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Enhancing Learning Outcomes in Electronic and Digital Engineering through Interactive Teaching Modules

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ABSTRACT

The development of instructional modules is crucial for enhancing the effectiveness and efficiency of learning. In Electronics and Digital Engineering education, current practices combine student-centered and teacher-centered approaches; however, existing modules remain predominantly printed and lack interactivity, limiting students' conceptual understanding. This study employed a Research and Development (R&D) approach using the Alessi and Trollip model, consisting of planning, design, and development stages. Data were collected through questionnaires, tests, interviews, and observations. Instruments were validated by material and media experts, and reliability testing using Cronbach's Alpha yielded a coefficient of 0.87, indicating high internal consistency. A purposive sample of 48 students participated, divided into small and large groups for feasibility and effectiveness testing. Quantitative data were obtained during Alpha Test 1 and Alpha Test 2. The implementation of the interactive flipbook-based module resulted in an average post-test score of 83.5%. The normalized gain (N-Gain) between pre-test and post-test scores was 0.7, categorized as high, indicating substantial improvement in students' conceptual understanding. The findings demonstrate that interactive teaching modules significantly enhance learning outcomes compared to traditional printed materials. The integration of interactivity supports both instructional approaches and facilitates deeper conceptual comprehension. Thus, the developed flipbook module is an effective supplementary learning medium in Electronics and Digital Engineering education.

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1. INTRODUCTION

Education plays a fundamental role in developing human resources and enabling the effective use of technology in learning environments. In this context, educators are expected to function not only as knowledge transmitters but also as facilitators who design meaningful and engaging learning experiences. Instructional media are therefore essential, as they can stimulate students' cognitive processes and support the transition from concrete to abstract thinking (Sudjana & Rivai, 2002). Moreover, well-designed learning approaches should be flexible, structured, and responsive to students' needs, interests, and learning styles in order to foster an effective and inclusive learning environment (Sabur et al., 2023).

Despite these expectations, the teaching and learning process in Electronics and Digital Engineering education continues to rely heavily on conventional approaches that combine teacher-centered and student-centered methods without fully leveraging digital innovation. In particular, instructional modules are still predominantly presented in printed formats, which limits interactivity and reduces students' opportunities to actively engage with complex and abstract concepts. As a result, students often experience difficulties in understanding key topics and applying theoretical knowledge to problem-solving situations. Previous studies have emphasized that the integration of innovative and technology-based instructional media is necessary to enhance learning effectiveness and improve student engagement (Purmadi & Surjono, 2015).

Empirical observations further highlight these challenges. Data from first-semester students in the Airport Technology Study Program indicate that average achievement levels remain close to the minimum passing grade, suggesting limited conceptual mastery. In addition, interviews with lecturers reveal that students tend to show low enthusiasm during learning sessions and struggle particularly with topics that require visualization and abstract reasoning. These issues underscore the need for more effective instructional strategies and learning resources that can better support students' understanding. The development of teaching modules, therefore, becomes a critical step in improving both the efficiency and effectiveness of the learning process (Ishartiwi, 2014).

Advancements in digital technology provide opportunities to address these limitations through the development of interactive and technology-enhanced learning media. Digital learning tools not only increase accessibility but also promote autonomous and student-centered learning environments, where learners can interact with content more dynamically (Fletcher et al., 2020; Haleem et al., 2022). In engineering education, particularly in areas involving abstract and visualization-intensive concepts, interactive media such as animations, videos, and simulations have been shown to significantly improve comprehension and engagement. These tools allow students to explore concepts at their own pace while reinforcing understanding through multimodal representations.

In response to these challenges, this study proposes the development of an interactive teaching module in the form of a digital flipbook for Electronics and Digital Engineering. The module integrates various multimedia elements, including text, images, and instructional videos, to create a more engaging and effective learning experience. Additionally, the inclusion of barcode features enables seamless access to supplementary materials, supporting both classroom instruction and independent study. By using devices such as laptops and smartphones, students can interact with the module in a flexible, accessible way.

Ultimately, the development of this interactive module aims to enhance students' conceptual understanding and learning outcomes in Electronics and Digital Engineering. By bridging the gap between traditional instructional methods and modern technological capabilities, this study seeks to contribute to the advancement of innovative teaching practices in engineering education.

2. METHOD

This study employed a research and development (R&D) approach using the development model proposed by M.Alessi and Stanley R. Trollip. The research subjects consisted of students from the Airport Technology Study Program and an interactive teaching module for electronics and digital engineering. The research procedure followed three main stages: Planning, Design, and Development. The research instruments included questionnaires, tests, interviews, and observations. The study participants were first-year students who were accustomed to using digital devices. This characteristic was intentionally selected to ensure that the research subjects were aligned with the context of implementing an interactive digital module in a technology-based learning. Data collection techniques were carried out using quantitative data obtained from questionnaires, which were then analyzed using the Miles and Huberman approach consisting of three steps: data reduction, data display, and conclusion drawing. In addition, responses and suggestions were collected from media experts, material experts, and students who used the interactive teaching module during the alpha testing stage.

Qualitative analysis was also employed to strengthen the quantitative findings, particularly in explaining aspects of students' learning experiences that could not be represented numerically. The reliability test was conducted using the Cronbach's Alpha coefficient on the results of the student response questionnaire. The expert validation process involved two material experts and two media experts, while the student response test involved 48 participants divided into two classes. Before the instruments were used, they were first validated by both groups of experts. The material experts evaluated aspects such as content relevance, conceptual accuracy, alignment with learning outcomes, and instructional language, while the media experts assessed visual appearance, navigation, readability, and the appropriateness of multimedia elements. Both quantitative and qualitative data analysis techniques were utilized in this study. An open-ended survey was conducted to obtain feedback from experts regarding the quality of the media and learning content, as well as students' responses to the interactive module used during the Electronics and Digital Engineering learning process. The analysis of pre-test and post-test results was conducted by administering conceptual understanding tests to measure learning outcomes and determine the effectiveness level of the developed product. Improvements in students' learning outcomes before and after using the interactive teaching module were calculated using the N-Gain formula, which was determined based on the average gain score to identify the module's level of effectiveness in improving learning outcomes. The gain score (g) was obtained by comparing the mean pre-test and post-test values, with the interpretation of gain values presented in Table 1.

Table 1. Interpretation of Gain Scores

No	Gain Score (g)	Classification
1	(N-gain) ≥ 0,7	High
2	0,7 > (N-gain) ≥ 0,3	Medium
3	(N-gain) < 0,3	Low

3. FINDINGS AND DISCUSSION

3.1 Findings

At the Alessi and Trollip development model stage, beta testing was conducted in two phases: Beta Test 1 (small-group trial) and Beta Test 2 (large-group trial). The success of the interactive module was strongly influenced by the role of visualization and interactivity in bridging abstract concepts in Electronics and Digital Engineering to make them easier to understand. The main contributing factor was the integration of visual elements, including images, animations, and instructional videos embedded within the flipbook module, which clarified theoretical explanations and accelerated students' cognitive processes. Through this visualization, learners were no longer required to imagine complex abstract processes. The interactive flipbook also allowed students to directly engage with the content by scanning barcodes that linked to supplementary instructional videos, thereby enabling students to explore and reinforce learning materials independently. The purpose of the beta testing was to assess students' responses to the developed interactive teaching module before conducting the trials with small and large groups. The beta test questionnaire used to measure student responses included three aspects: learning, visual appearance, and product usability.

3.1.1 Beta Test 1 (Small-Group Trial)

The Beta Test 1 (small-group trial) of the interactive teaching module was conducted with six students from the Airport Technology Study Program who had previously completed the Electronics and Digital Engineering course. Based on the results presented in the small-group assessment table, the product was considered highly feasible for use in Beta Test 2 (large-group trial), following several revisions suggested by participants. The overall average score across the three evaluated aspects, learning, appearance, and usability, was 3.5, which is qualitatively categorized as "very feasible" (X ≥ 3.0), as presented in Table 2.

Table 2. Small Group Evaluation Result on Three Aspects

Aspect	Average Score	Category
Learning	3.5	Highly Feasible
Display	3.6	Highly Feasible
Product Usability	3.4	Highly Feasible
Overall Average Score	**3.5**	**Highly Feasible**

The results of the small group evaluation on the three aspects can be visually represented in the diagram below:

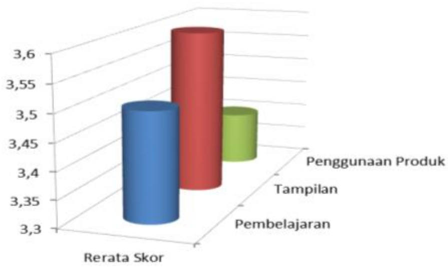

Figure 1. Bar Chart of Beta Test 1 Evaluation Results

Based on the diagram above, the learning aspect, which consists of content relevance, conceptual accuracy, clarity of learning objectives, and alignment with competency standards, was assessed by material experts who stated that the content of the module aligns with the syllabus and effectively reinforces the concepts taught in digital electronics practicum sessions. In the visual appearance aspect, media experts provided suggestions to increase color contrast and improve the clarity of interactive navigation buttons. Among all three aspects, the visual appearance obtained a higher average score compared to the others. This indicates that, qualitatively, the learning aspect received an average score categorized as "very feasible", while the visual appearance and product usability aspects also achieved overall average scores that remained within the high category, with values of 3.17 and 3.5, respectively (X ≥ 3.0).

3.1.2 Beta Test 2 (Large-Group Trial)

During the Beta Test 2 (large-group trial), two types of data were collected. The first included student response questionnaires evaluating the interactive teaching module, and the second involved eight essay questions administered during the pre-test (before using the interactive teaching module) and the post-test (after using the interactive teaching module). The student response questionnaire consisted of three main aspects. Learning aspect, which included 10 evaluation items; Visual appearance aspect, which included 9 evaluation items; and Product usability aspect, which included 6 evaluation items. The results of the assessment for these three aspects obtained from Beta Test 2 (large-group trial) are presented in the following table:

Table 3. Results of the Assessment of the Three Aspects by Beta Test 2

Aspect	Average Score
Learning	3.2
Display	3.2
Product Usability	3.2
Overall Average Score	3.2
Category	**Highly Feasible**

After revisions were made, the overall average score in the large-group trial increased to 3.2, which falls into the "very feasible" category. Based on the results presented in Table 3, it can be concluded that the interactive teaching module product is classified as "very feasible", with an overall average score across the three assessed aspects of 3.2, which is qualitatively categorized as very feasible ($X \geq 3.0$).

The results of the beta test 2 evaluation on the three aspects can be visually represented in the diagram below:

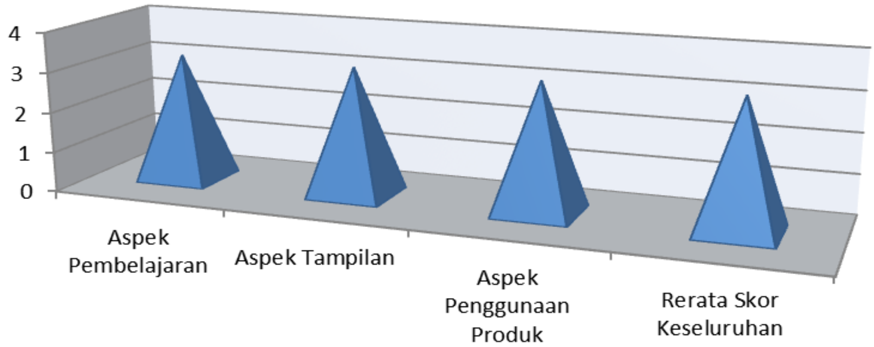

Figure 2. Bar Chart of Beta result

The improvement in students' learning outcomes in the Electronics and Digital Engineering course was measured through the administration of pre-tests and post-tests, which aimed to determine the effectiveness level of the developed interactive teaching module in enhancing students' conceptual understanding. The effectiveness was evaluated by comparing students' scores before and after using the interactive teaching module. The pre-test and post-test activities were conducted after the completion of Beta Test 2 (large-group trial) involving two classes with a total of 48 students. The interactive teaching module product had been revised based on feedback from two material experts, two media experts, and six students during the Alpha Test (small-group trial) stage. The test instruments (pre-test and post-test) were administered to 24 students from the Airport Technology Study Program. Both tests were carried out in the Alpha Building classroom, with all 24 students in full attendance. In the Electronics and Digital Engineering learning process using the interactive module, students were given eight essay questions that had previously been validated by material experts. The number and content of the test questions were determined collaboratively by the material experts and the course lecturer for Electronics and Digital Engineering in the Airport Technology Study Program. The eight conceptual indicators were assessed through eight corresponding essay questions in both the pre-test and post-test. The analysis of students' performance results showed a significant improvement across most indicators, as presented in the following section:

Table 4. Effectiveness of the Digital Electronics Module Based on Posttest Results

No	Topic	Average Posttest Score	Module Effectiveness Description
1	Basic Concepts of Digital Electronics	8.3	Effective – foundational visualizations support initial understanding
2	Binary and Decimal Number Systems	8.6	Highly effective – interactive exercises strengthen conversion logic
3	Basic Logic Operations (AND, OR, NOT)	8.4	Effective – logic gate animations facilitate conceptual mastery
4	Arithmetic Operations in Number Systems	8.8 (highest)	Highly effective – step-by-step visualizations are easy to follow
5	Complex Logic Gates (XOR, XNOR)	7.4 (lowest)	Moderately effective – requires more detailed interactive simulations
6	Application of Logic in Digital Circuits	8.2	Effective – case-based exercises support conceptual application
7	Error Analysis in Logic Circuits	8.1	Effective – explanatory video features assist in error analysis
8	Integration of Digital Circuits	8.5	Highly effective – interactivity and visualizations support concept integration

The administration of pre-tests and post-tests aimed to determine the effectiveness level of the developed interactive teaching module in improving students' conceptual understanding of Electronics and Digital Engineering. The effectiveness was evaluated by analyzing the difference in scores before and after the use of the interactive teaching module. The following data present the pre-test and post-test results obtained before and after students used the interactive teaching module.

Table 5. Comparison of Pretest and Posttest Results

No	Respondent	Pre-test Score	Post-test Score
1	Student 1	42	84
2	Student 2	42	78
3	Student 3	44	87
4	Student 4	43	86
5	Student 5	48	93
6	Student 6	45	83
7	Student 7	45	81
8	Student 8	49	80
9	Student	49	81
10	Student 10	46	81
11	Student 11	46	80
12	Student 12	41	87
13	Student 13	41	87
14	Student 14	49	86
15	Student 15	43	81
16	Student 16	47	87
17	Student 17	49	90
18	Student 18	42	88
19	Student 19	47	78
20	Student 20	42	78

No	Respondent	Pre-test Score	Post-test Score
21	Student 21	40	84
22	Student 22	47	81
23	Student 23	47	81
24	Student 24	42	81
Average Score		**44.83**	**83.5**

The conceptual understanding indicators in this study consisted of eight indicators, represented by ten questions administered in both the pre-test and post-test. The difference between the overall average pre-test and post-test scores showed an increase of 38.6%. This finding indicates that students' ability to identify and comprehend concepts improved significantly after using the interactive teaching module. This improvement was reflected in students' learning outcomes, where the increase in learning achievement was distributed as follows: an improvement of 31% for 2 students, 32% for 1 student, 34% for 3 students, 35% for 1 student, 36% for 3 students, 37% for 1 student, 38% for 2 students, 39% for 1 student, 40% for 1 student, 41% for 1 student, 42% for 1 student, 43% for 2 students, 44% for 1 student, 45% for 1 student, and 46% for 3 students. Overall, the percentage increase in students' learning outcomes was 38.6%, indicating a substantial improvement in conceptual understanding after utilizing the interactive teaching module. The differences between the average pre-test and post-test scores for each question item are presented in Figure 1 below.

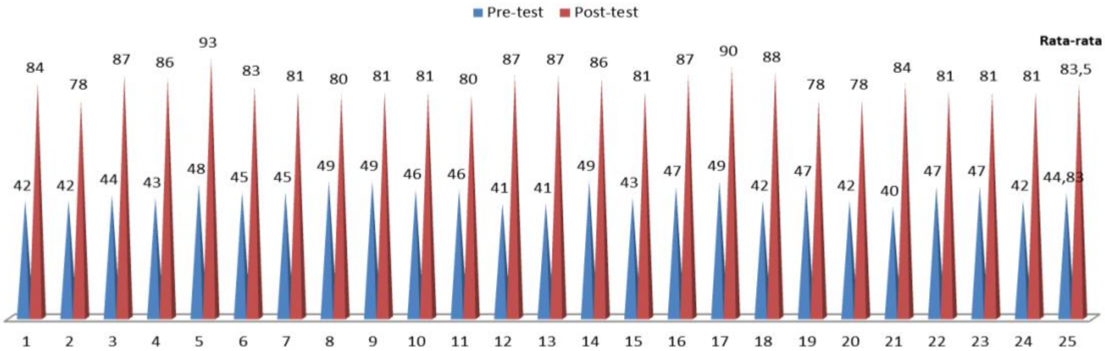

Figure 3. Comparison Results Diagram of Pretest and Posttest Average Scores.

Based on the table, the average pre-test score was 44.83, while the average post-test score reached 83.5. This indicates a significant improvement in students' learning outcomes. Furthermore, the data show that three students achieved scores that only slightly surpassed the minimum passing grade of 75, with each obtaining a score of 78. The average results obtained from the pre-test and post-test were then analyzed using the gain score, as presented below:

$$s = \frac{S_{post} - S_{Pre}}{S_{Maks} - S_{Pre}}$$

$$= \frac{83{,}5-44{,}83}{100-44{,}83} = \frac{38{,}67}{55{,}1}$$

$$= 0.70$$

Based on the above calculation, the gain score obtained from comparing the average pre-test and post-test results in learning using the interactive teaching module was 0.7, which falls under the "high" category (N-Gain ≥ 0.7). The increase in the average post-test score indicates that, in general, the interactive teaching module was effective in improving students' conceptual understanding of *Electronics and Digital Engineering* after using the digital flipbook-based learning product.

3.2 Discussion

The discussion of findings demonstrates that the developed interactive teaching module, designed using a flipbook format, substantially enhances students' conceptual understanding in Electronics and Digital Engineering. The results from both small-group and large-group trials consistently indicate high feasibility across the evaluated dimensions of learning quality, visual appearance, and usability. In the initial trial, the module achieved a "very feasible" classification, which was maintained after revisions in the larger-scale implementation. This consistency suggests that the module not only meets instructional design standards but is also well received by students, particularly in terms of clarity, accessibility, and engagement (Nur & Sabur, 2026).

A key factor underlying the module's effectiveness is the integration of interactive and visual elements, including animations, images, and instructional videos. These features support cognitive processing by transforming abstract concepts into more concrete and comprehensible representations, consistent with multimedia learning theory, which posits that combining visual and verbal information enhances understanding (Mayer, 2009). In digital electronics, where topics such as logic gates and number systems require abstract reasoning, visualization reduces cognitive load and improves comprehension (Sudjana & Rivai, 2002). Furthermore, the inclusion of barcode-linked supplementary materials promotes self-directed learning, enabling students to independently explore and reinforce concepts (Fletcher et al., 2020).

The effectiveness of the module is further evidenced by the significant improvement in students' learning outcomes. The average score increased from 44.83 in the pre-test to 83.5 in the post-test, yielding a high normalized gain (N-Gain) of 0.7. This indicates a strong positive effect on students' conceptual mastery (Nur & Sabur, 2026). The improvement was observed across most participants, suggesting that the module is effective for diverse learner abilities. However, variation across topics was noted. While arithmetic operations achieved the highest performance, more complex concepts such as XOR and XNOR logic gates yielded lower scores, indicating the need for more advanced or targeted interactive simulations for these topics.

These findings are consistent with previous studies highlighting the effectiveness of interactive digital modules in enhancing learning outcomes. For instance, Azzarkasyi et al. (2019) reported a high N-Gain in science learning using e-modules, while Zakiyah and Dwiningsih (2022) found similar improvements in students' visual-spatial understanding through interactive media. Such evidence reinforces the argument that technology-enhanced instructional tools can significantly improve both engagement and conceptual understanding in science and engineering education.

Despite these positive results, further refinement is warranted. Although the module is effective as a supplementary learning tool, its integration into a broader pedagogical framework could be strengthened. Future development should consider incorporating adaptive learning features and more sophisticated simulations, particularly for complex logical operations. Additionally, expanding the module into immersive formats such as three-dimensional or augmented reality environments may further enhance learning engagement and outcomes (Haleem et al., 2022).

In conclusion, the interactive flipbook-based teaching module demonstrates strong pedagogical value by effectively bridging abstract theoretical concepts and practical understanding. Its high feasibility and significant impact on student performance confirm its potential as an innovative instructional medium in Electronics and Digital Engineering education.

The average post-test score achieved by students was 83.5%. Among the test items, Question 4, which focused on addition and subtraction operations in number systems, obtained the highest average score of 8.8, while Question 5, which dealt with more complex logic gates such as XNOR and XOR, received the lowest average score of 7.4. The remaining questions had average scores ranging between 8.1 and 8.7. The gain score of 0.7, derived from the comparison of pre-test and post-test averages, was again categorized as "high" (N-Gain $\geq$ 0.7). This consistent improvement in post-test results demonstrates that the interactive teaching module in the form of a digital flipbook effectively enhanced students' conceptual understanding of *Electronics and Digital Engineering*. These findings align with Agustina Setyaningsih et al. (2024), who asserted that the integration of technology enables faster and more responsive evaluation, providing a more comprehensive understanding of students' mastery of scientific concepts. The increase in post-test performance further confirms that the interactive flipbook-based teaching module serves as an effective supplementary learning medium, significantly improving students' comprehension of *Electronics and Digital Engineering* concepts.

These findings are consistent with recent studies that have demonstrated the effectiveness of interactive modules or flipbooks in science and technology education. For example, the study *"Development of E-Modules on Problem-Based Learning to Enhance Students' Science Literacy"* reported an N-Gain of approximately 0.70, categorized as *high*, in the topic of elasticity and Hooke's Law (Azzarkasyi, Rizal, & Kasmawati, 2019). Similarly, the study *"The Effectivity of Interactive E-Module to Increase Students' Visual-Spatial Intelligence on Ionic Bonds"* reported an N-Gain of 0.81, also classified as *high*, among senior high school students learning ionic bonding content (Zakiyah & Dwiningsih, 2022).

4. CONCLUSION

Students' responses to the development of the interactive teaching module in the form of digital flipbooks, tested through both small-group (Beta Test 1) and large-group (Beta Test 2) trials, were evaluated across three aspects: learning, visual appearance, and product usability. In Beta Test 1, the overall average score across all three aspects was 3.5, which is qualitatively categorized as "very feasible" ($X \geq 3.0$). In Beta Test 2, the overall average score was 3.2, which also falls within the "very feasible" category ($X \geq 3.0$). Based on these findings, it can be concluded that the interactive teaching module is considered highly feasible for use in the learning process. The average post-test score obtained was 83.5%, with a gain score (N-Gain) of 0.7, categorized as "high" (N-Gain $\geq$ 0.7). These results indicate that, overall, the interactive teaching module in flipbook format serves as an effective learning support medium that enhances students' conceptual understanding of *Electronics and Digital Engineering* after its implementation in the classroom. Furthermore, the design of the interactive teaching module can be further developed into a 3-dimensional application, making the module more engaging and diverse as a supplementary learning resource to improve students' learning outcomes, particularly in *Electronics and Digital Engineering* materials

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