The Effect of Using PJBL-Based Interactive E-Modules on Improving Learning Outcomes

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Abstract: This study aims to evaluate how interactive e-modules designed with the Project-Based Learning (PJBL) approach effectively improve students' learning achievement at the elementary school level, especially on ecosystem material. The method used was a narrative-descriptive literature study of 20 national and international scientific articles published from 2020-2025. The literature was selected based on inclusion criteria focusing on e-module development, implementation of PPA, and relevance to learning in elementary schools. The results showed that the integration of PJBL in the interactive e-module significantly contributed to the improvement of concept understanding (40%), learning motivation (35%), and active student involvement (25%). In addition, this media is considered effective in building 21st-century skills such as critical thinking, collaboration, and independence. The implications of these findings emphasize the importance of systemic support in the form of teacher training, provision of digital infrastructure, and education policies that encourage learning innovation. Thus, interactive e-modules based on PJBL are a potential strategy to improve the quality of learning in the Independent Curriculum era.

Ahstrack : Tujuan dari penelitian ini adalah untuk mengevaluasi sejauh mana e-modul interaktif yang dirancang dengan pendekatan Project-Based Learning (PJBL) efektif dalam meningkatkan pencapaian belajar peserta didik di tingkat sekolah dasar, khususnya pada materi ekosistem. Metode yang digunakan adalah studi literatur naratif-deskriptif terhadap 20 artikel ilmiah nasional dan internasional yang diterbitkan dalam rentang 2020-2025. Literatur dipilih berdasarkan kriteria inklusi yang meliputi fokus pada pengembangan e-modul, penerapan PJBL, serta relevansi dengan pembelajaran di sekolah dasar. Hasil kajian menunjukkan bahwa integrasi PJBL dalam e-modul interaktif berkontribusi signifikan terhadap peningkatan pemahaman konsep (40%), motivasi belajar (35%), dan keterlibatan aktif siswa (25%). Selain itu, media ini dinilai efektif dalam membangun keterampilan abad ke-21 seperti berpikir kritis, kolaboratif, dan mandiri. Namun demikian, tantangan masih dihadapi pada aspek kompetensi guru, akses teknologi, dan ketersediaan pelatihan pengembangan media ajar. Implikasi dari temuan ini menegaskan pentingnya dukungan sistemik berupa pelatihan guru, penyediaan infrastruktur digital, serta kebijakan pendidikan yang mendorong inovasi pembelajaran. Dengan demikian, e-modul interaktif berbasis PJBL menjadi strategi potensial untuk meningkatkan kualitas pembelajaran di era Kurikulum Merdeka.

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A. Introduction

Learning is crucial in creating a resilient, innovative generation that can address challenges in the 21st-century global era. The rapid progress in information and communication technology (ICT) has significantly impacted various aspects of life, including education. In the Industrial Revolution 4.0 era, students must master critical thinking skills, the ability to work together, digital literacy, and the ability to solve problems creatively (Cahyani & Huda, 2016). This condition requires the world of education to adjust curriculum, learning approaches, and technology as a learning medium.

One of the significant changes in the field of education is the shift in learning approaches from those that focus on the dominant role of the teacher to learning models that prioritize the active involvement of learners (Antari et al., 2023). Student-centered Learning emphasizes the active role of learners in constructing understanding through exploration, interaction, and reflection. However, the reality in the field still shows that most elementary schools still apply the lecture method and conventional printed media that tend to be one-way. This has an impact on low student participation in the learning process, which then causes concept understanding to be less in-depth and the achievement of learning outcomes that are not optimal (Kusumawati & Mustadi, 2021).

Several studies have shown that primary school students' learning achievements in science subjects are still low. This is due to the difficulties students experience in understanding various abstract concepts because the material is delivered in a non-contextual and less interactive way (Wulandari et al., 2024). In addition, students' critical thinking skills, learning independence, and problem-solving abilities are not well developed due to the limited innovative learning approaches applied.

In response to these conditions, a learning solution is needed to encourage learning motivation and increase student involvement, actively contributing to improving their learning achievement. One of the potential approaches is the use of interactive e-modules based on PJBL. E-modules are digital-based learning tools containing comprehensive material content supported by interactive features such as animations, learning videos, simulations, interactive quizzes, and automatic evaluation systems (Navila & Tuharto, 2023). The advantages of interactive e-modules lie in their ability to deliver material in an attractive, flexible manner and encourage active student involvement.

The PJBL-based learning approach has proven effective in developing important 21st-century skills in learners. Through involvement in real projects, students are invited to work together, explore, solve problems, and convey their findings. This makes the learning process not limited to theory alone but more applicable in everyday life (Syarifudin et al., 2024). The combination of interactive e-modules with the PPA model creates a strong collaboration in realizing relevant, meaningful, and enjoyable Learning for students at the elementary school level.

Several studies have shown that PPA positively impacts learning outcomes by significantly increasing concept understanding and post-test scores in students who follow project-based Learning (Sari & Isdaryani, 2024). Similarly, e-modules increase student

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interest and motivation due to their more interesting and interactive presentation (Maghfiroh et al., 2024). However, few studies still specifically integrate interactive e-modules with the PJBL model in ecosystem learning in elementary schools. This indicates a gap or research gap that needs to be answered.

This gap is an important basis for conducting this study. Previous research generally highlights e-modules and Project-Based Learning (PjBL) models separately without examining the integration of both in science learning that demands complex understanding, such as in ecosystem material. Ecosystem material requires conceptual and contextual understanding, thus requiring innovative and project-based learning approaches. This research is intended to address the existing gap by making a new contribution in the form of applying interactive e-modules based on Project-Based Learning (PJBL) to improve the learning achievement of elementary school students on the topic of ecosystems (Dewi & Lestari, 2020).

Another contribution of this study lies in the effort to systematically map the various research results that support the effectiveness of integrating PPA and interactive e-modules. With a narrative-descriptive literature study approach, this article summarizes previous research results and critically evaluates how, why, and in what contexts PJBL e-modules can be applied effectively (Hayati et al., 2025). This study will provide evidence-based recommendations to teachers, learning media developers, and education policymakers.

The significance of this research is also reinforced by the fact that many elementary schools in Indonesia have not been optimal in integrating digital technology into Learning. The Merdeka Curriculum, which carries the Pancasila Learner Profile with critical, collaborative, and creative characters, has not been fully matched by teacher training and the provision of adequate digital learning tools. For this reason, this research aims to provide a conceptual and practical basis for developing interactive e-modules based on PJBL that are adaptive and applicable in various primary school contexts.

A strong theoretical foundation also supports the PJBL e-module approach. According to Piaget's constructivism theory, students construct knowledge through meaningful learning experiences. PJBL is very relevant to this principle because it emphasizes exploration and discovery. In addition, Bandura's social cognitivism theory emphasizes the importance of learning through observation, direct experience, and social interaction, all of which can be facilitated through features in interactive e-modules (Pratama et al., 2023). The digital pedagogy approach also emphasizes that technology in Learning is not only technical but must have a pedagogical dimension that builds a complete and meaningful learning experience.

Recent studies support the effectiveness of this approach. Implementing PJBL with interactive e-modules can significantly improve science learning outcomes in elementary schools, both in cognitive aspects and learning interests (Wulandari et al., 2024). However, challenges remain, especially concerning limited infrastructure and teacher competence in optimally developing and utilizing learning technology (Capah et al., 2025).

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Based on the previous explanation, the main objective of this study is to compile a systematic review of the effectiveness of using interactive e-modules based on Project-Based Learning in improving student learning outcomes at the primary school level, especially on ecosystem material. The specific objectives of this study include (1) identifying theories and concepts underlying the development of interactive e-modules and the PPA approach; (2) evaluating the results of previous relevant research on PPA e-modules in science learning in elementary schools; (3) analyzing the advantages and limitations of the approach in the context of implementation in elementary schools; and (4) providing strategic recommendations to teachers, schools, and learning media developers regarding the development and implementation of PPA e-modules (Jaenudin et al., 2020).

By understanding this approach more deeply and comprehensively, it is hoped that educators and education stakeholders will be able to utilize technology wisely and innovatively to improve the quality of Learning and create active, critical, and outstanding students in the digital era (F.T.H et al., 2022).

B. Method

With a literature study approach, this article is used to review and explore the influence of literature studies on the utilization of interactive e-modules designed with a Project-Based Learning (PJBL) approach to improve student learning outcomes at the primary school level. A literature study was chosen because it allows the author to collect, analyze, and synthesize results from previous studies that align with the theme of this discussion. By utilizing published sources of scientific information, this article aims to provide a comprehensive understanding of the effectiveness of e-module integration and PJBL in the learning process and its contribution to improving student learning outcomes (Capah et al., 2025).

In this study, the authors did not only refer to one type of source but also a variety of scientific articles obtained from various academic databases such as Google Scholar, Garuda, DOAJ, and ResearchGate. The literature search was conducted using keywords such as "interactive e-module," "Project-Based Learning in Elementary School," "digital learning media," and "learning outcomes of elementary school students." The articles found were then systematically selected based on the topic's relevance and the publication's quality. Articles prioritized in the selection process were on developing project-oriented learning media and analyzing student learning outcomes at the elementary school level (Triyanto & Aryani, 2022).

To provide clarity to the process, the stages of this literature review are presented in Figure 1 below:

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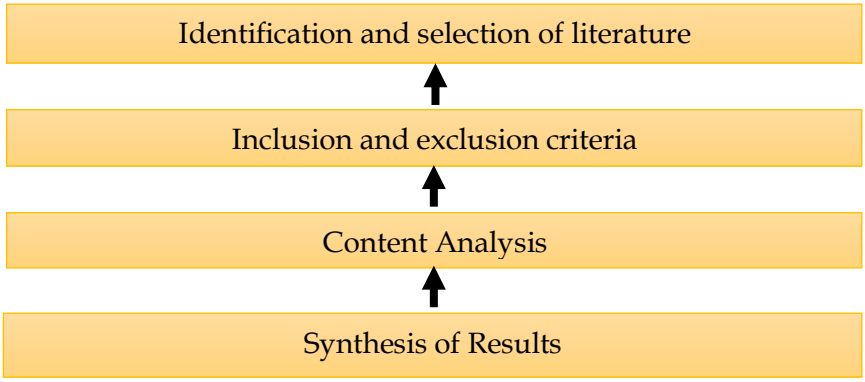

Figure 1. Research Flow

The selection of articles concerned predetermined inclusion and exclusion provisions was carried out. The inclusion criteria consisted of the publication of articles that:

- Discuss the development or use of interactive e-modules
- Moreover, it examines the application of the PBL model in the context of learning in elementary school.
- Released in the last ten-year period (2020-2025)
- Available in Indonesian or English and
- Published in an accredited scientific journal. On the contrary,

Articles are excluded if:
(1) not relevant to the topic,
(2) only contains theory without empirical research results,
(3) not available in full-text,
(4) published in languages other than Indonesian and English.

A description of the article selection criteria can be found in Table 1 below :

Table 1. Article Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Article tyoe	Scientific publications published in journals that have obtained official accreditation.	Articles not published in scientific journals or non-accredited journals
Article topic	Articles that discuss critical thinking skills in education and teaching strategies to develop them	Articles that are not relevant to the topic of critical thinking skills or education
Year of publication	Articles published in the last 5 years (2020-2025)	Articles published more than 5 years ago
Language	Language Published papers use English or Indonesian.	Papers published in languages other than English and Indonesian
Research Methode	Articles that use literature review or meta-analysis related to critical thinking skills	Articles that use research methodologies that are irrelevant or unrelated to the development of critical thinking skills

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Several articles that met the criteria were analyzed to identify previous researchers' contributions, methods, findings, and recommendations. The author also categorizes the findings based on the characteristics of the e-module media, the PJBL approach, and the student learning outcomes achieved. This review integrates various perspectives in learning media design, especially in the context of 21st-century education that demands renewal and efficiency in the instructional process (Maghfiroh et al., 2024)

With this literature study approach, this article aims to provide a more structured direction for educators and media developers in designing learning strategies relevant to today's students' learning needs. In addition, the results of this study are expected to provide empirical and theoretical evidence that can be used as a basis for formulating educational policies and curriculum development at the primary school level.

In the analysis process, the authors applied the thematic synthesis technique to categorize the main findings from the selected articles. Each article was analyzed based on the primary focus of the study, such as the design of interactive e-modules, the implementation of the Project-Based Learning model, the integration of digital methods in Learning, and the evaluation of student learning success indicators (Sholeh et al., 2020). This process allows the author to identify patterns, gaps, and contributions that are consistent or different between one study and another. The analysis was conducted in a descriptive-qualitative manner to describe the relationship between the variables studied without statistical tests by the non-empirical characteristics of literature studies (Sari & Isdaryani, 2024).

In addition, the authors also considered the methodological quality of the articles analyzed by paying attention to aspects of data validity, clarity of research procedures, and completeness of the results report. Articles that did not meet minimum methodological standards, such as not explicitly listing research methods or not presenting verifiable outcome data, were eliminated from further analysis. Thus, the study results presented in this article were obtained from credible sources and can be scientifically accounted for.

The results of the literature synthesis are presented as a systematic description that discusses the characteristics of interactive e-module development, the basic principles of the Project-Based Learning model, and the combined impact of both on the learning achievement of elementary school students analyzed in this study. This study also explores how combining digital technology with a project-based learning model can encourage active student participation, deepen understanding of the material, and build consistent and sustainable learning motivation (Hayati et al., 2025). Therefore, this review is not limited to presenting the findings from the analyzed literature but also provides strategic directions in developing learning models relevant to the needs of basic education in the digital era. The findings of this literature synthesis can serve as a foundation for educators, media developers, and policymakers to design interactive e-modules that are visually appealing and pedagogically profound. Furthermore, integrating the Project-Based Learning approach and digital technology allows for a more active, contextual, and meaningful learning

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environment, leading to improved learning outcomes and 21st-century competencies in primary school students (Meriatami et al., 2025).

C. Result and Discussion

Result

1. Data Analysis

The data analysis process in this literature review is carried out by identifying and selecting articles relevant to making interactive e-modules that adopt the Project-Based Learning (PJBL) approach for ecosystem learning materials at the elementary school level. The search results obtained several nationally accredited scientific articles from Google Scholar and Garuda databases. The selection was made based on the suitability of the topic, the quality of the research methodology, the year of publication, and the direct relationship with the aspects of e-module media development, the PPA approach, and the learning outcomes of elementary school students.

Primary data analyzed include (1) research objectives, (2) methods used, (3) types and forms of e-modules developed, and (4) results and their impact on student learning outcomes. The analysis process was done qualitatively descriptively by grouping the research results into themes such as media effectiveness, relevance to the PPA approach, and its impact on student learning outcomes and motivation.

The literature study results from 20 analyzed articles indicated that using interactive electronic modules based on PPA significantly improves learning outcomes, motivation, and student engagement in the learning process. In general, the research focus is divided into three major themes: e-module development (43%), implementation of PPA (23%), and integration of both (34%). This finding aligns with Dewi & Lestari's research, which proves that using e-modules significantly improves student learning outcomes through a project-based approach (Dewi & Lestari, 2020).

The literature analyzed in this study consisted of 20 scientific articles published between 2020 and 2025. Articles were selected based on their suitability for developing interactive e-modules based on Project-Based Learning (PJBL) on ecosystem learning in elementary schools. Three main categories were found in the coding and classification process of the articles, namely: (1) development of interactive e-modules, (2) implementation of PJBL in Learning, and (3) integration of e-modules with PJBL. The distribution of articles by topic can be seen in the following table and bar chart :

Table 1. Classification of Articles Based on Study Focus

Study Focus	Number of Articles
Interactive E-Module Development	9
Implementation of the PPA Model	6
Integration of E-Modules and PJBL	5

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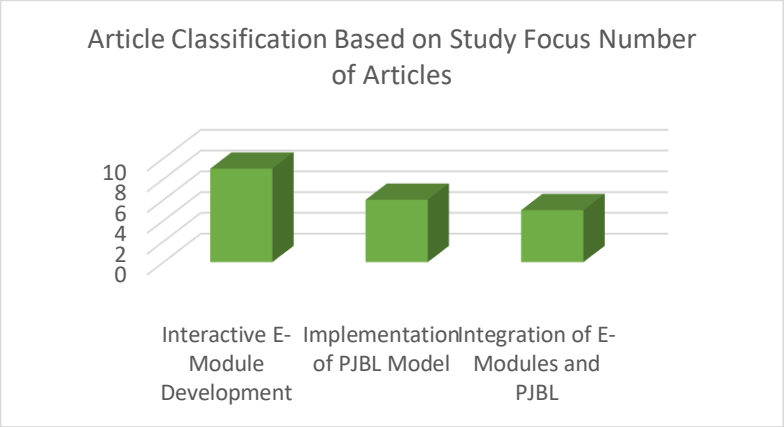

Figure 2. Diagram of the Number of Articles

2. Critical Appraisal

In conducting a critical appraisal, researchers evaluate the methodological quality of the articles analyzed. Most articles applied the Research and Development (Kusumawati & Mustadi, 2021) (R&D) approach with the ADDIE development model that provides a systematic media creation and testing structure. The content validity of e-modules is generally tested through expert judgment, while their effectiveness is measured with a quasi-experimental approach or pre-test and post-test design. To assess the methodological quality and scientific contribution, each article was reviewed and assessed based on the following criteria :

a. Clarity of problem formulation: Is the research focus clear and by the needs of elementary school learning?
b. Appropriateness of the method: Are the development or experimental methods appropriate to address the research objectives?
c. Instrument quality: Are the evaluation tools used to demonstrate adequate validity and reliability in assessing learning outcomes or other variables under study?
d. Significance of results: Do the results show a meaningful contribution to improving the quality of Learning?

A critical evaluation was conducted to assess the methodological quality, instrument validity, and strength of evidence of the articles analyzed. The assessment was conducted using an appraisal framework based on CASP standards. It included five indicators: research methods, data collection techniques, quality of data analysis, measurability of results, and contribution to learning media development

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Table 2. Critical Appraisal Results of Literature Study Articles

No	Author & Year	Research Methode	Instrument Validity	Theoretical Contribution	Appraisal core (1 – 5)
1	Navila & Tuharto (2023)	R&D (ADDIE)	Expert validation effectiveness test	Web-based inquiry e-module improves learning interest achievement	5
2	Capah et al (2025)	Qualitative literature study	Not explicitly Explained	Identifying teacher barriers in the Merdeka Curriculum	3
3	Maghfiroh et al (2024)	R&D (4D)	Expert validation & N-gain	PjBL e-modules improve students' science literacy	5
4	Chung et al (2020)	Design Research 4 D	Questionnaire test documentation	Integration of im imagination into iSTEAM learning	5
5	Jaenudin et al (2020)	Quasi experiment	Tes & N-gain	PJBL improves problem-solving skills and creativity	4
6	F.T.H. et al (2022)	R&D (ADDIE - tahap awal)	Expert validation student questionnaire	The digital interactive module supports math self-study	4
7	Cahyani & Huda (2025)	Single Subject Research (A-B-A)	Graph and overlap analysis	Concrete media is effective for students with disabilities to understand the concept of weight	4
8	Kusumawati & Mustadi (2021)	R&D (ADDIE)	Media material, teacher-student expert validation	Interactive multimedia motivates students to learn math	4
9	Navila & Tuharto (2023)	Classroom action research	Vakudatuib by experts and collaborating teacher	The talking stick model increases student learning activity	3
10	Pratama et al (2023)	Quasi experiment	Content validity test by expert lectures	Using e-modules has been proven to significantly increase student learning achievement in IPAS subjects at the elementary level.	4
11	Antari (2023)	R&D (ADDIE)	Competent experts in materials, learning media,	Improving IPAS learning outcomes	5

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No	Author & Year	Research Methode	Instrument Validity	Theoretical Contribution	Appraisal core (1 – 5)
			and language use conducted the evaluation.	through PjBL e-modules	
12	Sholeh et al (2021)	Classroom action research	Expert validation cycle reflection	The TGT learning model within a cooperative framework can improve student learning achievement.	4
13	Sari & Isdaryani (2024)	Experiment (Nonequivalent Control Group)	Uji N-gain & t-test	Effectiveness of PJBL with e-module flipbook on IPAS learning outcomes	4
14	Dewi & Lestari, 2020 (2021)	Quasi experiment	Content validation by experts	The educational game "LABA" can improve students' counting skills	4
15	Hayati et al (2021)	PTK	Validation through teacher reflection and cycle	PBL model improves motivation and math learning outcomes	4
16	Syarifudin et al (2024)	Classroom action research	Validation by principal and peer teachers	The project-based learning model can improve student achievement in science subjects at the elementary school level.	4
17	Wulandari et al (2021)	Classroom action research	Validation through teacher reflection and cycle	The application of the contextual approach contributes to the improvement of students' activities and learning outcomes.	4
18	Wahyudi et al (2021)	Quantitative experiment	Expert validation limited trial	Indicates the impact of animated video media on science learning achievement.	4
19	Wijnia et al (2024)	Systematic literature study (review)	Relevance and study selection on PRISMA criteria	Providing an empirical synthesis of motivation and problem-based learning questions	5

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No	Author & Year	Research Methode	Instrument Validity	Theoretical Contribution	Appraisal core (1 – 5)
20	Meriatami et al (2021)	Classroom action research	Validation through cycle reflection	Encourage students' motivation and learning outcomes by applying the Problem-Based Learning approach.	4

A critical review of the twenty articles found that most studies were well-structured and highly methodological. Most of these studies applied the development method (R&D) by referring to instructional design models such as ADDIE and the 4D model. The validity of the instruments was usually obtained through evaluation by material, media, and language experts, which was then reinforced by limited trials on students and educational practitioners. In addition, some studies have successfully combined the Project-Based Learning (PjBL) approach with digital technologies, such as 2D/3D animation and flipbook formats, resulting in interactive e-modules that support the development of 21st-century skills, including competencies in teamwork, communication, innovation, and problem-solving. However, some methodological limitations were also found. Some articles did not present detailed instrument reliability reports and involved subjects limited to one class or educational unit, which resulted in low generalizability of the findings. In addition, most studies did not include a long-term evaluation of student retention of learning outcomes. In terms of theoretical contributions, although some studies provide significant practical innovations, strengthening the conceptual framework of project-based Learning in digital and science contexts at the primary school level still needs to be improved.

3. Literature Review Results

Based on the analysis of twenty relevant articles, some important findings related to creating interactive e-modules based on the Project-Based Learning model for elementary school students were obtained. First, e-modules that adopt PJBL are proven effective in improving student learning achievement, especially in Natural Science (IPA) lessons focusing on ecosystems. Second, interactive elements in e-modules, such as flipbooks, learning videos, and interactive quizzes, can create a more interesting and meaningful learning experience for students. Third, applying the PPA approach in this e-module can encourage students to be actively involved in the completion of real projects, thus increasing their involvement and sense of responsibility in the learning process. Furthermore, the effectiveness of e-modules is highly dependent on the quality of the media design, the extent to which the project element is integrated, and the role of the teacher in assisting its implementation in the classroom. Nonetheless, most of the developed e-modules are still tested in a limited scope, so expanding the trials to a broader field context is necessary to measure the effectiveness more thoroughly. Based on the analysis of 20 relevant articles, the following important findings were obtained:

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a. Concept Understanding: Average "The increase in student learning outcomes after utilizing PJBL-based e-modules is 20% to 30%. For example, in the study of Nisrina et al. (2021), students' pre-test scores of 59.37 increased to 78.56 after using e-modules.
b. Learning Motivation: Asri and Andaryani (2024) stated that e-modules equipped with animations and interactive quizzes can encourage increased learning motivation, as evidenced by the results of media validation, which reached more than 90 %.
c. Active Engagement: Wiranata and Margunayasa (2021) noted increased student participation in project activities after the e-module was implemented, especially in group work and the completion of contextual-based tasks.

Therefore, the development of interactive e-modules that adopt PJBL can be a strategic choice in technology-based Learning for students at the elementary school level. Aside from being a learning support facility, this media also improves students' learning outcomes and fosters analytical thinking skills, teamwork, and a sense of responsibility. The data is listed in the following table:

Table 3. E-Module Impact Proportion

Impact	Percentage
Concept Understanding	40%
Motivation to learn	35%
Active Involvement	25%

Table 3 shows the proportion of the impact of using E-Modules in the learning process. The most significant impact is concept understanding at 40%, followed by motivation to learn at 35%, and active involvement at 25%. This percentage indicates that E-Modules not only help students master the material but also increase motivation and active involvement in the learning process. Pi also plays a role in increasing students' motivation and active involvement in Learning. This information is further visualized through the following pie chart, which illustrates the proportional distribution of the three impact aspects. In this case, the picture is in the following diagram:

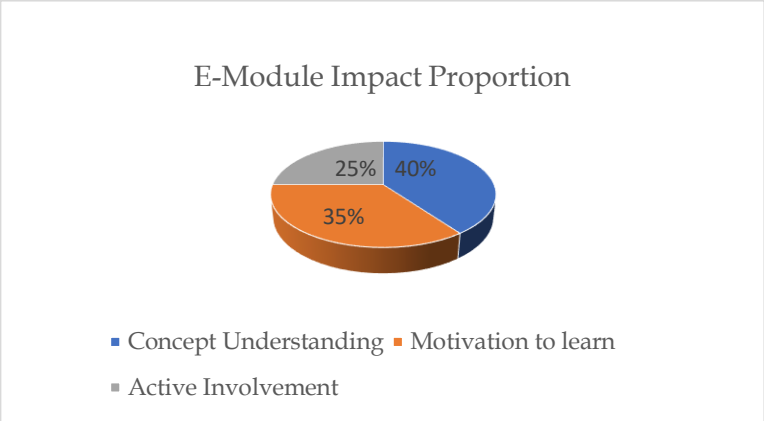

Figure 3. E-Module Impact Proportion Diagram

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4. Literature Data Analysis Matrix

To strengthen the study's results and provide a comprehensive picture of the trends of relevant findings, a data analysis matrix was compiled based on 20 scientific articles that met the inclusion criteria. This matrix contains the main information from each article, which includes the author's name and year, research objectives, the approach or model used, the main results found, and the relationship with the development of e-modules and the application of the Project-Based Learning (PJBL) approach.

This matrix aims to extract thematic patterns from the reviewed literature and facilitate the identification of each study's empirical contribution to the effectiveness of interactive e-modules based on PPA. By systematically presenting the key elements of each study, readers can gain a more complete understanding of the methodological quality and impact of PPA e-modules in ecosystem learning in primary schools.

The following matrix summarizes the 20 articles that have been analyzed, focusing on the research objectives, methods used, main results, and the relevance of the findings to integrating Project-Based Learning (PJBL) and e-modules in inclusive and regular learning contexts. The following table supports synthesizing the literature and developing the conceptual framework for further research.

Table 4. Literature Synthesis Process and Conceptual Framework Development

No.	Author (Year)	Research Objectives	Method or Model	Key Results	Relevance to PJBL and E module
1	Syarifudin et al (2024)	Literature review on the implementation of PPA in elementary school	Literature study	PPA increases motivation and deep understanding	Directly relevant to LGAP in primary education
2	Navila & Tuharto (2023)	Developing web-based inquiry e-modules for math opportunities	R&D (ADDIE)	E-modules are valid, practical, and effective in increasing interest and achievement in learning mathematics	Relevant in the context of e-modules and inquiry methods
3	Capah et al (2025)	Analyze the challenges educators face at the primary level in designing modules based on the Merdeka Curriculum.	Qualitative literature study	Qualitative teachers have difficulty understanding the application of PjBL and the limited resources available.	Relevant in the context of implementing PPA and e-modules in the field
4	Maghfiroh et al (2024)	Developing PJBL-based e-modules	R&D (4D)	E-modules are feasible and	Highly relevant for the

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No.	Author (Year)	Research Objectives	Method or Model	Key Results	Relevance to PJBL and E module
		for science literacy		effective in improving science literacy.	integration of PPA and e-modules
5	Chung et al (2020)	Developing the iSTEAM model for intermediate technology learners	Design Research	The iSTEAM model enhances imagination and STEAM competence	Relevant in project-based learning design and technology integration
6	Jaenudin et al (2020)	Developing students' problem-solving and creative thinking skills through applying a project-based learning model.	Quasi-experimental design	implementation of project-based learning strategies	Directly relevant to PJBL
7	F.T.H et al (2022)	Developing an interactive digital module for elementary math	R&D (ADDIE – initial stage)	The module is feasible to use, supports independent Learning	Relevant as an example of e-module development
8	Cahyani & Huda (2025)	Examining the effects of media scales on students with disabilities	Single Subject Research (A-B-A)	Concrete media improves understanding of weight concepts	Indirect but important for innovation learning media
9	Isdaryati & Izazi (2024)	Evaluation of the effectiveness of flipbook-based PPA	Quasi-experiment	Flipbook PJBL is effective enough to improve IPAS learning outcomes	Relevant to the integration of media (flipbook) with PJBL
10	Kusumawati & Mustadi (2021)	Evaluating the effectiveness of interactive learning multimedia in mathematics subject	R&D (ADDIE)	This multimedia is proven to encourage student motivation in Learning	This finding closely relates to developing e-modules integrating interactive media in mathematics learning.
11	Maghfiroh et al (2024)	PBL-based e-modules to improve the science literacy of elementary school student	R&D (4D)	E-modules are valid and significantly effective	Very relevant
12	Navila & Tuharto (2023)	Improving learning activities and outcomes through the	PTK	The talking stick model improves activeness and	Relevant to the active approach, but

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No.	Author (Year)	Research Objectives	Method or Model	Key Results	Relevance to PJBL and E module
		talking stick model		learning outcomes	not directly PJB / e-modules
13	Pratama et al (2023)	Measuring the effect of IPAS e modules on student learning outcomes	Quasi-experiment	E-modules have proven effective in improving IPAS learning achievement	Use of e-modules in IPAS learning activities.
14	Antari (2023)	Design a PjBL-based e-module for IPAS learning that has been proven valid and easy to implement.	R&D (ADDIE)	The utilization of e-modules can significantly improve student learning outcomes.	The results of this study are very relevant to the application of PJBL integrated with the use of e-modules
15	Sholeh et al (2021)	The application of the TGT model in Learning can improve student learning outcomes	PTK	Learning outcomes improved through group work and games	Not directly relevant, but supports interactive and collaborative models
16	Sari & Isdaryani (2024)	Testing the effectiveness of PJBL-based flipbook e-modules	Eksperimen (Nonequivalent Control Group)	Effectively improve IPAS learning outcomes	Highly relevant: direct integration of PPA & e-modules
17	Dewi & Lestari (2020)	Assessing the effectiveness of LABA educational games	Quasi-experiment	LABA game improves elementary students' counting skills	Relevant to the development of digital-based interactive media
18	Hayati et al (2021)	Using PBL to improve math learning outcomes	PTK	PBL improves student motivation and learning outcomes in math	Directly relevant to LGAP
19	Wulandari et al (2024)	Test the effectiveness of PBL-based e-modules for flat buildings	Pseudo-experiment (post-test only)	E-modules effectively improve critical thinking	Relevant for problem-based e-modules (PBL) in mathematics
20	Meriatami et al (2021)	Increase learning motivation with the PBL method	Classroom Action Research (PTK)	Motivation and learning outcomes improved after the PBL implementation	Directly relevant to LGAP

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Discussion

The transformation of Learning in the digital era has encouraged the need for teaching media innovations that can respond to the needs of 21st-century students. One form of innovation that has received wide attention in various studies is the preparation of interactive e-modules that adopt the Project-Based Learning (PjBL) approach. This model integrates technology in a real project-based learning process, which is believed to improve concept understanding and critical thinking skills and form students' independent learning character.

Several studies show that using PjBL-based e-modules can create a more active and student-focused learning experience. Project-based e-modules can also increase elementary school student's involvement in the learning process and their ability to solve problems systematically. The projects in the module are designed to stimulate critical thinking through the stages of investigation, data collection, processing, and reporting (Jaenudin et al., 2020).

Furthermore, implementing the project-based STEAM model in secondary schools confirms that this kind of Learning can enhance creativity and collaboration skills, which is very relevant if implemented since primary education. This model combines science, technology, engineering, art, and math elements in project-based activities. In the elementary context, this approach can be adapted through simple projects that remain challenging and involve honest exploration (Chung et al., 2022).

On the other hand, consistent implementation of PJBL in elementary schools improves students' understanding of linking theory with practice. Students' Learning is sourced from textbooks and their practical experiences packaged in projects in e-modules. This encourages students to become active and reflective learners (Syarifudin et al., 2024).

However, there are also many challenges in developing and implementing PjBL e-modules. Capah et al (2025) highlighted that most elementary school teachers have difficulty designing teaching modules in accordance with the principles of the Merdeka Curriculum, especially in inserting digital elements and projects appropriate to the student context. Teachers need technical training support and clear conceptual guidance to design e-modules that are not only interactive but also pedagogically meaningful.

Not only from the teacher's side, infrastructure readiness is also a determining factor for the success of project-based e-module implementation. Limited access to digital devices and stable internet networks is still a significant obstacle in some areas, especially in remote areas. Therefore, e-module development needs to consider the availability of technology and student accessibility as part of the planning.

Another study conducted by Hayati et al (2025) showed that the application of PJBL e-modules improved student learning outcomes and formed characters such as responsibility, cooperation, and independence. This happens because each project in the e-module requires students to design strategies, share roles, and be accountable for their work. Support from teachers in the form of mentoring is an important element for this process to run effectively.

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Regarding interest and motivation to learn, it is proven that website-based interactive e-modules with an inquiry approach can increase students' enthusiasm for learning mathematics (Navila & Tuharto, 2023). Triyanto & Aryani (2022) also stated that contextually designed module media had a good effect on the enthusiasm for Learning and academic achievement of elementary school students.

Meanwhile, the results of systematic studies state that the application of technology in PjBL-based Learning shows a positive impact and deserves to be continuously improved. Combining technology with pedagogical approaches such as PjBL is believed to be a potential solution to strengthen students' skills in STEM and digital literacy from an early age (Wahyudi et al., 2024)

In addition, interactive e-modules designed using the Problem-Based Learning (PBL) approach have been proven to improve student competence in the ability to analyze in depth, especially when facing and solving various problems based on real-life contexts. This shows that PjBL and PBL can complement each other in developing innovative e-modules (Wulandari et al., 2024).

Findings from the meta-analysis show that the project-based learning model has a more significant impact on increasing students' motivation than conventional learning approaches. This method also opens wider opportunities to encourage students to actively participate in learning activities to determine learning steps, make decisions, and evaluate results independently, all of which contribute to forming strong learning characters (Wijnia et al., 2024).

Finally, efforts to develop project-based interactive e-modules must be accompanied by increased teacher capacity and adequate education system support. In this context, it emphasizes the importance of integrating PjBL in learning in elementary schools as a strategic step to prepare a generation that excels in academics and can overcome various real-life problems.

D. Conclusion

The results of the literature review that has been conducted show that the application of interactive e-modules with PJBL-based Learning contributes significantly to strengthening student learning outcomes at the elementary school level, especially on ecosystem material. This strategy improves in-depth mastery of concepts and fosters important 21st-century skills such as critical thinking, problem-solving, cooperation, and responsibility. The use of e-modules that are attractively and interactively designed makes the learning process more meaningful and fun. In addition, integrating PJBL into the e-module allows students to learn actively through direct involvement in project activities adapted to the context of students' daily lives.

The findings of this study have important implications for the world of basic education, especially in developing teaching media based on the demands of the Merdeka Curriculum. Teachers and learning developers must integrate PJBL and digital technology thoroughly in the teaching and learning process. The development of interactive e-modules

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based on PJBL has proven to overcome the weaknesses of conventional approaches still dominant in schools, such as lectures and one-way exercises. On the other hand, the results of this study also highlight the need for systemic support in the form of teacher training, strengthening ICT competencies, and providing adequate digital infrastructure so that the implementation of PJBL e-modules can run effectively and evenly in various regions.

For further scientific development, research on e-modules of PPA should be extended to various other learning contexts at primary and secondary education levels. Further research must also be conducted longitudinally to evaluate the long-term impact of using PPA e-modules on students' academic development and character. In addition, exploration of the integration of PPA with other innovative approaches, such as problem-based Learning (PBL), and technology-based approaches, such as gamification, can strengthen the design of digital Learning that is responsive, functional, and by the demands of the modern era. Therefore, e-modules developed through the PJBL approach have the potential to be a strategic step in realizing innovative and sustainable education.

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