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The effect of e-modules on physics learning in senior high school: A meta-analysis

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ABSTRACT

This study aims to investigate the impact of using e-modules in physics education on senior high school through a meta-analysis. The method used is quantitative meta-analysis to evaluate the effectiveness of e-modules in the context of physics learning. Out of 995 papers screened, 15 articles were selected for further analysis. The results show that e-modules are significantly more effective than traditional learning, with an effect size of d = 18.45, Z = 5.79 (P < 0.00001). Subgroup analysis revealed that the effectiveness of e-modules varies based on learning dimensions, teaching models, and the physics topics being taught. Thus, e-modules significantly positively impact various aspects of student learning, including creative thinking, critical thinking, learning outcomes, science process skills, conceptual understanding, and science literacy. This study highlights the potential of e-modules to enhance physics learning. However, some data limitations exist in certain dimensions, such as creative thinking, science process skills, conceptual understanding, and science literacy.

Pengaruh e-modul terhadap pembelajaran fisika di sekolah menengah atas: Sebuah meta-analisis

Kata Kunci:

e-modul, hasil belajar, meta-analisis, pendidikan fisika, sekolah menengah atas

ABSTRAK

Studi ini bertujuan untuk meneliti dampak penggunaan e-modul dalam pembelajaran fisika di sekolah menengah atas melalui meta-analisis. Metode yang digunakan adalah meta-analisis kuantitatif untuk mengevaluasi efektivitas e-modul dalam konteks pembelajaran fisika. Dari 995 makalah yang disaring, 15 artikel dipilih untuk dianalisis lebih lanjut. Hasil penelitian menunjukkan bahwa e-modul secara signifikan lebih efektif dibandingkan dengan pembelajaran tradisional, dengan nilai efek d = 18,45, Z = 5,79 (P < 0,00001). Analisis sub-kelompok mengungkapkan bahwa efektivitas e-modul bervariasi berdasarkan dimensi pembelajaran, model pembelajaran, serta materi fisika yang diajarkan. Dengan demikian, e-modul memiliki dampak positif yang signifikan pada berbagai aspek pembelajaran siswa, termasuk pengembangan berpikir kreatif, berpikir kritis, hasil belajar, keterampilan proses sains, pemahaman konsep, dan literasi sains. Penelitian ini memberikan implikasi penting dalam menyoroti potensi e-modul sebagai alat untuk meningkatkan pembelajaran fisika, meskipun terdapat keterbatasan data pada beberapa dimensi seperti berpikir kreatif, keterampilan proses sains, pemahaman konsep, dan literasi sains.

Contribution to the literature

This research contributes to:

- Providing a quantitative synthesis of the impact of e-modules on physics learning in senior high schools through a meta-analysis of 15 relevant studies.
- Highlighting the effectiveness of e-modules in enhancing various learning outcomes, such as critical thinking, problem-solving, conceptual understanding, and science literacy.
- This paper offers insights into the conditions under which e-modules are most effective, thereby advancing the understanding of digital tools in physics education.

1. INTRODUCTION

In the era of advanced globalization, education plays a central role in forming qualified, competent, and insightful individuals [1]–[3]. Education is a necessity and an essential investment capable of producing a generation that can compete and adapt on a changing world stage [4]–[6]. In physics education, the material is significantly relevant to daily human activities [7], [8]. Before formal education, learners develop an initial understanding of the physical world through everyday interactions [9]. However, this abundance of experience can lead to misconceptions, highlighting the importance of emphasizing the active role of learners in the physics learning process [10]. Physics learning should ideally create an environment that supports learners' understanding of concepts and scientific processes [11], [12]. Therefore, it is essential to take a holistic approach to learners' prior experiences and emphasize active participation and concept understanding to overcome the challenges of physics learning [13].

In education implementation, success and overcoming challenges in the learning process can be achieved through several components, including teaching materials [14]. Digital technology has emerged as a transformational force in education, improving the quality of learning [15]–[19]. Technological developments not only change the way students access information but also transform the learning process itself [11], [20], [21]. Technology can enhance the teaching and learning process, improve student self-regulation and self-efficacy, and increase participation and engagement [22]. For instance, electronic books and other technologies can update teaching materials, making them more dynamic and relevant to contemporary demands [23], [24]. Teaching materials are a crucial element that supports and shapes the learning experience [25], [26].

Technological transformation has impacted the concept of learning resources beyond just teaching materials [27]. Previously, learning resources were limited to physical libraries and teachers [28]. However, with the advent of the internet, access to learning resources has expanded to the virtual world [29]. The use of learning resources has evolved from conventional printed modules to electronic modules or e-modules [30]–[32]. This transition aims to increase accessibility and demonstrates a commitment to the sustainability of education in the digital era [23], [33]–[35]. The implementation of e-modules not only considers environmental sustainability but also provides benefits in terms of ease of access [36]. Students can access learning materials flexibly, overcoming time and space constraints [37]. The evolution from printed modules to e-modules is a response to the demands of the times and creates a new dimension in learning resources. It answers the challenges and dynamics of learning in the contemporary era [36], [38].

The rapid expansion of e-module use in science education highlights a pressing need to understand their impact on critical thinking, creativity, and learning outcomes. In an era where digital learning is pivotal, fostering critical thinking and creativity is essential, particularly within science education, which requires complex problem-solving and deep conceptual understanding. While e-modules offer significant potential for developing these skills, comprehensive empirical evidence remains limited. Therefore, this meta-analysis is crucial in systematically examining the effects of e-modules on these key competencies, providing educators with a clearer framework for employing e-modules as an effective learning tool.

Numerous studies underscore the influence of e-modules on critical thinking, creativity, and learning outcomes. Asrizal *et al.* [22] conducted a meta-analysis of 20 articles, showing that e-modules significantly enhance students' critical and creative thinking skills across different educational levels (junior high school, high school, and college) and subjects (Physics, Chemistry, Biology). This analysis confirms the high efficacy of e-modules in promoting essential cognitive skills in science education. Additionally, Hadianto and Festiyed [21] examined ten articles, demonstrating that e-modules based on research-driven learning methods significantly improve learning outcomes compared to conventional methods. Similarly, Liana and Indrowati [23] analyzed ten articles, revealing that e-modules are practical tools that effectively support the learning process.

Despite these findings, research on e-modules has yet to fully explore diverse approaches and their specific impact on physics learning outcomes. Meta-analysis of the influence of e-modules on thinking skills [38], meta-analysis of the use of e-modules based on research-based learning models [36], and meta-analysis of the ease of use of e-modules in learning [39] underscore the benefits of e-modules in enhancing critical thinking, creativity, and overall learning effectiveness. However, a notable gap remains in understanding the specific contributions of e-modules within physics education, particularly regarding how different instructional approaches within e-modules influence complex problem-solving, conceptual understanding, and the application of critical and creative thinking skills in physics contexts. This indicates the need for further investigation to clarify these unique impacts and to provide a more targeted framework for integrating e-modules effectively in physics education.

This study aims to examine the effectiveness of e-modules in enhancing student performance in senior high school physics learning by identifying and analyzing the variables that influence their impact. Given the rapid integration of e-modules in education, understanding their general effectiveness and the specific factors, such as instructional approaches, content design, and interactivity levels, that affect their success in fostering learning outcomes is crucial. By focusing on these aspects, this study addresses a key gap in the literature: the lack of comprehensive insight into what makes e-modules effective for physics education specifically, as previous studies primarily focus on general content development without considering how these variables impact learning outcomes in a physics context.

To address this, the meta-analysis approach in this study systematically examines the overall impact of e-modules and the underlying factors that may enhance or limit their effectiveness in physics education. This approach provides valuable insights for educators and researchers by offering a targeted analysis of e-modules tailored to physics learning, thereby guiding future e-module development and implementation. The study investigates two main aspects: the specific impact of e-modules on students' performance in physics and the potential variables that affect their effectiveness. These research objectives directly respond to the need to understand the conditions under which e-modules are most beneficial, thus supporting the development of optimized e-learning tools for physics education.

2. METHOD

Meta-analysis is a statistical method that enables multiple studies' simultaneous and quantitative evaluation [40]–[43]. Its objective is to determine trends in quantitative findings by calculating effect sizes, which measure differences between control and experimental groups [44]–[46]. For this meta-analysis, relevant articles published between 2018 and 2023 were selected. The literature search was conducted using the Google Scholar database, assisted by the Publish or Perish (PoP) software, following the methodology of previous meta-analysis studies by Antonio & Castro [44] and Funa & Prudente [47]. Search terms included "e-module," "physics," and "experimental." No restrictions were applied regarding language or geographical region, and only articles were included in the selection to maintain consistency in document type. After receiving athics approval the research was conducted.

2.1 Eligibility Criteria and Selection Process

To be eligible for inclusion in the meta-analysis, we established explicit inclusion and exclusion criteria to select relevant studies. The inclusion criteria were as follows: (1) the research topic must focus on the effect of e-modules on physics learning; (2) the research design must be experimental, quasi-experimental, or mixed methods with pre-test/post-test; and (3) complete research data must be available for meta-analysis. Exclusion criteria included studies that did not address high school or physics, were irrelevant to the research topic, or lacked primary data such as sample size, mean, and standard deviation.

The selection process utilized a flowchart based on PRISMA guidelines to enhance the quality of systematic reviews [48]. This flowchart outlines several stages: initial identification of studies, screening for relevance based on titles and abstracts, and full-text review of potentially eligible studies to confirm they meet inclusion criteria. By systematically applying these selection steps, we ensured that the literature included in the meta-analysis was relevant and high-quality. After screening and excluding ineligible literature, 15 relevant articles were included in the meta-analysis, as shown in Figure 1.

Following this, we coded the 15 eligible articles to answer the research questions. The coding process included categorizing the e-module outcomes for students, specifying the approach/model used in each study, and identifying the physics content addressed. In this context, "approach/model" refers to the instructional strategies or frameworks applied in the studies, such as project-based learning, inquiry-based learning, or flipped classroom models. This specification allows for a more nuanced understanding of how different pedagogical approaches may influence the effectiveness of e-modules in physics education.

3.2 Statistical Analysis

A meta-analysis was performed using Review Manager 5.4, employing a random effects model to calculate the total effect size with 95% confidence intervals (CIs) and mean differences. The effect size criteria were based on Cohen's classification [49]: large for 0.80 and above, medium for 0.50 to 0.79, small for 0.20 to 0.49, and no effect for less than 0.19. The I^2 statistic and the Cochran Q test were used to analyze the heterogeneity of the included studies. Zou et al. [49] classify heterogeneity in meta-analysis as low (25%), medium (50%), and high (75%).

Funnel plots were then employed to test for publication bias, which is critical in meta-analyses as it assesses whether the results are skewed due to the selective publication of studies. Publication bias can occur when studies with significant or favourable outcomes are more likely to be published than those with null or unfavourable results, potentially leading to misleading conclusions. Funnel plots visually represent the relationship between study size and effect size; without bias, the plot should resemble a symmetrical inverted funnel. Additionally, we utilized Egger's test to quantitatively assess the presence of publication bias, which complements the visual analysis provided by funnel plots and ensures the accuracy of the results [50], [51].

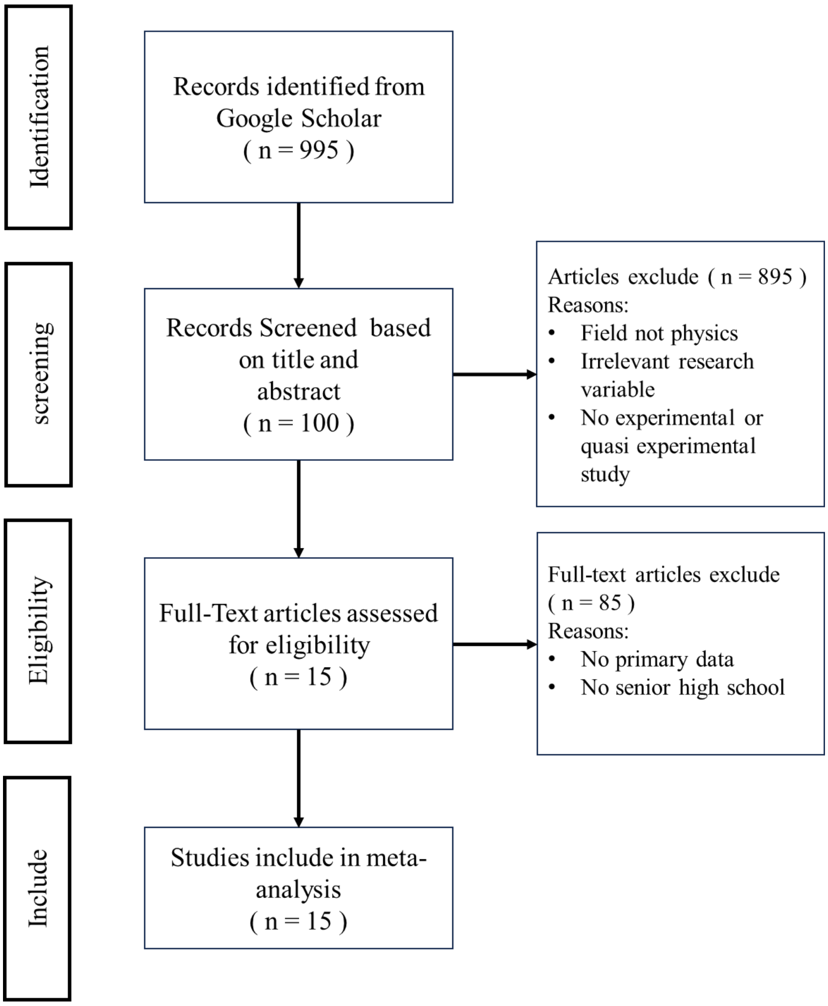

Figure 1. The Diagram of the Literature Screening Process

3. RESULTS AND DISCUSSION

The selection process began with 995 records identified from the Google Scholar database. After screening the titles and abstracts, 100 articles were determined to be relevant, while 895 were excluded for reasons such as being outside the field of physics, addressing irrelevant research variables, or lacking experimental or quasi-experimental designs. Next, full-text articles were assessed for eligibility, resulting in 15 articles being included in the final analysis. An additional 85 full-text articles were excluded because they did not contain primary data or did not focus on senior high school education.

It is important to note that the 15 articles in the meta-analysis provided data from 22 studies. For example, the article by Asrizal *et al.* [32] contributed three separate results. Table 1 summarizes the included articles, presenting key information such as the number of studies, student outcomes from the e-modules, the approaches/models used, and the physics content addressed. Figure 2 summarizes the overall effect of e-modules on Physics learning with a 95% confidence interval of 12.20-24.70. The results indicate that e-modules are significantly more effective than traditional learning in Physics. The overall effect size was d=18.45, Z=5.79 ($P<0.00001$). Statistical analysis revealed heterogeneity in effect size among the 22 included studies (Q=3171.51) in the high category (I^2=99%). A funnel plot was used to test for publication bias and ensure the accuracy of the calculation results. Figure 3 displays the funnel plot of the data analysis results, indicating a symmetrical distribution of effect sizes on both sides of the mean effect size. It suggests a relatively small publication bias in the included studies and increases the reliability of the conclusions [52]. The forest and funnel plot results confirm the feasibility of using the random effects model for data analysis and highlight the importance of identifying potentially significant moderator variables through subgroup analysis [50].

Table 1. The Included Studies

No	Author and Year	Included Studies	Module Outcomes for Students	Approach/ Model	Physics Content
1	Asrizal *et al.* (2022)	Study 1	Learning outcomes	STEM	Static fluids
	Asrizal *et al.* (2022)	Study 2	Learning outcomes	STEM	Static fluids
	Asrizal *et al.* (2022)	Study 3	Learning outcomes	STEM	Static fluids
2	Desnita *et al.* (2022)	Study 1	Creative thinking	CTL	Global warming
	Desnita *et al.* (2022)	Study 2	Critical thinking	CTL	Global warming
3	Endaryati *et al.* (2023)	Study 1	Critical thinking	PBL	Momentum, Work and Energy
4	Fitria & Asrizal (2022)	Study 1	Learning outcomes	STEM	Momentum, Work and Energy
	Fitria & Asrizal (2022)	Study 2	Learning outcomes	STEM	Momentum, Work and Energy
	Fitria & Asrizal (2022)	Study 3	Learning outcomes	STEM	Momentum, Work and Energy
5	Fitriani *et al.* (2023)	Study 1	Critical thinking	STEM	Not Reported
6	Hasibuan & Sani (2023)	Study 1	Learning outcomes	IBL	Static fluids
7	Kristiantari *et al.* (2023)	Study 1	Critical thinking	PBL	Static electricity
	Kristiantari *et al.* (2023)	Study 2	Critical thinking	PBL	Static electricity
	Kristiantari *et al.* (2023)	Study 3	Critical thinking	PBL	Static electricity
8	Mayanty *et al.* (2020)	Study 1	Science process skills	PBL	Heat and temperature
9	Nurmahmuddin *et al.* (2023)	Study 1	Critical thinking	IBL	Momentum, Work and Energy
10	Permata & Safitri (2021)	Study 1	Concept of Understanding	Not Reported	Global warming
11	Rahmadani *et al.* (2023)	Study 1	Creative thinking	STEM	Light and Sound Waves
12	Ramadhanty *et al.* (2020)	Study 1	Learning outcomes	CTL	Momentum, Work and Energy
13	Safitri *et al.* (2021)	Study 1	Critical thinking	Not Reported	Global warming
14	Sujanem *et al.* (2022)	Study 1	Critical thinking	PBL	Rotational Dynamics and Equilibrium of Rigid Bodies
15	Yulyanti *et al.* (2022)	Study 1	Science literacy	Ethnoscien ce	Momentum, Work and Energy

Information:
STEM : Science, Technology, Engineering, and Mathematics
CTL : Contextual Teaching and Learning
PBL : Problem-Based Learning
IBL : Inquiry-Based Learning

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Asrizal et al. 2022 (Study 1)	83	11	68	77	14	68	4.5%	6.00 [1.77, 10.23]
Asrizal et al. 2022 (Study 2)	73	8	68	61	6	68	4.6%	12.00 [9.62, 14.38]
Asrizal et al. 2022 (Study 3)	81	7	68	73	8	68	4.6%	8.00 [5.47, 10.53]
Desnita et al. 2022 (Study 1)	81.85	5.51	30	66.3	5.93	30	4.6%	15.55 [12.65, 18.45]
Desnita et al. 2022 (Study 2)	81.81	5.16	30	69.44	6.94	30	4.6%	12.37 [9.28, 15.46]
Endaryati et al. 2023	78.7	8.6	70	67.9	12.6	31	4.5%	10.80 [5.93, 15.67]
Fitria & Asrizal 2021 (Study 1)	80.28	6.7	28	72.95	6.03	28	4.6%	7.33 [3.99, 10.67]
Fitria & Asrizal 2021 (Study 2)	67.14	12.44	28	45.68	10.76	28	4.4%	21.46 [15.37, 27.55]
Fitria & Asrizal 2021 (Study 3)	79.43	6.29	28	71.5	7.62	28	4.6%	7.93 [4.27, 11.59]
Fitriani et al. 2023	71.04	4.67	30	57.42	11.72	32	4.5%	13.62 [9.23, 18.01]
Hasibuan & Sani 2023	89.67	4.64	31	82.75	3.42	29	4.6%	6.92 [4.87, 8.97]
Kristiantari et al. 2023 (Study 1)	78.57	8.16	35	33.33	7.83	35	4.6%	45.24 [41.49, 48.99]
Kristiantari et al. 2023 (Study 2)	76.67	5.64	35	26.19	6.11	35	4.6%	50.48 [47.73, 53.23]
Kristiantari et al. 2023 (Study 3)	83.33	9.04	35	27.62	10.06	35	4.5%	55.71 [51.23, 60.19]
Mayanty et al. 2020	18.63	2.25	559	16.87	2.42	506	4.6%	1.76 [1.48, 2.04]
Nurmahmuddin et al. 2023	23.11	6.47	35	18.17	4.34	35	4.6%	4.94 [2.36, 7.52]
Permata & Safitri 2021	84.9	8.05	31	61.94	7.46	31	4.5%	22.96 [19.10, 26.82]
Rahmadani et al. 2023	76.95	14.8	25	66.7	12.18	28	4.3%	10.25 [2.90, 17.60]
Ramadhanty et al. 2020	80.4	9.16	36	71.8	9.7	36	4.5%	8.60 [4.24, 12.96]
Safitri et al. 2021	83.62	8.63	31	62.21	6.69	31	4.5%	21.41 [17.57, 25.25]
Sujanem et al. 2022	73.1	11.48	31	30.6	9.24	31	4.5%	42.50 [37.31, 47.69]
Yulyanti et al. 2022	88.93	3.55	30	68.26	4.54	30	4.6%	20.67 [18.61, 22.73]
Total (95% CI)			**1362**			**1273**	**100.0%**	**18.45 [12.20, 24.70]**

Heterogeneity: $Tau^2 = 219.49$; $Chi^2 = 3171.51$, df = 21 (P < 0.00001); $I^2 = 99\%$
Test for overall effect: Z = 5.79 (P < 0.00001)

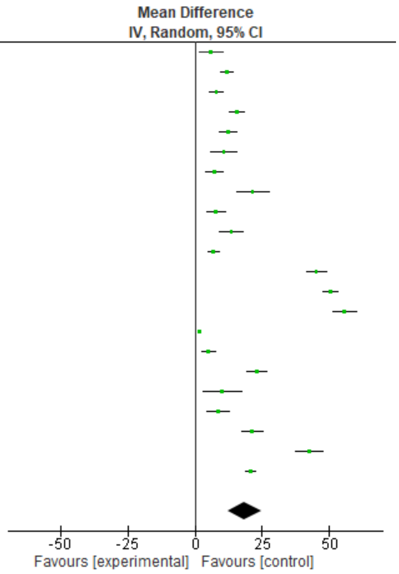

Figure 2. The Forest Plot of the Effect of E-modules on Physics Learning

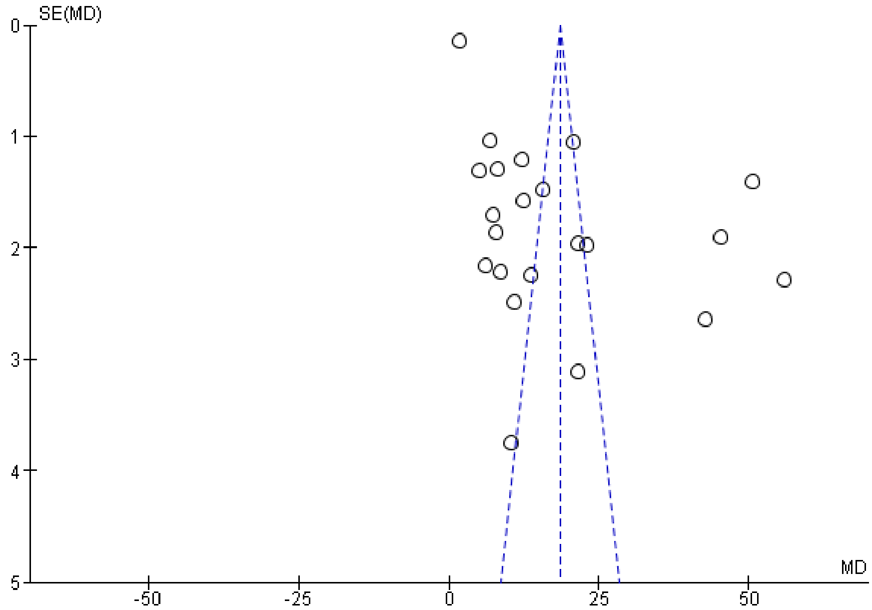

Figure 3. The Funnel Plot of the Effect of E-modules on Physics Learning

3.1 The Effect of E-modules on Students

Table 2 presents research results on students' e-module outcomes, focusing on various dimensions. The results indicate that the e-modules were successful in developing creative thinking skills, as shown by high scores on creative thinking (d = 14.02, Z = 5.84, $p < 0.0001$) with moderate heterogeneity (Q = 1.73, $I^2 = 42\%$). Similarly, e-modules have a significant positive impact on critical thinking skills (d = 28.55, Z = 4.11, $p < 0.0001$) despite high heterogeneity (Q = 1014.67, $I^2 = 99\%$). The module also led to significant improvement in student learning outcomes, as evidenced by high scores on learning outcomes (d = 9.26, Z = 7.71, p < 0.0001) despite high heterogeneity (Q = 9.26, I^2 = 77%). The e-module contributed to developing science process skills, as demonstrated by the positive results (d = 1.76, Z = 12.25, p < 0.0001). Additionally, it effectively enhanced concept understanding, with a significant value on the Concept of Understanding (d = 22.96, Z = 11.65, p < 0.0001). Moreover, the e-module played a crucial role in improving students' science literacy, as evidenced by the positive results on science literacy (d = 20.67, Z = 19.64, p < 0.0001). This analysis's limited number of studies means that the heterogeneity of science process skills, the concept of understanding, and science literacy is unknown. However, the data from this study supports the notion that implementing e-modules has a significant positive impact on various aspects of student learning, including creative and critical thinking, learning outcomes, science process skills, concept of understanding, and science literacy. These findings highlight the importance of integrating e-modules into science education to maximize learning effectiveness. Future research is encouraged to explore the long-term impact of e-modules on diverse student populations.

Table 2. The Effect of E-modules on Students in Physics Learning

Module Outcomes for Students	Included Studies	d	Q	I^2	CI (95%)	Z
Creative thinking	2	14.02	1.73	42%	9.31-18.73	5.84***
Critical thinking	9	28.55	1014.67	99%	14.93-42.17	4.11***
Learning outcomes	8	9.26	29.80	77%	6.90-11.61	7.71***
Science process skills	1	1.76	-	-	1.48-2.04	12.25***
Concept of Understanding	1	22.96	-	-	19.10-26.82	11.65***
Science literacy	1	20.67	-	-	18.61-22.73	19.64***

Note: overall effect (Z), confidence interval (CI), *** *P* < 0.0001

3.2 The Effect of E-modules on Physics Learning in Various Approaches/models

Table 3 presents research results related to the effect of e-modules on physics learning in various approaches/models. The results indicate that e-modules with CTL were significantly successful in physics learning (d = 12.46, Z = 6.64, p < 0.0001) with high heterogeneity (Q = 7.50, I^2 = 72%). Similarly, the IBL e-module had a considerable positive impact (d = 6.09, Z = 6.23, p < 0.0001) with low heterogeneity (Q = 1.38, I^2 = 28%). The use of e-modules with PBL had a significant impact on physics learning (d = 34.40, Z = 2.69, p < 0.0001), although with high heterogeneity (Q = 2467.00, I^2 = 100%). Similarly, e-modules with STEM also had a positive impact on physics learning (d = 10.38, Z = 7.59, p < 0.0001), albeit with high heterogeneity (Q = 28.42, I^2 = 75%). Meanwhile, the study found that ethnoscience-integrated e-modules in physics learning had a significant positive impact (d = 20.67, Z = 19.64, p < 0.0001), although the approach is not widely explored. The results support the implementation of e-modules in physics learning across different approaches and models. These findings highlight the versatility of e-modules in adapting to diverse instructional strategies. Furthermore, they suggest the need for further exploration of underutilized approaches such as ethnoscience integration.

Table 3. The Effect of E-modules on Physics Learning in Various Approaches/Models

Module Outcomes for Students	Included Studies	d	Q	I^2	CI (95%)	Z
CTL	3	12.46	7.50	72%	8.78-16.14	6.64***
IBL	2	6.09	1.38	28%	4.18-8.01	6.23***
PBL	6	34.40	2467.00	100%	9.29-59.51	2.69***
STEM	8	10.38	28.42	75%	7.70-13.06	7.59***
Ethnoscience	1	20.67			18.61-22.73	19.64***

Note: overall effect (Z), confidence interval (CI), *** *P* < 0.0001

3.3 The Effect of E-modules on Learning Physics in Various Physics Content

Table 4 presents the research results related to the effect of e-modules on physics learning in various physics content. The results indicate that the momentum, work, and energy modules have a significantly positive impact ($d = 11.58$, $Z = 3.94$, $p < 0.0001$). There was high heterogeneity between studies ($Q = 120.28$, $I^2 = 95\%$), confirming the success of the modules in improving students' understanding of these topics. It also showed a significant positive impact ($d = 8.40$, $Z = 6.20$, $p < 0.0001$). The module for static fluids effectively improved students' understanding of static fluids despite the high heterogeneity between studies ($Q = 12.09$, $I^2 = 75\%$). In the context of global warming, the module had a significant impact ($d = 17.94$, $Z = 7.39$, $p < 0.0001$). Despite the high heterogeneity of results among studies ($Q = 23.74$, $I^2 = 87\%$), the module consistently improved students' understanding of climate change issues. The static electricity module had a significant positive impact ($d = 50.36$, $Z = 18.88$, $p < 0.0001$), making it stand out. The studies exhibited high heterogeneity ($Q = 12.55$, $I^2 = 84\%$). The module was effective in improving students' understanding of static electricity. The heat and temperature module results showed a significant positive impact ($d = 1.76$, $Z = 12.25$, $p < 0.001$). Although only one study was included, this module improved students' understanding of heat and temperature. The module on light and sound waves had a positive impact ($d = 10.25$, $Z = 2.73$, $p < 0.0001$). Although only one study was conducted, this module improved students' understanding of light and sound waves. Additionally, the module on rotational dynamics and equilibrium of rigid bodies also had a significant impact ($d = 42.50$, $Z = 16.06$, $p < 0.0001$). Although the module successfully improved students' understanding of rotational dynamics and the equilibrium of rigid bodies, it is essential to note that only one study was included. The results also showed variation in the success of the modules in improving students' understanding of a range of physics topics across different studies. Nevertheless, these modules can potentially enhance students' learning experiences in various physics learning contexts.

Table 4. The Effect of E-modules on Learning Physics in Various Physics Content

Module Outcomes for Students	Included Studies	d	Q	I^2	CI (95%)	Z
Momentum, Work and Energy	7	11.58	120.28	95%	5.81-17.34	3.94^{***}
Static fluids	4	8.40	12.09	75%	5.75-11.06	6.20^{***}
Global warming	4	17.94	23.74	87%	13.18-22.71	7.39^{***}
Static electricity	3	50.36	12.55	84%	45.13-55.59	18.88^{***}
Heat and temperature	1	1.76			1.48-2.04	12.25^{***}
Light and Sound Waves	1	10.25			2.90-17.60	2.73^{***}
Rotational Dynamics and Equilibrium of Rigid Bodies	1	42.50			37.31-47.69	16.06^{***}

Note: overall effect (Z), confidence interval (CI), *** $P < 0.0001$

This study conducted a meta-analysis to investigate the impact of e-modules on physics learning. The results indicate a significant positive effect of e-modules on students' physics learning, with an overall effect value of $d = 18.45$, $Z = 5.79$ ($P < 0.00001$), suggesting that e-modules are consistently more effective than traditional learning methods. This study confirms the advantages of e-modules in enhancing learning effectiveness, as previously reported [36], [38], [39]. The accuracy of the results was tested using a funnel plot, which showed a symmetrical distribution of effects, indicating slight publication bias. Therefore, the results of this meta-analysis are considered reliable [52]. However, a deeper understanding is necessary because the study results show a high level of heterogeneity, as measured by an I^2 of 99%, which exceeds the 50% limit and is generally considered a sign of significant heterogeneity [53]. High heterogeneity can arise from variations in study design, sample characteristics, implementation of e-modules, or different contexts in which the studies were conducted. This variability can complicate the interpretation of the overall effect, as it suggests that the effect of e-modules may not be uniform across all studies. To address this issue, we conducted a subgroup analysis to identify moderating variables that may influence the effectiveness of e-modules in different physics learning environments and to answer the second research question.

The impact of e-modules on students in the context of physics learning is an important aspect that has been analyzed. E-modules not only improve students' understanding of physics material but also enhance their creative and critical thinking skills, as demonstrated by several studies [25], [31], [54]–[59]. The studies conducted by Bergdahl *et al.* [20], Antonio & Castro [44], Mufit *et al*. [45], Fadillah *et al.* [46], Funa *et al.* [47], Moher *et al*.[48], Cohen *et al.* [49] have significantly improved student learning outcomes, science process skills, concept understanding, and science literacy. While the findings suggest that e-modules effectively improve various aspects of student learning, it is essential to note that the analysis is based on a limited number of studies. The variation in the number of studies for each dimension, such as creative thinking (2 studies), science process skills (1 study), concept of understanding (1 study), and science literacy (1 study), indicates the limited empirical data available for analysis. These limitations indicate that some areas of physics education have yet to be thoroughly explored in existing research. Therefore, to gain a more comprehensive and in-depth understanding of the impact of e-modules, further research should be conducted to investigate other aspects that affect students.

Integrating e-modules with various teaching strategies, such as CTL, IBL, PBL, STEM, and ethnoscience, is compelling. However, further investigation is needed to identify potential variables that may influence the effectiveness of e-modules. Specific learning approaches or models, such as CTL, IBL, PBL, STEM, and ethnoscience integration, may have varying impacts on the effectiveness of e-modules [31], [32], [56], [60], [61]. Additionally, the results of studies based on specific physics materials suggest that content selection may also be a crucial factor in the success of e-modules. While these results provide insights into the effectiveness of e-modules in specific learning models, it is essential to note that the number of studies on some models, such as CTL [31], [62], IBL [57], [60], and ethnoscience [61], is still limited. Further exploration of the research literature related to these learning models is necessary to gain a more comprehensive understanding.

Content factors play a crucial role in the impact of e-modules, which varies depending on the physics topic being taught, highlighting the necessity for tailored e-module development to ensure relevance and success in stimulating student understanding [36], [38], [39]. These findings offer insight into the impact of e-modules on various physics topics. As shown in Figure 2, the most effective study was conducted by Kristiantari *et al.* [56], where Study 1 achieved an effect size of 45.24, Study 2 yielded 50.48, and Study 3 reached 55.71, resulting in an average effect size of 53.48. Their research focused on critical thinking as a module outcome for students. It utilized PBL on static electricity, demonstrating the effectiveness of this pedagogical approach in enhancing student learning outcomes.

In contrast, the least effective study was by Mayanty et al. [63], which reported an effect size of only 1.76 related to science process skills as a module outcome for students, also employing PBL but focusing on heat and temperature. This stark difference in effectiveness underscores how content factors and the specific context of the e-module can significantly influence the results. It is essential to note that some topics, including heat and temperature [63], light and sound waves [58], and rotational dynamics and equilibrium of rigid bodies [59], have only been studied once. Further exploration is needed in the research literature related to certain physics topics in the context of e-modules to provide a more comprehensive understanding. The limited empirical data emphasizes the need for additional research.

4. CONCLUSION

This study finds that e-modules effectively enhance various aspects of student learning in the context of physics education. The analysis indicates a significant positive impact, demonstrating that e-modules improve students' understanding of physics concepts and enhance their creative thinking and science process skills. E-modules designed with appropriate approaches, such as PBL, have consistently proven effective in improving student learning outcomes. For instance, the research by Kristiantari et al. revealed that e-modules significantly enhance students' critical thinking, with an average effect size reaching 53.48, indicating high effectiveness.

However, this study also highlights data limitations concerning science process skills, concept understanding, and science literacy. These limitations arise from the variability in the available studies; for example, only two studies focus on creative thinking, one on science process skills, one on concept understanding, and one on science literacy. This limited data suggests that some areas of physics education have yet to be thoroughly explored in existing literature.

Therefore, further research is necessary to investigate the factors influencing the effectiveness of e-modules, including the impact of various learning models. Some models, such as CTL, IBL, and STEM, require additional research to understand how each model contributes to the effectiveness of e-modules. Additionally, selecting the appropriate content is a crucial factor in the success of e-modules. By enhancing our understanding of how e-modules function and the factors influencing their success, this study contributes to developing innovative strategies in physics education. The implication of this research is to provide insight into how e-modules can be effective learning tools if designed with a relevant approach and used strategically to answer the challenges of 21st-century education.

AUTHOR CONTRIBUTION STATEMENT

MAF was responsible for conceptualizing the research, writing the manuscript, and collecting and analyzing data. AA contributed to data collection and analysis and supervised the research process. FF played a significant role in the study design, revising the paper, developing the methodology, and providing writing support through review and editing, as well as research supervision. UU contributed to the study design, paper revisions, research supervision, and writing support through review and editing.

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