Development of a Basic Logic Gate Practicum Module to Support Quality Engineering Education in Digital Electronics

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Abstract: Meaningful learning in digital electronics requires hands-on practicum activities to support students' understanding of abstract logic concepts. However, limited access to appropriate practicum media often hinders effective learning experiences. This study aims to develop and validate a physical Basic Logic Gate practicum module designed to support hands-on learning in digital electronics courses. The study employed a Research and Development approach using the 4D model, completing the Define, Design, and Develop stages up to expert validation and student practicality testing. The developed module consists of a hardware-based logic gate kit that enables students to assemble and test basic logic gate circuits directly during practicum sessions. Content and media validation were conducted by a material expert and a media expert using a Likert-scale instrument, while practicality testing involved 28 undergraduate students. The validation results indicated high validity, with scores of 96.19% from the material expert and 97.14% from the media expert. Practicality testing yielded an average score of 98.57%, indicating that the module is highly practical in terms of usability, functionality, and suitability for practicum implementation. These findings demonstrate that the developed Basic Logic Gate practicum module meets quality standards for instructional media and is feasible for use in digital electronics practicum learning.

Keywords: Basic logic gate module; Digital electronics practicum; Learning enhancement; Module development

Introduction

Digital electronics is a fundamental subject in engineering and technology education, as it provides the conceptual and practical foundation for modern computing systems, embedded devices, and digital communication technologies (Farhan et al., 2023). Central to this subject is the concept of logic gates, which function as the basic building blocks of digital circuits. A solid understanding of logic gate operations is therefore essential for students to master more advanced topics, such as combinational and sequential logic, microprocessor systems, and digital system design (Merianti & Kurniawan, 2023; LaMeres, 2024).

Despite its importance, learning logic gates remains challenging for many students. Instructional practices in digital electronics courses often emphasize theoretical explanations, while opportunities for direct interaction with physical circuits are limited (Radhakrishnan & Chen, 2024). As a result, students may struggle to visualize logic operations, interpret circuit behavior, and apply abstract concepts to real-world problem solving (Dewantara et al., 2021; Zhao, 2021; Singh & Sharma, 2023; Zhu & Howell, 2023). This gap between theoretical understanding and hands-on experience highlights the need for effective practicum media that can support meaningful learning in digital electronics education.

Practical learning modules play a crucial role in addressing this challenge by enabling students to directly assemble circuits, observe real-time outputs, and experiment with various logic configurations. Previous studies have shown that hands-on modules can enhance conceptual understanding, promote active learning, and improve student engagement during laboratory activities (Widiarini et al., 2022; Tokatlidis et al., 2024). However, many existing logic gate learning tools are either simulation-based or lack structured guidance, durability, and ease of use, which limits their effectiveness in supporting practicum-based learning, particularly in undergraduate engineering programs (Negahban, 2024; Yulando et al., 2019; Pang, 2015; Tindan & Anaba, 2024; Zhu & Howell, 2023).

In response to these limitations, this study develops a physical Basic Logic Gate practicum module, designed as a hardware-based learning kit that allows students to directly construct and test basic logic gate circuits during laboratory sessions (Elaraby et al., 2024; Lee, 2025; Yulando et al., 2019; Zhu & Howell, 2023). The novelty of this research lies in the design of a practicum module that integrates clear instructional guidance, reusable hardware components, and curriculum-aligned learning objectives within a single learning medium (Desky et al., 2025). Unlike simulation-only approaches, the proposed module emphasizes direct manipulation of electronic components to strengthen the connection between abstract logic concepts and tangible circuit behavior (Baum et al., 2021) (Asnur et al., 2025).

This research is important because providing accessible and practical laboratory media is essential to support quality engineering education, particularly in contexts where laboratory resources are limited and learning outcomes rely heavily on students' hands-on competencies (Deng et al., 2019). To ensure instructional quality, the module was developed using a Research and Development approach based on the 4D model, completing the Define, Design, and Develop stages up to expert validation and student practicality testing (Maksum & Purwanto, 2022; Anshari et al., 2019; Yulando et al., 2019). Validation focused on content accuracy and media design, while practicality testing evaluated usability and suitability for digital electronics practicum implementation.

Accordingly, this study aims to design and evaluate the validity and practicality of a Basic Logic Gate practicum module as an instructional medium for digital electronics learning. By providing empirically validated practicum media, this research is expected to contribute to the improvement of practicum-based learning experiences and support the development of students' foundational competencies in digital electronics education (Habib et al., 2025).

Method

This study employed a Research and Development (R&D) approach using the 4D development model (Define, Design, Develop, and Disseminate) proposed by Thiagarajan et al. (1974). In this research, the development process was carried out up to the Develop stage, including expert validation and limited practicality testing. The Disseminate stage was implemented in a limited form as a practicum try-out and did not include large-scale dissemination or effectiveness evaluation (Maksum & Purwanto, 2022; Yulando et al., 2019).

Define Stage

The Define stage aimed to identify learning needs and problems in digital electronics practicum. This stage involved a curriculum review and observation of existing practicum activities to identify gaps between theoretical instruction and hands-on learning. The analysis focused on students' difficulties in understanding abstract logic gate concepts and the limited availability of structured practicum media to support laboratory learning.

Design Stage

At the Design stage, a physical Basic Logic Gate practicum module was designed as a hardware-based learning kit. The module includes basic logic gate circuits (AND, OR, NOT, NAND, NOR, and XOR), schematic diagrams, and step-by-step practicum instructions. Design considerations emphasized usability, component durability, safety, and compatibility with standard laboratory equipment. The module prototype was developed using commonly available electronic components to ensure accessibility and cost efficiency.

Develop Stage

The Develop stage consisted of expert validation and student practicality testing.

Expert Validation

Validation was conducted by one material expert and one media expert. A Likert-scale validation instrument was used to assess aspects of content accuracy, relevance to learning objectives, clarity of instructions, and media design quality. The purpose of expert validation was to determine whether the module met instructional media quality standards prior to implementation.

Practicality Testing

Practicality testing involved 28 undergraduate students enrolled in a digital electronics practicum

course. Students used the module during practicum activities and completed a practicality questionnaire. The questionnaire evaluated ease of use, clarity of instructions, functionality of the module, and suitability for practicum implementation. Data were collected through questionnaires and observation sheets during the practicum sessions.

Disseminate Stage (Limited Try-Out)

The Disseminate stage was conducted in a limited form through implementation of the validated module in a digital electronics laboratory setting. This stage functioned as a small-scale try-out to observe module usability in an actual practicum environment. Data collected at this stage were limited to user feedback and were not intended to measure learning effectiveness or learning outcomes.

Data Analysis

Validation and practicality data were analyzed using descriptive quantitative techniques. Scores obtained from expert validation and student questionnaires were converted into percentages and categorized based on predetermined validity and practicality criteria. Descriptive statistics were used to summarize student responses (Anshari et al., 2019; Siregar et al., 2024).

Result and Discussion

Expert Validation Results

Table 1. Validation results

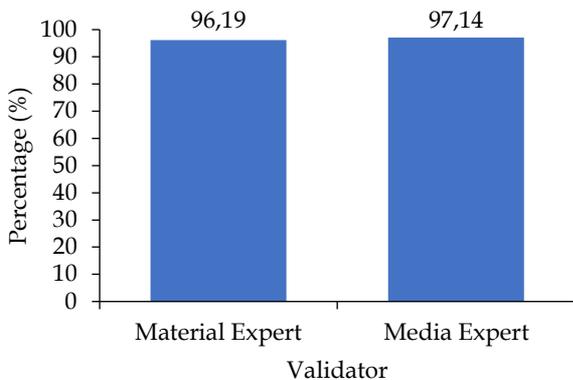| Aspect	Score	Percentage (%)	Category
Material Expert Validity	33.67/35	96.19	Highly Valid
Media Expert Validity	34.00/35	97.14	Highly Valid

Figure 1. Validation summary chart

The validation process involved: a material expert and a media expert. The material expert provided an

average score of 33.67 out of 35, equivalent to 96.19%, while the media expert scored 34.00 out of 35, equivalent to 97.14%. Based on the validity criteria (Rahmadani & Sunarmi, 2023), both results fall into the "Highly Valid" category. These findings indicate that the module content is accurate, relevant, and aligned with the learning objectives, and the media design meets usability and clarity standards (Dewantara et al., 2021; Merianti & Kurniawan, 2023).

Practicality Test Results

Practicality testing was conducted with 28 students during a digital electronics practicum. The results showed an average score of 54.21 out of 55, equivalent to 98.57%, categorized as "Highly Practical". The standard deviation was 0.96, indicating that student responses were highly consistent. The histogram analysis revealed that most students gave scores of 55, demonstrating strong agreement on the module's ease of use, functionality, and reliability. These results confirm that the module is not only valid but also practical for classroom implementation. The high practicality score suggests that students found the module intuitive and effective for hands-on learning, which supports previous research emphasizing the importance of practical tools in enhancing conceptual understanding (Widiarini et al., 2022; Dahal et al., 2023).
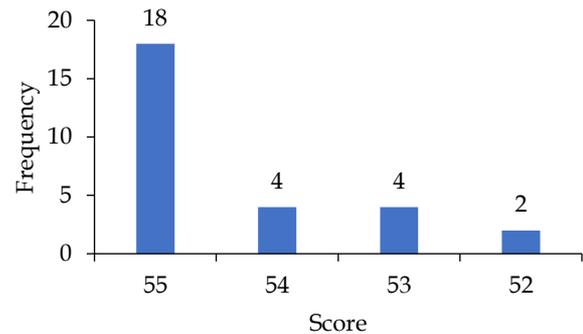

Figure 2. Practicality summary chart

The findings of this study confirm that the Basic Logic Gate module demonstrates high validity and practicality, serving as an effective instructional tool to enhance students' learning experience in digital electronics practicum. Validation by the material expert emphasized indicators such as accuracy and relevance of content, clarity of theoretical explanations, and alignment with curriculum objectives, ensuring that the module provides comprehensive and correct information for mastering logic gate concepts. Similarly, the media expert highlighted indicators including ease of use, component durability, and visual clarity, which

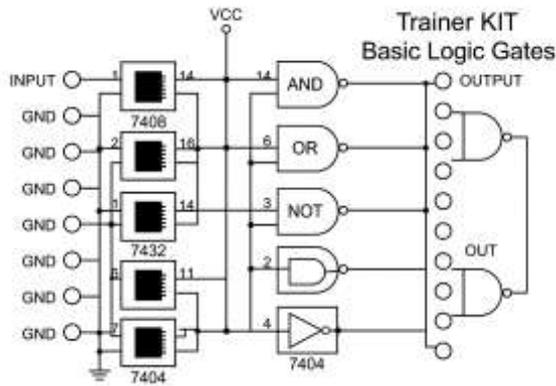are essential for creating an engaging and safe learning environment.

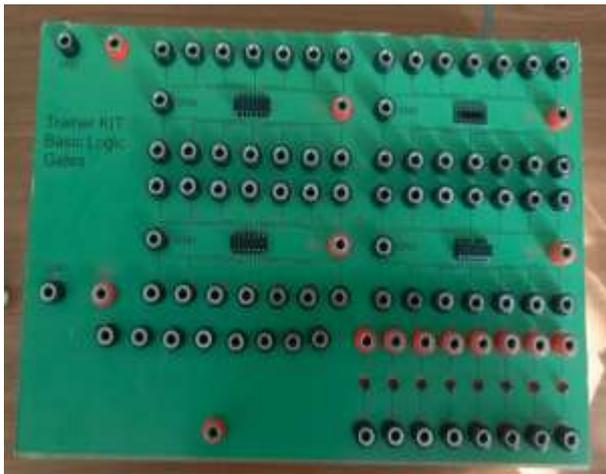**Figure 3.** Basic logic gates schematic

Figure 4. Basic logic gates modules

The practicality test results, with a score of 98.57%, indicate that students found the module highly usable and effective. Indicators such as ease of assembly, consistency of circuit outputs, and safety during repeated use were rated positively. This consistency reflects the module's ability to support hands-on learning without technical difficulties, which is critical for bridging the gap between theory and practice and enhancing student confidence and engagement.

These results align with constructivist learning theory, which emphasizes active engagement through direct manipulation of learning materials to foster deeper understanding and critical thinking (McLeod, 2025). Hands-on activities allow students to construct knowledge through experimentation and reflection rather than passively receiving information (Tokatlidis et al., 2024; Li et al., 2023; Ngo, 2024; Zhu & Howell, 2023). Previous studies also show that practical modules significantly improve conceptual understanding and

problem-solving skills compared to traditional lecture-based methods (Ritenour et al., 2023).

The dissemination stage demonstrated that the module encourages collaborative learning and critical thinking, as students worked in groups to explore different logic configurations. This hands-on experience not only improves comprehension but also cultivates creativity and technical competence—skills essential for future engineers. Media experts noted that the module's design promotes active learning, allowing students to manipulate circuits and observe real-time results, which enhances motivation and retention (Amaravati et al., 2025).

In summary, the combination of high validity and practicality, supported by expert insights and constructivist principles, confirms that the Basic Logic Gate module is an innovative instructional tool for digital electronics practicum. It enhances student engagement, promotes deeper understanding of digital logic concepts, and provides a strong foundation for advanced topics in digital electronics.

Conclusion

This study concludes that the developed Basic Logic Gate practicum module meets the criteria of a valid and practical instructional medium for digital electronics practicum. Expert assessments indicate that the module is appropriate in terms of content accuracy, instructional design, and media quality, while student evaluations show that the module is easy to use and suitable for practicum activities. These findings confirm that the module aligns with curriculum requirements and can be feasibly implemented as supporting media in digital electronics laboratory learning. As the development and evaluation of the module were limited to validity and practicality testing, the results of this study do not address the effectiveness of the module in improving students' learning outcomes. Therefore, conclusions regarding cognitive achievement or skill improvement cannot be drawn at this stage. Nevertheless, the validated module provides a structured and accessible practicum medium that supports hands-on learning activities in digital electronics courses. Based on these findings, it is recommended that digital electronics practicum instructors and laboratory coordinators utilize the developed module as an alternative or complementary practicum medium to support hands-on learning activities. For future research, further studies are encouraged to examine the instructional effectiveness of the module through experimental designs, such as pre-test and post-test assessments, and to explore the integration of complementary digital tools to enhance scalability and learning flexibility. Continuous evaluation involving instructors and

students is also suggested to ensure the module remains relevant to evolving curriculum needs (Hao et al., 2025).

Conflicts of Interest
Authors declare that no conflict of interest in this publication.

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