursid et al., 2025). The questionnaire consisted of 20 items measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Classroom observations were conducted using a structured observation sheet designed to document collaborative interactions, participation patterns, learning engagement, and evidence of conceptual understanding during Biology lessons (Sitorus et al., 2025). In addition, a semi-structured interview protocol was employed to explore the teacher's perceptions regarding instructional challenges, existing learning resources, student learning difficulties, and expectations for the implementation of DL-PjBL-based e-modules (Taufik et al., 2025). The combination of these instruments enabled methodological triangulation and enhanced the comprehensiveness of the findings (Dermawan et al., 2021).

Instrument Validity and Reliability

Prior to data collection, all research instruments underwent content validation through expert review involving three specialists in Biology education, educational technology, and instructional design. The experts evaluated the relevance, clarity, representativeness, and appropriateness of each instrument item with respect to the research objectives. Suggestions provided during the validation process were incorporated into the final version of the instruments. The Content Validity Index (CVI) was calculated to determine the adequacy of item representation, and all items achieved acceptable validity criteria. Subsequently, the questionnaire was pilot-tested with students who were not included in the main study sample to evaluate item clarity and response consistency. Internal consistency reliability was assessed using Cronbach's alpha coefficient, with values greater than 0.70 considered acceptable for educational research. The final questionnaire achieved a Cronbach's alpha coefficient exceeding the recommended threshold, indicating satisfactory reliability. The observation and interview instruments were also reviewed for consistency and alignment with the conceptual framework of collaboration skills, conceptual understanding, and Deep Learning principles.

Data Collection Procedures

Data collection was conducted systematically in several stages. The first stage involved obtaining institutional permission from the school administration and securing informed consent from all participants. The second stage consisted of preliminary classroom observations aimed at identifying existing instructional practices, student participation patterns, and learning challenges within Biology classrooms. During the third stage, the student needs questionnaire was administered to all participating students under the supervision of the researcher. Participants completed the questionnaire individually and anonymously to minimize response bias. The fourth stage involved conducting semi-structured interviews with the Biology teacher to gain deeper insights into pedagogical challenges and expectations regarding digital learning innovations. Interview sessions were audio-recorded with participant permission and subsequently transcribed verbatim for analysis. Finally, all quantitative and qualitative data were organized, verified, and prepared for subsequent analysis. This sequential procedure ensured systematic data collection and facilitated the integration of findings from multiple sources (Hanum et al., 2026; Hudawati et al., 2024).

Data Analysis

Quantitative and qualitative data were analyzed separately before being integrated during the interpretation stage. Quantitative data obtained from the student questionnaire were analyzed using descriptive statistical techniques, including frequency distributions, percentages, means, and standard deviations, to identify patterns of perceived needs and learning challenges (Agusningtyas et al., 2024; Kumala et al., 2025). Statistical analyses were conducted using IBM SPSS Statistics version 27. The interpretation of need levels followed percentage-based criteria, with higher percentages indicating stronger urgency for instructional innovation. Qualitative data derived from classroom observations and teacher interviews were analyzed using thematic analysis procedures (Heryensi et al., 2025). The analysis involved several stages, including data familiarization, open coding, categorization, theme development, and interpretation. Emerging themes were continuously compared across data sources to identify recurring patterns and explanatory insights. To enhance credibility, data triangulation was performed by comparing findings from questionnaires, observations, and interviews. Finally, quantitative and qualitative findings were integrated through a convergent interpretation process to develop a comprehensive understanding of the educational needs underlying the proposed DL-PjBL Biology e-module (Mursid et al., 2025).

Ethical Considerations

This study adhered to established ethical principles governing educational research. Prior to participation, all participants received information regarding the objectives, procedures, and voluntary nature of the study. Written informed consent was obtained from the participating teacher and students, while parental permission was secured when required by school regulations. Participants were informed of their right to withdraw from the study at any stage without penalty. To protect confidentiality, all personal information was anonymized, and participant identities were replaced with coded identifiers during data analysis and reporting. Research data were securely stored and used exclusively for academic purposes. Throughout the study, the researcher maintained transparency, objectivity, and respect for participant rights in accordance with accepted standards of educational research ethics.

RESULTS AND DISCUSSION

This research was carried out in the Analysis phase in the ADDIE model cycle, using a simple mixed-method approach. Data was collected from 30 students and one biology teacher. The results of the study are divided into two main parts, namely the results of quantitative analysis from student questionnaires and the results of qualitative analysis from observations and teacher interviews.

Quantitative Analysis: Student Needs Questionnaire

Based on the results of the distribution of questionnaires with a Likert scale to 30 students, data was obtained on the level of difficulty in learning biology and the urgency of using interactive media. The responses of students who answered "Agree" and "Strongly Agree" were accumulated to see the percentage of the level of need. The results show a very high percentage of e-module need indicators and project-based learning. The frequency distribution of such data is presented in the bar chart below.

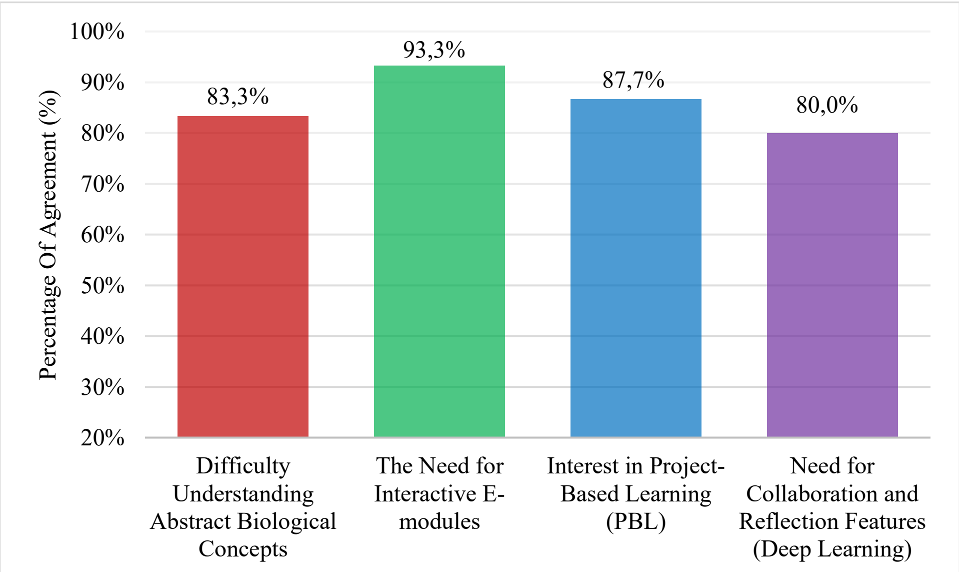

Figure 1. Analysis of Student Needs for the Development of Biology E-Modules

Based on Figure 1, the majority of students (93.3%) stated that they urgently need the presence of digital teaching media in the form of interactive e-modules to help them learn independently. This is directly correlated with the high percentage of students (83.3%) who still experience cognitive burden in understanding abstract biology material. In addition, 86.7% of students are interested in learning packaged in the form of group projects, and 80.0% of students agree on the need for collaboration guidance and problem-solving reflection (Deep Learning principles) in the module.

Qualitative Analysis: Classroom Observation and Teacher-Researcher Deep Reflection

Quantitative data related to the high urgency of media development were further validated through participatory classroom observation and pedagogical reflection. The advantage of this finding lies in the position of the researcher who acts directly as a practitioner (biology teacher), so as to be able to capture factual dynamics related to the main variables of the research: collaboration skills and understanding of students' concepts.

1. Class Observation Results (Collaboration Skills and Concept Understanding)

Participatory observations are conducted in a structured manner to see how students interact and process science information during conventional learning. The results of observations on these two variables are presented in Table 1 and Table 2 below.

Table 1. Results of Student Collaboration Skills Observation

Aspects of Collaborative Observation	Factual Conditions of Conventional Learning	Gap Analysis
Interaction Between Students	Very minimal. *Teacher-centered learning*. Communication occurs predominantly one-way.	There is no authentic investigative space that facilitates peer dialogue.
Division of Roles & Duties	The majority assignment is individual. If there is group work, the assignment is only done by 1-2 dominant students.	Students are not yet familiar with the shared responsibility (positive interdependence) typical *of Project-Based Learning* (PjBL).
Joint Problem-Solving	Students are passive and only wait for instructions/answers from textbooks or teachers.	The lack of stimulus in the form of real projects that demand collaborative ideas contributions.

Table 2. Results of Initial Analysis of Students' Understanding of Biology Concepts

Concept Understanding Indicators	Qualitative Findings in the Field (Cognitive Symptoms)	The Root of the Problem
Mastery of Abstract Concepts	Students experience *cognitive overload* when facing microscopic/abstract material.	The absence of visual/interactive media (*e-modules*) to concretize the material.
Connection Between Concepts (Meaning-Making)	Students' understanding is fragmented. Students tend to memorize terms (Rote Learning) without understanding the meaning of biology in its entirety.	Learning has not touched the realm of *Deep Learning*; students have not been invited to do critical reflection.
Knowledge Transfer (Application)	Students have difficulty answering analysis questions or applying biological concepts to real-world phenomena.	The learning model has not been based on solving real-life (contextual) project problems.

2. Results of Deep Reflection (Teacher's Findings as a Researcher)

Based on the observation data above, through critical self-reflection and pedagogical evaluation, the researcher as a practitioner of biology teachers found a dissonance between the demands of the curriculum and the availability of teaching materials. The teacher as the researcher confirmed that the application of the pure Project-Based Learning (PjBL) model often has gaps; students focus too much on the technical completion of the project's "physical product" (making posters, mockups, etc.) but fail to grasp the essence and understanding of the underlying biological concepts. As a result, the project is completed, but the understanding of the concept remains low.

This is where the core findings of the teacher-researchers lie: a media intervention is needed that is able to bridge project activities with high-level cognitive reflection. Referring to the title of the research, the teacher-researcher emphasized that the development of the Project-Based Deep Learning Biology E-Module (DL-PjBL) is the most precise pedagogical solution.

The presence of this e-module is very urgent because it is designed to perform two crucial functions simultaneously: 1) Improving Collaboration Skills, namely Through the PjBL syntax guide in the e-module, students will be directed to investigate, divide roles, and collaborate to create solutions to biological problems. 2) Strengthening Conceptual Understanding, namely Through the integration of the Deep Learning framework (mindful, meaningful, and joyful learning), the e-module will not let students just create projects blindly. The e-module will provide interactive visualizations and reflective stages (deep trigger questions) that "force" students to connect their project activities with the underlying science concepts.

The convergence between the observation results (Table 1 and Table 2) and the authentic reflections of these guru-researchers validates the urgency of the research. The condition of passive collaboration and understanding of concepts that are limited to memorization proves indisputably that the analysis of the needs for the Biology E-Module based on DL-PjBL is very valid and critical to be immediately continued to the design stage.

Based on the results of quantitative and qualitative needs analysis, it is empirically proven that the development of Biology e-modules is based on Deep Learning integrated with Project-Based Learning (DL-PjBL) is very urgent and rational. Factual conditions show that 83.3% of students experience cognitive overload (excessive cognitive load) towards abstract biological concepts due to the absence of adequate media visualization, and 93.3% of them agreed on the urgency of using interactive e-modules. This phenomenon is in line with previous research that confirms that E-Module is an innovation of teaching materials that has been proven to be effective in facilitating independence, providing meaningful visualization, and reducing misconceptions in the understanding of science (Anggraini et al., 2024; Fatmianeri et al., 2021). Furthermore, the adoption of technology in the form of e-modules has been proven to significantly minimize Extraneous cognitive load which is often the main obstacle to conventional biology learning methods (Hsu et al., 2023; Sweller, 2010).

The observational findings also highlight the lack of collaboration involvement between students due to the teacher-centered. Consolidation (convergence) Project-Based Learning (PjBL) and Deep Learning become a very logical problem-solving instrument. On the one hand, PjBL inherently facilitates 21st century skills through group collaboration, scientific investigation, and contextual product creation (Altatri & Ardi, 2024; Hamidah & Citra, 2021; Shefaya et al., 2024). Collaboratively packaged project-based learning is also reported to have effect size high to increase reasoning power and active interaction between students (Zhang et al., 2024). On the other hand, the syntax Deep Learning is present to close the pedagogical weaknesses of conventional PjBL by "forceing" students to reflect on their projects critically so that a process Meaning-Making (meaning). The integration of DL-PjBL in the form of e-modules is considered as an innovative measurable pedagogical intervention to improve the understanding of biological concepts in an integrated manner (Suryani et al., 2024). This finding supports the argument that meaningful conceptual learning is more likely to occur when students actively construct knowledge through authentic experiences and structured reflection processes (Biggs & Tang, 2011; Bransford et al., 2000).

Early-stage research (needs analysis) this brings crucial theoretical and practical implications for science education. Theoretically, this study provides the foundation for a new paradigm based on empirical evidence (Evidence-Based) which brings together the methodology of product creation (PjBL) with the psychological/cognitive process of deep meaning (Deep Learning). Practically, the high percentage of student and teacher needs provides a foundation (Blueprint) that is robust for educators, curriculum designers, and educational technologists in formulating the initial design stages of biology e-modules that specifically target the improvement of collaboration skills (Ahmad et al., 2021).

This research has several limitations. First, this research focuses purely on the Analysis phase (analysis of pedagogical and technical needs) within the framework of Research & Development (R&D) instructional design. Second, the sample size of the research is relatively limited, relying on 30 students and one teacher in one educational institution through convenience sampling techniques. Therefore, the specific findings of this research are very contextual and cannot be used as a basis for statistical generalizations that are representative of all demographics or school characteristics globally.

Based on the evidence of pedagogical gaps found, it is recommended that further development studies (R&D) can be immediately formulated to execute the Design and Develop stages to validate the effectiveness of the DL-PjBL-based biology e-module prototype. In addition, in order to ensure theoretical and practical efficacy in stimulating collaboration skills and facilitating scientific understanding, further researchers are strongly recommended to conduct empirical trials on a more massive scale with heterogeneous student demographics (Implementation & Evaluation).

CONCLUSION

This study investigated the needs of teachers and students for the development of a Biology e-module integrating Deep Learning and Project-Based Learning (DL-PjBL). The findings revealed a strong demand for interactive digital learning resources, driven by students' difficulties in understanding abstract biological concepts, limited collaborative learning experiences, and the predominance of teacher-centered instruction. Quantitative and qualitative evidence consistently indicated that existing learning practices have not adequately supported meaningful conceptual understanding or the development of collaboration skills. The study highlights the potential of a DL-PjBL-based Biology e-module as a pedagogical innovation capable of integrating authentic project activities with reflective and meaningful learning processes. These findings provide an empirical foundation for the subsequent design and development stages of the e-module. Although the results are context-specific due to the limited sample size, they offer valuable insights for educators, instructional designers, and curriculum developers seeking to create more engaging, collaborative, and conceptually rich Biology learning environments in the digital era.

AUTHOR CONTRIBUTIONS STATEMENT

AA contributed to the conceptualization of the study, research design, data collection, data analysis, investigation, and preparation of the original manuscript draft. **S** contributed to the development of the methodological framework, academic supervision, validation of the research design, and critical revision of the manuscript. **NRD** contributed to instrument validation, interpretation of findings, manuscript review and editing, and overall quality assurance of the study.

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