Development of Project Based Learning E-Modules on Android Based Embedded System Subjects

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Abstract: This study aims to develop an e-module based on Project Based Learning (PjBL) for the subject of Embedded Systems that can be accessed via Android devices. The development of this e-module is motivated by the need for interactive, contextual, and project-based learning materials, particularly to enhance students' competencies in Industrial Electronics Engineering that are valid, practical, and effective for the Embedded Systems subject in Grade X Industrial Electronics Engineering at SMKN 1 Sumbar. The development of this e-module is intended to enhance students' understanding, motivation, and independent learning, thereby improving their learning outcomes. The research method used is Research and Development (R&D), employing the 4D development model (define, design, develop, and disseminate). Primary data in this study were obtained from validators, teachers, and students. The data were analysed descriptively to determine the validity, practicality, and effectiveness of the developed learning media. The validity test results showed that this learning media, with a media aspect score of 0.895 and a material aspect score of 0.960, was deemed valid by experts. The media was also deemed practical, with a practicality score of 98.94% from teacher responses and 95.25% from student responses. In the effectiveness test, the Gain Score obtained was 0.69, placing it in the moderate category. Meanwhile, the t-test showed a Sig value (2-tailed) of 0.002 (2-tailed < 0.05) and a t_{count} value of 3.375 ($t_{count} > t_{table}$), indicating a significant difference in learning outcomes between students using this learning media (experimental class) and those not using it (control class). Thus, this PjBL-based e-module can be used as an interactive teaching material alternative that is suitable for 21 st-century learning needs and is valid, practical, and effective.

Keywords: Android; Embedded system; E-module; Project based learning

Introduction

Learning is a communication process between learners, educators, and learning materials. Communication cannot take place without the aid of communication tools or media. The message to be communicated is the learning content contained in the curriculum, which is translated by educators, facilitators, or other sources into communication symbols, both verbal and nonverbal or visual symbols (Maqfiro et al., 2021). Learning media should be viewed as an integral part of a learning system, not merely as an auxiliary tool used only when deemed necessary and only occasionally. The role of educators as conveyors of educational messages appears to require the assistance of educational media, primarily because the learning materials to be conveyed are becoming increasingly diverse and extensive due to the rapid advancement of science and technology (Admojo, 2021).

The role of educators as developers of knowledge is very important in selecting and implementing appropriate learning methods. Good learning requires a

conducive atmosphere and effective communication between educators and students (Junaedi et al., 2022). The rapid development of science and technology and the increasingly fast development of communication systems have led to changes and progress in various aspects of life. The rapid advancement of technology and information has brought changes to lifestyles, as well as to the world of education (Maritsa et al., 2021). With these changes and advancements, there is a need for an adaptive mindset to continuously learn in order to keep pace with the ever-evolving technological advancements (Annawa et al., 2024).

There are various learning models that can be applied, such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Problem-Based Introduction (PBI). In the Project-Based Learning approach, students are expected to be able to complete projects independently with the aim of developing problem-solving skills, independence, and proficiency (Irman et al., 2020). The advancement of science and technology has further driven efforts to innovate in the use of technological outcomes in education. Creating an engaging and enjoyable learning process can be achieved by leveraging technological knowledge as instructional materials to support the learning process (Sukardi et al., 2024). Therefore, educators are expected to have diverse learning resources and be able to design learning activities with the aim of enhancing student engagement and learning outcomes.

The use of e-modules also helps students understand the material better because it can present interactive content such as animations, audio, video, and digital navigation. E-modules can also be developed using software such as Adobe Flash Player/CorelDraw to produce attractive applications that can be accessed through the Android operating system, in accordance with the devices owned by students (Maskar et al., 2020).

Currently, teachers can use websites to monitor the learning process of students. One website that supports this learning process is Google Classroom (Taali et al., 2024). Google Classroom is a Learning Management System (LMS) application, a web-based service provided by Google as an online system for distance learning conducted virtually via the internet (Thahir, 2021). The various features provided by Google Classroom can be used in learning and are easy to use and free of charge, making them accessible to anyone, including teachers and students. This also makes it easier for teachers to evaluate each activity carried out by students. Google Classroom serves as a platform for learning activities between teachers and students without direct face-to-face interaction, making it more effective and saving time and space.

Android is a Linux-based operating system designed for use on various touchscreen mobile devices,

including tablets and smartphones (Novaliendry et al., 2022). Because the Android operating system is open source (free to use) (El-Sofany et al., 2014; Sofyan et al., 2020), one of its advantages is that it is easy to develop. Students can learn more easily on their own with the help of this Android-based interactive learning media (Hasyim et al., 2020). Compared to other media, such as e-learning, which requires an internet connection to function, this media is more affordable and effective (Hingide et al., 2021). Meanwhile, Android media can be accessed online and offline via smartphones (Mulyana et al., 2024; Stevani et al., 2022). Additionally, Android simplifies usage by providing features that are straightforward for students to understand (Riyan, 2021). The widespread adoption of Android can be attributed to its user-friendly features and affordable price for the general public (Rizki et al., 2023). Thus, the creation of Android-based learning media is very beneficial for the educational process and can help students' understanding of the subject matter (Murtiningsih et al., 2025; Muskhir et al., 2024).
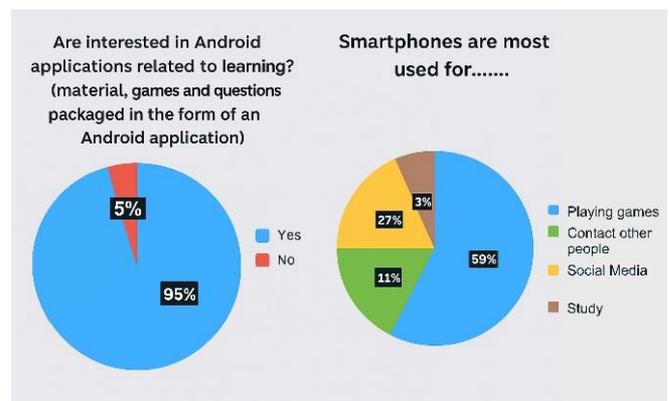

Figure 1. Analysis of student needs data

After that, we conducted a study on the learning needs of Grade X Industrial Electronics Technology students at SMKN 1 Sumbar. The findings of the study revealed that 59% of students use their mobile phones for gaming, 27% for social media, 11% for communication, and only 3% for learning activities. Additionally, according to the data, 95% of students are interested in using Android applications as a learning tool. This indicates a significant potential to enhance the quality of learning in the 10th-grade Industrial Electronics Technology class by leveraging technology in the form of Android applications as a learning tool.

Based on these issues, innovation in the use of learning media is needed. One such innovation is the development of interactive web-based learning media on Android. In the Embedded Systems subject taught in the 10th grade Industrial Electronics class at SMKN 1 Sumbar, interactive Android-based learning media can be developed. This is because there is currently no

interactive Android-based learning media being used at the school. With this medium, it is hoped that students can learn anytime and anywhere, thereby increasing their motivation and understanding in learning. Therefore, the author is interested in conducting research with the title Development of E-Modules for Project-Based Learning in Embedded Systems Based on Android.

Method

Research and development techniques were used in this study. The research methodology, known as research and development, aims to produce a specific product and test its validity, practicality, and effectiveness in its application (Mulyana et al., 2024). Thirty-five students from the 10th grade Industrial Electronics Engineering class at SMKN 1 Sumbar were the subjects of this study. Two groups of participants were formed: class X TEI A, consisting of 17 students, was the experimental group, and class X TEI B, consisting of 18 students, was the control group. Before being tested on the students, the product was first evaluated by two media experts from the teachers responsible for the Embedded System subject at SMKN 1 Sumbar and three media experts from the engineering department at UNP. The Thiagarajan 4-D development model, which consists of four processes: define, design, develop, and disseminate, will be used as the development model in this study (Sugiyono, 2019).
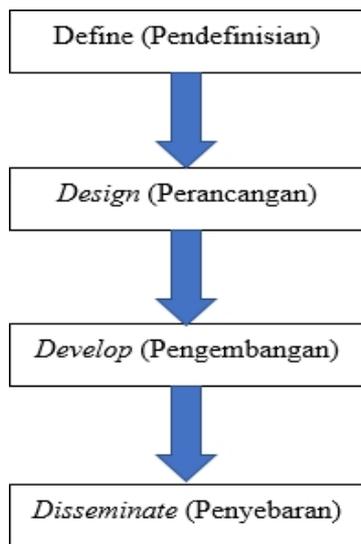

Figure 2. Model 4D

The objective of the Define stage is to identify the fundamental issues necessary for creating interactive learning media based on Android applications (Sugiwati et al., 2023). The objective of the Design stage is to create a working prototype or initial model of the learning

media being produced (Sartono et al., 2022). The objective of the third stage, Develop, is to produce valid, practical, and effective learning media (Setyaedhi et al., 2023). To determine the validity of the designed learning media, a validity test is conducted, obtained from the results of validation by media experts and subject matter experts. To determine the practicality of the produced learning media, a practicality test is conducted. Meanwhile, an effectiveness test is conducted to evaluate whether the media created can be used as intended to enhance student participation and learning outcomes. The final step is to disseminate this interactive Android-based learning media and make it available to other classes and schools offering this subject (Tamami & Dwiningsih, 2020).

Three different data collection methods were used in this study to assess the validity, practicality, and effectiveness of the Android-based learning media being developed. Data collection techniques were carried out by validators using validation sheets as instruments as part of the data collection strategy to ensure the validity of the media. Furthermore, teachers and students were given response questionnaires as part of the data collection approach to assess the practicality of the media produced. The instruments used were teacher and student response questionnaires. The Likert scale with five response options was designed to evaluate the attitudes, views, and perceptions of an individual or group towards a social event or phenomenon, used to investigate responses to the validation sheet and student response questionnaire (Sugiyono, 2019). Using Aiken's V statistical method, the data analysis technique for validity and practicality was determined. Meanwhile, the data collection method for effectiveness used objective pretest and posttest assessments of student learning outcomes given to students in the experimental class and control class. To analyse the effectiveness data, an independent sample t-test, normality test, homogeneity test, and N Gain formula (gain score) were used to analyse the effectiveness data.

Result and Discussion

Result
Define Stage

From observations at SMKN 1 Sumbar, it was found that in the learning process, educators only use media in the form of PowerPoint presentations or printed materials. The delivery of material is still one-way, where educators deliver the material and students only listen and take notes in their books. This causes learning to be less effective and feel monotonous. Based on the problems described, learning media is needed that can meet the needs of students inside and outside the classroom independently. In field observations, the

researcher found that all students in the Industrial Electronics and Lighting Technology department at SMKN 1 Sumbar have Android smartphones, but they have not been using them in the learning process.

Therefore, as an alternative solution based on the issues and phenomena identified, it is proposed to utilise students' Android smartphones as learning media in the form of e-modules. The learning objectives for the Project-Based Embedded System e-module are aimed at developing the necessary materials for students. The objectives in studying the Embedded System subject are greatly influenced by an understanding of basic concepts, programming logic, and practical skills in using hardware such as microcontrollers. Students with a strong foundation in technology and programming knowledge tend to grasp the material more quickly and are able to develop embedded system-based projects independently.

However, many students face difficulties due to the limited theoretical content in job sheets or a lack of hands-on experience. Therefore, interactive and contextual teaching materials, such as e-modules based on Project-Based Learning, are needed to enhance students' abilities comprehensively in cognitive, affective, and psychomotor aspects. The ultimate goal is for students to meet school standards and successfully achieve the desired learning objectives.

Define Stage

This presentation explains the initial draft of the development plan for an Android-based embedded system electronic module (e-module) and the Project-Based Learning approach in vocational secondary schools (SMK). This electronic module is designed to include text, images, and videos to help students understand the material. The e-module follows the principles of Project-Based Learning, which aims to support classroom learning through a practical and hands-on approach. The initial development phase focuses on creating the e-module design framework, which includes the main menu, subject menu, evaluation menu with questions to assess students' understanding, and project tasks to guide students in applying these concepts. Various components are involved in the design of this e-module.

The main menu page acts as the first point of interaction between the user and the application, offering a welcoming and informative interface. It prominently displays the name of the application along with the specific topic being developed, which in this case is Embedded Systems—a crucial area of study in modern technology and engineering education. This introductory page is not only meant to greet users but also to immediately provide clarity about the purpose, scope, and focus of the application. It sets the tone for

the learning journey that lies ahead by giving users an overview of what they can expect from the platform.

In terms of design and layout, the main menu is intentionally crafted to be intuitive and user-friendly, allowing users of various levels—particularly students—to easily understand and navigate through the features without confusion. Key visual elements such as icons, illustrations, and headings are used to draw attention and provide a clear structure. The color scheme, typography, and button placement are also optimized to enhance usability and reduce cognitive load, creating a smooth and engaging user experience right from the start.

Moreover, this page typically includes navigation buttons or menus that are clearly labeled and strategically positioned to guide users toward the next step. These buttons, when clicked or tapped, lead users seamlessly to other parts of the application, especially the main content area where the core materials, modules, or interactive features are housed. Whether it's beginning a learning module, accessing a tutorial, or reviewing key concepts, the main menu acts as a central hub that connects every essential component of the application.

Figure 3. Start menu page

The indicator menu displays a comprehensive and essential set of learning elements to guide the learning process. These elements include learning outcomes (Learning Outcomes/LO), which describe the competencies that students are expected to achieve after participating in learning activities. Additionally, this menu outlines learning objectives (Learning Objectives/LO), which serve as more detailed targets that must be achieved in each lesson or activity. Furthermore, this menu displays the learning objective sequence (Learning Objective Sequence/LOS), which organises the sequence of objectives to ensure a structured and progressive learning experience. All of

this content is specifically designed for the Embedded Systems subject, particularly for students in Phase E or Grade 10 of the Industrial Electronics Technology programme. This menu serves as a foundational reference, enabling both educators and learners to clearly understand the direction and scope of the learning journey within the application.
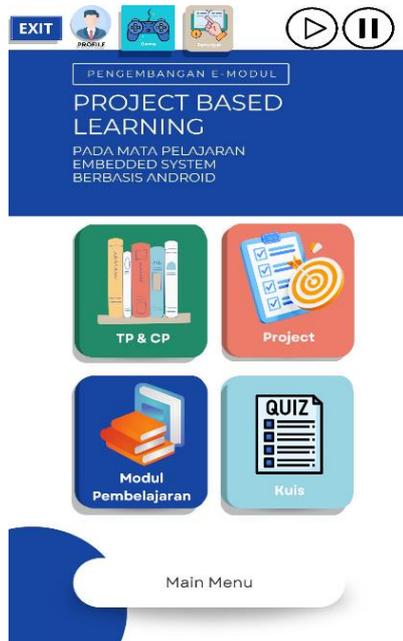

Figure 4. Indicator menu

The element material menu is presented in the form of a PDF file that will be used during the research process.
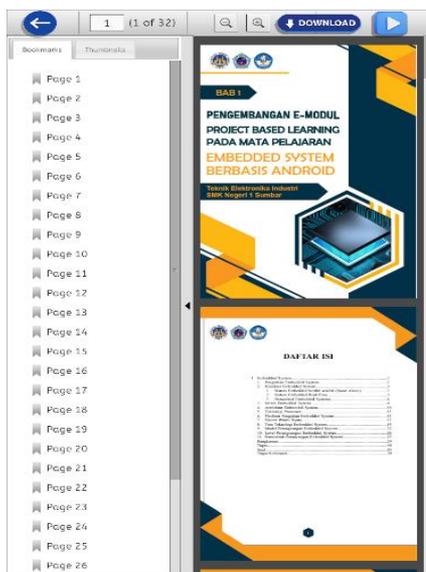

Figure 5. Attendance

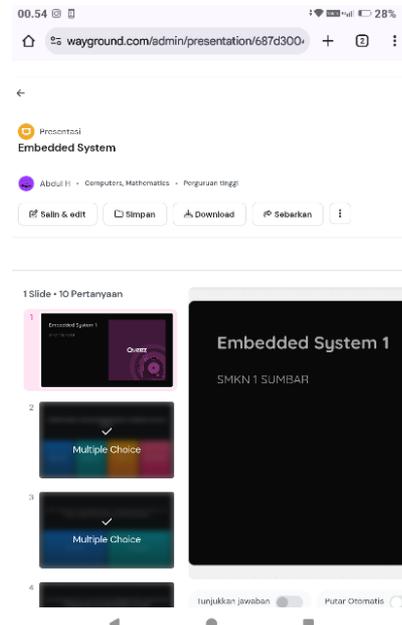The Quiz page includes a series of quiz questions on the topic of embedded systems.

Figure 6. Quiz page

The Project Page contains comprehensive information and instructions regarding the implementation of project activities designed as part of the learning process. This project is carried out in groups, with the aim of training teamwork, communication, and critical and creative thinking skills among students. The primary focus of this project is on Embedded Systems, where students will apply concepts previously learned, such as basic programming, microcontroller usage, sensors, and actuators, to create a simple product or system that can function automatically.
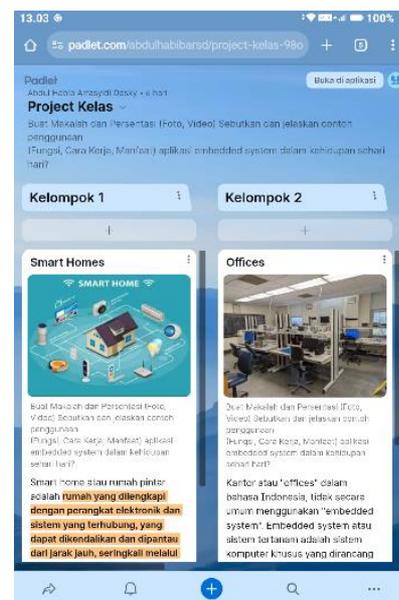

Figure 7. Project page

The game menu includes snakes and ladders and a picture matching game that corresponds to the Embedded System learning material. Components, component parts, and embedded systems are all covered in the picture matching game menu. The snakes and ladders game menu can be used by two students and is equipped with questions related to the learning material.
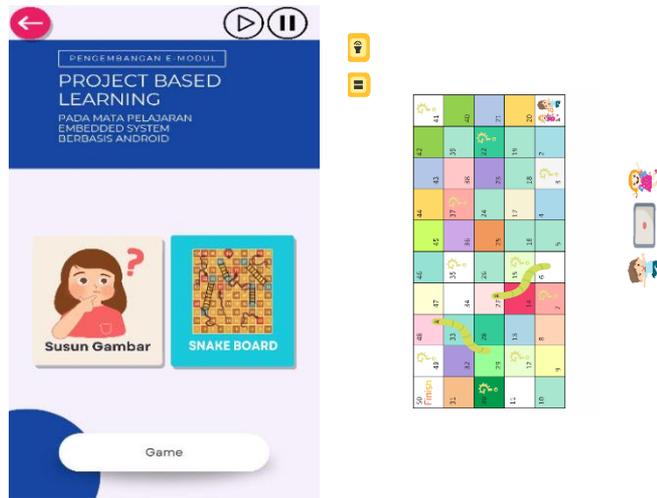

Figure 8. Game

Considering the assessment by media and material experts, a validation test was used to determine whether the resulting learning material was appropriate. Validators who are experts in the field of media and material filled out an instrument to determine the validity assessment results. The findings of the study show the feasibility of the developed learning media. The table below shows a summary of the validation findings from media experts on several aspects of learning media.

Table 1. Media Expert Validation Results

Assessment spects	Average Validator Value	Categories
Presentation Display	0.908	Valid
Usage	0.900	Valid
Function	0.867	Valid
Language	0.892	Valid

Table 2. Material Expert Validation Results

Assessment Aspects	Average validator value	Categories
Independent Learning	0.911	Valid
Learn thoroughly	0.975	Valid
Stand alone	0.975	Valid
Adaptive	0.989	Valid
Friendly/Close	0.990	Valid
E-module components	0.992	Valid
Aspects of the PjBL approach	0.990	Valid

Table 3. Validity Level Categories (Irsyadunas et al., 2021)

Achievement Level	Categories
0-0.666	Invalid
≥ 0.666	Valid

The assessment of each aspect of material validation falls within the valid category. The average validity score in the material validation reached 0.992, which also falls under the valid category. Considering the assessment of media and material experts acting as validators, this Android application-based project-based learning e-module is deemed suitable and appropriate for use in the learning process, both in the classroom and independently.

Table 4. Practical Data Results from Teacher and Student Response Questionnaires

Indicator	Percentage % Teacher Assessment	Practicality Criteria	Percentage % Student Assessment	Practicality Criteria
Technical	98.33	Very Practical	98.33	Very Practical
Effective	97.50	Very Practical	97.50	Very Practical
Design	95.00	Very Practical	95.00	Very Practical
Equivalence	90.00	Very Practical	90.00	Very Practical
Use of Media	95.00	Very Practical	95.00	Very Practical
Average Percentage (%)	96.94	Very Practical	96.94	Very Practical

The practicality test of learning media aims to measure the practicality level of the developed learning media (Purnomo & Nuryanto, 2021). Based on the practicality test, this media obtained an average practicality score of 92.94% in the very practical category on the teacher response questionnaire. In the student response questionnaire, an average practicality score of 94.25% was obtained, which also falls under the 'very practical' category. Therefore, based on the responses from teachers and students regarding the use of interactive learning media based on the Android application, it can be concluded that this learning media is very practical to use.

Effectiveness of e-learning modules

The e-learning modules that have been developed have undergone a process of validation and practical testing. Furthermore, the effectiveness of this media was tested using gain score tests and independent sample t-tests to measure its success.

Gain Score

When pretest and posttest results are compared using the N-Gain or gain score, the effectiveness of the learning media can be observed through improvements in student learning outcomes, as these scores indicate the extent to which students have progressed after using the media. If the gain score achieved by students reaches a minimum threshold of ≥0.3, which falls into the moderate category, the learning media is then considered effective in enhancing student understanding and performance.
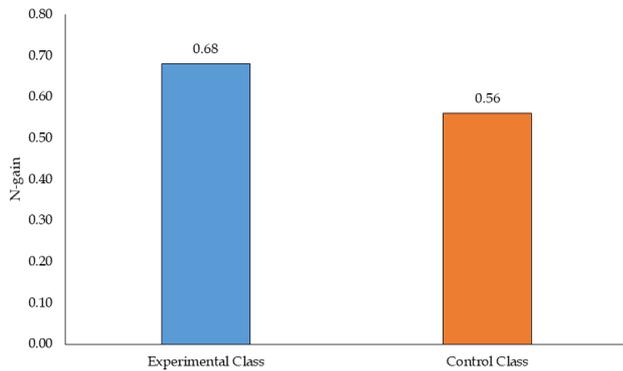

Figure 9. Effectiveness test analysis of gain score value

Based on the results of the analysis, it can be shown that the gain score in the experiment group was higher than the control group, with a value of 0.68 in the medium category. Meanwhile, the control group's gain score is 0.56 in this category as well. It may be inferred from the data on the gain score on the above graph that android app-based interactive learning media can be considered effective.

Table 5. Normality Test of Pre-test and Post-test Data of Experimental and Control Classes

Class	Data	Shapiro-Wilk		
		Statistic	df	Sig
Experimental	PreTest	.946	32	.111
	PostTest	.935	32	.053
Control	PreTest	.952	31	.175
	PostTest	.964	31	.371

Based on the variance normality test that using the Shapiro-Wilk test was used to analyze the pretest-posttest results in the experimental and control classes. The results showed that the experimental class pretest data had a Sig. value of 0.111, while the control posttest data had a Sig. value of 0.053. Meanwhile, for the experimental class pretest data, the Sig. value was 0.175 and for the control class posttest data, the Sig. value was 0.371. Because the significance value of both classes is more than 0.05, it can be said that the experimental class and control class are normally distributed and can be continued with the next analysis.

Table 6. Homogeneity Test of Experimental Class and Control Class Pre-test and Post- test

Velue	Levene Statistic	df1	df2	Sig.
Pre-test	.923	1	17	.341
Post-tes	.126	1	17	.724

Based on data analysis, the Sig (Based on Mean) value of the pretest results is 0.341 and the posttest value is 0.724 greater than 0.05. This indicates that the research data has a homogeneously distributed variation, thus fulfilling the necessary requirements to conduct an independent sample t-test.

Table 7. Homogeneity Test of Experimental Class and Control Class Pre-test and Post- test

Independent Samples Test				
Levene's Test for Equality of Variances		t- Test for Equality of Means		
	F	Sig.(2-tailed)	T	Df
Equal Variances Assumed	.126	0.00	4.075	61
Equal Variances Assumed		0.00	4.086	59.859

Based on table 7, the analysis results, it can be shown that the gain score in the experimental group is higher compared to the control group, with a value of 0.68 in the moderate category. Meanwhile, the control group's gain score also amounted to 0.52 in this category. From the gain score data in the graph above, it can be concluded that the project-based learning e-module based on Android application can be considered effective.

Discussion

The development of project-based e-learning modules for embedded systems is a series of activities or processes carried out with the aim of creating project-based e-learning modules based on development principles. The purpose of developing these project-based e-learning modules is to create Basic Electrical Engineering modules that are valid, practical, and effective. This e-learning module is developed using the 4D development methodology, which includes four stages: definition, design, development, and implementation (Xue et al., 2023).

In the first stage, definition, a situation analysis, learner analysis, concept analysis, and learning objective formulation are conducted. The situation analysis is conducted to identify obstacles and problems that arise during the learning process, with the aim of creating solutions that are appropriate to the situation and conditions at the school (Meepung & Pratsri, 2022). The main focus is on the Fundamentals of Electrical Engineering for Grade X students majoring in Electrical Installation Engineering (TITL). Learner analysis is conducted to evaluate students' abilities, knowledge,

and thinking skills. Concept analysis aims to review the basic competency concepts used in the development of project-based e-learning modules for the Fundamentals of Electrical Engineering subject. By detailing the concept analysis, indicators are obtained that will be used in the design of project-based e-learning modules for the subject of Fundamentals of Electrical Engineering, particularly in the elements of Electrical Measuring Instruments and Testing Equipment (Siew & Chai, 2024).

In the next stage, the design stage, the e-module design is carried out by considering the material in accordance with the learning outcomes, learning objectives, and the sequence of achieving learning objectives in the Fundamentals of Electrical Engineering course, particularly in the Electrical Measurement Instruments and Testing Equipment section. The main actions in this stage include writing, evaluating, and editing the proposed e-module while considering language, word structure, objective format, evaluation, project tasks, and video material. The e-module design is based on the results of situation analysis, learner analysis, idea analysis, and learning objective formulation. Therefore, the e-module built using Android Studio can be accessed by students via their mobile phones anytime and anywhere. This e-module follows the m-learning function as a learning aid. When learning only uses presentation media such as PowerPoint, this e-module can provide additional material for students to use in their personal learning. Additionally, the e-module can also be used as a self-learning resource for students, both within and outside the school environment.

Conclusion

This research successfully developed a project-based e-learning module on Android-based embedded systems. This e-learning module includes learning materials, videos, quizzes, and project assignments, which can be accessed anytime and anywhere via a smartphone. The e-learning module has been proven to be valid, practical, and effective based on feedback from experts, teachers, and students. This module supports modern teaching methods, aligns with the current curriculum and national educational objectives, and promotes self-directed, creative, and enjoyable learning. Teachers are advised to consider this e-learning module as an additional learning tool and to receive training to create and use similar e-learning modules for other subjects, enhancing the availability of flexible and engaging learning materials in schools. This study focuses exclusively on embedded systems, thereby limiting generalisation to other subjects. The assessment of e-module effectiveness relies heavily on qualitative

feedback, which may introduce bias. Additionally, this study does not explore long-term knowledge retention or broader impacts on academic performance. Future research should expand to include other subjects and different educational levels to enhance generalisation. Integrating quantitative measures and longitudinal studies will provide a more comprehensive evaluation of the impact of e-modules. Furthermore, exploring diverse educational environments and student demographics, as well as integrating advanced features such as adaptive learning technology, can further enhance the effectiveness and engagement of e-modules.

Conflicts of Interest
There is no conflict of interest.

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