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The Use of E-Modules to Enhance Students' Cognitive Achievement in Understanding Milling Machine Components

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Abstract

This study aimed to develop and evaluate the effectiveness of a digital-based interactive e-module to improve students' cognitive learning achievement on the topic of milling machine components. The research employed the 4D development model (Define, Design, Develop, Disseminate) and used a quantitative approach with a one-group pretest-posttest design. The participants consisted of 66 Grade X students from the Mechanical Engineering program at SMK Negeri 5 Semarang. The evaluation instrument comprised multiple-choice questions at cognitive levels C1 to C3, which were validated using Aiken's V. The results indicated that the average pretest score was 53.18, while the posttest score increased to 68.72. The N-Gain score was 0.33, categorized as moderate. A paired sample t-test revealed a significant difference between pretest and posttest scores. In addition, the effect size analysis using Cohen's *d* produced a value of 0.88, which falls under the large effect category. These findings demonstrate that the e-module significantly and practically enhanced students' cognitive achievement. The study recommends integrating digital e-modules as effective, independent learning tools in vocational education and suggests future studies adopt quasi-experimental designs with control groups and authentic assessment strategies.

Key words: e-module, milling machine, cognitive learning, media development, R&D

INTRODUCTION

The rapid advancement of digital technology has significantly transformed the educational landscape. This transformation is evident in the increasing use of digital devices and online learning platforms, which have enhanced access to education, improved learning effectiveness, and fostered innovation in instructional methods. Digital transformation now permeates nearly all sectors of life, including politics, economics, governance, and education (Azizi et al., 2024). Reinforcing this view, (Yohanes et al., 2024) stated that the digital era has fundamentally reshaped education, with institutions actively integrating, managing, and utilizing digital media. This indicates that digitalization is not merely a trend, but an integral part of contemporary teaching and learning processes.

One key example of this transformation in education is the implementation of e-modules as digital learning media. E-modules provide students with flexible, self-directed access to learning materials, while also promoting cognitive engagement through interactive and appealing content. (Kismiati, 2020) found that the use of e-modules significantly enhanced students' cognitive outcomes, with an N-Gain of 0.846 and a statistically significant t-test result (p = 0.000). Similarly, (Fadhillah et al., 2022) demonstrated the effectiveness of web-based e-modules in improving student achievement in production technology courses.

E-modules, or electronic modules, consist of digital learning resources combining text, visuals, and interactive features, often including simulations to support conceptual understanding (Herawati and Muhtadi, 2018). (Ricu Sidiq and Najuah, 2020) emphasized that interactive e-modules can substantially increase student motivation and learning outcomes compared to traditional print-based modules. (Budiarto et al., 2024) also found that e-modules and e-learning tools can foster essential 21st-century skills such as digital literacy, collaboration, and critical thinking—skills particularly relevant in vocational education.

With ongoing advancements in information and communication technology, the learning process has evolved significantly. One innovation that supports independent and student-centered learning is the development of interactive e-modules. According to (Hamid et al., 2025), e-modules are structured digital instructional materials designed to enable students to study autonomously with minimal teacher assistance. As such, they are well-suited for the needs of 21st-century education, which emphasizes student agency and digital fluency.

To ensure the effective implementation of e-modules, instructional approaches must align with the characteristics of digital learning media. One relevant approach is cognitive learning theory, which emphasizes the internal mental processes involved in learning. (Vera, 2024) explain that cognitive theory is grounded in the notion of developmental mechanisms, whereby individuals progress from basic to higher-order reasoning skills. In educational terms, cognitive learning involves organizing mental and perceptual processes to foster understanding (Helmy, 2011). This suggests that students' mental engagement is critical to achieving meaningful learning outcomes.

The use of e-modules aligns closely with cognitive learning approaches. Bruner, as cited in (Vera, 2024), asserted that learning is an active process in which students build new knowledge based on prior understanding. He highlighted the value of discovery learning and scaffolding. Hence, well-designed interactive e-modules can stimulate students to actively construct their own knowledge.

The effectiveness of e-modules in technical education is also supported by constructivist models such as problem-based learning (PBL) and project-based learning (PjBL). These models encourage students to engage in problem-solving, contextual applications, and exploration to build knowledge. In the context of vocational education, interactive e-modules provide opportunities for students to engage with technical content both visually and practically. (Delianti and Jalinus, 2020) showed that PjBL-based e-modules significantly improved vocational students' performance in visual programming subjects. Similarly, (Najwa and Sabariman, 2021) found that PBL-model e-modules enhanced students' conceptual understanding and critical thinking in technical mechanics. (Laili et al., 2019) further demonstrated that interactive e-modules for electrical motor installation promoted self-directed learning and improved student achievement.

In machining engineering education, particularly concerning milling machine components, conceptual understanding is a core competency that students must master. Traditional learning methods often fall short in meeting the visual and technical demands of such content. Thus, implementing e-modules enriched with illustrations, animations, and videos can help improve students' cognitive outcomes.

(Bariroh and Sujatmiko, 2024) found that e-modules significantly supported skill development among vocational students, particularly in programming-related competencies. This confirms that e-modules can facilitate the comprehension of complex and abstract material.

However, although the benefits of e-modules have been well documented, most studies have focused on general academic subjects, with limited research addressing vocational topics such as machining. Moreover, few studies have investigated the role of e-modules in enhancing cognitive learning outcomes in highly visual and technical content like milling machine components.

This study aims to fill that gap by evaluating the effectiveness of an interactive e-module in improving students' cognitive achievement in understanding the components of a milling machine. The e-module was designed in line with cognitive learning principles, featuring structured content, visual aids, and problem-based exercises. The assessment instruments were aligned with Bloom's taxonomy (C1–C3) to systematically measure students' cognitive progress.

By focusing on a technical subject rarely explored in previous studies, this research seeks to contribute to the development of effective and innovative digital learning tools in vocational education, offering a practical alternative to conventional instructional methods.

METHODS

Research Design

This study employed a Research and Development (R&D) methodology. The research adopted a one-group pretest-posttest design as part of the formative evaluation during the early development stage of the learning media. Although this approach has limitations in drawing strong causal inferences, it is commonly used in R&D studies to evaluate the initial effectiveness of an instructional product prior to widespread implementation. According to (Arif Rachman et al., 2024), R&D is a research method used to produce a specific product and test its effectiveness before broader application.

This study used the 4D development model (Define, Design, Develop, Disseminate) developed by (Thiagarajan et al., 1974). This model was chosen because it provides a systematic framework for developing instructional tools—from needs analysis to product dissemination.

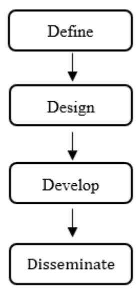

Figure 1. Flowchart Diagram

Research Procedure

1. Define Stage

This initial stage aimed to identify students' learning needs, analyze basic competencies, and determine the scope of the milling machine components material, which is often perceived as difficult by students. The Define stage focused on Grade X students in the Machining Engineering program at SMK Negeri 5 Semarang. The needs analysis was conducted through curriculum document analysis, including syllabi and learning outcomes outlined in the Merdeka Curriculum.

2. Design Stage

This stage involved designing the e-module tailored to the characteristics of vocational school students. The e-module was formatted as an interactive digital module accessible via computer or smartphone, facilitating self-paced and repeated learning. The design emphasized integration of text, illustrative images, and contextual exercises to promote active thinking and reflection. Practice questions were aligned with Lower Order Thinking Skills (LOTS) based on Bloom's taxonomy.

3. Develop Stage

The e-module was digitally developed and validated by subject matter and media experts. Following expert validation, involving teachers and lecturers, revisions were made. The revised e-module was then tested on 66 Grade X Machining Engineering students using the following design:

$$O_1 \rightarrow X \rightarrow O_2$$

Description :

O_1 : Pre-test – measurement of cognitive learning outcomes before the e-module intervention.

X : Treatment – learning process using the e-module on milling machine components.

O_2 : Post-test – measurement of cognitive learning outcomes after the intervention.

4. Disseminate Stage

At this stage, the validated and revised e-module was finalized and prepared for wider implementation, particularly in the Machining Engineering specialization at vocational schools.

Research Subjects and Location

The study was conducted at SMK Negeri 5 Semarang with a total of 66 students (22 female and 44 male) from Grade X Machining Engineering classes 1 and 2, aged 15–17. These two classes were merged for analysis as they received the same treatment and used identical learning instruments.

Research Instruments

The primary instruments used in this study were pre-test and post-test questions developed to assess students' cognitive achievement related to milling machine components. The questions were based on the basic competencies outlined in the machining subject curriculum.

Instrument validation was conducted using Aiken's V method, which is widely recognized for converting qualitative expert judgments into objective quantitative validity coefficients (An Nabil et al., 2022). This method offers statistical evidence to support acceptance, revision, or rejection of test items based on measurable data.

$$V = \frac{\sum s}{[n(c-1)]}$$

Where:

V = Aiken's content validity coefficient

s = r – lo (rating score minus the lowest score)

n = number of raters

c = number of rating categories

r = score assigned by the rater

lo = lowest score on the rating scale

In this study, the assessment instrument used a dichotomous scale ("Yes" = 1 and "No" = 0). On this scale, the lowest score (lo) is 0 and the number of categories (c) is 2. Thus, the denominator becomes [n(2−1)] = n. The formula can then be simplified as follows:

$$V = \frac{\text{Number of 'Yes'}}{\text{Number Validator (n)}}$$

The resulting V value is then interpreted by comparing it to Aiken's critical value table to determine the validity of each item. An item is considered "Valid" if the computed V value meets or exceeds the critical value at a specified level of significance.

Table 1. Aiken's V Criteria

Significance	Critical V Value	Interpretation
P<.05	1.00	Item is considered Valid
	<1.00	Item is considered Not Valid

Based on the table above, with six raters (n = 6), an item is considered significantly "Valid" if the V coefficient is 1.00. Items that do not reach this threshold are considered "Not Valid" and require revision.

Data Analysis Techniques

The data analysis in this study is divided into two main parts: (1) analysis of the product validation results by experts, and (2) analysis of students' learning outcomes.

1. Analysis of E-Module Validation Data
2. Analysis of Student Learning Outcomes

The data analysis in this study aims to determine the improvement in students' cognitive learning achievement before and after using the e-module on the topic of milling machine components. Since the study involved only one group (two classes combined), the analysis focused on changes in the learning scores of 66 students from the pretest to the posttest within that group. The analysis stages are as follows:

Descriptive Statistical Analysis

Descriptive statistics were used to identify the mean, minimum and maximum scores, and standard deviation of the pretest and posttest results. This analysis provides a general overview of students' cognitive performance before and after the learning process using the e-module.

Normality Test

A normality test was conducted on the pretest and posttest data to ensure that the data were normally distributed. The test was performed using the Shapiro-Wilk or Kolmogorov-Smirnov method with the assistance of SPSS software. The results of this test determined whether parametric statistical tests could be applied in the next stage. The decision criteria are as follows: If the significance value (Sig.) > 0.05, the data are considered to be normally distributed.

Paired Sample T-Test

To determine whether there is a significant difference between the pretest and posttest results, a paired sample t-test was used, as the data came from the same group before and after the intervention. The test was conducted at a 0.05 significance level. If the p-value < 0.05, it indicates a significant difference between the pretest and posttest scores, showing that the use of the e-module had an effect on improving students' learning outcomes.

N-Gain Calculation

Student learning improvement was also analyzed using the N-Gain formula:

$$\text{N-gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}$$

The average N-Gain score was calculated for all students and classified into three categories. The N-Gain score classification is presented in Table 2 as follows:

Table 2. N-Gain Score

N-Gain (g)	Improvement Category
g> 0.7	High
0,3 ≤ g ≤ 0,7	Medium
g < 0,3	Low

Cohen's d Calculation

In addition to the t-test and N-Gain calculation, this study also employed an effect size analysis using Cohen's *d* to determine the practical significance of the e-module's impact on students' learning improvement. Cohen's *d* is calculated by dividing the difference between the post-test and pre-test mean scores by the pooled standard deviation. The results are then interpreted based on Cohen's (1988) classification. The obtained Cohen's *d* value is interpreted using the criteria established by Cohen (1988), as presented in Table 3 below.

Table 3. Interpretation of Cohen's d

Cohen's *d* Value	Interpretation Category
d < 0,20	Small effect
0,20 ≤ d < 0,50	Low to moderate effect
0,50 ≤ d < 0,80	Moderate effect
d ≥ 0,80	Large effect

This study received approval from SMK Negeri 5 Semarang and the Regional Branch Office 1 of the Central Java Provincial Department of Education and Culture. It was conducted with informed consent obtained from the students prior to implementation.

RESULTS AND DISCUSSION

The results and discussion section aims to present the data collected during the implementation of the study, describe the emerging findings, and analyze their significance. This section explains how the activities were carried out, the challenges encountered, the impact on the target participants, and the measures taken to ensure the sustainability of the outcomes.

This study employed a one-group pretest-posttest design as part of a formative evaluation to examine the initial feasibility and effectiveness of the developed e-module. Although this design has limitations in drawing strong causal conclusions, it is commonly used in the early stages of instructional media development to explore the potential impact on students' learning outcomes.

Tahap Define

The results of the Define stage revealed that students' understanding of the milling machine components was still relatively low. Based on the analysis of pretest scores from 10th-grade Mechanical Engineering students at SMK Negeri 5 Semarang, it was found that the majority of students had not yet reached the minimum competency standards set by the school. This indicates a weak grasp of basic concepts related to the names, functions, and locations of milling machine components.

Several factors contributed to the low learning outcomes, including the limited use of instructional media, which was still primarily focused on textbooks and oral explanations from the teacher. This approach did not adequately support the students' visual learning needs in comprehending the structure and function of the components. Additionally, students lacked access to self-instructional learning materials that could be studied flexibly outside the classroom.

From the needs analysis, it can be concluded that there is a need for an instructional medium that is interactive, engaging, and easily accessible to enhance students' comprehensive understanding. Therefore, the development of a digital e-module is seen as an appropriate solution to address these issues and serves as the foundation for the subsequent development stage.

Design Stage

In the Design stage, a draft of the e-module was developed specifically to facilitate the learning of milling machine components for 10th-grade Mechanical Engineering students at SMK Negeri 5 Semarang. The design process took into account the characteristics of vocational high school students, who tend to prefer practice-oriented and visual-based learning.

The platforms used for development included **Canva Pro**, **Google Forms**, and **Shapr3D**, selected to produce a product with professional and engaging visuals. Therefore, the e-module was designed in a digital format that integrates a combination of text, illustrative images, and interactive exercises, arranged progressively according to the students' level of understanding.

The selection of appropriate tools was crucial to achieving instructional goals:

Canva Pro was chosen for its professional features, such as access to thousands of icons, vector illustrations, ready-made layouts, and the ability to manage color palettes and fonts consistently—greatly supporting the creation of informative and aesthetic e-module pages.

Google Forms was utilized as a tool for collecting data through pre-tests and post-tests. It was chosen for its accessibility across various devices, automatic data storage in Google Sheets, and the ability to quickly analyze students' responses.

Shapr3D was employed to create precise and professional 3D models of milling machine components. This application was selected for its ability to produce realistic, interactive, and easy-to-understand technical visualizations for students.

The results of the e-module design are shown in **Figure 2**.

Figure 2. E-Module Design

Develop Stage

The Develop stage is the core of the research cycle, where the product is realized, validated, and tested for its effectiveness.

E-Module Feasibility Validation Results

In R&D studies, the validation process is an essential component aimed at evaluating the quality and feasibility of the product prior to implementation. Previous studies emphasize that expert validation—including subject matter experts, media experts, and instructional design experts—is a critical step in assessing the appropriateness of digital instructional materials before they are applied to students (Isfahani et al., 2023).

The feasibility validation of the designed e-module was carried out by content experts, media experts, and assessment experts. The validators included five Mechanical Engineering teachers from SMK Negeri 5 Semarang and one lecturer from the Mechanical Engineering Department at Universitas Negeri Semarang.

The data analysis used Aiken's V coefficient, with the criterion that an item is considered "Valid" if it reaches a V value of 1.00.

The validation results for the content of the e-module were analyzed based on seven items, covering aspects of content accuracy, material presentation, and practicality.

Tabel 4. Content Validation Results

No	Indicator	Total	Value	Category
A. Content				
1	The material presents lathe machine parts	6	1.00	Valid
2	The content is delivered clearly	6	1.00	Valid
B. Presentation				
3	The presentation encourages student activity	6	1.00	Valid
4	The presentation is engaging	5	0,83	Not Valid
5	The presentation is attractive	6	1.00	Valid
C. Practicality				
6	Can be used (played) anytime	6	1.00	Valid
7	Easily accessible online/offline	6	1.00	Valid

The results in Table X show that 6 out of 7 items, or 85.7%, were deemed "Valid." Core aspects such as Content and Practicality received very positive evaluations. However, one note was made regarding the presentation of content, specifically the item "The presentation of material attracts students' interest in learning," which did not reach a significant level of validity. This serves as valuable feedback for improving the e-module to better promote student engagement.

The media validation of the e-module was analyzed based on 8 items, covering aspects of visual design, supporting materials, and media usability.

Tabel 5. Media Validation Results

No	Indicator	Total	Value	Category
A. Visual Design				
1	Media includes images	6	1.00	Valid
2	Media includes text	6	1.00	Valid
3	Media includes navigation	5	0,83	Not Valid
4	Media is interesting and not boring	6	1.00	Valid
B. Content				
5	Media presents welding defect material	6	1.00	Valid
6	Media includes practice questions	6	1.00	Valid
C. Practicality				
7	Media is easy to use independently	6	1.00	Valid
8	Media can be saved and read again	6	1.00	Valid

The results in Table 5 show that 7 out of 8 items, or 87.5%, were deemed "Valid." Core aspects such as Content and Practicality received very positive evaluations. However, one note was made regarding the visual design aspect, specifically the item "The learning media includes navigation features," which did not reach a significant level of validity. This provides valuable input for refining the e-module to better support student interaction.

The validation of the test instrument was conducted on 6 items, covering aspects of visual clarity, question construction, and language usage.

Table 6. Test Instrument Validation Results

No	Indicator	Total	Value	Category
A. Appearance				
1	Each question has one correct answer	6	1.00	Valid
2	The question matches the indicator	6	1.00	Valid
B. Construction				
3	The stem is clearly and firmly formulated	6	1.00	Valid
4	The stem does not give clues to the correct answer	6	1.00	Valid
C. Language				
5	The language follows proper Indonesian grammar	5	0,83	Not Valid
6	The language is communicative	6	1.00	Valid

The results in Table 6 indicate that, overall, the test items demonstrated a high level of content validity, with 5 out of 6 items (83.3%) classified as "Valid." However, similar to the material validation, Item 5 did not reach a significant level of validity. As a result, several questions were revised to ensure that all statements were clearly understood before being used in the pretest and posttest instruments.

E-Module Effectiveness Test Results

After being declared feasible based on the validation results, the e-module was implemented in classroom learning. To evaluate its effectiveness, the researcher analyzed students' learning outcome data using SPSS software. The effectiveness of the e-module was measured by comparing the **pretest** and **posttest** scores, as presented in **Table 7** below:

Table 7. Descriptive Statistical Analysis Results

Statistics	Pre-test	Post-test
Number of Students (N)	66	66
Average (Mean)	53,18	68,72
Standard Deviation	19,56	15,94
Minimum Score	20,00	30,00
Maximum Score	90,00	95,00

The descriptive analysis of pre-test and post-test scores indicates an improvement in students' cognitive learning achievement after using the e-module. A total of 66 students were analyzed. The average pre-test score was 53.18 with a standard deviation of 19.56, while the average post-test score increased to 68.72 with a standard deviation of 15.94. The minimum score in the pre-test was 20.00, which increased to 30.00 in the post-test. Meanwhile, the maximum pre-test score was 90.00, rising slightly to 95.00 in the post-test.

To determine whether this improvement was statistically significant, a paired sample t-test was conducted after fulfilling the normality test prerequisite. The normality test was performed using the Shapiro-Wilk method to assess whether the data were drawn from a normally distributed population. The results of this test are presented in Table 8.

Table 8. Shapiro-Wilk Normality Test Results

Data Group	Statistic W	Sig value (p-Value)	Results
Pre-test	0,966	0,064	Normal
Post-test	0,972	0,147	Normal

Based on the table above, the significance value (Sig.) for the pre-test data is 0.064, and for the post-test data is 0.147. Since both values are greater than 0.05, it can be concluded that the pre-test and post-test data are normally distributed.

Therefore, the data meet the assumption of normality and can be analyzed using a parametric statistical test, namely the paired sample t-test, to determine the difference in learning outcomes before and after the use of the e-module. The results of the paired sample t-test are presented in Table 9.

Table 9. Paired Sample t-Test Results

Data Group	Statistics-t	Sig value (p-value)
Pre-test & Post-test	-11,404	0,000

The test results showed a t-value of –11.404 with a p-value of 0.000 (less than 0.05). This indicates that there is a highly significant difference between the students' pre-test and post-test scores after using the e-module.

Based on the t-test results, it can be concluded that there was a significant improvement in students' learning outcomes after the implementation of the e-module. To further determine the extent of this improvement quantitatively, an additional analysis was conducted using the N-Gain calculation. This analysis aimed to measure the effectiveness of the e-module in improving students' cognitive abilities by examining the difference between pre-test and post-test scores.

The average N-Gain score of 0.4075 indicates that the improvement in students' learning outcomes falls into the moderate category. The N-Gain analysis results are presented in Table 10.

Table 10. N-Gain Analysis Results.

Category	Number of Students	Percentage %
High	10	15,15 %
Medium	38	57,58 %
Low	18	27,27 %
Total	66	100%

Based on the N-Gain data analysis of 66 students, it was found that 18 students (27.27%) were in the low category, 38 students (57.58%) were in the moderate category, and 10 students (15.15%) were in the high category. These results indicate that the majority of students experienced a notable improvement in learning outcomes after using the e-module, although some students still showed a relatively low level of improvement.

In addition to the t-test and N-Gain results, which demonstrate statistically significant improvements, a further analysis was conducted to determine the practical significance of the e-module's implementation. Therefore, an effect size calculation using Cohen's *d* formula was performed. The effect size analysis results are presented in Table 11 below.

Table 11. Cohen's *d* Effect Size Results

Statistic	Value
Mean Pre-test Score	53,18
Mean Post-test Score	68,72
Standard Deviation (Pre-test)	19,56
Standard Deviation (Post-test)	15,94
Pooled Standard Deviation	17,84
Cohen's d	0,88
Interpretation	Large Effect

To gain a deeper understanding of the practical impact of the developed e-module, an effect size analysis was conducted using Cohen's *d* formula. This statistical measure provides insight not only into the statistical significance of the improvement but also into its practical meaning in the educational context.

Based on the data presented in Table 6, the mean score before the intervention (pre-test) was 53.18 with a standard deviation of 19.56, while the mean score after the intervention (post-test) was 68.72 with a standard deviation of 15.94. The pooled standard deviation was calculated as follows:

$SD\_pooled = \sqrt{[(19{,}56^2 + 15{,}94^2) / 2]} \approx 17{,}84$
Cohen's $d = (68{,}72 - 53{,}18) / 17{,}84 \approx 0{,}88$

According to Cohen's classification (1988), a *d* value of 0.88 is categorized as a large effect. This indicates that the use of the e-module had a strong impact on improving students' cognitive learning outcomes in understanding milling machine components. This strengthens the conclusion that the e-module is not only statistically significant but also educationally meaningful in the context of technical and vocational education at the secondary level.

Dissemination Stage

At the final stage, the e-module—having been proven valid and effective—was finalized for broader dissemination. The PDF-format e-module was transformed into a more interactive and engaging version using the Canva Pro platform. To maximize accessibility and distribution, a unique QR Code was generated via Canva Pro, providing direct access to the e-module content.

Figure 3. Displays the QR Code linking to the *Milling Machine Components* e-module.

Research Limitations

This study has several limitations. First, the one-group pretest-posttest design does not allow for full control over external variables such as student motivation, teacher support, or access to technology. Second, the sample was drawn from a single school, limiting the generalizability of the findings. Third, the relatively short implementation period of the e-module was not sufficient to assess its long-term impact or students' knowledge retention. For future research, it is recommended to employ a quasi-experimental design with a control group and delayed post-tests to evaluate the sustained impact of learning.

Furthermore, the assessment in this study was limited to multiple-choice questions. The development of authentic assessments, such as project-based tasks or machine operation demonstrations, is recommended to enhance the evaluation of vocational learning outcomes.

CONCLUSIONS

Based on the findings and discussion regarding the use of the e-module on milling machine components, the following conclusions can be drawn:

1. This study aimed to develop and evaluate the effectiveness of a digital-based interactive e-module in improving vocational high school students' cognitive learning achievement on the topic of milling machine components.
2. The e-module was developed using the 4D development model (Define, Design, Develop, Disseminate) and was tested on 66 Grade X students majoring in Mechanical Engineering at SMK Negeri 5 Semarang using a one-group pretest-posttest design.
3. The e-module content includes technical material supported by 3D illustrations, visual simulations, interactive exercises, and self-evaluation activities, all designed based on cognitive learning theory and a constructivist approach through PBL and PjBL methods.
4. Validation of the e-module and evaluation instruments was conducted by six expert validators using the Aiken's V method, and all items were declared valid.
5. The pretest results showed an average cognitive score of 53.18, which increased to 68.72 in the posttest. The paired sample t-test showed a statistically significant difference, and the N-Gain score fell into the moderate-to-high category.
6. The effect size analysis using Cohen's *d* yielded a value of 0.88, which is categorized as a large effect, indicating that the e-module had a strong practical impact on improving students' cognitive learning outcomes.
7. The developed e-module proved effective in increasing students' engagement in understanding visual-spatial concepts, particularly in complex and abstract machining topics.
8. This study also supports the importance of utilizing interactive digital media in vocational education to facilitate self-directed, flexible, and contextual learning.
9. The limitations of this study include the absence of a control group, the lack of analysis on student subgroups, and the use of assessment limited to multiple-choice questions.
10. Future research is recommended to apply a quasi-experimental design with a control

group, develop authentic performance-based assessments, and analyze learning outcomes based on students' backgrounds or initial abilities.

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