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Development of Project-Based Electronic Circuit Learning Modules in the Department of Informatics and Computer Engineering

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ABSTRACT

Background/Context: The rapid development of digital technology has increased the need for structured and standardized instructional materials in Electronic Circuits courses within Computer Engineering programs. Existing modules have not systematically integrated circuit simulations, laboratory activities, and project-based learning, leading to inconsistencies across parallel classes and limited support for independent learning.
Objective/Purpose: This study aimed to develop a project-based Electronic Circuits e-module that is valid and practical as a standardized digital learning resource for higher education.
Method: The research applied a Research and Development approach using the four-D development model, consisting of Define, Design, Develop, and Disseminate stages. Validation was conducted by subject matter experts, media experts, and instrument experts. Product trials involved small-group and large-group testing with students who had taken the Electronic Circuits course.
Results: The developed e-module achieved very high validity scores from both material and media experts. Student responses from small and large group trials indicated very positive perceptions regarding usability, clarity of content, and learning support, with overall results categorized as very good.
Conclusion: The project-based Electronic Circuits e-module is feasible, practical, and well accepted as instructional material. It has strong potential to support structured, independent, and standardized learning across parallel classes in Computer Engineering education.

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INTRODUCTION

The rapid development of digital technology and electronic systems has brought significant changes to the fields of computer engineering and information technology. Computer Engineering study programmes play a strategic role in producing graduates who are capable of designing and implementing integrated systems based on hardware and software. One of the fundamental competencies that must be mastered by Computer Engineering students is an understanding of electronic circuits, which serves as the foundation for the development of communication systems, control systems, embedded systems, and other modern computing technologies(Lyngdorf et al., 2024; Pasricha, 2022; Tokatlidis et al., 2024).

The Electronic Circuits course is a core subject that requires students not only to understand theoretical concepts but also to engage in a structured learning process. Ideally, learning in this course should be supported by systematic and relevant instructional materials, including the use of digital media and contextual learning approaches. Several studies indicate that the use of interactive digital

media, circuit simulations, and project-based learning has the potential to support a more structured and contextual learning process in electronics education (Awwad, 2025; Tian et al., 2025).

Based on a preliminary study conducted through observations and interviews with lecturers teaching the Electronic Circuits course in the Computer Engineering Study Programme within the Department of Informatics and Computer Engineering, several learning-related issues were identified. The instructional modules currently used have not been systematically designed to include guidance for electronic circuit simulations and laboratory practical activities as integral components of the learning process. In addition, the available modules have not been explicitly structured to accommodate project-based learning activities. Another issue identified is the existence of multiple parallel classes, which may lead to variations in the presentation of learning materials. The absence of a standardised instructional module has resulted in differences in the teaching materials used across classes. This condition highlights the need for standardised learning resources, particularly for the Electronic Circuits course, which requires consistent and well-sequenced content delivery.

In response to the demands of 21st-century learning, the Project-Based Learning (PBL) approach has been increasingly recommended in engineering education, as it is considered capable of supporting the development of critical thinking and problem-solving skills through contextual learning activities (Rosário & Dias, 2024). In addition, interactive digital e-modules enable learning materials to be presented in a more systematic, visual, and flexible manner, allowing them to function as supportive resources for students' independent learning (Tian et al., 2025).

The development of a project-based Electronic Circuits e-module is therefore regarded as an alternative approach to providing structured and user-friendly digital instructional materials. The e-module is designed to present learning content systematically, incorporating learning guidelines, electronic circuit simulations, and project activities as part of the instructional design within a single, well-organised electronic module.

A review of the literature indicates that numerous studies have developed e-modules or digital learning media in engineering education. However, most of these studies remain focused on general interactive multimedia or on evaluating the feasibility and practicality of learning media, without specifically integrating electronic circuit simulations and project activities into a single, structured digital module (Naimah et al., 2023; Renaldy et al., 2024). Furthermore, research on the development of e-modules for the Electronic Circuits course within the context of Computer Engineering higher education, particularly those aimed at providing standardised learning materials across parallel classes, remains limited.

Based on these conditions, this study focuses on the development of a project-based Electronic Circuits e-module using the 4D development model (*Define, Design, Develop, Disseminate*). The development aims to produce digital instructional materials that are valid and practical, and that can be used as supporting learning resources for the Electronic Circuits course in the Computer Engineering Study Programme.

METHOD

The research method employed in this study was Research and Development (R&D). According to Sugiyono (2019), R&D is a research approach aimed at producing specific products through systematic development stages and evaluating their feasibility and effectiveness in educational contexts. This method was selected as it aligns with the objective of the study, which was to develop a project-based learning module for the Electronic Circuits course to be used as instructional material in higher education. Through the R&D approach, the product development process was carried out in a structured manner, beginning with needs analysis, followed by product design, development, and dissemination, resulting in a valid, practical, and suitable learning module.

The development model applied in this study was the four-D (4D) model proposed by Thiagarajan (1974), which consists of four main stages: Define, Design, Develop, and Disseminate. The Define stage aimed to identify learning needs, student characteristics, learning problems, as well as relevant concept and task analyses for the Electronic Circuits course. The Design stage involved developing the module structure, formulating learning objectives, selecting media and module formats, and creating the initial product design. The Develop stage included the module production process, expert

validation, and product revisions based on feedback received. The Disseminate stage was conducted through limited implementation of the validated module as an initial step towards its application in learning activities.

The research subjects comprised expert validators and product trial participants. The expert validators included two media experts, two subject matter experts, and two instrument experts who were lecturers in the Department of Informatics and Computer Engineering. Validation was conducted to assess the feasibility of the module in terms of content quality, media presentation, and clarity of assessment instruments. Product trials were conducted in two phases: a small group trial involving ten students and a large group trial involving thirty-two active students who had undertaken the Electronic Circuits course. The data obtained from validation and trials were analysed to determine the feasibility, practicality, and student responses towards the developed learning module.

RESULTS AND DISCUSSION

The results of this study are in the form of a Distributed System Learning Module product developed at the Department of Informatics and Computer Engineering, Faculty of Engineering, Makassar State University, using the 4D development model.

The first stage was the definition stage. At this stage, researchers conducted a preliminary analysis to identify learning conditions, field facts, and issues underlying the need to develop an Electronics Circuit learning module. The preliminary analysis was conducted through interviews with one of the lecturers teaching the Electronics Circuit course as the main source of information. Based on the results of these interviews, several problems were identified, namely: (1) the structure of the Electronics Circuits course module was not equipped with material that guided students towards learning experiences through the use of electronics simulation programs and practical activities in the laboratory; (2) the modules used did not reflect project-based learning; (3) the large number of parallel classes in the Computer Engineering Study Programme has the potential to cause inconsistencies in the presentation of material; (4) not all courses are equipped with standardised learning modules; and (5) the Electronic Circuits course is a course that requires conceptual understanding and adequate practical experience. In addition, the researchers also conducted concept analysis and task analysis to strengthen the data obtained in the learning module development process.

The next stage is the design stage, which includes the preparation of the module framework, media selection, format selection, and initial module design. The module framework is prepared to plan the structure and systematics of the module to be developed. The selection of media aims to determine the applications used in the module design process. The media used in this study are the Canva Pro application to design the cover, layout, and supporting images for the module, and Microsoft Word 2010 to compile the module manuscript or draft. After the draft is completed, design elements such as covers, headers, and footers are added to produce the Electronic Circuits course learning module product. Furthermore, the initial module design was consulted with the supervising lecturer to obtain input and suggestions for improvement and refinement.

The results of the learning module development were then presented in the form of the following module visualisation:

1. Front and Back Covers
   The front cover consists of the title, supporting images and the author's name. Meanwhile, the back cover consists of a brief description of the module, with visualisations presented in Figure 1.

Figure 1 Front and Back Covers of the Module

2. Foreword, Instructions for use and Table of contents
   The introductory pages include a foreword, table of contents, instructions for use, and a glossary intended for lecturers and students. The introductory pages are shown in Figures 2, 3, 4, and 5.

Figure 2 Foreword Display

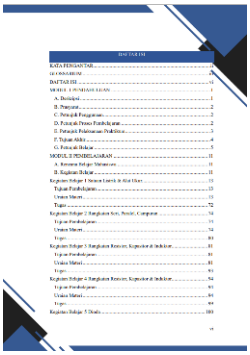

Figure 3 Table of Contents Display

Figure 4 Display of Instructions for Use

Figure 5 Glossary display

The next stage is the development stage. This stage aims to produce a finished product in the form of a module that has undergone validation and revision. Validation carried out by expert validators is useful for identifying deficiencies or weaknesses in the module. Revisions are then made to refine and improve the product. Once the revision stage is complete, the module is tested by students. The trial is conducted to gauge student response to the developed Electronics Circuits course module.

A summary of the results of subject matter experts' validation of the developed learning modules can be seen in Table 1 below.

Table 1 Results of Subject Matter Expert Validation

No	Indikator	Skor Ahli Materi		Jumlah
		Ahli Materi 1	Ahli Materi 2	
1	Self Instruction	99	104	203
2	Contained	10	10	20
3	Stand Alone	9	8	17
4	Adaptive	5	5	10
5	User Friendly	10	10	20
Skor total				270
Jumlah Skor Ideal				280
Persentase Penilaian				96,4%
Kategori : Sangat Baik				

Source: Data processing results

Based on the validation results by two subject matter experts, the total score for the aspects of Self Instructional, Self Contained, Stand Alone, Adaptive, and User Friendly is 203 + 20 + 17 + 10 + 20 = 270 and the ideal score based on the number of statements in the questionnaire is 210 + 20 + 20 + 10 + 20 = 65Therefore, the assessment percentage of 96.4% of the total score percentage for all aspects is a maximum of 100%, which falls into the category of "Very Good / Very Meritorious".

A summary of the results of media expert validation of the learning modules is presented in detail in Table 2 below.

Table 2 Media Expert Validation Results

No	Indikator	Skor Ahli Materi		Jumlah
		Ahli Media 1	Ahli Media 2	
1	Format	15	15	30
2	Organisasi	25	23	48
3	Daya Tarik	35	34	69
4	Bentuk dan Ukuran Huruf	20	17	37
5	Ruang (Spasi Kosong)	10	8	18
6	Konsistensi	20	20	40
Skor total				242
Jumlah Skor Ideal				250
Persentase Penilaian				96,8%
Kategori : Sangat Baik				

Source: Data processing results

Based on the validation results of two media experts, the total score for the aspects of format, organisation, appeal, font type and size, spacing (white space), and consistency is as follow 30 + 48 + 69 + 37 + 18 + 40 = 242 and the ideal score based on the number of statements in the questionnaire is 30 + 50 + 70 + 40 + 20 + 40 = 250. Therefore, the assessment percentage of 96.8% of the total score percentage of all aspects is a maximum of 100%, which falls into the "Very Good / Very Meritorious" category. As the module is in the very meritorious category, the developed Electronic Circuits course learning module can be used in the next stage.

After undergoing a revision process and being validated by validators, the Electronic Circuit Module was then implemented by conducting product trials, namely small group trials and large group trials. These trials were conducted to determine the response and feedback of users or students to the developed module. The small group test was conducted on 10 students from the Computer Engineering Study Programme who were randomly selected as representatives of students who had programmed the Electronic Circuitry course. This test was conducted after the students viewed the learning module independently and were then given a questionnaire in the form of a Likert scale to determine their responses and feedback on the developed module. The results of the small group test can be seen in Table 3

.

Table 3 Small Group Trial Results

No	Responden	Aspek			Total	Total Max
		Media	Materi	Implementasi		
1	R1	24	40	32	96%	100%
2	R2	21	35	30	86%	100%
3	R3	23	36	31	90%	100%
4	R4	23	37	34	94%	100%
5	R5	25	40	35	100%	100%
6	R6	23	31	30	84%	100%
7	R7	19	30	34	83%	100%
8	R8	21	32	28	81%	100%
9	R9	22	38	31	91%	100%
10	R10	22	35	26	83%	100%
Skor total					**888**	
Skor ideal					**1000**	
Persentase Rata-rata					**88,4%**	
Kategori					**Sangat Baik**	

Source: Data processing results

Table 3 shows that the results of the 10 respondents had an average score of 88.4%, which falls into the Excellent category. In addition, students tested in small groups also gave positive responses regarding the use of the Electronics Circuit learning module.

Next, a large-scale trial was conducted on 32 students who had taken the Electronic Circuits course in the Computer Engineering Study Programme at the Faculty of Engineering, UNM. Before this module was used, its purpose was explained to the students, and they used the module before filling out the questionnaire provided. The questionnaire consisted of three aspects to provide feedback or responses to the developed module. The following is a summary of the responses from 32 students who had taken the Electronic Circuits course in the Computer Engineering Study Programme at the Faculty of Engineering, UNM. The results of the large group trial can be seen in Table 4.

Table 4 Results of Large Group Trials

No	Responden	Aspek			Total	Total Max
		Materi	Media	Implementasi		
1	R1	25	40	35	100%	100%
2	R2	23	39	33	95%	100%
3	R3	23	37	34	94%	100%
4	R4	24	35	29	88%	100%
5	R5	25	39	35	99%	100%
6	R6	24	40	32	96%	100%
7	R7	25	38	35	98%	100%
8	R8	23	36	32	91%	100%
9	R9	23	39	29	91%	100%
10	R10	22	35	30	87%	100%
11	R11	24	37	33	94%	100%
12	R12	22	36	24	82%	100%
13	R13	20	33	26	79%	100%
14	R14	22	38	32	92%	100%
15	R15	20	35	31	86%	100%
16	R16	23	31	30	84%	100%
17	R17	25	38	33	96%	100%
18	R18	22	38	31	91%	100%
19	R19	22	35	30	87%	100%
20	R20	23	36	31	90%	100%
21	R21	20	35	28	83%	100%
22	R22	22	38	31	91%	100%
23	R23	22	37	31	90%	100%
24	R24	23	37	31	91%	100%
25	R25	20	37	31	88%	100%
26	R26	22	39	32	93%	100%
27	R27	21	32	28	81%	100%
28	R28	22	37	32	91%	100%
29	R29	25	38	31	94%	100%
30	R30	22	35	32	89%	100%
31	R31	19	30	34	83%	100%
32	R32	22	38	30	90%	100%
Persentase Rata-rata					90,1%	

Source: Data processing results

Based on Table 4, it shows that the results of the large group test conducted by 32 students concluded that the results of the module trial received positive responses from students. The

questionnaire contained three aspects, with a total score of 2884 out of a total expected score of 3200. Thus, the assessment results from 32 students had an average percentage score of 91.0% in the "Very Good" category. Based on the above assessment, it can be concluded that the Electronics Circuit Learning Module is in the "Very Good" category, so it can be used as teaching material in such learning.

After all stages have been completed, the module is published and distributed. In this study, only limited dissemination was carried out, namely by distributing and promoting the final product of the Electronics Circuit Learning Module to lecturers teaching Electronics Circuit courses.

Discussion

The results of this study indicate that the Electronic Circuits learning module developed using the 4D model achieved very high levels of validity from both subject matter experts and media experts. In addition, students responses in both small-group and large-group trials were categorised as very good. These findings suggest that the developed module is not only academically sound but also practical and well accepted by students as the primary users. The high levels of feasibility and practicality demonstrate that a systematic development process is capable of producing instructional materials that meet the learning needs of higher technical education.

These findings are supported by previous studies indicating that interactive learning modules can function as flexible self-learning resources that facilitate students understanding of course materials(Nurhasanah et al., 2022). Furthermore, earlier research has reported that the use of interactive learning modules receives positive responses from students and is considered practical in supporting the learning process (Mujib et al., 2020). This suggests that modules designed using multimedia approaches and systematic structures can enhance learning comfort and effectively facilitate students' comprehension of learning content.

Several other studies have also emphasised that interactive multimedia serves as an effective and practical learning medium for improving students understanding of both technical and conceptual materials (Syahputra & Maksum, 2020). E-modules that have undergone practicality testing are also recommended for use in learning, as they have been shown to effectively improve learning outcomes(Lestari & Parmiti, 2020). Moreover, the use of e-modules has been reported to increase students learning motivation, improve learning literacy, and encourage active participation in the learning process (Awwaliyah et al., 2021; Rahmadhani & Efronia, 2021; Wulandari et al., 2022). These findings further strengthen the results of this study, indicating that the Electronic Circuits module not only meets feasibility criteria but also contributes positively to student engagement in learning.

The findings of this study also show that the Electronic Circuits module is practical and can be used independently by students. This is consistent with research on the development of interactive e-modules in multimedia courses, which found that digital modules are practical and effective for use in higher education and support students in accessing learning materials according to their individual needs (Nurhikmah et al., 2021). Other literature reviews have demonstrated that students engagement with interactive e-module content is associated with increased involvement in digital learning processes, which is particularly important in contemporary higher education contexts (Goode et al., 2022). In addition, studies on e-module usage trends highlight the importance of developing and validating e-modules to support students' independent learning in higher education environments (Evenddy et al., 2024).

Although the results of this study indicate very high levels of validity and practicality, the research remains focused on product feasibility and user responses. Several previous studies have suggested that instructional material development should not be limited to validation and practicality stages but should be followed by effectiveness testing to measure the impact of the module on students' learning outcomes more comprehensively. Therefore, further research is recommended to examine the effects of the Electronic Circuits module on students conceptual understanding, practical skills, and academic achievement through experimental or quasi-experimental designs.

Overall, the findings of this study reinforce previous research suggesting that systematically developed interactive multimedia-based learning modules can produce high-quality, practical, and well-accepted instructional materials for higher education students. The Electronic Circuits module developed in this study successfully addresses the initial problems related to limitations in previous

teaching materials, including content structure, support for independent learning, and media quality. Consequently, this module has strong potential to serve as an effective instructional resource in supporting Electronic Circuits learning in higher technical education, provided that further evaluation of its learning effectiveness is conducted.

CONCLUSIONS

Based on the results of the study and the discussion on the development of the Electronic Circuits learning module, a project-based learning module was successfully produced using the four-stage development model consisting of Define, Design, Development, and Dissemination. The validation results from material experts indicated a very high level of feasibility, while the media expert validation also showed a very good category, confirming that the module is highly valid and suitable for use as a learning medium. Furthermore, students' responses demonstrated a very positive perception of the module, indicating that it is easy to use, supports understanding of the learning materials, and facilitates the learning process.

In line with these findings, several recommendations are proposed to support the implementation and further development of the module. Lecturers are encouraged to apply the project-based learning module as an alternative instructional material for the Electronic Circuits course in the Department of Informatics and Computer Engineering. Students are expected to utilise the module effectively to enhance their learning comprehension. Additionally, future researchers are advised to refine the module in terms of both content and visual presentation, and to use it as a reference for developing more engaging and effective learning modules.

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