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Project-Based Learning in Elaborating Interactive Media Based on E-Modules for Prospective Physics Teachers

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ABSTRACT

This study aims to explore the implementation of the Project-Based Learning (PjBL) model in the development of interactive e-module-based learning media by prospective physics teachers. The research method used is qualitative descriptive research, with subjects being students of the Physics Education study program who are enrolled in the learning media course. The learning process follows the stages of PjBL, starting from problem identification, project planning, product development, to presentation and reflection. The results of the study show that the PjBL approach can enhance students' creativity, critical thinking skills, and technological abilities in designing interactive learning media relevant to the needs of physics education. In addition, the developed e-modules feature interactive elements that support deeper and more engaging conceptual understanding. In conclusion, PjBL is effective in equipping prospective physics teachers with the pedagogical and technological competencies needed in the era of digital learning.

Keywords
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Interactive Media
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Introduction

Entering the 21st century, the national education system faces challenges in preparing high-quality human resources (HR) capable of competing in the global era. Education is the primary and most effective means to build such quality human resources. It serves as the foundation for a nation's progress-the better the quality of education provided by a country, the higher the quality of the nation itself. Education holds a vital role in Indonesia, as it is considered essential for shaping a dignified national civilization. Due to its importance, the purpose of education is clearly regulated in the National Education System Law No. 20 of 2003, Article 3. Education is central in preparing human resources who can respond to the challenges of changing times [1]. Considering its importance in life processes, the development of human resources must focus on improving attitudes, knowledge, and skills so individuals can adapt to their environment.

In general, education aims to provide a platform for learners to develop their skills and potential optimally so they can be useful not only for themselves but also for society. These skills and potentials are nurtured through the learning process. Meaningful learning is something that every physics teacher should strive for. As stated by Johnson [2], when students learn something and find meaning in it, that meaning gives them a reason to learn. Thus, one of the factors that motivates students to learn is the presence of meaningful learning experiences.

Many variables determine the level of meaningfulness in school learning, one of which is the quality of teachers. Teachers who do not meet quality standards can lead to less meaningful learning. The standard of teacher quality determines the extent to which a teacher is trusted and accepted by students [3]. According to Fathurrohman [4], PjBL is a learning model that uses projects or activities as a medium to achieve learning competencies in attitudes, knowledge, and skills. It is a method that allows students to explore, assess, interpret, synthesize, and present information to produce various forms of learning outcomes.

A module is a book designed to allow learners to study independently with or without teacher assistance. A module contains, at a minimum, the fundamental components of instructional material mentioned earlier [5]. It plays an important role in the learning process, as its availability can help students access information about the learning material. A module is a learning tool that includes materials, methods, limitations, and evaluation techniques, systematically and attractively designed to achieve specific competencies according to the level of complexity. Moreover, it is a scholarly work written to facilitate independent learning with minimal teacher guidance.

Physics Education students at the Faculty of Teacher Training and Education, Halu Oleo University (Universitas Halu Oleo or UHO), are being prepared to become future physics teachers. This means that the future of physics education in schools will largely be shaped by them. Given that many existing physics learning modules are still considered less meaningful and often fail to

engage students, prospective physics teachers currently in college are expected to improve these modules. This study examines the implementation of the PjBL model in the process of creating interactive learning media in the form of e-modules by prospective physics teachers. Through this approach, students not only develop technical skills in designing e-modules but also enhance their critical thinking and creativity. The interactive media produced is expected to support effective and engaging physics learning. Furthermore, this research contributes to the development of pedagogical and technological competencies among prospective physics teachers in the digital era. Based on the explanation above, the researcher aims to elaborate on interactive media based on e-modules using PjBL.

Literature Review

A. Project-Based Learning

Project-Based Learning is a learning model that has been widely developed in advanced countries. A more comprehensive definition of Project-Based Learning, according to The George Lucas Educational Foundation [6], is as follows:

- PjBL is curriculum-fueled and standards-based. It is an instructional approach that requires the presence of content standards within its curriculum. Through PjBL, the inquiry process begins with the emergence of a guiding question and leads students through a collaborative project that integrates various subjects in the curriculum. As students find the answers to the guiding question, they directly engage with major elements and key principles of the discipline they are studying.
- PjBL asks a question or poses a problem that each student can answer. It is a model that requires the teacher and/or students to develop a guiding question. Considering that each student has a different learning style, PjBL allows students to explore content in ways that are meaningful to them and to experiment collaboratively. This approach enables each student to eventually answer the guiding question.
- PjBL asks students to investigate issues and topics addressing real-world problems while integrating subjects across the curriculum. PjBL is an instructional approach that encourages students to create "bridges" connecting various subject matters. Through this process, students can view knowledge holistically. Moreover, PjBL involves an in-depth investigation of real-world topics, making it highly engaging and meaningful for students.
- PjBL is a method that fosters abstract, intellectual tasks to explore complex issues. PjBL emphasizes understanding. Students are encouraged to explore, assess, interpret, and synthesize information in meaningful ways.

Based on these definitions, it can be stated that the PjBL approach is developed based on the philosophy of constructivism in learning. Constructivism creates a learning environment

that requires students to construct their own knowledge [7]. PjBL is a student-centered approach that grants students the freedom to plan learning activities, carry out projects collaboratively, and eventually produce work products that can be presented to others.

In the PjBL approach, the teacher acts as a facilitator to help students find answers to the guiding question. In contrast, in a conventional classroom, the teacher is seen as the main source of knowledge and therefore delivers information directly to the students. In a PjBL classroom, students are encouraged to work collaboratively, assessments are authentic, and learning resources are flexible and evolving. This is in stark contrast to conventional classrooms, which typically emphasize individual work, outcome-based assessments, and limited, static learning resources.

The steps of Project-Based Learning, as developed by The George Lucas Educational Foundation [6], include:

- Start With the Essential Question. Learning begins with an essential question—one that requires students to engage in an activity. It is based on a real-world topic and launched through deep investigation. The teacher ensures that the topic is relevant and meaningful to the students.
- Design a Plan for the Project. Planning is done collaboratively between the teacher and students. This encourages students to feel a sense of ownership over the project. The plan includes rules, the selection of activities that support answering the essential question, integration of various subjects where possible, and identification of tools and resources available to complete the project.
- Create a Schedule. The teacher and students work together to develop a timeline for completing the project. This includes: Creating a timeline to finish the project, Setting deadlines, Encouraging students to devise new strategies, Guiding students when their methods are off-track, and Asking students to justify their chosen strategies.
- Monitor the Students and the Progress of the Project. The teacher is responsible for monitoring students' activities throughout the project. Monitoring is done by facilitating each step of the process, essentially acting as a mentor. To ease the monitoring process, a rubric is used to record all key activities.
- Assess the Outcome. Assessment helps the teacher measure the achievement of learning standards, evaluate individual progress, provide feedback on student understanding, and inform future teaching strategies.
- Evaluate the Experience. At the end of the learning process, both the teacher and students reflect on the activities and project outcomes. This reflection is conducted individually and in groups. Students are asked to express their feelings and experiences during the project. The teacher and students then engage in discussions to improve learning

performance, ultimately leading to new inquiries that address the problems posed at the beginning of the project.

B. Learning Module

A module is defined as a concept presented in a single instructional unit containing learning materials or content. In teaching using modules, students are required to master one module unit before progressing to the next. Modules are presented in a self-instructional manner, meaning that students can carry out the learning process without direct supervision from the teacher. Therefore, each student can regulate their own learning pace and intensity.

A learning module is a form of instructional material that systematically contains core content, usage procedures, and learning outcome evaluations. It includes competencies that can be achieved individually or in groups. A module is an instructional unit written independently by an educator to facilitate the learning process for students. Modules function as independent learning materials, tools for evaluating students' learning outcomes, and reference sources in the learning process. They can also serve as a substitute for the role of the teacher. The effectiveness of student learning largely depends on the quality of the instructional materials used. Therefore, educators are expected to select teaching materials that align with the intended competencies.

C. Electronic Modules

An electronic module (e-module) is a learning material consisting of information presented in text, images, or both, developed in digital or electronic form. E-modules are also accompanied by instructional methods or demonstrations to ensure their feasibility in learning activities. E-modules address classroom issues such as limited instructional time despite a large amount of content to be covered. E-modules can act as a learning guide that activates student-centered learning. Furthermore, they can help improve student learning outcomes. The innovation of developing instructional materials in the form of e-modules can increase student interest in learning. E-modules are one of many forms of learning guides that direct students toward independent learning. Technological advancement has prompted educators to develop more adaptive teaching material innovations. In this case, existing printed modules are edited and developed into electronic modules or digital formats. The characteristics of a good and engaging e-module are as follows:

- Self-Instructional. This means that students can engage in the learning process independently without guidance from others. This characteristic appears when the module contains clearly stated objectives, detailed explanations of the material, and illustrations that support conceptual understanding. It also includes practice questions, task instructions that allow learners to respond and self-assess, and assessment instruments.

- Self-contained. The module includes the entire learning content comprehensively, covering one unit of competence and its sub-competencies. The goal is for learners to gain a complete understanding of the content within a single, unified learning experience.
- Stand Alone. Users do not depend on or need to use other reference sources to complete the learning process using the module.
- Adaptive. A quality module should be highly adaptive to the development of science and technology. Adaptive means being competitive with the times and flexible in use.
- User Friendly. The module should be easy to use. User convenience is one of the most essential characteristics. This includes clarity of language, accessibility, and intuitive design.

Digital modules (e-modules), unlike conventional modules, utilize internet connectivity. This allows users to freely access online resources while using internet-connected e-modules [14]. E-modules can contain materials in formats such as PDFs, videos, and animations that encourage active learning. E-modules are a technological innovation that offer advantages over printed modules, as audio, video, images, animations, and assessments provide immediate feedback to students [18]. E-modules can also be used as a remedial tool for correcting misconceptions [12].

E-module development can be combined with the PjBL model. It is a learning model that encourages students to actively collaborate in solving problems and constructing the core of learning through tasks or projects. This model trains students to analyze problems, explore, gather information, interpret, and assess data when completing projects related to the studied topic [13].

A project is a complex task based on a challenging question or problem that requires students to design, solve problems, make decisions, conduct investigations, and engage in independent activities over an extended period. The project culminates in a realistic product and a presentation [8]. PjBL is a suitable model for fostering student independence in constructing learning through project tasks [11]. Instructional modules based on PjBL can enhance student creativity, create a comfortable learning environment, and help students understand subject matter more effectively [17].

Project-Based Learning improves learning effectiveness, creates meaningful learning experiences, and influences students' attitudes toward pursuing future careers [16]. The application of the PjBL model impacts students' creativity, particularly in learning physics [9]. Therefore, this study develops a physics experiment e-module based on Project-Based Learning to assess the feasibility of the resulting e-module product.

Material and Methods

This research will be conducted in the Physics Education Laboratory. The variables to be measured in this study are: PjBL model, Interactive Media Based on E-Modules. This research uses a qualitative method. The research stages consist of planning, implementation, evaluation, and revision [10]. In this study, both qualitative and quantitative data were obtained through literature studies and questionnaires for students and teachers.

Results and Discussion

Table 1 summarizes the implementation of the PjBL model in developing interactive physics e-modules. It outlines each stage, from driving question formulation to project planning, scheduling, progress monitoring, and assessment, highlighting student activities, lecturer guidance, and the outcomes, including successful creation of interactive, multimedia-rich e-modules.

Table 1. Implementation of PjBL in Interactive E-Module Development

Component/ Stage	Description	Results / Evidence
Driving Question	Students analyzed an authentic problem: "How to develop interactive e-modules for high school physics learning based on Merdeka Curriculum?"	Problem-oriented learning triggers are successfully understood by students.
Project Planning Design	Students were grouped and designed e-modules using a scientific and problem-solving approach.	Design based on physics content and TPACK integration.
Scheduling	8-week structured schedule (design, development, validation, presentation).	Time management is structured systematically for collaborative work.
Monitoring Project Progress	Weekly lecturer monitoring + feedback on content quality, media interactivity, and TPACK alignment.	Iterative improvement occurred every week.
Assessment of Project Outcomes & Learning Evaluation	Rubrics included pedagogy, accuracy, visual design, originality, and interactivity; students filled reflection questionnaires/interviews.	85% successfully created interactive e-modules; topics: Newton's Laws, Static Fluids, Mechanical Waves, Electric Current; features: simulations, videos, auto-feedback exercises, QR resources.

Fig. 1 shows the average scores of different aspects in e-module development. The highest scores are seen in "Use of technology" (4.6) and "Innovation and creativity" (4.5), while "Media interactivity" scored slightly lower (4.1), indicating room for improvement in interactive features.

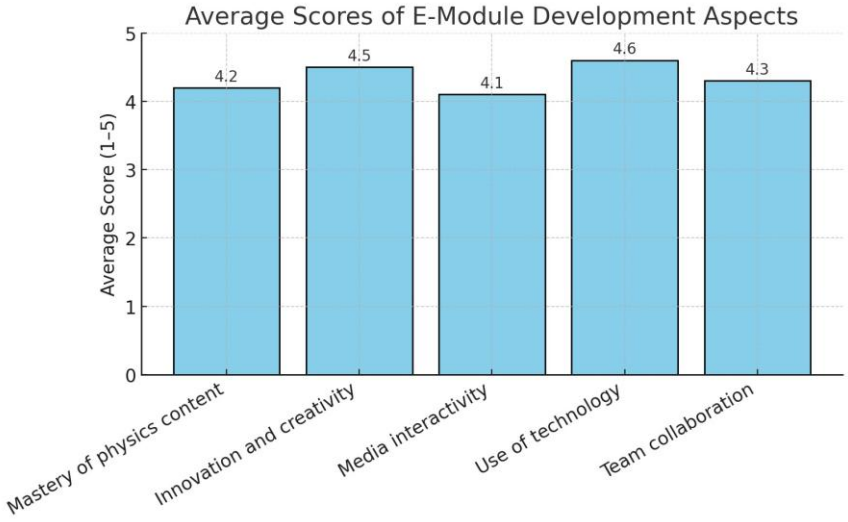


Fig. 1. The Score in Every Aspect

Student responses to the PjBL model indicate a high level of engagement and perceived learning benefits. Quantitative data reveal that 93% of students felt more actively involved in the learning process, suggesting that PjBL effectively motivates learners by placing them at the center of their own educational experience. Additionally, 88% of students reported that the model enhanced their creativity in developing media, highlighting PjBL's capacity to foster innovative thinking and practical skills that extend beyond theoretical knowledge. Furthermore, 91% of students acknowledged a deeper understanding of the importance of mastering TPACK for their future teaching careers, indicating that PjBL supports both content mastery and the integration of technology in educational practice.

Qualitative insights from interviews provide further depth to these findings. Students emphasized that PjBL encouraged critical and reflective thinking, as they had to plan, execute, and evaluate projects in a structured yet flexible manner. The collaborative nature of the model was also highlighted, with many students noting that peer interactions allowed them to exchange ideas, learn from diverse perspectives, and develop teamwork skills crucial for professional growth. Despite these benefits, students identified technical limitations and time constraints as primary challenges during the project implementation. However, they perceived these obstacles as valuable learning experiences, reinforcing resilience, problem-solving abilities, and adaptive strategies. Overall, the responses suggest that PjBL not only enhances engagement, creativity, and TPACK-related competencies but also cultivates critical thinking, collaboration, and practical problem-solving skills, making it a holistic approach to preparing students for real-world teaching environments.

Discussion

The research results indicate that the implementation of the PjBL model has a positive impact on the ability of prospective physics teacher students to develop interactive learning media based on e-modules. This is reflected in the high average scores in aspects such as content mastery, media creativity, and technology use. These findings align with Thomas [19], who stated that PjBL allows learners to actively engage in meaningful and complex tasks that require the integration of cross-disciplinary knowledge and skills. Moreover, PjBL has been shown to increase student engagement and motivation [20], improve creativity in learning media development [21], and enhance understanding of TPACK in teacher preparation [22].

A. Effectiveness of the PjBL Model in Teacher Education

The implementation of six key stages in the PjBL model (from driving questions to evaluation of learning experiences) provides students with authentic learning experiences. The challenging, project-oriented activities encourage students to integrate pedagogical competence, physics content, and technology simultaneously [23]. This aligns with the TPACK framework, which is highly relevant in the context of teacher education in the digital age [24]. Through this process, students not only understand physics concepts but also how to present them engagingly and interactively for their future students [25].

B. Development of E-Module-Based Media as Project Outcomes

The success of students in producing interactive e-modules demonstrates their ability to elaborate learning content creatively and in accordance with 21st-century educational needs [26]. The e-module products not only present content in textual form, but also include interactive elements such as simulations, instructional videos, interactive exercises, and QR code links. This shows that students were able to apply the multimedia learning principles by Mayer [27], which argue that learning is more effective when presented through complementary forms of media.

C. Enhancement of Collaborative and Reflective Skills

Through the project-based activities, students were also involved in collaborative work—discussing, planning, and reviewing each other's work. This experience supported the development of essential soft skills for educators, such as communication, responsibility, and teamwork [28]. Interviews revealed that students felt challenged yet motivated to produce high-quality work. This indicates that PjBL functions as an effective reflective tool, allowing students to learn from both the process and their peers [20][21].

D. Challenges and Learning Implications

Despite the positive outcomes, several challenges were identified, including limited time for project completion, unequal access to technology, and variations in students' technical abilities [22]. These challenges need to be considered in future implementations of PjBL, especially in terms of designing more flexible learning schedules and providing adequate technical support

[23][24]. Nonetheless, overall, the PjBL model has proven to provide ample opportunities for students to learn actively, productively, and in ways that are relevant to the teaching profession [25][26]. This study supports the idea that prospective teachers should be trained through approaches oriented toward real-world practice and the integrated development of professional skills [27][28].

Conclusion

The overall results of this research conclude that the implementation of the PjBL model provides significant positive impacts on developing the pedagogical, technological, and content integration skills of prospective physics teachers, especially in the context of producing interactive e-module-based learning media. The integration of the six PjBL stages successfully creates an authentic learning ecosystem that not only supports mastery of physics concepts but also encourages students to understand how such concepts must be transformed into forms of digital instructional materials that are relevant, engaging, and adaptive to the learning needs of Generation Z and future learners. This also confirms that the TPACK framework becomes more meaningful when practiced through real project activities, rather than being conveyed only as theoretical constructs in lectures.

In addition, students' ability to develop interactive e-modules proves that PjBL is effective in stimulating creativity, multimedia design skills, critical thinking, and decision-making in the learning design process. The experiences of planning, producing, testing, and revising project outputs strengthen their collaborative work abilities, peer evaluation literacy, and reflective capacity toward the learning process itself. Although several obstacles were found—particularly related to limited time and uneven technological access—these conditions become part of the learning journey that actually trains resilience, problem-solving skills, independence, and adaptive attitudes required for future professional educators.

Therefore, this study emphasizes that PjBL should continue to be integrated within physics teacher education programs because it ensures that prospective teachers experience real-world-oriented learning, gain future-ready professional competencies, and are prepared to implement innovative technology-based pedagogy in schools.

Conflict of Interest

The author declares that there are no conflicts of interest in this study, whether financial, commercial, or personal, that could influence the results or interpretation of the research conducted.

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