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The Use of E-Modules to Improve Critical Thinking Skills of Physics Education Students

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Abstract: Critical thinking skills are essential in physics education, particularly in understanding abstract concepts like wave functions in quantum mechanics. However, traditional teaching methods often fail to foster these skills effectively. This study explores the use of an interactive e-module titled Quantum Physics: Wave Function to enhance critical thinking skills among students in a physics education program. A quasi-experimental design was employed with an experimental group using the e-module and a control group following conventional methods. Pretest and posttest results showed a significant improvement in critical thinking skills for the experimental group (average increase: 26.30) compared to the control group (average increase: 11.70). Statistical analysis confirmed the e-module's effectiveness ($t = 2.95$, $p = 0.01$). The e-module fostered active participation, problem-solving, and independent exploration, demonstrating its potential to improve critical thinking and engagement in complex physics topics. These findings highlight the value of integrating technology into physics education to enhance learning outcomes.

Keywords: Critical thinking skills; E-modules; Quantum physics

Introduction

Critical thinking skills are essential in modern education, particularly in physics, which often involves abstract concepts such as wave functions in quantum mechanics. These skills enable students to engage deeply with abstract ideas, allowing them to understand better and apply complex concepts like quantum wave functions (Kartini et al., 2019; Susilawati et al., 2022; Syuzita et al., 2023). Critical thinking empowers students to analyze, evaluate, and solve problems independently and creatively—skills that are crucial for addressing the challenges of the modern workplace (Ennis, 1993; Ghanizadeh, 2017; Putra et al., 2023). However, conventional teaching methods are often less effective in fostering these skills, particularly when understanding abstract concepts. Several studies have highlighted that traditional pedagogical approaches are limited in promoting critical thinking, suggesting a need for more interactive and innovative teaching strategies (Ledistika et al., 2024; Suarsana, 2013). According to Li (2016), conventional teaching methods restrict opportunities for creative thinking and fail to accommodate individual learning differences. To address these challenges, the integration of technology, such as interactive e-modules, is recommended.

E-modules represent a significant technological innovation, offering structured, interactive learning materials that enhance students' conceptual understanding and engagement. These digital resources have been shown to provide flexible learning experiences and promote active student participation through features such as simulations and practice questions (Syahiddah et al., 2021). Well-designed e-modules can increase student engagement and motivation, and strengthen critical thinking skills by facilitating a deeper interaction with the material (Syahfitri & Safitri, 2024). Moreover, e-modules allow students continuous access to learning resources, which is vital for a more thorough understanding of complex

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concepts (Nufus & Susilawati, 2020; Ramli, 2022; Rizki et al., 2024). Research on e-modules in education has demonstrated their effectiveness in improving learning outcomes, enhancing critical thinking, and increasing students' motivation to learn (Asmi et al., 2024; Muniroh et al., 2023; Permatasari et al., 2023; Rahmat et al., 2020). Research also shows that e-modules are very effective in encouraging active learning and fostering critical thinking across disciplines. For example, Zakiyah et al. (2022) found that e-modules equipped with animations and interactive simulations help students visualize challenging concepts, while Aspriyani et al. (2020) reported improvements in student learning outcomes when e-modules were used in mathematics.

In physics learning, especially in complex topics such as quantum physics, critical thinking skills are essential to help students understand abstract concepts in depth and apply them in broader contexts. However, traditional learning approaches are often insufficient to meet these needs. Thus, this study is important to explore how e-modules can be used effectively to improve critical thinking skills, provide new insights into technology in physics education, and address challenges in understanding abstract concepts.

In the context of physics education, e-modules have the potential to overcome the challenges students face in understanding abstract topics, such as quantum mechanics. Despite the promising results from previous research, studies specifically focused on the use of e-modules to develop critical thinking skills in physics—especially in complex subjects like quantum physics—remain limited. For instance, while Suarsana (2013) demonstrated the effectiveness of e-modules in enhancing learning outcomes, their impact on critical thinking skills in quantum physics was not specifically addressed. Similarly, Ledistika et al. (2024) focused more on learning motivation than the in-depth understanding of abstract quantum physics concepts. This study aims to fill this gap by focusing on the development and evaluation of an e-module titled Quantum Physics: Wave Function, designed to improve critical thinking skills in physics students. The topic of quantum physics was selected due to its inherent complexity and the common difficulties students face in grasping its principles. This e-module is based on a constructivist approach, encouraging active student participation, discussion, and critical evaluation of quantum concepts, particularly the core principles of wave functions and quantum probability. The results of the study are expected to contribute to the development of more effective physics learning media and offer insight into the importance of technology integration in science learning to improve students' critical thinking skills.

Method

This study used a quasi-experimental method with a pretest-posttest control group design that only used matching to measure the effectiveness of the e-module on students' critical thinking skills. The quasi-experimental design was chosen because it allows the implementation of research in field conditions that do not allow random group division. In this design, the experimental group uses a learning method using e-modules as a learning medium and the control group uses conventional teaching methods without e-modules (Fraenkel & Wallen, 2009).

The subjects of this research consisted of students from the Physics Education study program at Jambi University who had taken Basic Physics courses and were currently taking Quantum Physics courses. Using a purposive sampling technique, two classes were obtained with 10 students placed in the experimental group and 14 students in the control group. This selection was made with the consideration that participants have sufficient background knowledge in physics, which will make it easier for them to understand the material taught through the Quantum Physics e-module (Creswell, 2014).

The research instruments used in this study were a critical thinking skills test and a questionnaire. The test, which consisted of four questions for both the pretest and posttest, was validated by two experts. The validation process assessed several aspects of the questions, including critical thinking indicators, clarity of statements, and contextual relevance. The average validity score was 87%, classifying the questions as highly valid. In addition to the test, a questionnaire was used to measure critical thinking skills. This questionnaire was developed based on seven indicators: the ability to ask questions, provide answers and responses, express opinions, confidently express opinions, solve problems to complete tasks, and explore independently.

The study was conducted in three main stages. First, both groups completed a pretest to assess their initial critical thinking abilities before receiving treatment. Next, during the treatment phase, the experimental group engaged in learning using an e-module designed to promote independent learning, featuring simulations and interactive exercises. In contrast, the control group followed conventional learning methods, primarily consisting of lectures and discussions. In the final stage, both groups completed the same posttest to measure improvements in their critical thinking skills following the treatment. Additionally, students in the experimental group filled

out a questionnaire to provide further insights into their perceptions of the e-module.

Table 1. Pretest-posttest control group design

Group	Pretest	Treatment	Posttest
Experimental group	O	X_1	O
Control group	O	X_2	O

The data were analyzed using parametric statistical tests. Normality was assessed using the Shapiro-Wilk test, which yielded significance values of 0.15 for the experimental group and 0.09 for the control group, indicating normal distribution (sig. > 0.05). The homogeneity test, conducted with Levene's test, showed that the data were homogeneous, with a significance value of 0.26 (sig. > 0.05). Based on these prerequisite tests, the pretest and posttest results were analyzed using a t-test to assess the difference in critical thinking skills between the experimental and control groups (Field, 2018).

Result and Discussion

This study aims to evaluate the effectiveness of using e-modules to enhance critical thinking skills among students in the Physics Education program at the University of Jambi. To assess this effectiveness, pretest and posttest data on students' critical thinking skills were compared between the experimental and control groups, followed by statistical analysis to determine significant differences between the two groups.

The results of the pretest and posttest of students' critical thinking skills are presented in Table 2.

Table 2. Descriptive Statistics of Students' Critical Thinking Skills

Group	N	Mean pre	Mean post	Standard deviation pre	Standard deviation post
Experiment	10	53.2	79.5	4.10	5.30
Control	14	52.6	64.3	3.80	4.90

As shown in Table 2, the experimental group using the e-module demonstrated an average increase of 26.30 in critical thinking skills, while the control group showed an average increase of 11.70. These results indicate a significantly greater improvement in the experimental group compared to the control group. This suggests that the use of e-modules effectively supports the enhancement of students' critical thinking skills.

In the experimental group, the pretest standard deviation of 4.10 and the posttest standard deviation of 5.30 indicate an increase in score variability following the e-module treatment. In contrast, the control group showed a more modest increase, with a pretest standard deviation of 3.80 and a posttest of 4.90. Although the control group also experienced some variability, the increase was less pronounced than in the experimental group. This greater variability in the experimental group suggests a wider distribution of critical thinking skills in the final results, likely reflecting individual differences in response to the e-module. These variations could be attributed to factors such as student motivation or their level of engagement with the e-module, which may have influenced the extent of improvement in critical thinking.

With a significantly higher average increase in the experimental group (26.30) compared to the control group (11.70), as shown in Table 2, it can be concluded that e-modules have a substantial positive effect on critical thinking development. The increased score variability in the experimental group may further suggest that e-modules encourage critical thinking at varying levels, depending on students' initial abilities and their active participation. The difference in average improvement between the two groups provides preliminary evidence supporting the efficacy of e-modules as a learning tool, particularly in subjects like physics, which require a deep understanding of complex concepts. Additionally, the higher variability in the experimental group highlights the adaptability of e-modules, allowing students to learn at a pace and depth that suits their individual needs.

The results of the pretest and posttest of students' critical thinking skills are summarized in Table 3.

Table 3. Critical Thinking Skills t-Test Results

Variable	t-score	df	Sig. (2-tailed)	Description
Critical thinking skills	2.95	22	0.01	Significant

The inferential analysis section of this study aims to test the hypothesis regarding the effectiveness of using e-modules in improving students' critical thinking skills in physics learning. An independent t-test was employed to examine the difference in the average improvement in critical thinking scores between the experimental group (using the e-module) and the control group (utilizing conventional learning methods).

The independent t-test results yielded a t-value of 2.95, with 22 degrees of freedom (df) and a significance level (p-value) of 0.01. Since the p-value is smaller than the 0.05 threshold, it indicates a statistically significant difference between the two groups. This finding supports the research hypothesis, demonstrating that e-

modules are effective in improving the critical thinking skills of physics education students.

Beyond statistical significance, the relatively high t-value (2.95) reflects a considerable difference in the average improvement of critical thinking skills between the experimental and control groups. This suggests that the e-module provides a meaningful positive impact on the learning process, likely due to its interactive features, which encourage students to think critically and grasp complex concepts more deeply. To further quantify the magnitude of this effect, the Cohen's d method can be applied. If the effect size exceeds 0.80, it would confirm that the e-module has a substantial impact, underscoring its efficacy as a learning tool.

The results highlight that students using the e-module are significantly more supported in developing critical thinking skills compared to those following conventional learning methods. The e-module fosters independent learning, facilitates self-assessment, and encourages in-depth exploration of materials, all of which contribute to the development of critical thinking—an essential skill in physics education.

These findings underscore the importance of integrating technological tools into the learning process, particularly for challenging topics such as quantum physics. Active and interactive approaches, like those offered by e-modules, enable students to engage deeply with the material, enhancing their conceptual understanding and critical analysis. This study provides empirical evidence that innovative learning media, such as e-modules, are highly beneficial for fostering critical thinking skills in higher education, particularly in physics education programs.

Empirical evidence from this study aligns with previous research highlighting the benefits of innovative learning media. For instance, Cynthia et al. (2023) demonstrated that interactive physics e-modules significantly enhance students' critical thinking skills. Similarly, Dewi et al. (2023) found that augmented reality-assisted physics e-modules effectively improve mathematical communication and critical thinking abilities. In summary, the integration of e-modules in physics education offers a promising avenue for enhancing critical thinking skills, supporting the advancement of educational practices in higher education.

Students' critical thinking skills were assessed using a Likert scale-based questionnaire with 23 items, rated on a scale from 1 (Strongly Disagree) to 4 (Strongly Agree). These items covered various aspects of critical thinking. The analysis of critical thinking aspects is presented in Table 4.

This study aimed to evaluate the impact of the e-module on enhancing the critical thinking skills of students in the Physics Education program, Jambi University. The results indicate that the use of the e-module significantly enhanced various aspects of students' critical thinking skills, including their ability to ask questions, provide answers, express opinions, and solve problems. These findings align with the constructivist perspective, where learners are seen as active participants in their own learning processes, and technology, such as e-modules, provides a dynamic platform to foster these abilities (Jonassen et al., 1998).

Table 4. Average Score of Students' Critical Thinking Skills Questionnaire in Each Aspect

Critical thinking skills aspect	Experiment group (mean)	Control group (mean)	Δ
Actively asking questions	3.60	2.80	0.80
Answering and giving responses	3.70	2.90	0.80
Ability to express opinions	3.50	3.00	0.50
Confidence in expressing opinions	3.60	2.80	0.80
Problem-solving	3.80	3.10	0.70
Ability to complete tasks	3.90	3.20	0.70
Independent exploration	3.40	2.70	0.70

In the aspect of active questioning, the experimental group achieved an average score of 3.60, while the control group only reached 2.80, reflecting a difference of 0.80. This finding highlights that students using the e-module were more likely to engage in critical thinking through active questioning. Active questioning not only facilitates deeper engagement with content but also enhances metacognitive skills by prompting students to reflect on their understanding and seek clarification (Akyol & Garrison, 2008). As noted by Garrison et al. (2001), fostering a community of inquiry where students ask meaningful questions is crucial for promoting critical thinking and sustained engagement in online learning environments. E-modules create such an environment, encouraging students to be more inquisitive and reflective, thus improving their overall comprehension of complex topics like quantum physics.

The aspect of answering and responding demonstrated a significant improvement, with the experimental group scoring an average of 3.70, compared to 2.90 in the control group, a difference of 0.80. This result suggests that e-modules provide a

platform for students to develop greater confidence in articulating and defending their ideas. Engaging in discussions and providing responses to questions is central to critical thinking, as it requires students to justify their reasoning and consider multiple perspectives (Mason, 2008). Research by Anderson et al. (2001) further supports this, emphasizing that the ability to respond effectively in discussions helps cultivate higher-order cognitive skills, such as analysis and synthesis, which are essential components of critical thinking.

An interesting finding emerged in the aspect of expressing opinions, where the experimental group recorded an average score of 3.50, compared to 3.00 in the control group, with a difference of 0.50. This improvement suggests that the e-module promoted an environment conducive to the development of students' ability to articulate their thoughts critically. Jonassen (2000) argues that learning environments that integrate problem-solving activities and group discussions are especially effective in encouraging students to refine their opinions and engage in critical analysis. By engaging with the e-module's interactive content, students are encouraged to articulate their views and assess alternative solutions, fostering deeper critical engagement with the material.

Confidence in expressing opinions was notably higher in the experimental group, which scored an average of 3.60, while the control group only achieved 2.80, reflecting a difference of 0.80. This finding highlights the role of e-modules in creating a supportive learning environment where students feel more comfortable expressing their views, even when their opinions diverge from those of their peers. Confidence is a key driver of critical thinking, as students who feel assured in their abilities are more likely to engage in thoughtful discussions and complex problem-solving activities (Mason, 2008). Furthermore, Pithers et al. (2000) suggest that self-confidence is directly linked to the development of critical thinking, as students who trust their cognitive abilities are more willing to critically evaluate their own reasoning and consider alternative viewpoints.

The experimental group also showed improvements in problem-solving, with an average score of 3.80, compared to 3.10 in the control group, reflecting a difference of 0.70. This result suggests that the e-module was particularly effective in encouraging students to apply critical thinking skills to solve complex problems. Problem-solving is a cornerstone of critical thinking, as it involves the application of knowledge to unfamiliar situations, which enhances analytical thinking and decision-making (Haseli & Rezaii, 2013; Jamaludin et al., 2022; Jasmi & Yulkifli, 2024; Savery, 2006). Technology-based learning platforms like e-modules support problem-solving by presenting students with real-world scenarios and allowing them to experiment with solutions, thereby fostering a deeper understanding of theoretical concepts.

In terms of task completion ability, the experimental group scored an average of 3.90, while the control group reached only 3.20, with a difference of 0.70. This suggests that e-modules help students work more efficiently and independently. The structured, interactive nature of e-modules likely provides students with clear guidance and immediate feedback, enhancing their ability to complete tasks with greater precision and autonomy. These elements are crucial for the development of critical thinking, as students learn to manage their learning processes and evaluate their progress.

Finally, in the aspect of independent exploration, the experimental group scored an average of 3.40, compared to 2.70 in the control group, with a difference of 0.70. This indicates that students who used the e-module were more motivated to explore the material independently. Independent exploration is integral to deep learning, as it encourages intrinsic motivation and enhances students' ability to self-regulate their learning (Schunk, 2019).

Overall, the analysis reveals that the use of the Quantum Physics e-module: Wave Function contributed positively to improving various aspects of students' critical thinking skills. The results demonstrate that technology-based learning can significantly enhance students' analytical and critical abilities in the context of physics education. This finding aligns with the researches, which emphasizes that digital learning technologies, such as e-modules, can foster student engagement, promote deep learning, and improve critical thinking skills (Adhelacahya et al., 2023; Asrizal et al., 2023; Cynthia et al., 2023; Heryani et al., 2023).

Conclusion

This study demonstrates that the use of e-modules in physics education, particularly on quantum physics topics like wave functions, significantly enhances students' critical thinking skills compared to traditional teaching methods. The experimental group, using the e-module, showed an average increase of 26.30 in critical thinking scores, while the control group, following conventional methods, showed an increase of 11.70. Statistical analysis ($t = 2.95$, $p = 0.01$) confirmed the e-module's effectiveness in promoting active participation, problem-solving, and self-exploration. These findings suggest that e-modules can be broadly applied across various physics topics and other STEM

disciplines to foster critical thinking skills. As a practical implication, educators and institutions should consider incorporating interactive e-modules into their curriculum to address the growing demand for innovative and effective teaching tools. By leveraging technology, such approaches can enhance students' analytical abilities and better prepare them to tackle complex real-world problems, aligning with the goals of 21st-century education.

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Conflicts of Interest
The authors of this article declare no conflict of interest.

References

Adhelacahya, K., Sukarmin, S., & Sarwanto, S. (2023). The Impact of Problem-Based Learning Electronics Module Integrated with STEM on Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 4869–4878. https://doi.org/10.29303/jppipa.v9i7.3931

Akyol, Z., & Garrison, D. (2008). The development of a Community of Inquiry over time in an online course: Understanding the progression and integration of social, cognitive and teaching presence. *Journal of Asynchronous Learning Networks*, *12*, 3–22. https://doi.org/10.24059/olj.v12i3.72

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Pearson.

Asmi, A., Silaban, S., & Silaban, R. (2024). Developing An Interactive Chemistry E-module Based on Problem-based Learning to Improve Critical Thinking Skills of High School Students. *Jurnal Paedagogy*, *11*, 94. https://doi.org/10.33394/jp.v11i1.9875

Aspriyani, R., & Suzana, A. (2020). Pengembangan E-Modul Interaktif Materi Persamaan Lingkaran Berbasis Realistic Mathematics Education Berbantuan Geogebra. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*, 1099. https://doi.org/10.24127/ajpm.v9i4.3123

Asrizal, A., Marjuni, M., Habibah, R., & Asiah, S. (2023). Meta-Analysis of the Effect of E Module on Students' Critical and Creative Thinking Skill in Science Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 141–147. https://doi.org/10.29303/jppipa.v9i6.2696

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE.

Cynthia, C., Arafah, K., & Palloan, P. (2023). Development of Interactive Physics E-Module to Improve Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 3943–3952. https://doi.org/10.29303/jppipa.v9i5.2302

Dewi, P. S., & Kuswanto, H. (2023). The effectiveness of the use of augmented reality-assisted physics e-module based on pedicab to improve mathematical communication and critical thinking abilities. *Journal of Technology and Science Education*, *13*(1), 53–64. https://doi.org/10.3926/jotse.1714

Ennis, R. H. (1993). Critical thinking assessment. *Theory Into Practice*, *32*(3), 179–186. https://doi.org/10.1080/00405849309543594

Field, A. P. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). Newbury Park: SAGE.

Fraenkel, J. R., & Wallen, N. E. (2009). *How To Design And Evaluate Research In Education* (7th ed.). New York: McGraw-Hill Higher Education.

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, *15*(1), 7–23. https://doi.org/10.1080/08923640109527071

Ghanizadeh, A. (2017). The interplay between reflective thinking, critical thinking, self-monitoring, and academic achievement in higher education. *Higher Education*, *74*(1), 101–114. https://doi.org/10.1007/s10734-016-0031-y

Haseli, Z., & Rezaii, F. (2013). The Effect of Teaching Critical Thinking on Educational Achievement and Test Anxiety among Junior High School Students in Saveh. *European Online Journal of Natural and Social Sciences*, *2*(2), 168–175. Retrieved from https://european-science.com/eojnss/article/view/151

Heryani, T. P., Suwarma, I. R., & Chandra, D. T. (2023). Development of STEM-Based Physics Module with Self-Regulated Learning to Train Students Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4245–4252. https://doi.org/10.29303/jppipa.v9i6.3578

Jamaludin, J., Kakaly, S., & Batlolona, J. R. (2022). Critical thinking skills and concepts mastery on the topic

of temperature and heat. *Journal of Education and Learning (EduLearn)*, *16*(1), 51–57. https://doi.org/10.11591/edulearn.v16i1.20344

Jasmi, L., & Yulkifli. (2024). Development of Natural Science E-Module Based on ICARE Model Integrated with SETS Approach to Improve Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 89–99. https://doi.org/10.29303/jppipa.v10iSpecialIssue.7817

Jonassen, D., Carr, C., & Yueh, H.-P. (1998). Computers as Mindtools for engaging learners in critical thinking. *Techtrends*, *43*, 24–32. https://doi.org/10.1007/BF02818172

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, *48*(4), 63–85. https://doi.org/10.1007/BF02300500

Kartini, K., Doyan, A., Kosim, K., Susilawati, S., Khasanah, B. U., Hakim, S., & Muliyadi, L. (2019). Analysis of Validation Development Learning Model Attainment Concept to Improve Critical Thinking Skills and Student Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *5*(2), 185–188. https://doi.org/10.29303/jppipa.v5i2.262

Ledistika, M., Medriati, R., & Setiawan, I. (2024). Development Of Stem-Based E-Modules (Science, Technology, Engineering, And Mathematics) On Circular Motion Material To Enhance High School Students' Critical Thinking Skills. *Jurnal Pendidikan Matematika Dan IPA*, *15*(3), 355–368. http://dx.doi.org/10.26418/jpmipa.v15i3.80616

Li, Y. W. (2016). Transforming Conventional Teaching Classroom to Learner-Centred Teaching Classroom Using Multimedia-Mediated Learning Module. *International Journal of Information and Education Technology*, *6*(2), 105–112. https://doi.org/10.7763/IJIET.2016.V6.667

Mason, M. (2008). *Critical Thinking and Learning*. Singapore: Blackwell Publishing.

Muniroh, J., Pratiwi, S., Ariswan, A., Jumadi, J., & Wilujeng, I. (2023). SETS-Based Electronic Module Innovation: Analysis of Students Responses on Waves and Sound Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6701–6706. https://doi.org/10.29303/jppipa.v9i8.4131

Nufus, H., & Susilawati, S. (2020). Implementation of E-Module Stoiciometry Based on Kvisoft Flipbook Maker for Increasing Understanding Study Learning Concepts of Class X Senior High School. *Journal of Educational Sciences*, *4*, 261. https://doi.org/10.31258/jes.4.2.p.261-272

Permatasari, H. H. N., Suharno, & Suryana, R. (2023). The Effectiveness of the Predict-Observe-Explain (POE) Model in The Physics Electronic Modules to Improve Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10679–10688. https://doi.org/10.29303/jppipa.v9i12.4681

Pithers, R. T., & Soden, R. (2000). Critical thinking in education: A review. *Educational Research*, *42*(3), 237–249. https://doi.org/10.1080/001318800440579

Putra, P. D. A., Sulaeman, N. F., Supeno, & Wahyuni, S. (2023). Exploring Students' Critical Thinking Skills Using the Engineering Design Process in a Physics Classroom. *The Asia-Pacific Education Researcher*, *32*(1), 141–149. https://doi.org/10.1007/s40299-021-00640-3

Rahmat, M. R., Arip, A. G., & Nur, S. H. (2020). Implementation of Problem- Based Learning Model Assisted by E-Modules on Students' Critical Thinking Ability. *JPI (Jurnal Pendidikan Indonesia)*, *9*(3), 339–346. https://doi.org/10.23887/jpi-undiksha.v9i3.22410

Ramli, R. (2022). Development of Discovery Learning-Based E-Modules to Improve Concept Understanding Ability in Flat Building Materials. *Indonesian Journal of Multidisciplinary Science*, *1*(10), 1272–1287. https://doi.org/10.55324/ijoms.v1i10.200

Rizki, I. N., Marlina, L., & Ismet, I. (2024). Preliminary Study on Students Critical Thinking Skills on Temperature and Heat Material. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10528–10537. https://doi.org/10.29303/jppipa.v10i12.9537

Savery, J. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1). https://doi.org/10.7771/1541-5015.1002

Schunk, D. (2019). *Learning Theories: An Educational Perspective* (8th edition). New York: Pearson.

Suarsana, I. M. (2013). Pengembangan E-Modul Berorientasi Pemecahan Masalah untuk Meningkatkan Keterampilan Berpikir Kritis Mahasiswa. *JPI (Jurnal Pendidikan Indonesia)*, *2*(2). https://doi.org/10.23887/jpi-undiksha.v2i2.2171

Susilawati, Doyan, A., Wahyudi, Ayub, S., & Ardhuha, J. (2022). Concept understanding of students through core physics learning tools based on guided inquiry assisted by PhET virtual media. *Journal of Physics: Conference Series*, *2165*(1), 012045–012045. https://doi.org/10.1088/1742-6596/2165/1/012045

Syahfitri, J., & Safitri, D. (2024). The Effect of Digital-Based Interactive Modules to Improve Student's Critical Thinking Skills and Learning Motivation on Biology Learning. *Jurnal Penelitian Pendidikan*

IPA, *10*(5), 2495–2502. https://doi.org/10.29303/jppipa.v10i5.3878

Syahiddah, D. S., Putra, P. D. A., & Supriadi, B. (2021). Pengembangan E-Modul Fisika Berbasis STEM (Science, Technology, Engineering, and Mathematics) pada Materi Bunyi di SMA/MA. *Jurnal Literasi Pendidikan Fisika (JLPF)*, *2*(1), 1–8. https://doi.org/10.30872/jlpf.v2i1.438

Syuzita, A., Susilawati, S., & Sukarso, A. (2023). Validation of E-Module Based on Argument-Driven Inquiry using 3D Page Flip Professional to Improve Students' Generic Science, Critical Thinking and Scientific Argumentation Abilities. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6272–6277. https://doi.org/10.29303/jppipa.v9i8.4947

Zakiyah, W. I., & Dwiningsih, K. (2022). The Effectivity of Interactive E-Module to Increase the Students' Visual-Spatial Intelligence on Ionic. *Jurnal Inovasi Teknologi Pendidikan*, *9*(1), 91–100. https://doi.org/10.21831/jitp.v9i1.46561