



The Effectiveness of E-Modules Based on Cognitive Load Theory on Learning Outcomes and Cognitive Load of Vocational High School Students

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ARTICLE INFO

Article history:

Received: 09 April 2026

Accepted: 28 April 2026

Available Online: 05 May 2026

Keywords:

E-module,
Cognitive Load,
Learning Outcomes,
Vocational Education,
Instructional Design

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Article Doi:

<https://doi.org/10.31258/jes.10.5.p.587-600>

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ABSTRACT

The goal of this project is to create an e-module with cognitive load management in mind and assess how it affects vocational high school students' learning results. The study uses a pre-experimental experimental design of the one-shot case study type and a descriptive quantitative methodology. A cognitive load questionnaire was used to quantify intrinsic, extraneous, and relevant cognitive load, and a post-test was used to determine learning outcomes. A one-sample binomial test and the Shapiro Wilk normality test were used for data analysis. A binomial test with a significance threshold of 0.035 (<0.05) was employed since the results demonstrated that the data were not normally distributed, suggesting that the e-module design had an impact on student learning outcomes. According to descriptive analysis, the average student learning outcome of 83.33 is classified as "good." Furthermore, extraneous cognitive load fell into the "very low" category (mean = 1.70), intrinsic cognitive load into the "low" category (mean = 2.48), and germane cognitive burden into the "very high" category (mean = 3.44). In conclusion, the findings indicate that the e-module is associated with structured learning and favorable cognitive load conditions among students, but the results remain descriptive and cannot be interpreted as causal evidence.

1. Introduction

Vocational High Schools (SMK) play a crucial role in preparing graduates who are job-ready in accordance with industry needs. However, to date SMK graduates remain one of the main contributors to the relatively high unemployment rate. This indicates that the learning process has not yet been fully capable of developing competencies relevant to the world of work, particularly in terms of conceptual understanding and thinking skills. A number of previous studies have shown that instructional design plays a crucial role in enhancing student learning effectiveness.

Additionally, (Sweller, 2010), through Cognitive Load Theory, explain that managing cognitive load is crucial to the success of the learning process. Other studies also indicate that the use of e-modules can improve student learning outcomes when designed systematically and interactively. However, most studies still focus on learning outcomes without comprehensively considering the aspect of cognitive load.

Furthermore, the development of e-modules that specifically integrate the principles of Cognitive Load Theory remains limited, particularly in the context of vocational education. This indicates a research gap in the development of instructional materials that are not only effective but also efficient in managing students' cognitive load (Caeiro-Rodriguez et al., 2021). Based on this, this study aims to analyze the relationship between the use of Cognitive Load Theory-based e-modules and the learning outcomes and cognitive load of vocational high school students. Work competencies in vocational education in Indonesia are based on the Indonesian National Qualifications Framework (KKNI), which emphasizes the ability to work according to procedures as well as an understanding of the basic principles of work (Peraturan Presiden (Perpres) Nomor 8 Tahun 2012 Tentang Kerangka Kualifikasi Nasional Indonesia, 2012).

These competencies are not limited to technical proficiency but also encompass problem-solving skills and collaboration as part of work readiness (Elkhayma & Ezzaidi, 2024). Therefore, the learning process must be systematically designed to optimally develop students' cognitive abilities. An example of a key element in the learning process is instructional materials. Instructional modules that are systematically and structurally organized can help improve learning effectiveness and encourage active student engagement (Arinie & Azmah, 2025)

However, in practice, many modules still emphasize learning outcomes over the learning process, resulting in an imbalance in learning (Imrotin & Sari, 2022). With the advancement of technology, e-modules have emerged as interactive, flexible digital learning materials capable of supporting students' independent learning (Rahma et al., 2020). Various studies have shown that e-modules can optimize student learning outcomes, but the majority of studies still focus on product feasibility and the achievement of cognitive learning outcomes, without considering how the student learning process takes place (Erawati et al., 2022). In digital learning, instructional material design plays a crucial role in determining the effectiveness of learning. Unstructured material design that does not align with students' learning characteristics has the potential to create irrelevant cognitive load, thereby hindering student understanding (Skulmowski & Xu, 2022). In this context, Cognitive Load Theory emphasizes that the learning process will be more optimal if cognitive load is managed effectively by reducing extraneous cognitive load, regulating intrinsic cognitive load, and enhancing germane cognitive load.

Proper management of cognitive load can support the more efficient utilization of students' cognitive capacities in understanding the material. Additionally, cognitive load management contributes to students' active engagement in the learning process, which is linked to their self-regulated learning abilities in managing

cognitive and metacognitive strategies during instruction (Azevedo et al., 2022). This is reinforced by the concept of "assessment as learning," which emphasizes assessments that encompass learning stages that encourage reflection and active student engagement (Andrade & Brookhart, 2020). Although some studies have demonstrated that e-modules can optimize student learning outcomes, the majority of studies still focus on product feasibility and cognitive achievements without deeply examining the student learning process. Furthermore, research linking digital instructional design to the management of students' cognitive load remains limited, particularly in analyzing the three main components of cognitive load intrinsic, extraneous, and germane in an integrated manner. In other words, few studies have comprehensively linked the design of digital instructional materials to the distribution of cognitive load and its implications for student learning outcomes.

Given this gap, this study is important to conduct in order to examine in greater depth the impact of the relationship between the design of e-modules based on Cognitive Load Theory and student learning outcomes as well as cognitive load, because in practice it is still found that many digital learning materials have not been optimally designed to manage students' cognitive capacity, thereby potentially causing excessive cognitive load that actually hinders the learning process.

Therefore, the analysis in this study is focused on learning outcomes as the final indicator, as well as on the distribution of intrinsic cognitive load, extraneous cognitive load, and germane cognitive load as a representation of students' cognitive activities during the learning process. Thus, the aim of this study is to develop a Cognitive Load Theory based e-module and examine its impact on vocational high school students' learning outcomes and cognitive load. Furthermore, the results of this study are expected to serve as a foundation for the development of digital instructional materials that are more adaptive, efficient, and aligned with students' cognitive characteristics, thereby enhancing overall learning quality and supporting more effective and sustainable educational goals.

2. Methodology

This study employs a descriptive quantitative approach using a quasi experimental design (pre-experimental design) of the one-shot case study type. This design was used to obtain an initial overview of students' learning outcomes and cognitive load following the use of the e-module. The research subjects consisted of 33 11th-grade students at a vocational high school in Purwakarta Regency. The research instruments included a learning outcome test (post-test) and a cognitive load questionnaire covering intrinsic, extraneous, and germane cognitive load.

Data analysis was conducted using the Shapiro Wilk normality test and the one sample binomial test. Questionnaire data were analyzed descriptively to determine the categories of cognitive load. A limitation of this study is the absence of a control group; therefore, the results cannot be used to draw causal conclusions but only to indicate trends. It should be noted that the one-shot case study design does not use a control group; therefore, the results of this study cannot be fully used to draw

causal conclusions but are limited to showing trends or indications of a relationship between the use of e-modules and student learning outcomes. The one-shot case study design used in this study is presented in Table 1.

Table 1. Research Design

Group	Treatment	Observation
11th-grade students at Vocational High School	X	O

Description:

X = Implementation of e-modules

O = Post-test and cognitive load questionnaire

To observe trends in student learning outcomes after the implementation of the e-module design, a hypothesis test was conducted, formulated as follows:

H₀: The e-module design does not show a trend in student learning achievement at above the Minimum Passing Grade (MPG).

H₁: The e-module design shows a trend in student learning achievement above the Minimum Passing Grade (MPG).

The subjects of this study were 33 students from a sample of 11th-grade classes at a Vocational High School (SMK) located in Purwakarta Regency. The sample was selected using purposive sampling based on considerations of class availability and relevance to the learning implementation using the developed e-module, and was confirmed in coordination with the subject teacher. After determining the study subjects, the research procedures were carried out. A summary of the research procedures is shown in Figure 1.

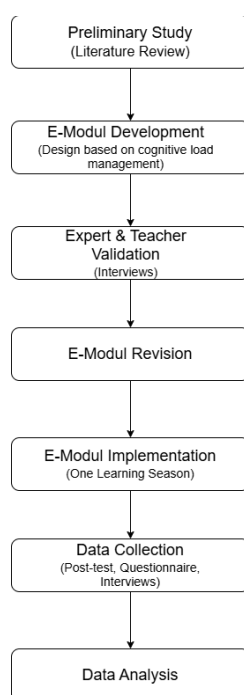


Figure 1. Research Implementation Stages

This study began with a preliminary study involving a literature review aimed at identifying issues in the development of e-modules compared to previous research, particularly regarding instructional design that has not yet addressed the management of students' cognitive load and has not been optimal in facilitating active and meaningful student learning. Subsequently, based on the results of the preliminary study, an e-module was developed that was designed with consideration for cognitive load and to support the student learning process. The learning outcome scores were then interpreted using the learning outcome category intervals as presented in Table 2.

Table 2. Interpretation Intervals for Student Learning Outcomes

No	Score Range	Category
1	86 – 100	Excellent
2	71 – 85	Good
3	56 – 70	Fair
4	≤55	Insufficient

(Peraturan Menteri Pendidikan Dan Kebudayaan Nomor 3 Tahun 2017, 2017).

Furthermore, data on students' perceptions of cognitive load during learning were collected via a questionnaire. The questionnaire was designed based on the cognitive load theory instrument developed by (Krieglstein et al., 2023), which measures three dimensions of cognitive load: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. This instrument was adapted by adjusting the language and learning context without altering the original construct's meaning. It has been tested in previous research and revalidated through expert judgment to ensure alignment with the study's context. The questionnaire consists of 15 items (5 items per dimension) and was distributed via Google Forms. The questionnaire uses a four-point Likert scale with scores ranging from 1 = strongly disagree to 4 = strongly agree. Scores for each dimension were calculated by averaging to obtain the mean cognitive load score for students, which was then interpreted using cognitive load categories with a score range of 1.00–4.00, as shown in the following table 3.

Table 3. Interpretation Intervals for Cognitive

Load Scores	Category
1.00 – 1.75	Very Low
1.76 – 2.50	Low
2.51 – 3.25	High
3.26 – 4.00	Very High

In addition to supplementing this quantitative data, interviews were conducted with 5 students to gain a deeper understanding of the students' learning experiences using the improved e-module. This interview data will be used to support the discussion of the results. Data analysis was performed using descriptive and inferential statistics. A normality test was performed using the Shapiro Wilk test to understand the data distribution. Since the data were not normally distributed, a one-sample binomial test was used. This test was chosen because the analysis focused on the proportion of students who achieved a score exceeding the Minimum

Passing Grade (MPG) of 75, which refers to the standard used by the school where the study was conducted.

3. Results and Discussion

Result

The study was conducted in one class consisting of 33 students of vocational high school level. The participants were enrolled in the selected class based on coordination with the subject teacher and the suitability of the learning schedule. The class consisted of male and female students with relatively diverse academic abilities based on the teacher's initial information. During regular classroom instruction, students commonly received learning materials through teacher explanations, and presentation slides. Most learning activities were still teacher-centered, with students relying on explanations delivered during class sessions. As a result, students had limited opportunities to study the material independently outside the classroom. This condition made the class relevant for examining the initial implementation of an e-module developed as a supplementary learning medium for classroom and independent study.

Based on preliminary communication with the teacher, students had previously used smartphones for learning activities, but the use of structured digital teaching materials was still limited. Most students were familiar with accessing online information, but they had never previously used interactive e-modules in classroom learning. Internet access and basic digital devices were generally available, although differences in device performance among students were still found. The selected class was considered appropriate because students had sufficient basic digital literacy and were willing to participate in the study. Therefore, the classroom context provided an opportunity to obtain an initial description of how students responded to e-module-based learning designed according to cognitive load management principles.

The learning implementation began with an introductory session in which the teacher explained the learning objectives, the topic to be studied, and the procedures for using the e-module. Students were informed that the learning activity would use digital teaching materials containing explanations, examples, guided exercises, and evaluation tasks. At this stage, students were also given directions regarding the completion of the post-test, questionnaire, and interview activities after the learning session. This initial orientation was intended to ensure that students understood the flow of the learning process and could use the e-module properly.

After the introduction stage, students accessed the e-module individually using their available devices. The e-module presented learning materials in sequential sections, beginning with basic concepts and continuing to more applied examples. Important information was highlighted using headings, icons, and visual cues to help students focus on relevant content. The presentation of the material was divided into manageable sections so that students could study step by step. This learning

arrangement was intended to provide a more organized learning experience and to avoid excessive information load during the session. The appearance of the e-module used in this study is presented in the following figures.



Figure 1. Cover Page



Figure 3. Material Page



Figure 4. Evaluation Page

During the core learning activities, students were given time to read the material, observe examples, and carry out the practical steps provided in the e-module. The teacher acted as a facilitator by answering questions, clarifying misconceptions, and guiding students who encountered difficulties. Several students were observed discussing the material with peers while continuing to work through the module content. This indicates that the learning process involved both individual engagement and limited collaborative interaction. The use of the e-module allowed students to revisit previous sections whenever they needed additional clarification.

At the end of the learning session, students completed a post-test to provide an initial description of learning outcomes after using the e-module. In addition, students responded to a cognitive load questionnaire covering intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. These data were collected immediately after learning to capture students' responses while the

experience was still recent. The questionnaire results were then processed descriptively to identify the tendency of students' cognitive load during the implementation. Meanwhile, the post-test results were analyzed to examine students' achievement after participating in e-module-based learning. The collected data were then used as the basis for presenting the research findings in the following section.

To complement the quantitative findings, several students were interviewed after the learning activity. The interviews explored students' perceptions regarding the clarity of the material, ease of navigation, attractiveness of the design, and perceived usefulness of the e-module. Students were also asked whether the module helped them understand the topic more independently. These qualitative responses were used as supporting information to enrich the interpretation of the quantitative data and to provide preliminary evidence regarding students' learning experiences. The interview findings were used to provide additional insight into how students experienced the learning process and responded to the use of the e-module during the implementation.

Following the implementation of the e-module, data on student learning outcomes were collected to obtain an initial description of students' achievement after participating in the learning session. The data were gathered through a post-test administered at the end of the lesson. The post-test aimed to identify the extent to which students were able to understand the material presented through the e-module. The results were then processed using descriptive and inferential statistical analysis. These analyses were conducted to identify the general pattern of student performance after the learning activity. A summary of the student learning outcomes is presented in Table 4.

Table 4. Summary of Learning Outcomes

Statistical test	Indicator/Statistic	Result
Normality Test	Shapiro Wilk (Sig.)	0,000
Binomial Test	Proporsi nilai > MPG (75)	23 dari 33 siswa (70%)
	Exact Sig. (2-tailed)	0,035
	Mean	83,33
Statistic Descriptive	Median	90,00
	Minimum - Maximum	45-100
	Standard deviation	17,883

Based on Table 4, the significance value of the Shapiro Wilk normality test, is 0.000 (<0.05), indicating that the data were not normally distributed. The results of the binomial test show a significance value of 0.035 (<0.05), with 23 out of 33 students (70%) achieving scores above the passing grade. Based on these findings, H_0 is rejected and H_1 is accepted, indicating a tendency for students' learning outcomes to exceed the passing score following the implementation of the e-module design. Descriptively, the mean of students' learning outcomes is 83.33 with a median of 90.00.

After obtaining an overview of student learning outcomes, data was also collected to examine students' cognitive load, during the implementation of the e-module. These data were gathered through a questionnaire administered after the learning session was completed. The questionnaire was intended to identify students' perceptions related to intrinsic cognitive load, extraneous cognitive load, and germane cognitive load experienced during the learning process. The collected responses were then processed descriptively to determine the general tendency of students' cognitive load while using the e-module. This analysis was considered important to complement the learning outcomes data by providing information about students' cognitive experiences during instruction. The results of the cognitive load analysis are presented in Table 5.

Table 5. Results of the Analysis of Students' Cognitive Load

Variable	N	Minimum	Maximum	Mean	Category
Intrinsic Cognitive Load	33	1.20	3.20	2.4848	Low
Extraneous Cognitive Load	33	1.00	4.00	1.7030	Very Low
Germane Cognitive Load	33	1.40	4.00	3.4485	Very High

Based on Table 5, the average extraneous cognitive load score was 1.70, which falls into the very low category. The average intrinsic cognitive load score was 2.48, categorized as low. Meanwhile, the average germane cognitive load score was 3.44, categorized as very high. These findings indicate a descriptive tendency that students experienced relatively low irrelevant cognitive load while showing high cognitive engagement during learning with the e-module. This condition shows that students tended to be more engaged in learning activities related to the instructional materials. In addition, the results describe a general tendency of students' cognitive engagement during the learning process using the e-module.

Interview results showed generally positive responses toward the use of the e-module. Several students stated that the material was easier to follow because it was presented gradually and supported by clear explanations. For example, one student mentioned that "the material in the e-module is easier to understand because it is explained step by step." Students also reported that they could study more independently by revisiting previous sections when needed. In addition, some students mentioned that the digital format made the learning process more practical and easier to access through their personal devices. The structured presentation of the material helped students remain focused during the learning session.

Discussion

The research results show that the average student learning outcome reached 83.33, with the majority of students scoring above the Minimum Passing Grade (MPG). Additionally, the extraneous cognitive load was in the very low category, the intrinsic cognitive load in the low category, and the germane cognitive load in the very high category. These findings indicate a descriptive tendency that students

achieved relatively high learning outcomes and experienced lower levels of irrelevant cognitive load during the learning process. Similar outcomes regarding module implementation were also reported by (Hafni et al., 2025), who found that a problem-based physics e-module was associated with improved student motivation and learning outcomes. Similar findings were also reported by (Maisaroh et al., 2025), who developed a multiple representation-based physics module that improved students' conceptual understanding and scientific attitudes.

Theoretically, these findings are consistent with cognitive load theory, which suggests that learning may be more effective when irrelevant cognitive load (extraneous load) is minimized and learning-supportive cognitive load (germane load) is optimized. The relatively low extraneous load observed in this study may indicate that the e-module design did not impose excessive unnecessary information on students. In line with this, (Suarmita et al., 2025) reported that multimedia-based interactive modules were associated with increased student learning independence, indicating that organized digital modules may support more structured learning experiences.

These research results align with the multimedia learning theory proposed by (Mayer, 2009), which emphasizes that structured multimedia-based learning designs aligned with cognitive principles can significantly enhance student understanding. These principles include reducing irrelevant information, presenting material in segmented segments, and utilizing visual elements that support students' thinking processes. A related finding was reported by (Safitri & Andromeda, 2025), who developed an e-module integrating Problem Based Learning and STEAM elements, highlighting the importance of systematic and interactive material presentation.

Furthermore, these findings are supported by research by (Plass et al., 2010), which demonstrates that managing cognitive load in multimedia learning directly influences improved learning outcomes. This study indicates that learning may become more effective when extraneous cognitive load is minimized and germane cognitive load is maximized through appropriate instructional design. In line with this, (Hasibuan et al., 2025) found that interactive e-modules based on Kvisoft Flipbook were positively associated with student learning outcomes, particularly when the materials were presented in an interactive and structured format.

Overall, the findings of this study should be interpreted as preliminary descriptive evidence rather than evidence of effectiveness, because the study was conducted using a one-shot case study design. This design only allows the researcher to describe students' learning outcomes and cognitive load after the implementation of the e-module, without providing a basis for comparison with initial conditions or alternative learning approaches. The absence of pretest and control group data limits the ability to determine whether changes in learning outcomes can be attributed directly to the use of the e-module. Therefore, causal conclusions regarding the impact of the e-module cannot be established from this study design, and the results should be understood as an initial overview of student learning conditions in the given instructional context.

The study's findings also indicate that extraneous cognitive load is very low. This suggests that the e-module design can reduce irrelevant cognitive load throughout the learning process. These findings align with studies by (Candido & Cattaneo, 2025) and (Surbakti et al., 2024), which indicate that structured digital learning designs can reduce irrelevant cognitive load. Additionally, a study by (Lolang et al., 2023) also found that technology-based learning media with controlled information presentation can minimize extraneous cognitive load. Similar results were reported by (Hanis et al., 2025), this study's findings indicate that content design that minimizes cognitive load can maximize the effectiveness of public learning initiatives, thereby reducing unnecessary cognitive load on the audience. Thus, the application of signaling and segmenting techniques can serve as effective strategies for reducing unnecessary cognitive load on the audience during the digital learning process. (Sailer et al., 2023) also explain that the systematic application of visual design principles in multimedia environments is effective in reducing cognitive load and optimizing information processing efficiency.

However, the interpretation of the binomial test results is limited because it only describes the proportion of students who achieved scores above the passing grade. It does not measure individual learning improvement or learning gain over time. Since no pretest was conducted, changes in student performance cannot be statistically determined. In addition, the absence of a control group reduces the ability to compare learning outcomes with other instructional conditions, which limits the internal validity of the findings. Interview findings provide additional contextual information supporting the quantitative results. Students reported that the e-module helped them follow the material step by step, revisit explanations when needed, and learn more independently. These responses are consistent with the descriptive findings of relatively low extraneous cognitive load and high germane cognitive load, although these perceptions remain subjective and cannot be generalized without further verification.

Although the findings show positive tendencies, they should be interpreted carefully due to methodological limitations. The one-shot case study design limits causal inference, and the absence of pretest-posttest comparison restricts the ability to determine learning improvement. Therefore, the findings should be positioned as preliminary evidence describing students' learning conditions and cognitive load during the implementation of the e-module. Overall, this study provides preliminary evidence that e-modules designed based on Cognitive Load Theory have potential relevance in supporting learning processes in vocational high school contexts. Future research is recommended to employ experimental or quasi-experimental designs with control groups and larger samples to allow stronger evaluation of effectiveness.

4. Conclusion

This study aimed to describe students' learning outcomes and cognitive load after the implementation of an e-module based on Cognitive Load Theory. The findings indicate that the e-module was used within a structured learning process and helped

students understand the learning materials during classroom activities. In addition, students showed a tendency to follow the learning sequence more independently through the use of the e-module. This suggests that the e-module provides a more guided learning experience in the vocational high school context. However, these findings are still at a preliminary descriptive level because they are based on post-implementation conditions. Therefore, the results cannot be used to draw causal conclusions regarding the impact of the e-module. Overall, the results indicate a tendency that the e-module based on Cognitive Load Theory can be considered as an alternative learning medium that supports students' learning process. However, since this study used a one-shot case study design without a control group or pretest, the findings cannot be interpreted as evidence of cause-and-effect relationships. Thus, the results remain descriptive in nature and require further investigation to obtain stronger evidence. Future research is recommended to apply experimental or quasi-experimental designs with control groups and pretest-posttest measurements. This is necessary to provide a more comprehensive understanding of the impact of e-modules on students' learning processes and outcomes.

Acknowledgement

The authors would like to express their sincere gratitude to the school, teachers, and students who participated in this study for their cooperation and support. Special thanks are also extended to all parties who contributed to the implementation of this research. The authors also appreciate the guidance and support provided by the lecturers of the Information System and Technology Education Study Program, Universitas Pendidikan Indonesia, in completing this research.

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How to cite this article:

Sari, F. K., Hikmawan, R., & Setiawan, A. (2026). The Effectiveness of E-Modules Based on Cognitive Load Theory on Learning Outcomes and Cognitive Load of Vocational High School Students. *Journal of Educational Sciences*, 10(5), 587-600.
