

Meta-Analysis: The Effect of E-Module Learning Media on Biology Materials on Learning Outcomes of High School Student

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ABSTRACT

This research investigates the effectiveness of e-module learning media on high school students' biology learning outcomes through a comprehensive meta-analysis. By synthesizing data from 20 empirical studies, Cohen's *d* was used to calculate effect sizes and evaluate the impact of e-modules on students' academic performance. The selected studies met specific criteria, including being published between 2020 and 2024, employing experimental or quasi-experimental designs, and focusing on high school biology learning outcomes. The analysis revealed that most studies reported large to very large effect sizes, with values reaching up to 6.10, indicating a substantial positive influence of e-modules on students' cognitive achievement. Furthermore, various types of e-modules—such as those based on scientific literacy, POEI (Predict-Observe-Explain-Interpret), problem-based learning, and COVID-19-contextualized content—were shown to enhance independent learning, critical thinking, and adaptability within digital learning environments. These findings suggest that e-modules are a promising and impactful innovation for 21st-century biology education, offering considerable potential to support student-centered and technology-integrated instructional practices.

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Introduction

The advancement of information and communication technology has had a significant impact on education, particularly on school learning processes (Azis et al., 2024). One of the rapidly growing innovations is the use of digital learning media, such as e-modules (Zhang et al., 2022). E-modules are digital-based learning resources accessible through electronic devices such as computers, tablets, or smartphones, enabling students to learn independently, interactively, and flexibly (Sumatraputra et al., 2023).

Beyond examining the overall effectiveness of e-modules, it is also important to consider the supporting factors that contribute to teaching and learning, one of which is the role of teaching materials. Teaching materials are a crucial component of the learning process, as they form the foundation of instructional activities. They encompass all forms of resources used to assist teachers in delivering lessons, whether written or unwritten (Wulandari et al., 2023). In the 2013 Curriculum, learning emphasizes a student-centered approach, requiring students to actively seek solutions and study independently through media such as modules (Rachmawati & Rosy, 2021). To enhance engagement and learning effectiveness, printed modules often considered monotonous are now being transformed into interactive e-modules enriched with images, animations, audio, and video. This shift aligns with technological developments and the habits of high school students who are already familiar with digital devices (Sidiq & Najuah, 2020).

In biology learning at the senior high school (SMA) level, complex and abstract concepts often pose challenges for students (Andriani, 2023). The use of digital media such as e-modules offers a promising alternative to improve comprehension and learning outcomes (Sabrina, 2023). Previous studies have examined the effectiveness of e-modules in biology education; however, their findings are inconsistent. Some report very high effectiveness, with effect sizes above 2.0, while others indicate negligible or small effects (Miharja & Juniawan, 2020; Sari et al., 2025). This inconsistency underscores a research gap and highlights the need for systematic quantitative synthesis through meta-analysis.

The urgency of this research is further supported by the increasing adoption of digital learning in Indonesia. A recent survey by the Ministry of Education and Culture (Kemendikbud, 2023) found that more than 75% of high schools have

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integrated digital learning media, yet only about 40% of biology teachers reported confidence in the effectiveness of e-modules. This gap between adoption and perceived effectiveness further emphasizes the importance of conducting a comprehensive evaluation.

Therefore, this study aims to conduct a meta-analysis to examine the impact of e-module learning media on high school students' biology learning outcomes. The findings are expected to contribute significantly to the development of effective learning media and provide evidence-based support for decision-making in educational practice. To achieve these objectives, this study systematically identified, selected, and analyzed empirical research articles that met specific criteria. The extracted data included the number of students in the experimental (Ne) and control (Nc) groups, the mean scores of both groups (Xe and Xc), and their respective standard deviations (Sde and Sdc). Based on these data, effect size calculations were conducted to determine the magnitude of the impact of e-modules on biology learning outcomes. This approach is expected to provide an objective and measurable understanding of e-module effectiveness while also identifying factors that may influence variations in student performance.

Methods

This study employed a meta-analysis approach, which involves summarizing, reviewing, and analyzing data from previous research. In simple terms, meta-analysis can be understood as a quantitative review of published studies with similar characteristics. This method allows researchers to systematically synthesize findings and assess the overall magnitude of an intervention's effect.

The main sources of data in this study were articles published in scientific journals. Data collection was conducted through electronic searches using platforms such as Google Scholar and other journal databases. The keywords applied included: learning media, e-modules for students, e-modules and learning outcomes, high school biology materials, problem-based learning, learning motivation, and elementary schools. From the initial search results, 30 articles relevant to the research topic were identified, of which 25 were deemed the most suitable for further analysis (Wahyuningtyas & Kristin, 2021).

Data Analysis

Effect size calculations were conducted using Cohen's d, a common measure in meta-analysis for quantifying the magnitude of differences between groups. The formula is as follows :

$$d = \frac{M_2 - M_1}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}} \dots\dots\dots (1)$$

Description:

d = effect size / magnitude of effect

M1 = average pretest score

M2 = average posttest score

SD1 = standard deviation pretest

SD2 = standard deviation posttest

Results and Discussions

Based on the literature review, 20 articles were obtained for comparison and meta-analysis. To gain a deeper understanding of the impact of the intervention across different paired comparisons, an effect size analysis was conducted using Cohen's d. This statistical measure provides insight into the magnitude of differences observed, independent of sample size. Interpreting effect sizes allows researchers to assess not only whether changes are statistically significant but also whether they are practically meaningful. Table 1 summarizes the calculated effect sizes for each pair, along with their interpretations based on commonly accepted thresholds.

Table 1 presents the effect sizes (Cohen's d) for each paired comparison. The interpretation follows Cohen's (1988) guidelines, where values around 0.2 indicate a small effect, 0.5 a medium effect, and 0.8 or above a large effect. Some values exceed 2.0, indicating very large or even extreme effect sizes. The findings show considerable variability across studies. For example, Sari et al. reported negligible effects (d = 0.013), while Agung et al. (2021), found extremely large effects (d = 6.10). This wide range suggests heterogeneity in how e-modules influence learning, depending on their design, implementation, and context.

Table 1. Effect size of the Use of e-module Learning Media on Learning Outcomes

Author	Effect Size (d)	Interpretation
Mulyaningsih & Mubarak (2020)	0.575	Medium
Sari & Ahmad (2025)	0.013	Negligible
Wahyuningsih & Kristin (2021)	0.956	Large
Lativa, et al. (2024)	2.897	Very Large
Khafah, et al. (2023)	0.540	Medium
Safitri, et al. (2024)	4.25	Very Large
Rawat, et al. (2023)	1.236	Large
Maglinte, et al. (2023)	1.454	Large
Abuarab, et al. (2024)	1.505	Large
Wulandari, et al. (2023)	1.085	Large
Alfatia, et al. (2025)	2.13	Very Large
Winarko, et al. (2013)	0.80	Large
Marjanah, et al. (2024)	1.93	Very Large
Ramadani, et al. (2023)	5.11	Very Large
Purnamasari, et al. (2024)	0.86	Large
Fatmawati, et al. (2024)	1.35	Large
Miharja & Juniawan (2020)	0.19	Small
Hartati, et al. (2022)	1.88	Very Large
Safitri, et al. (2024)	1.79	Very Large
Agung, et al. (2021)	6.10	Very Large

This collection of studies consistently demonstrates the effectiveness of electronic modules (e-modules) in enhancing biology and science learning across various contexts. For instance, the application of science literacy-based e-modules in Langsa significantly improved students' mastery of the immune system, as reflected in the increase in average post-test scores from 35.44 to 78.08 (Safitri et al., 2024). Similarly, a problem-based e-module implemented at SMA Negeri 3 Pematangsiantar showed positive effects on both student activity and learning outcomes, with the average score reaching 63.20 (Silaban & Siagian, 2024).

Further evidence comes from the development of POEI-based e-modules (Prediction, Observation, Experimentation, and Interpretation) for sensory system material, where students in the experimental class achieved higher post-test scores (81.4) compared to the control group (73.0), confirming the effectiveness of the POEI approach in improving cognitive outcomes (Winarko et al., 2013). Likewise, e-modules integrating COVID-19 content on viral material were validated as practical and effective, particularly in online learning settings, with the experimental group achieving an N-gain score of 0.53 compared to 0.26 in the control group (Zukmadini et al., 2022).

Other studies highlight the role of interactivity and representation in e-modules. For example, interactive e-modules for Grade X students yielded an N-gain of 0.456 compared to 0.176 in the control group, contributing to a 30.8% improvement in learning outcomes (Wulandari et al., 2020). Similarly, multiple-representation e-modules on fungi material produced an N-gain of 0.56 and significantly improved students' written communication skills (Mulyaningsih & Mubarak, 2022).

In chemistry learning, problem-based learning (PBL) supported by e-modules enhanced 11th-grade vocational students' understanding of acid-base topics, with significant improvements confirmed by the Wilcoxon test (Sari & Ahmad, 2025). Meanwhile, an e-module on ecosystems and water pollution significantly improved cognitive skills, although it did not substantially influence students' environmental attitudes (Wahyuningsih et al., 2021). At the higher education level, a Google Sites-based e-module on plant diversity achieved high validity and practicality scores and significantly enhanced students' creative thinking, with an N-gain of 0.7338 (Lativa et al., 2024).

Critical thinking also benefited from e-modules, as demonstrated by the use of project-based learning (PjBL) e-modules, which produced significantly higher post-test scores compared to the control group (Khafah et al., 2023). Likewise, multimedia-integrated e-modules on the human excretory system improved students' analytical skills, with a gain value of 0.62 and statistically significant results (Miharja & Juniawan, 2020). However, Hartati (2022) reported that although interactive e-modules substantially improved learning outcomes, their effect on motivation was minimal, suggesting that their primary strength lies in fostering cognitive understanding.

Recent studies also explore the integration of curriculum innovations. For example, P5-loaded e-modules on Biological Technology Innovation received high validation and student response scores, indicating strong feasibility for wider implementation in supporting the Merdeka Curriculum (Alfatia et al., 2025). Similarly, STEM-PjBL e-modules oriented to character education were validated as highly effective, practical, and impactful, achieving an N-gain of 0.74 and a student completeness rate of 98.53% (Agung et al., 2021).

Overall, these findings suggest that e-modules whether designed with science literacy, PBL, POEI, multimedia integration, or curriculum innovations consistently improve cognitive outcomes, while their influence on affective aspects such as motivation and attitudes varies depending on the context and instructional design.

Conclusions

Based on the meta-analysis of 20 selected articles, it can be concluded that the use of e-module learning media in high school biology significantly enhances student learning outcomes. Most studies reported effect sizes in the large to very large categories, indicating that e-modules are effective in improving students' cognitive understanding. Additionally, e-modules support independent learning, foster critical thinking skills, and align with the demands of 21st-century education. Therefore, e-modules are considered a viable and impactful innovation in learning media that should be further developed and widely implemented in biology education within the digital learning context.

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